# 7 Environmental Science At-a-Glance:

**In the last unit, students learned about the rocky shore ecosystem and how all living things interact with and depend on other living things and the environment for survival. In this unit, they focus on the interactions among Earth's systems as they analyze the importance of water for life on Earth. They then combine scientific knowledge with engineering to design a water filtration device that purifies water.**

## Common Misconceptions:

- **Misconception**: Groundwater is stored in underground lakes.
  - ✓ **Fact**: Groundwater is stored in the pores that make up rocks, soil, and sand.
- **Misconception**: There is the same amount of groundwater everywhere on Earth.
  - ✓ **Fact**: Groundwater is distributed unevenly around the planet. Its presence depends on many factors, including the amount of precipitation that falls and the properties of the rock that make up a region—specifically whether the rocks are porous and permeable.

# A Breakdown of the Lesson Progression:

## 1 Groundwater Flow

Understanding the interactions of the hydrosphere and the geosphere allows scientists to study many Earth processes that shape the planet. When Earth materials are permeable and porous, they absorb and hold water. This groundwater is a part of the water cycle. Students use this knowledge to test which Earth materials can hold the most groundwater.

## 2 Groundwater Contamination

Once students understand that water moves around the planet through the water cycle, they discuss how human populations depend on fresh water for survival. However, there is a set amount of water on Earth, and fresh water is unevenly distributed around the planet. This water can become polluted, which creates problems for life on Earth.

## 3 Engineering Water Filtration Devices

Students apply their knowledge of groundwater and aquifer contamination to design a water filtration device that mitigates negative impacts on the environment by cleaning polluted water.

 

# Unit 7: Environmental Science

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# Unit 7:

# Environmental Science

**Overview:**

One day in 2012, a massive sinkhole opened beneath the swampy terrain of Bayou Corne in southern Louisiana. The force of the ground's upheaval was so strong that entire trees were flipped upside down with their roots facing the sky. Beneath the water, the hole measured 117 meters (384 feet) deep, roughly equivalent to a 40-story building.

***This is the Bayou Corne sinkhole.***

Almost a year later, the hole grew even larger. Within 30 seconds, the hole expanded, causing a row of 40-foot-tall cypress trees to get completely swallowed up by the water. Although the sinkhole seemed to occur out of the blue, scientists had picked up signals that the ground around the sinkhole in Louisiana was moving at least a month before it collapsed.

In this lesson, students focus on interactions between the hydrosphere and the geosphere as they explore the importance of groundwater in human development. They then build an aquifer simulation model to observe the effects of groundwater contamination on aquifer purity, and engineer a water filtration device to treat samples of simulated polluted stormwater runoff.

**Objectives:**

**1. Describe how energy drives the cycling of Earth's materials, shaping Earth's surface over time.**
**2. Analyze how human activities impact the natural environment.**
**3. Design an engineering solution that mitigates humans' impact on water quality.**

# Applying Next Generation Science Standards

This unit covers the following **Next Generation Science Standards**. Each standard includes where it is found in the unit, as well as how it applies the relevant crosscutting concepts (listed in green) and disciplinary core ideas (listed in orange). **Note: Science and engineering practices are listed separately because all of the practices are incorporated into every unit.*

## Focus Standards:

| MS-LS2 | Ecosystems: Interactions, Energy, and Dynamics |
|---|---|
| **MS-LS2-5.** | **Evaluate competing design solutions for maintaining biodiversity and ecosystem services.**<br>▪ **Developing Possible Solutions:** Students evaluate different water filtration prototypes they design to determine which one is most effective at filtering pollutants out of stormwater runoff. Lesson 3<br>▪ **Influence of Science, Engineering, and Technology on Society and the Natural World:** Students use scientific knowledge to design a water filtration device that solves the problem of water pollution. Lesson 3 |

| MS-ESS2 | Earth's Systems |
|---|---|
| **MS-ESS2-1.** | **Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.**<br>▪ **Earth's Materials and Systems:** Students use a model that shows the processes that cycle Earth materials through the rock cycle to support their understanding of how and where groundwater happens. Lesson 1<br>▪ **Stability and Change:** Students build on their knowledge of the rock cycle, exploring how the hydrosphere and geosphere interact to change Earth's surface. Lesson 1 |
| **MS-ESS2-2.** | **Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying times and spatial scales.**<br>▪ **Earth's Materials and Systems:** Students use sinkholes to analyze how interactions of the hydrosphere and geosphere cause Earth's surface to change over time. Lesson 1 |

- **Scale, Proportion, and Quantity:** Students evaluate how Earth's systems interact over various scales, from microscopic to global and from fractions of a second to billions of years. Lesson 1

| MS-ESS3 | Earth and Human Activity |
|---|---|
| **MS-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 geoscience processes.**<br>▪ **Natural Resources:** Students use what they know about rock permeability and porosity to evaluate how water is unevenly distributed around the planet as a result of interactions of Earth's systems. Lesson 2<br>▪ **Cause and Effect:** Students analyze how access to water affects human development around the planet. Lesson 2 |
| **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.**<br>▪ **Natural Hazards:** Students analyze how scientists are working to develop technologies to help them better predict exactly when sinkholes will occur. Lesson 1<br>▪ **Patterns:** Students obtain information from multiple resources about ways that engineers are in the process of developing technologies to mitigate the effects of sinkholes by predicting when they will occur. Lesson 1 |

| MS-ETS1 | Engineering |
|---|---|
| **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.**<br>▪ **Defining and Delimiting Engineering Problems:** Students define the criteria (needs that will be met by solving the problem) and constraints (time and material limits) to a design solution that solves the problem of water pollution. Lesson 3 |

- **Influence of Science, Engineering, and Technology on Society and the Natural World:** Students describe how engineers apply scientific knowledge to the challenges of purifying polluted water. Lesson 3

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

- **Developing Possible Solutions:** Students analyze the criteria and constraints of the problem, as well as the available materials, to come up with three possible solutions, and then choose which possible solution is most likely to solve the problem. Lesson 3
- **Influence of Science, Engineering, and Technology on Society and the Natural World:** Students use their scientific knowledge to evaluate their design solutions. Lesson 3

**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.**

- **Developing Possible Solutions:** Students analyze the most efficient design for their water filtration device, taking into account cost and filtration success. Lesson 3
- **Influence of Science, Engineering, and Technology on Society and the Natural World:** Students evaluate their data, deciding how best to make improvements. Lesson 3

**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.**

- **Optimizing the Design Solution:** Students develop a procedure for testing their prototype, and then follow that procedure to gather data about how well it solves the problem, addressing the criteria within the constraints of the problem. Lesson 3B
- **Influence of Science, Engineering, and Technology on Society and the Natural World:** Students work to achieve an optimal design for their water filtration device. Lesson 3

# Supporting Standards:

| MS-ESS2 | 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.**<br>▪ **The Roles of Water in Earth's Surface Processes:** In Lesson 1, students build on their knowledge of the water cycling by focusing on one part—groundwater—exploring how it becomes groundwater and how it cycles throughout the planet. In Lesson 2, students explore the interconnectedness of groundwater and surface water. Lessons 1 and 2<br>▪ **Energy and Matter:** Students analyze how energy from the sun propels the movement of water around the planet. Lessons 1 and 2 |

| MS-ESS3 | Earth and Human Activity |
|---|---|
| **MS-ESS3-3.** | **Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.**<br>▪ **Human Impacts on Earth Systems:** Students model the effects of groundwater contamination on aquifer purity and then engineer a water filtration device to treat samples of simulated polluted stormwater runoff. Lessons 2 and 3<br>▪ **Cause and Effect:** Students analyze how human actions can negatively impact the environment, but human actions can also minimize impacts on the environment. Lessons 2 and 3 |
| **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.**<br>▪ **Human Impacts on Earth Systems:** Students focus on how increases in human populations around the planet are placing added strains on water resources. Lesson 2<br>▪ **Cause and Effect:** Students discuss how human activities can lead to water shortages and pollution. Lesson 2 |

# Science and Engineering Practices

Students use the following science and engineering practices in the unit's lessons.

## Lesson 1: Groundwater Flow

**1. Asking questions (for science) and defining problems (for engineering)**

- Students work in teams to develop a question they can answer with an experiment about which Earth material (sand, gravel, or soil) is most permeable to groundwater.

**2. Developing and using models**

- Students create a visual model (scientific diagram) of their experiment-in-progress. Students use the model to visualize the experiment method and materials, and to communicate their experiment to others.

**3. Planning and carrying out investigations**

- Student teams collaboratively develop a plan, which they then follow to compare the rate that water filters through soil, sand, and gravel to see which is most permeable to groundwater.

**4. Analyzing and interpreting data**

- Students collect and analyze data on the relative pore size, height of the material, and time it takes water to filter through the material, looking for patterns that might indicate a relationship between the type of Earth material and its permeability.

**5. Using mathematics and computational thinking**

- Students record the relative pore size of the material, the height of the material, the time it takes water to filter through the material, and then calculate the speed of water filtration.

**6. Constructing explanations (for science) and designing solutions (for engineering)**

- Students use the data they gathered in the experiment to construct an explanation (conclusion) that either supports or rejects their hypothesis about which Earth material is most permeable to groundwater.

**7. Engaging in argument from evidence**

- Students come together as a class to compare team results, using their data from the experiment to analyze which materials are most permeable to water, connecting the properties of the materials to their ability to hold water.

**8. Obtaining, evaluating, and communicating information**

- Students use information from their readers and class discussion, along with their knowledge of properties, the rock cycle, the water cycle, and Earth's interacting systems, to analyze how water moves through different Earth materials.

## Lesson 2: Groundwater Contamination

**1. Asking questions (for science) and defining problems (for engineering)**

- Students create a model of an aquifer to answer the question of how groundwater can become polluted.

**2. Developing and using models**

- Students build an aquifer simulation model to observe the effects of groundwater contamination on aquifer purity.

**3. Planning and carrying out investigations**

- Students test how contaminated surface water can seep into aquifers, causing groundwater to become contaminated.

**6. Constructing explanations (for science) and designing solutions (for engineering)**

- Students use their observations to explain the role of gravity in the movement of water around the planet, how wells deplete aquifers, and how surface water can impact the purity of groundwater when the surface water is polluted.

**7. Engaging in argument from evidence**

- Students use the observations from their aquifer models to describe how all water on Earth is connected as it cycles from one form to another and moves from one location to another.

**8. Obtaining, evaluating, and communicating information**

- Students use information from their readers and class discussion, along with their scientific knowledge of the water cycle, human activities, and water pollution to evaluate how human development impacts Earth's systems.

## Lesson 3: Engineering Water Filtration Devices

**1. Asking questions (for science) and defining problems (for engineering)**

- Students design a water filtration device to solve the problem of aquifer contamination.

**2. Developing and using models**

- Students develop water filter solutions to solve the problem. They create a visual model (scientific diagram) of their proposed water filter prototype solution. Students use the model to visualize and later refine their design, and to communicate their design's features to others.

**3. Planning and carrying out investigations**

- Students come up with possible solutions to the problem, and then build a prototype of the solution they believe would have the greatest likelihood of success.

**4. Analyzing and interpreting data**

- Students test their filtration prototypes, recording data and observations for each prototype tested.

**6. Constructing explanations (for science) and designing solutions (for engineering)**

- Students use the data they gathered from their prototypes to analyze how well their prototypes solved the problem, and to revise their design to improve the cost and/or purity of the filtered water.

**7. Engaging in argument from evidence**

- Students review the results of their prototypes as a class, analyzing which solutions best solved the problem, and any problems they encountered in their designs.

**8. Obtaining, evaluating, and communicating information**

- Students use information from their readers and class discussion, along with their knowledge of the water cycle, rock properties, and aquifers to determine how to create a technology that solves the problem of aquifer contamination.

* Unit connections to Common Core Math practices: MP.2, MP.4, and MP. 6.

# Unit 7 Pacing Guide Example

All KnowAtom units are designed to take approximately one month. Lessons may span one or two weeks. This pacing guide provides one example for how to break down the lessons in this unit over a month. **Breakdown in this guide is based on 45- to 55-minute class periods.** Communities that have longer or shorter class periods or schedules where science class occurs more frequently can modify this guide accordingly.

Any days in this guide that appear unused take into account months with holidays, vacations, or times when a lab and/or investigation takes longer to complete. Note that at the beginning of the school year, when the engineering and scientific processes are new to students, labs may take longer to complete.

| **Unit 7: Environmental Science** | | | | |
|---|---|---|---|---|
| **Day 1** | **Day 2** | **Day 3** | **Day 4** | **Day 5** |
| **Week 1** | | | | |
| **Lesson 1**<br>**Start:** As a class, read Section 1 of the KnowAtom student lab manual.*<br><br>**Final Goal:** Transition to the Socratic dialogue. | **Lesson 1**<br>**Start:** Socratic dialogue.<br><br>**Final Goal:** Transition to Lab question. | **Lesson 1**<br>**Start:** Recap lab question.<br><br>**Final Goal:** Students develop majority of lab with check-ins (up to scientific diagram). | **Lesson 1**<br>**Start:** Teams complete lab development and may begin experiment.<br><br>**Final Goal:** Students begin experiment. | **Lesson 1**<br>**Start:** Teams carry out experiment, analyze data, and evaluate results.<br><br>**Final Goal:** Teams complete lab conclusions. |
| **Week 2** | | | | |
| **Lesson 1**<br>**Start:** As a class, review lab conclusions, wrap up the lab, and debrief.<br><br>**Final Goal:** Review assigned assessment questions (optional). | **Non-Science Day** | **Lesson 2**<br>**Start:** As a class, read Section 2 of the KnowAtom student lab manual.*<br><br>**Final Goal:** Transition to the Socratic dialogue. | **Lesson 2**<br>**Start:** Socratic dialogue.<br><br>**Final Goal:** Transition to the investigation. | **Lesson 2**<br>**Start:** Students carry out the Groundwater Contamination Investigation.<br><br>**Final Goal:** Wrap up the investigation and debrief. |

| Week 3 | | | | |
|---|---|---|---|---|
| **Lesson 3**<br>**Start:** As a class, read Section 3 of the KnowAtom student lab manual.*<br><br>**Final Goal:** Transition to the Socratic dialogue. | **Lesson 3**<br>**Start:** Socratic dialogue.<br><br>**Final Goal:** Transition to the engineering lab (Lab 9) scenario/problem. | **Lesson 3**<br>**Start:** Recap engineering problem.<br><br>**Final Goal:** Teams complete the lab problem through possible solutions steps of the lab with check-ins. | **Lesson 3**<br>**Start:** Teams complete lab development and begin prototype testing.<br><br>**Final Goal:** Teams complete Prototype 1 testing. | **Lesson 3**<br>**Start:** Teams build and test Prototypes 2-3.<br><br>**Final Goal:** Teams analyze test data and evaluate results. |
| **Week 4** | | | | |
| **Lesson 3**<br>**Start:** Teams analyze data and begin lab conclusions.<br><br>**Final Goal:** Teams complete lab conclusions. | **Lesson 3**<br>**Start:** As a class, review lab conclusions, wrap up the lab, and debrief.<br><br>**Final Goal:** Review assigned assessment questions (optional). | **Non-Science Day** | **Non-Science Day** | **Non-Science Day** |

<u>Pacing Guide Notes</u>

* As the school year progresses, students are expected to come to class having already read the lab manual so they can actively participate in the Socratic dialogue. When students read the lab manual outside of class time, this time can be used for deeper Socratic dialogue.

**Science Words to Know:**

This unit's vocabulary is divided into three lessons. Use the blank concept map visual to connect vocabulary once the unit is complete. An example concept map is displayed in Appendix 3.

**Lesson 1**

1. **aquifer** – an underground layer of rock, sand, or gravel that holds groundwater; a source of well and spring water

2. **groundwater** – the supply of fresh water found beneath Earth's surface in the pores of soil, sand, and rock

3. **hydrogeology** – the study of geology that is focused on the distribution and movement of groundwater in the soil and rocks of Earth's crust

4. **permeability** – the ease with which substances such as water move through a material

5. **porosity** – the amount of space between particles in a substance

6. **sinkhole** – a hole in the ground formed when water has dissolved underground rock to the point where it can no longer support the land surface

**Lesson 2**

7. **aquifer discharge** – when water leaves the aquifer, such as when it seeps into a spring

8. **aquifer recharge** – when water seeps into the ground and replenishes the aquifer, such as from precipitation

9. **nonpoint-source pollution** – pollution that is discharged over a wide land area and comes from many different sources and locations

10. **point-source pollution** – pollution that can be traced back to a single identifying incident, such as a leak in an underground storage tank or waste discharging from a factory

11. **water pollution** – the contamination of natural water bodies by substances that harm organisms and the environment

12. **water table** – the highest point in an aquifer from which water can be obtained

**Lesson 3**

13. **ecosystem service** – the positive benefits that an ecosystem provides to people

14. **filtration** – the process of separating solid matter from a fluid by having the fluid pass through the pores of another substance, called a filter

# Teacher Background

**Earth's Systems**

Earth's surface is constantly changing. Some of these changes are gradual, taking place over hundreds or thousands of years, such as the slow weathering and erosion of rock. Other changes seem to occur in an instant, such as when the ground suddenly falls away in a **sinkhole**— a hole in the ground formed when water has dissolved underground rock to the point where it can no longer support the land surface.

***A sinkhole formed in Maryland along the side of a highway.***

All of these changes take place because of interactions among Earth's four primary systems: the hydrosphere, the geosphere, the atmosphere, and the biosphere.

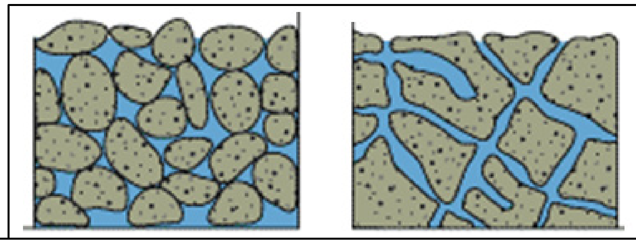
Weathering, erosion, and the formation of sinkholes occur primarily because of interactions among these systems as energy flows through them. In fact, all geoscience processes that occur on Earth result from energy flowing and matter cycling within and between Earth's systems.

Sinkholes form because of processes that occur underground. Sinkholes are common in areas where the land sits on top of rock that can naturally be dissolved by **groundwater**—the supply of fresh water found beneath Earth's surface in the pores of soil, sand, and rock.

**Groundwater and Aquifers**

Groundwater is distributed around the planet according to one underlying scientific principle—the more porous the rock is, the more water it can hold. **Porosity** refers to the amount of space between particles in a substance. Rocks that have a lower density are more likely to contain water because they are often porous. Density is the mass of a substance in a given volume. Sedimentary rocks are often porous and found in lakes, rivers, and oceans.



***Groundwater fills the spaces between porous soil particles and fractured rock underground.***

In addition to porosity, the presence of groundwater also depends on the permeability of the subsurface rock. **Permeability** refers to the ease with which substances such as water move through a material. If the rock has characteristics that allow water to move relatively freely through it, then groundwater can move a significant distance in a number of days. But groundwater can also sink into deep aquifers where it takes thousands of years to move back into the environment, or even go into deep groundwater storage, where it might stay for millions of years.

An **aquifer** is an underground layer of rock, sand, or gravel that holds groundwater. The word aquifer comes from two Latin words: "aqua," which means water, and "ferre," which means to bear or carry. Aquifers vary greatly in size and distance beneath the surface. Some aquifers are no more than a few feet thick, while others are hundreds of feet thick. Some are a few meters below the surface, and others are hundreds of meters underground. The water present in a shallow aquifer often is just a few hours old, while the water in the deepest aquifers may be several thousands of years old and take a million years to complete the water cycle and return to the oceans.

## How Sinkholes Form

Understanding how groundwater moves through and interacts with the soil and rocks of Earth's crust is essential to understanding how and why sinkholes occur. One such rock is limestone, a kind of porous sedimentary rock that is formed primarily from marine fossils. As groundwater seeps into the ground, it absorbs carbon dioxide and reacts with decaying vegetation. As a result, the water becomes slightly acidic. As the water moves into the pores of limestone, it dissolves the rock, leaving behind caverns and empty spaces within the rock. Over time, the limestone erodes to the point where it can no longer support the land above it.

Scientists believe that 10 percent of Earth's surface is shaped by rock that can naturally be dissolved by groundwater and can therefore experience sinkholes. In the United States, sinkholes cause the most damage in Alabama, Florida, Kentucky, Missouri, Pennsylvania, Tennessee, and Texas.

In addition to naturally occurring sinkholes, sinkholes can also occur because of human actions, including digging wells and drawing too much water from aquifers. When people withdraw too much water from an aquifer, they can increase the risk of a sinkhole forming. When too much groundwater is withdrawn from an aquifer, the pores that were once filled with water become filled with air. Because air provides less support than water, the land surface becomes less stable. When large amounts of precipitation fall, the underground rock can no longer support the added weight of the rain, and so the land collapses, forming a sinkhole.

***Scientists believe that 10 percent of Earth's surface is shaped by rock that can naturally be dissolved by groundwater and can therefore experience sinkholes. This sinkhole is in Belgium.***

**Accessing Water**

The study of geology that focuses on the distribution and movement of groundwater in the soil and rocks of Earth's crust is called **hydrogeology**. Scientists are particularly interested in this field because of the important role that groundwater plays in human development. Given that only 2.5 percent of all water on Earth is fresh water, and 70 percent of all fresh water is frozen in ice caps and glaciers, much of the population growth and economic development around the world has been possible because people have had access to groundwater.

About 1.5 billion people today depend on groundwater for their drinking water. In the United States, 50 percent of people in the United States use groundwater for drinking water, agriculture, and industry, especially in the western United States.

People drill wells into the ground to access groundwater. This water can then be brought to the land surface by a pump. However, the level of the water table can change over time. The **water table** is the highest point in an aquifer from which water can be obtained. Natural factors that influence the water table level include changes in the water cycle patterns and changes to the geology of the region. For example, in times of drought, the water table drops because the amount of precipitation seeping into the ground declines. However, people often turn to aquifers during times of drought to make up for the loss of available surface water, decreasing water levels even more.

***People drill wells in the ground to access groundwater.***

**Healthy Aquifers**

When people withdraw excessive amounts of groundwater, they upset the natural balance of the water cycle. Earth is constantly changing as matter cycles and energy flows through it. In the same way that the interacting parts of an ecosystem act as checks on one another, so to do the various parts of Earth's systems interact to maintain balance.

Aquifers remain stable when the amount of water being added to the aquifer from precipitation is roughly the same as the amount of water leaving the aquifer over time. **Aquifer recharge** occurs when water seeps into the ground and replenishes the aquifer, such as when precipitation soaks into the ground. **Aquifer discharge** occurs when water leaves the aquifer, such as when it seeps into a spring or when people use wells. When people pump too much groundwater, they deplete the aquifer, causing wells to run dry. If the rate of discharge from an aquifer is greater than the rate of recharge, the aquifer will become depleted. Some aquifers take hundreds or thousands of years to recharge.

Regions around the world are already experiencing groundwater depletion. For example, the largest aquifer in North America is called the Ogallala Aquifer, and it lies underneath seven western states: Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. It is used for human drinking water, as well as for industrial and agricultural use. The majority of the water that fills the Ogallala Aquifer has been there for millions of years. However, the Ogallala Aquifer is currently being depleted faster than it can be replenished. This worries many people because it is the single most important source of fresh water in this region.

Groundwater pumping can also harm ecosystems. Because groundwater is so connected to surface water, the removal of groundwater impacts the quality of surface water. Aquifers discharge groundwater to the surface, adding water to many streams and rivers. When people pump too much water from an aquifer, there is less water that is discharged to streams. This harms the aquatic habitats of many species, including fish and amphibians that live in streams.

**Studying Earth's Systems**

Keeping aquifers healthy is also important to scientists because groundwater is some of the cleanest water on Earth. After studying the structure of aquifers, scientists realized that the particles of rock that make up aquifers act as a natural filter as water moves through the layers of materials. **Filtration** is the process of separating solid matter from a fluid by having the fluid pass through the pores of another substance, called a filter. Because they act as filters, aquifers provide an **ecosystem service**—the positive benefits that an ecosystem provides to people. As water moves from Earth's surface underground, it is filtered, becoming purer. By the time water has moved through the aquifer, many pollutants have been removed.

The water quality in deeper aquifers is often better because more contaminants are filtered out. This is because aquifers are natural filters that trap sediment and other particles such as bacteria. Aquifers act like coffee filters. In the same way that coffee filters trap coffee grounds but allow the coffee to flow through, the pore spaces in an aquifer's rock or sediment prevent sediments and other larger particles from flowing through while allowing the movement of water.

However, different aquifers are made up of different kinds of rocks, which have different pore sizes. For example, some aquifers are igneous or metamorphic rock, which are generally impermeable. They hold water in cracks or fractures, and water does not filter through them as easily. As a result, they are less able to filter out contaminants.

***Scientists map the geology and the underground structures of different areas.***

Because of the critical role that groundwater has in supporting life, scientists are trying to better understand groundwater on Earth. Groundwater is difficult to study because it is underground. It is also unevenly distributed around the planet. As a result, scientists map the geology and the underground structures of different areas to understand how groundwater moves through different materials, how quickly it is recharged in various locations, and how it interacts with other Earth systems. To do this, scientists use deep wells up to 2,000 feet underground to monitor the groundwater and to observe what happens when additional groundwater is removed.

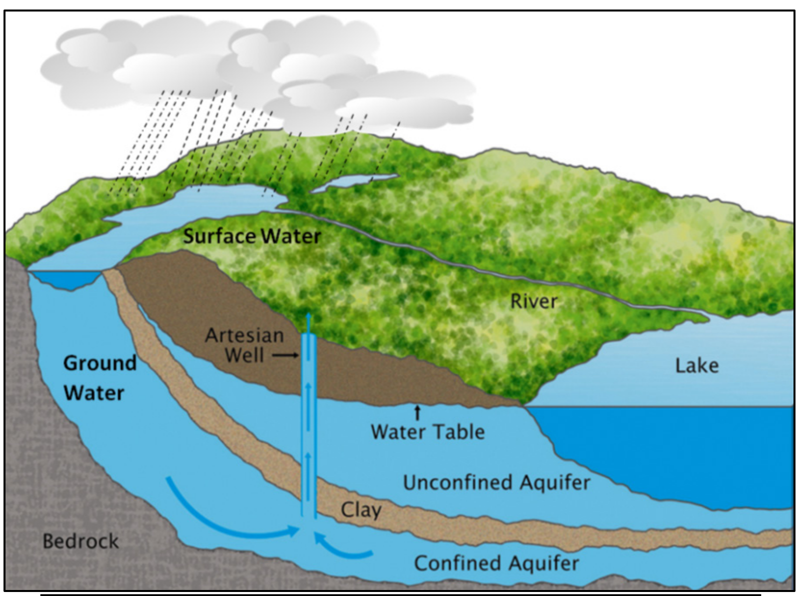
 

**Water Pollution**

Scientists also study the effects of water pollution on aquifers, which is increasingly becoming a problem. **Water pollution** is the contamination of natural water bodies by substances that harm organisms and the environment, and it can be natural or caused by humans. Natural contamination can occur from naturally occurring mineral or metallic deposits in sediment.

The kinds of rock that surround an aquifer play a role in the likelihood of the aquifer becoming polluted. A confined aquifer has a layer of nonporous material, such as clay or shale, between the water level and ground level that separates the water from ground level. This nonporous material acts as a buffer because water cannot move freely through it. Therefore, it can prevent or reduce the amount of pollution that reaches the aquifer.

In contrast, in an unconfined aquifer, there are no layers of nonporous material between the water level and the ground level. These aquifers are more at risk of becoming polluted because there is not an impermeable layer between them and the source of pollution. In other words, if anything leaks or spills into the soil above the unconfined aquifer, it will seep into and contaminate the water.




***Groundwater is connected to surface water and can become polluted.***

**Water Pollution**

There are two primary types of human-caused pollution: point-source pollution and nonpoint source pollution. **Point-source pollution** can be traced back to a single, identifiable incident, such as a leak in storage tank or waste discharging from a factory. **Nonpoint-source pollution** is discharged over a wide land area and comes from many different sources and locations, including excess fertilizer and pesticide runoff, pet waste, and oil leaks from cars.

***Sewage flowing from a pipe into a lake is an example of point-source pollution because it can be traced back to a single source.***

Water pollution is a growing problem for people around the world. Every day, 2 million tons of sewage and industrial and agricultural waste flow into water systems around the planet. According to some estimates, more than 1 billion people around the planet are affected by polluted water. Water pollution can cause disease and even death. Water-related disease causes more than half the world's hospitalizations.

**Designing Solutions**

Engineers use knowledge gathered by scientists about rock properties and the filtration capacity of different aquifers to design solutions to problems of water scarcity and water pollution.

In cities and towns, much of the precipitation that falls cannot soak into the ground because it falls on non-porous materials such as asphalt and concrete. It then flows into the local waterway, carrying pollutants from the ground. Many communities need engineers to help them solve the problem of contaminated water supplies.

Engineers interested in solving the problem of contaminated water could do background research to learn that groundwater is generally clean because aquifers have properties that make them natural filters. Engineers wanting to design a filtration technology would then do a survey of their available materials, evaluating them based on their pore size and permeability.

Once they decide on a design solution, engineers can then design a filtration prototype that uses sand, gravel, soil, or other porous material to filter water. They would then test it in a way that simulates how it would work to solve the problem. The goal of testing is to find out how well the prototype solves the problem. The engineer performs measurements and collects data to determine how well the prototype addresses the problem.

Using the test data, the engineer visualizes the limitations of the prototype. A *limitation* is a setback or weakness in the prototype's ability to solve the problem. Based on data from the test feedback, the engineer forms a conclusion, deciding whether to refine or replicate the technology. In some cases, the prototype needs a complete redesign. Engineers would want to know how well their mixture of sand and gravel filtered out pollutants.

# Lesson 1: Groundwater Flow

**Objective**: Students carry out an experiment to test the permeability of different Earth material (sand, gravel, and soil).

**Materials**:

**Consumable**

A. Goggles – 1 per student
B. Laboratory notebooks – 1 per student
C. Small plastic cups (3.5 oz.) – 1 per team
D. Large plastic cups (10 oz.) – 1 per team
E. Graduated cups (30 mL) – 1 per team
F. Water (90 mL per team) – teacher provides (not shown)
G. Gravel (small) – shared bag
H. Soil – shared bag*
I. Sand – shared bag*

**Non-Consumable**

J. Stopwatches – 1 per team
K. Thumbtacks – 1 per team
L. Rulers – 1 per team
M. Graduated cups – 1 per team
N. Graduated measuring containers – shared
O. Sinkholes Visual – (not shown)
P. Aquifers Visual – (not shown)

A


B



C


D


E

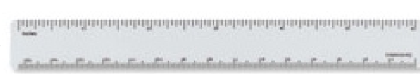

G


H


I


J


K


L


M


N


*Reserve any remaining soil or sand samples to use in Lesson 3. These samples will be used by the teacher to create simulated "contaminated" water.

**Teacher Preparation**:

- Download the visuals and the video (optional) from the KnowAtom Interactive website.
- To save time, prepare photocopies of the Blank Data Table for each student using the copy master on page 42.
- Arrange several water collection stations for teams to collect water as needed during the experiment. Each station should have graduated measuring container(s) filled with some water for teams to collect.
- Arrange several pick-up stations for students to collect materials during the lab. For example:
  - Pick-Up Station 1: large plastic cups (10 oz), small plastic cups, (3.5 ox) and graduated cups (30 mL)
  - Pick-Up Station 2: gravel, soil, and sand
  - Pick-Up Station 3: stopwatches, rulers, thumbtacks, and graduated cups (durable)

**Student Reading Preparation**:

- Students read Section 1 of the student lab manual. In 7th grade, students are expected to come to class having already read the lab manual so they can actively participate in the Socratic dialogue before the lab portion of the lesson. At the beginning of the school year (September-October), the lab manual can be read in class.
- If class time is used to read the lab manual together, model how to read closely for understanding. For example:
  - Emphasize connections between examples in the reading and broader concepts. For example, ask why a certain example was used to support the reading's main point.
  - Use "why" and "how" questions to connect ideas in the reading to student experiences.

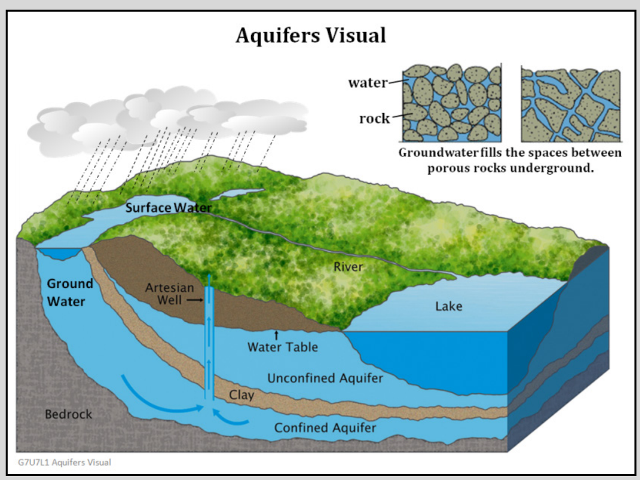
 

## **Socratic Dialogue**:

- The Socratic dialogue serves as the bridge between the nonfiction reading and the lab portion of the lesson.
- The example Socratic dialogue below describes one possible progression of ideas to engage students in higher order thinking. Blocks are used to divide the dialogue according to key organizing concepts. They are not meant to indicate how much time a dialogue should take; length of time may vary depending on the subject matter and student understanding of the concepts. Note that in a Socratic dialogue, the teacher is not the only one asking questions and challenging ideas. Students should be actively engaged in proposing questions, challenging assumptions, and using evidence to support their arguments. *Not sure how to set up a Socratic dialogue? Check out [www.knowatom.com/socratic](www.knowatom.com/socratic) for an in-depth look at how to hold a next generation Socratic dialogue in the classroom.*

Block 1: How Earth Materials Change

**1.** Display *Aquifers Visual*. Begin a dialogue with students about one part of the water cycle—groundwater. **Groundwater** is the supply of fresh water found beneath Earth's surface in the pores of soil, sand, and rock.




- ☐ **Big Idea 1**: Coach students toward the idea that groundwater is held in **aquifers**, which are underground layers of rock, sand, or gravel that hold water. For example:
  - ○ *Ask one student how groundwater gets underground. (Water on Earth's surface seeps into the ground, just like water is*

*slowly absorbed into a jar of sand. This is part of the water cycle.)*
- *Ask another student what causes groundwater to move. (The downward force of gravity pulls on groundwater, causing it to move downward. This is the same reason that water on Earth's surface moves (including in rivers and glaciers).)*
- *One at a time, provide multiple students with the chance to describe the relationship between water's movement and the downward pull of gravity.*

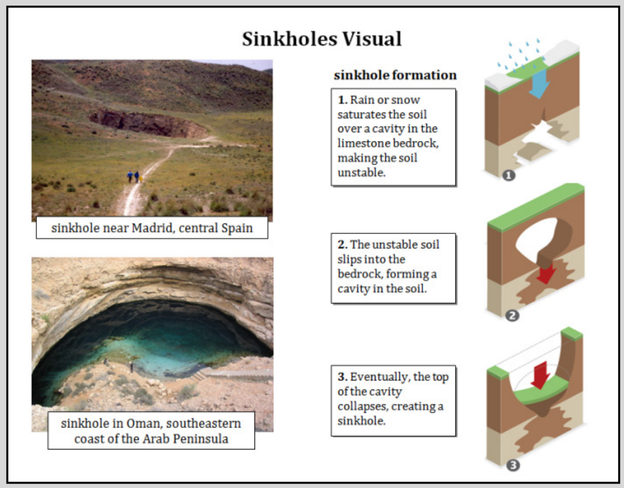
- **Big Idea 2:** Coach students toward the idea that different rocks hold water differently, so water does not move through the ground in the same way everywhere. For example:
  - *Ask one student why aquifers are similar to rigid sponges. (The materials that make up aquifers, such as clay, sand, and gravel, can hold water, similar to how sponges hold water.)*
  - *Ask another student why aquifers can hold water. (The materials that make up aquifers are porous and permeable.* ***Porosity*** *refers to the amount of space between particles in a substance.* ***Permeability*** *refers to the ease with which substances such as water move through a material. As water is pulled downward, it fills the pores of these different materials.)*
  - *Ask the first student how water moves through an aquifer. (Groundwater is in constant motion, although it generally moves more slowly than water in a stream or river moves because it must pass through the interconnected pores of the rock.)*
  - *Ask another student why the water in some aquifers moves more slowly than in other aquifers. (The speed at which groundwater moves depends on both the rock's porosity and its permeability. Groundwater that is stored in rocks that are more porous and permeable will move more quickly than it will through less porous or impermeable materials.)*

* **Note to teachers**: If time and resources permit, the following video segment can be watched here. The video shows the Bayou Corne sinkhole swallowing some trees as it gets bigger. It can be found at:

**http://www.nytimes.com/video/multimedia/100000002464501/the-bayou-corne-sinkhole.html**

**2.** Display *Sinkholes Visual*. Continue the dialogue with students, exploring the interactions of the hydrosphere and the geosphere that cause sinkholes to occur.




- **Big Idea 3:** Coach students toward the idea that **sinkholes** are holes in the ground formed when water has dissolved underground rock to the point where it can no longer support the land surface, and they form because of processes that occur underground, sometimes gradually and sometimes all of a sudden. For example:
    - *Ask one student how groundwater causes underground rock to erode. (As water moves over rocks, it breaks down Earth's materials into tiny pieces and carries those weathered materials to new places.)*
    - *Ask another student how else water can cause underground rock to erode. (As groundwater seeps into the ground, it absorbs carbon dioxide and becomes slightly acidic. As the water fills the limestone's pores, it dissolves the rock.)*

- *Ask the first student what causes a sinkhole to form. (As water seeps into the ground, it erodes underground rock. Sometimes it erodes it so much that the rock can no longer support the land above it. When this happens, a sudden collapse of the land on the surface can occur. The result is a sinkhole.)*

- **Big Idea 4:** Coach students toward the idea that some regions are more prone to sinkholes than others because of the kind of rocks underground. For example:
  - *Ask one student how scientists know which parts of the country are most likely to experience sinkholes. (Sinkholes are common in areas where the land sits on top of rock that can naturally be dissolved by groundwater. One such rock is limestone.)*
  - *Ask another student why sinkholes can be catastrophic. (Sinkholes can be large enough to swallow trees, cars, and even buildings. And scientists are still figuring out how to predict exactly when a sinkhole might occur, so it can be hard for people to prepare.)*
  - *Ask the first student how engineers are working with scientists to address this problem. (Engineers are developing technologies that will be better able to predict when a sinkhole might occur. For example, NASA engineers are developing a technology that uses a plane with radar technology that sends out electronic pulses. These pulses allow scientists to map out how Earth's surface is shifting.)*

**<u>Experiment</u>: Lab 8 – Groundwater Permeability**

> **SAFETY**: Students must wear goggles during this activity.

**1.** Divide students into teams of two. Students will have read and discussed how water shapes rocks on Earth's surface and underground. The properties of different types of rock determine how likely they are to hold water or enable the water to flow through them. Use Socratic dialogue to guide students toward asking a question they can answer with an experiment about how easily water can move through different types of Earth materials such as sand, gravel, and soil. Display the sand, gravel, and soil for the class to evaluate. See if any students get close enough to a question that could be framed into something that is usable as the experiment question. You may need to ask several leading questions to get students thinking. For example:

- How are the samples of sand, gravel and rock different? [*Answers will vary based on what students notice. Students might point out that each Earth material is a different size. As a result, the porosity (amount of space between the particles in each sample) is different*.]
- Which Earth materials (sand, gravel, and soil) do you think are more permeable to water? Why? [*Answers will vary. Students may argue that the more porous Earth materials are likely more permeable to water. Other students may argue that the porous materials will hold water, but not necessarily be permeable to water. There is no "correct" answer to this question. The purpose of the question is to get students thinking about different factors that might affect how permeable the Earth materials are to water. Differences in ideas are expected and encouraged*.]
- How could we test these ideas like a scientist? [*Students should recognize that they could design an experiment to answer a question related to the topic at hand (the permeability of sand, gravel, and soil to water.)*]

At this point, see if any student gets close enough to a question that could be framed into something that is usable as the experiment question. For example: “Which Earth material (sand, gravel, or soil) is most permeable to groundwater?” or “Are sand, gravel, or soil equally permeable to groundwater?”

**Question**

As a class, discuss the possible questions for the experiment and decide which question to explore for the lab. For example: “Which Earth material (sand, gravel, or soil) is most permeable to groundwater?” Once the experiment question is established for the lab, students record it in their lab notebooks. Students create a title for the new lab entry that is relevant to the question. In this example, a relevant title would be “Earth Materials and Permeability” or “Permeability” but other titles can be used as well.

**NOTE**: Use the *Scientific Process Visual* and/or the *Who is a Scientist* poster as a visual reference to guide students through the remaining steps of the lab process.

**Research**

For research, students list up to three facts relevant to the experiment question, using information from the student lab manual and/or discussion. For example:

- *Permeability is the ease with which water can move through a material.*
- *Porosity is the amount of space between particles in a substance.*
- *The porosity of an Earth material and the size of its pores (open spaces) help to determine how much water it can hold.*

**Hypothesis**
Teams form their own hypothesis and record it in their lab notebooks. The following examples represent the types of hypotheses teams could develop in this lab:

- "Sand is more permeable to groundwater than gravel or soil."
- "Gravel is more permeable to groundwater than sand or soil."
- "Soil is more permeable to groundwater than sand or gravel."
- "All Earth materials are equally permeable to groundwater."

**Checkpoint #1: After Question, Research, and Hypothesis**
As teams are ready, they should check in with the teacher to review their question, research, and hypothesis. Do the lab notebooks of both team members match and meet expectations? Can both students within the team explain their reasoning? If not, ask for areas of clarification or correction before they advance further. Not all teams will arrive at the lab check-points at the same time, so teams independently receive the go-ahead to move on in their lab after they have made the necessary modifications. Student lab notebook entries within the class will most likely have the same question, but variations from team to team in the remaining steps of the process are expected and encouraged.

**Summarize Experiment**
Stand by the materials stations to explain how the materials function and the general amounts that teams can collect. If students do not have access to the pick-up stations at this point in the lab, a general list of the materials each team can use for the lab can be written or displayed on the board (if needed). Teams summarize the experiment they will carry out to test their hypothesis, and then record their summary in their lab notebooks. Summaries should note the independent and dependent variables, constants, and a control (if applicable) in the experiment. For example: "Our experiment will

compare how quickly water filters through equal volumes of soil, sand, and gravel. The constants in the experiment are the volume of each Earth material and the volume of water added to each Earth material. The independent variables in the experiment are the different Earth materials (soil, sand, and gravel). The dependent variable is how long it takes for the water to filter through each material."

**Checkpoint #2: After Experiment Summary**
As teams are ready, they should check in with the teacher to review the experiment summary of their lab. Do the lab notebooks of each team member match and meet expectations? Can students explain their reasoning? The summary should not include a detailed procedure or materials quantities.

- ✓ Students describe what data will be collected to serve as evidence to address the lab question. The summary should include the basics of the data to be collected, the number of trials students will conduct, the independent and dependent variables, and the parts of the experiment they will keep constant in each test or trial.

**List Materials and Procedures**
Students list materials and all relevant safety precautions in their notebooks.

- 90 mL of water
- 2 30-mL cups of soil
- 2 30-mL cups of sand
- 2 30-mL cups of gravel
- 1 graduated cup (30 mL)
- 1 large plastic cup
- 1 small plastic cup
- 1 graduated cup (durable)
- 1 thumbtack
- 1 ruler

**Safety**

- goggles

Teams develop a standardized list of steps for their procedure. The procedure may vary from team to team depending on approach. Differences are expected and encouraged. Student procedures should include a level of detail comparable to this example procedure:

1. Put one hole in the bottom of the small plastic cup using a thumbtack.
2. Fill the small plastic cup with 2 30-mL cups full of soil. Tap the side of the cup a few times to settle the material.
3. Suspend the soil-filled plastic cup over the large plastic cup. Slowly pour 30 milliliters of water into the soil. Record the time it takes for the water to start dripping from the cup. Discard the used soil.
4. Repeat steps 2-3 for two more tests, first with the sand, then with the gravel.

**NOTE**: Teams should make sure the hole they poke in the plastic cup is clearly open. They may need to twist the thumbtack around to make sure the hole is wide enough.

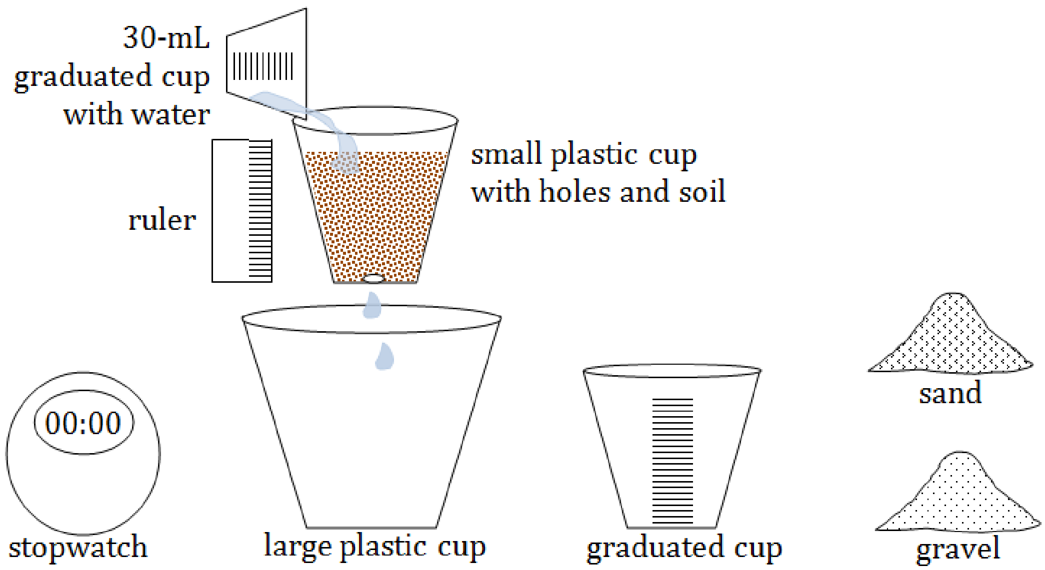
**Checkpoint #3: After Materials and Procedure**

As teams are ready, they should check in with the teacher to review the material and procedure steps of their lab. Are the materials and procedure in vertical lists and quantities included with all materials? Can you follow each team's procedure? Are the materials and quantities under "materials" all required by the procedure? Is it clear, concise, and specific? If not, clarify expectations. Students make corrections or any modifications and return to the checkpoint for the go-ahead.

**Scientific Diagram**
Students draw a titled scientific diagram of their experiment-in-progress. For example:

**Testing Permeability Diagram**




> **<u>Checkpoint #4</u>: After Scientific Diagram**
> As teams are ready, they should check in with the teacher to review their lab scientific diagram. Are the diagrams complete? Diagrams should be titled and materials labeled. If complete, students pick up blank data tables and graphs to tape inside their lab notebooks and then proceed to collect the materials needed to conduct their experiment after meeting at the checkpoint.

**Data**

Teams collect the materials from the pick-up stations to carry out their experiment. Students record data in their data tables as the experiment progresses. Photocopy and distribute blank data tables to save time.

| Table 1: Testing the Permeability of Different Earth Materials | | | | |
|---|---|---|---|---|
| **Earth Material** | **Relative Pore Size** (small, medium, or large) | **Soil Height** (mm) | **Water Filter Time** (s) | **Water Filtration Speed** (mm/s) |
| **Soil** | small | 40 | 35.8 | 1.11 |
| **Sand** | medium | 40 | 11.2 | 3.57 |
| **Gravel** | large | 40 | 1.2 | 33.3 |

**NOTE**: Example data represent one possible outcome. Individual results will vary.

**Conclusion**

Each student writes a conclusion that summarizes their findings and tells how the data did or did not support the hypothesis. For example: "Our hypothesis that gravel is more permeable to groundwater than sand or soil is true. Our data show that the water filtered fastest through gravel compared to the soil and sand samples. The water moved through the gravel between 32.1 and 29.7 mm/s faster than through the soil and sand samples. We also observed that the gravel sample had larger pores than the sand and soil samples, which helps to explain why the water moved faster through this material. We can conclude that sand, soil, and gravel each has a different permeability, and groundwater moves fastest through gravel."

**Final Checkpoint: After Data and Conclusion**
As teams are ready, they should check in with the teacher to review the data and conclusion steps of their lab. One team member reads the team's conclusion aloud to you while you review the other team member's lab notebook. Do they restate the hypothesis? Have they made a true/false/inconclusive claim? Look for key data points that students used to form their conclusion. Is it clear? Is it persuasive? Do the data support the claim? If the results are contrary to their research, what might be responsible? How could they test for that in the future?

**Wrap-Up:**

**1.** Come together as a class to share team results from the experiment. For example:

- Ask a student from one team to present their conclusion to the class. Were the data consistent with all teams in the class? If not, what may have caused some teams to have different data? [*Answers will vary. Ask students to compare their results and analyze possibilities for any differences, such as a difference in developing or carrying out the procedure.*]
- Ask a student from another team what, if any, challenges they experienced while conducting this experiment. [*Answers will vary. Challenges are a part of conducting experiments, and discussing them can help students think through their process, comparing their method with other student teams.*]
- Ask the student from the first team if they noticed any patterns in the data between the porosity of the material and the speed that water moved through it. [*The water moved quickest through the gravel, which also has the largest pores.*]

**2.** Continue the dialogue with students, reviewing the concepts of porosity and permeability illustrated in the experiment, and connecting these concepts to the distribution of groundwater on Earth and ongoing work to develop technologies that can predict when and where sinkholes are most likey to occur. For example:

- Ask one student why some rocks hold water and others don't. [*Rocks have different properties depending on how they form. Not all rocks are porous, which means they do not have space between their particles to hold and store water.*]
- Soil, sand, and gravel are all porous, so they can all hold water. Ask another student what a likely explanation is for why water does not move through all three substances at the same rate. [*Each substance has a different permeability—the ease with which substances such as water move through a material. For example, water will move through a substance much more quickly if all of the pores are connected together because those interconnected pores provide a channel through which the water can flow.*]
- Ask the first student how water moving through substances alters the shape of Earth's surface. [*As water moves over substances such as rocks and soil, it constantly rubs against them, eventually weathering and eroding the materials.*]
- Ask another student how the experiment provided evidence that supports the argument that groundwater isn't evenly distributed around the planet. [*The experiment showed that some kinds of rock are better able to absorb and hold water than other kinds of rock. There are different kinds of rock around Earth, and some areas have rocks that are better able to store groundwater than other areas.*]
- Ask another student how scientists can use what they know about the properties of rocks and how water interacts with rocks to predict where sinkholes are likely to occur. [*Scientists know that rock that is easily dissolvable, such as limestone, is most likely to have sinkholes because water easily erodes the rock, carving out holes that fill with air and eventually cannot support the weight of the land above.*]

**Unit 7: Lesson 1** – Example Lab Notebook

This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

Page

Permeability, Date, Partner Name

**Lab #8: Permeability**

**Question**: Which Earth material (sand, gravel, or soil) is most permeable to groundwater?

**Research**: Permeability is the ease with which water can move through a material. Porosity is the amount of space between particles in a substance. The porosity of an Earth material and the size of its pores help to determine how much water it can hold.

**Hypothesis**: Sand is more permeable to groundwater than gravel or soil.

**Summary of Experiment**: Our experiment will compare how quickly water moves through equal volumes of soil, sand, and gravel. The constants in the experiment are the volume of each Earth material and the volume of water poured on each Earth material. The independent variables in the experiment are the different Earth materials (soil, sand, and gravel). The dependent variable is how long it takes for the water to filter through each material.

**Materials**:

- 90 mL of water
- 2 30-mL cups of soil
- 2 30-mL cups of sand
- 2 30-mL cups of gravel
- 1 large plastic cup
- 1 small plastic cup
- 1 graduated cup (durable)
- 1 graduated cup (30 mL)
- 1 thumbtack
- 1 stopwatch
- 1 ruler

**Safety**:

- goggles

**Procedure**:

Step 1: Put one hole in the bottom of the small plastic cup using a thumbtack.

Step 2: Fill the small plastic cup with 2 30-mL cups of soil. Tape the side of the cup a few times to settle the material.

Step 3: Suspend the soil-filled plastic cup over the large plastic cup. Slowly pour 30 milliliters of water into the soil. Record the time it takes for the water to start dripping from the cup. Discard the used soil.

Step 4: Repeat steps 2-3 for two more tests, first with the sand, then with the gravel.

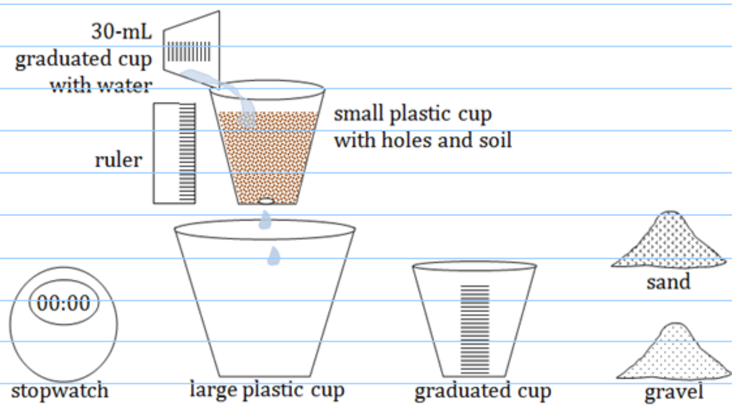
 

# **Unit 7: Lesson 1** – Example Lab Notebook

This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

**Scientific Diagram:**

Testing Permeability Diagram




**Data:**

| Earth Material | Relative Pore Size (small, medium, or large) | Soil Height (mm) | Water Filter Time (s) | Water Filtration Speed (mm/s) |
|---|---|---|---|---|
| **Soil** | small | 40 | 35.8 | 1.11 |
| **Sand** | medium | 40 | 11.2 | 3.57 |
| **Gravel** | large | 40 | 1.2 | 33.3 |

Table 1: Testing the Permeability of Different Earth Materials

**Conclusion:** Our hypothesis that gravel is more permeable to groundwater than sand or soil is true. Our data show that the water filtered fastest through gravel compared to the soil and sand samples. The water moved through the gravel between 32.1 and 29.7 mm/s faster than through the soil and sand samples. We also observed that the gravel sample had larger pores than the sand and soil samples, which helps to explain why the water was able to quickly filter through it. We can conclude that sand, soil, and gravel each has a different permeability, and groundwater moves fastest through gravel.

## **<u>Unit 7 Lesson 1</u>:** Blank Data Table

| **Table 1: Testing the Permeability of Different Earth Materials** | | | | |
|---|---|---|---|---|
| **Earth Material** | **Relative Pore Size** (small, medium, or large) | **Soil Height** (mm) | **Water Filter Time** (s) | **Water Filtration Speed** (mm/s) |
| **Soil** | | | | |
| **Sand** | | | | |
| **Gravel** | | | | |

## Lesson 2: Groundwater Contamination

**<u>Objective</u>**: Students build an aquifer model to simulate and observe the effects of surface water contamination on aquifer purity.

**<u>Materials</u>**:

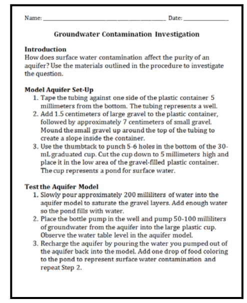
**Consumable**

A. Goggles – 1 per student

A

B. “Groundwater Contamination Investigation” – 1 per student (lab manual)

B



Name: ______________________ Date: __________

**Groundwater Contamination Investigation**

**Introduction**
How does surface water contamination affect the purity of an aquifer? Use the materials outlined in the procedure to investigate the question.

**Model Aquifer Set-Up**

1. Tape the tubing against one side of the plastic container 5 millimeters from the bottom. The tubing represents a well.
2. Add 1.5 centimeters of large gravel to the plastic container, followed by approximately 7 centimeters of small gravel. Mound the small gravel up around the top of the tubing to create a slope inside the container.
3. Use the thumbtack to punch 5-6 holes in the bottom of the 30-mL graduated cup. Cut the cup down to 5 millimeters high and place it in the low area of the gravel-filled plastic container. The cup represents a pond for surface water.

**Test the Aquifer Model**

1. Slowly pour approximately 200 milliliters of water into the aquifer model to saturate the gravel layers. Add enough water so the pond fills with water.
2. Place the bottle pump in the well and pump 50-100 milliliters of groundwater from the aquifer into the large plastic cup. Observe the water table level in the aquifer model.
3. Recharge the aquifer by pouring the water you pumped out of the aquifer back into the model. Add one drop of food coloring to the pond to represent surface water contamination and repeat Step 2.

C. Graduated cups (30 mL) – 1 per team

C

D. Gravel (large) – shared bag(s)

D

E. Gravel (small) – shared bag(s)

E

F. Small plastic cups (3.5 oz.) – 1 per team

F

G. Large plastic cups (10 oz.) – 1 per team

G

H. Red food coloring – shared

H

I. Water – teacher provides (not shown)

**Non-Consumable**

J. Graduated cups – 1 per team

J

K. Tubing – 1 per student

K

L. Thumbtacks – 1 per team

L

M. Plastic containers (32 oz) – 1 per team

M

N. Bottle pumps – 1 per team

N

O. Graduated measuring containers – shared

O

P. Aquifers Change Visual – (not shown)
Q. Earth's Water Visual – (not shown)
R. Polluted Aquifers Visual – (not shown)

**Teacher Tool Kit**
S. Invisible tape – 1 per team
T. Scissors – 1 per team
U. Rulers – 1 per team

S

T

U


## <u>Teacher Preparation</u>:

- Download the visuals from the KnowAtom Interactive website.
- Fill several graduated measuring containers with water. Each team will need approximately 200 mL of water for the investigation. Arrange a <u>water collection station</u> for teams to access water with durable graduated cups during the investigation.
- Arrange several pick-up stations for teams to collect materials for use at their desks during the investigation. For example:
    - <u>Pick-up Station 1</u>: large and small gravel samples
    - <u>Pick-up Station 2</u>: plastic containers, small plastic cups, invisible tape, rulers, and tubing
    - <u>Pick-up Station 3</u>: thumbtacks, small graduated cups (30 mL), and scissors
    - <u>Pick-Up Station 4</u>: bottle pumps, large plastic cups, and food coloring

## <u>Student Reading Preparation</u>:

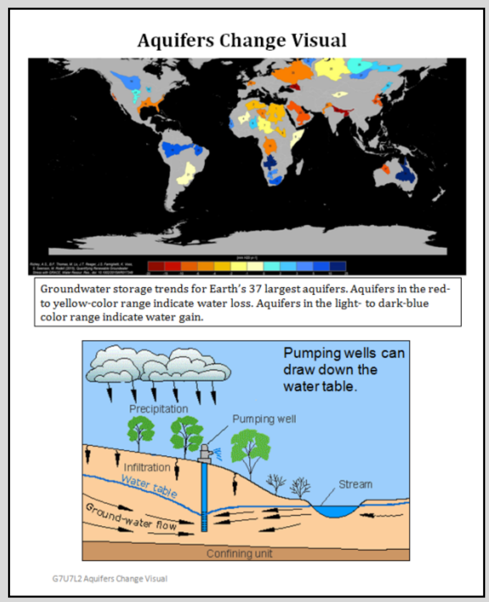
- Students read Section 2 of the student lab manual. In 7th grade, students are expected to come to class having already read the lab manual so they can actively participate in the Socratic dialogue before the lab portion of the lesson. At the beginning of the school year (September-October), the lab manual can be read in class.

- If class time is used to read the lab manual together, model how to read closely for understanding. For example:
    - Emphasize connections between examples in the reading and broader concepts. For example, ask why a certain example was used to support the reading's main point.
    - Use "why" and "how" questions to connect ideas in the reading to student experiences.

**<u>Socratic Dialogue</u>:**

<u>Block 2-1: Water's Role in Human Development</u>

**1.** Display *<u>Aquifers Change Visual</u>*. Continue the dialogue from the last lesson, focusing on how the amount of water is different around the world, from season to season, and from year to year.



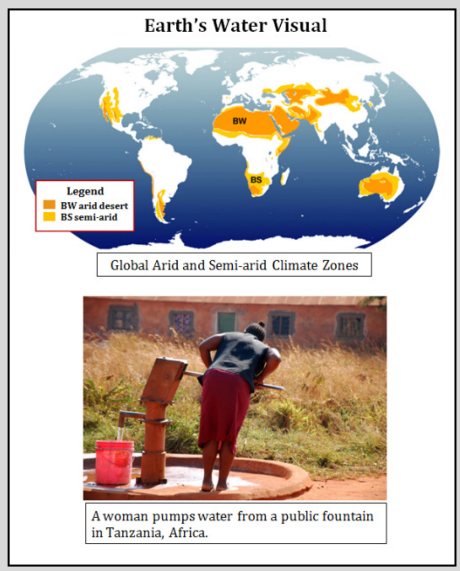

- ☐ **<u>Big Idea 5</u>:** Coach students toward the idea that the amount of water in an aquifer changes over time. For example:
    - *Ask one student what causes an aquifer to recharge. (**Aquifer recharge** happens when water reaches the aquifer to replenish it. This happens when precipitation seeps into the ground (such as from rain or melting snow) and adds water to the aquifer.)*
    - *Ask another student what causes an aquifer to lose water. (**Aquifer discharge** happens when water leaves the aquifer. This can happen when plants absorb some of the groundwater through their roots, or when the groundwater*

*seeps into a spring or river. Aquifer discharge can also happen when people use wells to access groundwater.)*

- *Ask the first student what makes an aquifer naturally balanced. (Aquifers are naturally balanced when the amount of water being added to the aquifer from precipitation is roughly the same as the amount of water leaving the aquifer.)*
- *Ask another student why it can be harmful to withdraw too much water from an aquifer too quickly. (Some aquifers take hundreds or thousands of years to recharge, so when too much water is withdrawn, they will remain dry.)*
- *Ask the first student what the map in the visual shows about the state of many of the aquifers in the world. (Many aquifers around the world are losing water. All aquifers that are in the red- to yellow-color range are losing water, while those in the blue range are gaining water.)*

**2.** Display _Earth's Water Visual_. Continue the dialogue with students about how many of Earth's aquifers are being depleted as human populations continue to grow.




- **Big Idea 6**: Coach students toward the idea that people who live in arid or semi-arid climates depend on the groundwater stored in aquifers. For example:
  - *Ask one student why people who live in arid or semi-arid climates are more likely to access groundwater than people who live in wet climates. (In arid or semi-arid regions, there is very little precipitation to replenish surface water resources such as lakes or rivers. This is why people depend on groundwater to survive.)*

- *Ask another student how wells allow people to reach groundwater. (A well is usually a pipe in the ground that reaches the* ***water table****, the highest point in an aquifer from which water can be obtained. This water can then be brought to the land surface by a pump.)*

Block 2-2: Human Impacts on Aquifers

**1.** Have a dialogue with students about how groundwater is part of the hydrosphere and therefore interacts with other Earth systems.

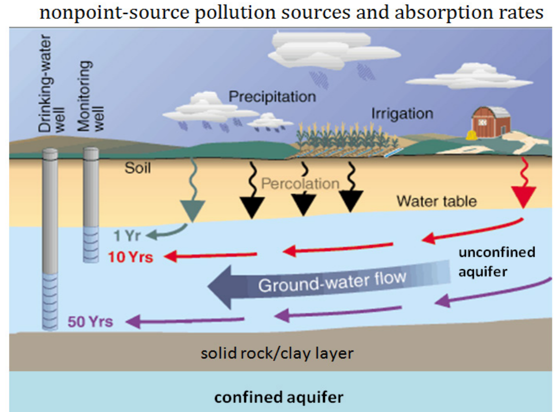
- **Big Idea 7:** Coach students toward the idea that human use of groundwater affects other living things as well. For example:
  - *Ask one student how pumping groundwater out of the ground affects natural ecosystems. (When people pump too much water from an aquifer, there is less water that is discharged to streams. This harms the aquatic habitats of many species, including fish and amphibians that live in streams.)*
  - *Ask another student how human development—specifically the use of materials such as concrete and pavement, influences aquifers. (Many human-made surfaces, such as pavement and concrete, are impermeable. When water falls to the ground, it cannot absorb into pavement or concrete. As a result, it does not reach the aquifers and therefore cannot recharge them.)*
  - *One at a time, provide multiple students with the chance to respond to this question so that students connect what they learned in the last lesson about porosity and permeability with the ability of aquifers to recharge.*

**2.** Display *Polluted Aquifers Visual*. Have a dialogue with students about how aquifers are at risk of becoming polluted. **Water pollution** is the contamination of natural water bodies by substances that harm organisms and the environment, and it can be natural or caused by humans

Polluted Aquifers Visual

nonpoint-source pollution sources and absorption rates




- ☐ **Big Idea 8:** Coach students toward the idea that water pollution is another problem that faces aquifers on Earth. For example:
  - *Ask one student how groundwater can become polluted. (Surface water can become polluted from various sources, including oil, fertilizer, pesticides, and animal waste. As surface water seeps into the ground and becomes part of an aquifer, it can carry these pollutants with it.)*
  - *Ask another student to build on what the first student said, either providing additional details to support their answer or respectfully contradicting it, using evidence to support their answer.*
  - *Ask another student why confined aquifers are less likely to become polluted than unconfined aquifers. (The nonporous material of a confined aquifer acts as a buffer and can prevent or reduce the amount of pollution that reaches the groundwater. In contrast, in an unconfined aquifer, there are no layers of nonporous material between the water level and the ground level. If anything leaks or spills into the soil above the unconfined aquifer, it will seep into and contaminate the water.)*

**<u>Investigation</u>:**

**SAFETY**: Students should wear goggles during this activity.

**1.** Divide students into teams of two. Stand by each materials station to explain how the materials will be used and the amount each team will receive. Teams should go to the stations to pick up materials they will use at their desks.

<u>Pick-Up Station 1</u>:

- gravel (large) – shared bag(s)
- gravel (small) – shared bag(s)

<u>Pick-Up Station 2</u>:

- plastic containers (32 oz) – 1 per team
- small plastic cups (3.5 oz) – 1 per team
- invisible tape – 1 per team
- rulers – 1 per team
- tubing – 1 per team

<u>Pick-Up Station 3</u>:

- thumbtacks – 1 per student
- graduated cups (30-mL) – 1 per team
- scissors – 1 per team

Each team will:

- ☐ Use the "Groundwater Contamination Investigation" to carry out the investigation and explore the focus question: How does surface water contamination affect the purity of an aquifer? Use the materials outlined in the procedure to investigate the question.
- ☐ **Set Up the Aquifer Model:**
  1. Tape the tubing against one side of the plastic container 5 millimeters from the bottom. The tubing represents a well.

2. Add 1.5 centimeters of large gravel to the plastic container, followed by approximately 7 centimeters of small gravel. Mound the small gravel up around the top of the tubing to create a slope inside the container.
3. Use the thumbtack to punch 5-6 holes in the bottom of the 30-mL graduated cup. Cut the cup down to 5 millimeters high and place it in the low area of the gravel-filled plastic container. The cup represents a pond for surface water.

***plastic container with large and small gravel layers***

***plastic container with sloped gravel and pond***

**2.** Teams collect materials from the pick-up stations to set up their aquifer models. Once the aquifers are set up, teams collect materials to test the models.

Pick-Up Station 4:

- bottle pumps – 1 per team
- large plastic cups (10 oz) – 1 per team
- food coloring – shared

Water Collection Station

- water – 200 mL per team

- graduated cups (durable) – 1 per team

Each team will:

- ☐ Test the aquifer model using the procedure detailed on the "Groundwater Contamination Investigation" sheet:
  1. Slowly pour approximately 200 milliliters of water into the aquifer model to saturate the gravel layers. Add enough water so the pond fills with water.
  2. Place the bottle pump in the well and pump 50-100 milliliters of groundwater from the aquifer into the large plastic cup. Observe the water table level in the aquifer model.
  3. Recharge the aquifer by pouring the water you pumped out of the aquifer back into the model. Add one drop of food coloring to the pond to represent surface water contamination and repeat Step 2.

***pumping water from the aquifer model***

***surface water contamination in pond***

- ☐ **Diagram and Analyze the Aquifer Model**
  1. Diagram your aquifer model. Label the key parts of the model. Use arrows to show the flow of water in the model.

2. How did the surface water contamination affect the purity of the aquifer? Use your observations when testing the model to answer the question.

**3.** Teams collect materials from the pick-up stations to test their aquifer models. Circulate throughout the class to ask questions to gauge student thinking as they test their models.

**Wrap-Up**:

**1.** Begin a dialogue with students to review the results of the investigation and how students used their results to answer the focus question. For example:

- Ask one student how they observed surface water contamination affecting the purity of the aquifer (Question 1). [*When surface water becomes polluted, it carries those contaminants with it as it seeps into the ground. This is because surface water is connected to groundwater as it seeps into the aquifer.*]
- Ask another student if there was anything that surprised them in their observations. [*Answers will vary, but students may be surprised at how long it takes for the well water to become contaminated.*]
- Ask the first student how the water table and aquifer were affected when the well discharged water. [*When the well discharged water, the water table lowered because water was removed from the aquifer.*]

**2.** Continue the dialogue with students to review how human development impacts Earth's systems. For example:

- Ask one student how this activity demonstrated the interconnectedness of water on Earth's surface. [*Surface water and groundwater are connected. Aquifers can be recharged when surface water seeps into the ground and reaches the aquifer.*

*Water that is discharged from an aquifer can also affect surface water by reducing those levels.*]

- Ask another student why it took some time for the surface water pollution to reach the groundwater. [*The polluted surface water had to work its way through the pores of the aquifer.*]

Name: ______________________________ Date: ____________

# Groundwater Contamination Investigation

## Introduction

How does surface water contamination affect the purity of an aquifer? Use the materials outlined in the procedure to investigate the question.

## Set Up the Aquifer Model

1. Tape the tubing against one side of the plastic container 5 millimeters from the bottom. The tubing represents a well.
2. Add 1.5 centimeters of large gravel to the plastic container, followed by approximately 7 centimeters of small gravel. Mound the small gravel up around the top of the tubing to create a slope inside the container.
3. Use the thumbtack to punch 5-6 holes in the bottom of the 30-mL graduated cup. Cut the cup down to 5 millimeters high and place it in the low area of the gravel-filled plastic container. The cup represents a pond for surface water.

## Test the Aquifer Model

1. Slowly pour approximately 200 milliliters of water into the aquifer model to saturate the gravel layers. Add enough water so the pond fills with water.
2. Place the bottle pump in the well and pump 50-100 milliliters of groundwater from the aquifer into the large plastic cup. Observe the water table level in the aquifer model.
3. Recharge the aquifer by pouring the water you pumped out of the aquifer back into the model. Add one drop of food coloring to the pond to represent surface water contamination and repeat Step 2.

**Diagram and Analyze the Aquifer Model**

Diagram your aquifer model in the space below. Label the key parts of the model. Use arrows to show the flow of water in the model.

**1.** How did the surface water contamination affect the purity of the aquifer? Use your observations when testing the model to answer the question.

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

## Lesson 3: Engineering Water Filters

**Objective**: Students solve the problem of aquifer contamination by engineering a water filtration device to treat samples of simulated polluted stormwater runoff.

**Materials**:

**Consumable**

A. Goggles – 1 per student
B. Lab notebooks –1 per student
C. Graduated cups (30 mL) – 1 per team
D. Small plastic cups (3.5 oz) – 1 per team
E. Burlap – shared roll
F. Plastic spoons – 1 per team
G. Cotton balls – 20 per team
H. Coffee filters – 6 per team
I. Felt – 1 per team
J. Nylon – 3 per team
K. Gravel (large) – shared bag
L. Water – 180 mL per team (not shown)
M. Soil – teacher use*
N. Sand – teacher use *
O. Baby oil – teacher use
P. Corn starch – teacher use

**Non-Consumable**

Q. Containers with hole (no covers) – 1 per team

A

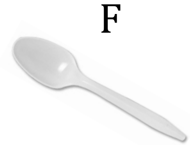

B



C


D


E


F


G


H


I


J


K


M


N


O


P


Q


*Use the leftover soil and sand samples from Lesson 1.

R. Graduated measuring containers
– shared
S. Test tubes (with covers)
– 1 per team + 4 per teacher
T. Graduated cups – 1 per team
U. Water Filtration Visual
– (not shown)
V . Engineering Scenario Visual
– (not shown)

**Teacher Tool Kit**
W. Scissors – 1 per team

R

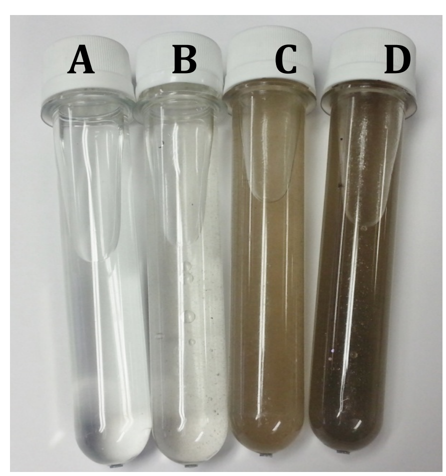
S

T

W

**<u>Teacher Preparation</u>:**

- Download the visuals from the KnowAtom Interactive website.
- To save time, prepare photocopies of the Materials Survey Chart and the Blank Data Table for each student using the copy masters on pages 76-77.
- <u>Prepare the polluted water for the lab</u>: Fill 1-3 graduated measuring containers with water (enough for ~180 mL per team). Add 1-2 spoonfuls of soil, sand, corn starch to the water so it becomes murky. Add up to 5 drops of baby oil to the water. Stir the mixture to combine the materials. Use the leftover soil and sand samples from Lesson 1 to make this water.
- <u>Prepare the water quality standards test tubes for the lab using a plastic cup and one of the containers with hole</u>:
    1. Label test tube covers with separate letters “A,” “B,” “C,” or “D.”
    2. Fill test tube A with plain water.
    3. Fill test tube B with polluted water filtered through <u>one</u> coffee filter.
    4. Fill test tube C with polluted water filtered through <u>one</u> nylon.



5. Fill test tube D with polluted water filtered through ~1 cm of gravel.

Rinse and return the plastic cup and container with hole used to create the test tubes for students to use during the lab. Students will use the prepared test tubes as a quality standard comparison for grading the purity of their filtered water. If you teach multiple class sections, the test tubes can be prepared once and reused. Students will need to shake the prepared test tubes when making comparisons as the sediments will settle in the test tubes.

- Arrange several pick-up stations for students to collect materials to complete the materials survey step of the lab. For example:
  - Pick-Up Station 1: plastic bottles, test tubes (with covers), plastic spoons, small plastic cups (3.5 oz), and small graduated cups (30 mL)
  - Pick-Up Station 2: containers with hole, cotton balls, felt, nylon, coffee filters, gravel, and burlap
  - Pick-Up Station 3: prepared polluted water (in grad. measuring containers) and graduated cups

**Socratic Dialogue:**

Block 3: Solving the Problem of Polluted Water

**1.** Continue the dialogue from the last lesson, connecting the pollution that can occur in aquifers with people's need for clean water, and engineering.

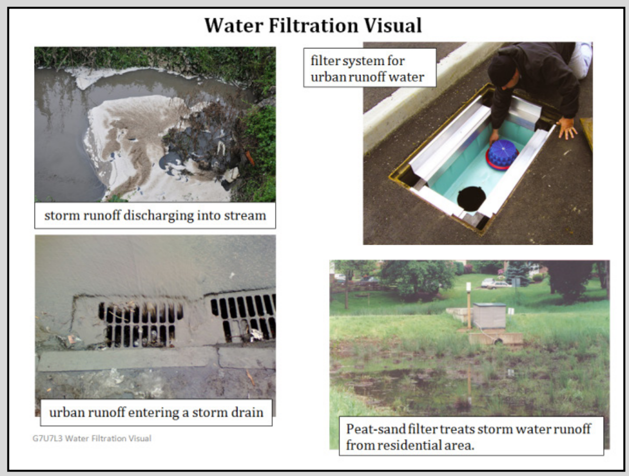
- **Big Idea 9:** Coach students toward the idea that according to some estimates, more than 1 billion people are affected by polluted water. For example:
  - *Ask one student to review how an aquifer can become polluted, using what they learned in the investigation from the last lesson. (Aquifers can become polluted when surface water becomes polluted. There are many ways that surface water can become polluted, either by point-source pollution*

*(pollution that occurs from a single source) or nonpoint-source pollution (pollution that comes from many sources over a wide land area). Over time, that polluted surface water can seep into the ground and contaminate the groundwater.)*

- *Ask another student to build on what the first student said, providing additional details to support their answer or respectfully contradicting it.*
- *Ask the first student why polluted groundwater is a problem that faces people. (Many people depend on clean groundwater for drinking water. When it becomes polluted, they cannot drink it safely.)*

**2.** Display <u>*Water Filtration Visual*</u>. Have a dialogue with students about how **filtration** is the process of separating solid matter from a fluid by having the fluid pass through the pores of another substance, called a filter.




☐ **<u>Big Idea 10</u>:** Coach students toward the idea that engineers can use what they know about Earth's water, aquifers, and pollution to design solutions that solve the problem of polluted water. For example:

- *Ask one student how engineers can address the growing problem of water pollution. (Engineers can design different technologies that can clean already-polluted water.)*
- *Ask another student why engineers who are trying to solve the problem of polluted water might research the properties of an aquifer. (Surface water becomes polluted more easily than groundwater, which is held in aquifers. The particles of rock that make up aquifers act as a natural filter as water moves through the layers of materials. As water moves from Earth's surface underground, it is filtered, becoming purer. By*

*the time water has moved through the aquifer, many pollutants have been removed.)*

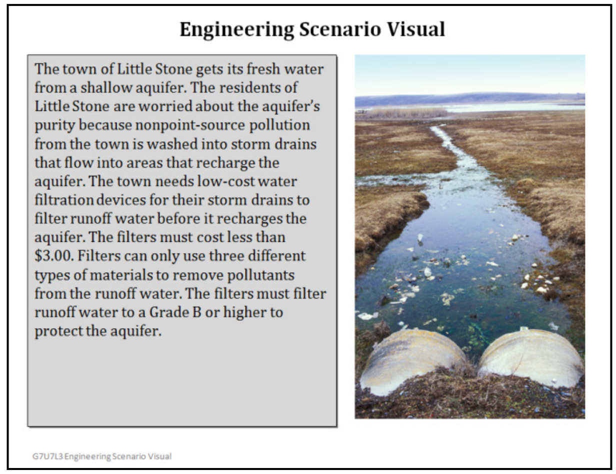
- *Ask the first student how this supports the argument that aquifers provide an ecosystem service. (An **ecosystem service** refers to the positive benefits that an ecosystem provides to people. Water purification is a positive benefit, which is why aquifers provide an ecosystem service.)*
- *Ask another student how engineers can apply what they know about aquifers to help them design a solution to water pollution. (Engineers sometimes design technologies that mimic the structure of an aquifer, using layers of different Earth materials that can filter polluted water as it moves through, straining out the pollutants.)*
- *Ask the first student what kinds of materials scientists could use to help them mimic an aquifer. (The smaller a material's pore size is, the purer the water will be because everything that cannot fit through the pores will be filtered out.)*
- *Ask another student why the speed that water can move through the materials needs to be considered. (In some aquifers, water moves so slowly that it can take hundreds of years for water to work its way through. This isn't practical for an engineering solution, so any filtration technology would need to balance the need to filter out pollutants with the need for the water to move through it.)*
- *One at a time, provide multiple students with the chance to respond to this question. There is no "right" answer, but students should be thinking about what scientific knowledge could help them solve the problem of water pollution.*

## <u>Engineering Lab 9</u> – Engineering Water Filters

**SAFETY**: Students should wear goggles during this activity.

### Engineering Scenario




Display the *<u>Engineering Scenario Visual</u>*. Read the engineering scenario with the class and be prepared to show them the different grades of water quality using the prepared water quality test tubes at the end. The visual can also be printed for each student, if needed. "The town of Little Stone gets its fresh water from a shallow aquifer. The residents of Little Stone are worried about the aquifer's purity because nonpoint-source pollution from the town is washed into storm drains that flow into areas that recharge the aquifer. The town needs low-cost water filtration devices for their storm drains to filter runoff water before it recharges the aquifer. The filters must cost less than $3.00. Filters can only use three different types of materials to remove pollutants from the runoff water. The filters must filter runoff water to a Grade B or higher to protect the aquifer."

### Problem

Divide students into teams of two. Students collect their lab notebooks to begin a new lab entry. Students summarize the problem presented in the engineering scenario in their lab notebooks, based on what they learned from the scenario. As part of their summary of the problem, students define the criteria (the needs or requirements the solution must meet) and constraints (ways the solution is limited) in their own words. It's important for students to be able to identify this information from the scenario so they know what their prototype needs to accomplish and the limitations they need to consider. For example:

<u>Problem:</u>

- *The residents of Little Stone are worried about the purity of the aquifer the town uses for drinking water because nonpoint-source pollution from the town washes into storm drains that flow into areas that eventually recharge the aquifer.*

<u>Criteria:</u>

- *The town needs low-cost water filtration devices for their storm drains to filter runoff water.*
- *The filters must filter runoff water to a Grade B or higher.*

<u>Constraints:</u>

- *The filters can only use three different types of materials to remove pollutants from the runoff water.*
- *Each filter must cost less than $3.00.*

When teams are finished recording the problem, including its criteria and constraints, have students briefly share what they recorded with the class to clear up any misunderstandings related to the specific criteria and constraints they identified in the scenario. When complete, students create a new title for the engineering lab that is relevant to the problem. In this example, a relevant title would be "Engineering Water Filters" or "Engineering Storm Drain Filters" but other titles can be used as well.

**NOTE:** When students are finished summarizing the problem, display the *<u>Engineering Process Visual</u>* in place of the *<u>Engineering Scenario Visual</u>* to help guide them through the lab process. The *<u>Who is an Engineer</u>* poster can also be used as a guide.

**Research**

For research, students use information from their lab manuals and/or dialogue to list up to three facts relevant to the problem. For example:

- *Nonpoint-source pollution is discharged over a wide land area and comes from many different sources and locations.*
- *Examples of nonpoint-source pollution include fertilizers and pesticides, oil from vehicles, and animal waste.*
- *Porous materials can filter water. Materials with small pores can trap particles when water filters through them.*

**Survey Available Materials**

As a class, survey the available materials. Stand by the pick-up stations and explain that each team will have access to the following materials for building the prototypes:

- 20 cotton balls
- 6 coffee filters
- 3 nylons
- 1 small cupful of gravel
- 1 felt sheet (1 foot/30 cm per team)
- 1 piece of burlap

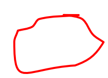
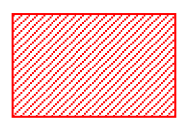
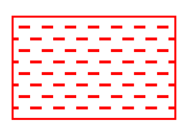
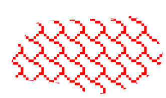
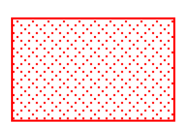
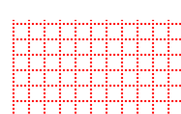
Teams will also have access to the following tools and testing materials for assembling and testing their prototypes. These items are not included in the materials survey chart:

- 1 container with hole
- 1 plastic spoon
- 1 small plastic cup (3.5 oz)
- 1 graduated cup (30 mL)
- 1 test tube with cover
- 1 graduated cup (durable)
- 1 pair of scissors
- 180 mL of contaminated water (prepared by teacher)

Students collect prototype materials (or a sample of each prototype material) from the pick-up stations according to the materials listed on their materials survey chart. Tools and testing materials are not included in the survey chart. Photocopy and distribute blank survey charts to save time. The name, cost, and quantity of each material are pre-filled in the survey chart. Students record:

- sketch of each material
- description of what each material is made from
- 1-2 useful physical properties of each material given the context of the problem (e.g., shape, porosity, thickness, flexibility, relative weight, or any other relevant property you notice)

**Materials Survey Chart**

| **Name** | **Cost** (per item) | **Quantity** | **Sketch** | **Made From** | **Properties** |
|---|---|---|---|---|---|
| cotton balls | $.12 | 20 |  | cotton | small pores and thick |
| coffee filter | $.25 | 6 |  | paper | small pores and thin |
| nylons | $.15 | 3 |  | nylon | medium pores and thin |
| gravel | $.15 per cupful | 1 small cupful |  | rocks | large pores |
| felt | $1.50 | 1 |  | fabric | medium pores and thick |
| burlap | $.50 | 1 piece |  | plant fibers | large pores and thin |

**<u>Checkpoint #1</u>: After Problem, Research, and Materials Survey**
As teams are ready, they should check in with the teacher to review their problem, research, and materials survey. Do the lab notebooks of both team members match and meet expectations? Can both students within the team describe the criteria and constraints of the problem? Are the research questions relevant to the problem? Are the properties of the materials included in the survey chart? If not, ask for areas of clarification or correction before they advance further. Not all teams will arrive at the lab check-points at the same time, so teams independently receive the go-ahead to move on in their lab after they have made the necessary modifications. <u>Student lab notebook entries within the class will have the same problem, but variations from team to team in the remaining steps of the process are expected and encouraged</u>.

**Possible solutions**
Students use what they know about the criteria and constraints of the problem, as well as their research, to list at least three possible solutions to the problem, given the available materials. Point out that the container with a hole will be used to replicate a storm drain. Prototype filter materials should be tested in the container. Students identify three different ways an engineer could design effective, low-cost filtration devices that filter the pollution from runoff water to a Grade B or higher. Teams can share their ideas with the class. Teams independently choose which of their ideas would have the greatest likelihood of success as their solution before proceeding. Examples solutions include:

- Design a water filtration device with three different materials, each with a small pore size.
- Design a water filtration device with three different materials layered by decreasing pore size: large, medium, then small.

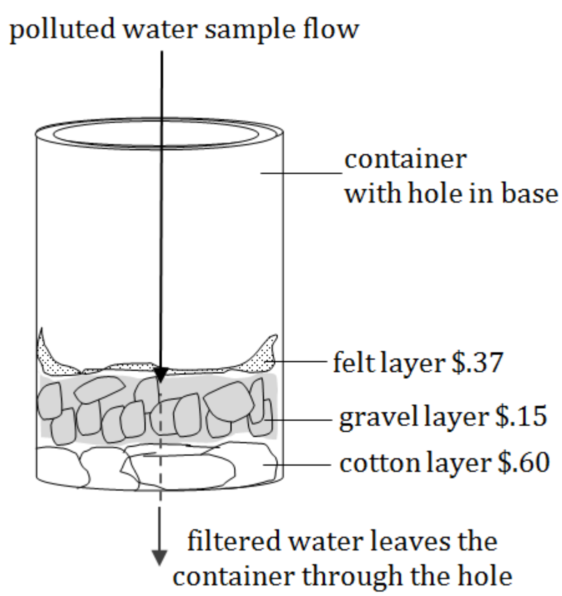
 

- Design a water filtration device with three different materials, two layers with medium pore size, and one with a small pore size.

**Checkpoint #2: After Possible Solutions**
As teams are ready, they should check in with the teacher to review the possible solutions for the problem. Do the lab notebooks of each team member match and meet expectations? Can students explain their reasoning for the possible solution they chose given the available materials? If not, ask for areas of clarification or correction before they advance further.

**Diagram and build prototype**
Students draw a scientific diagram of their prototype filter. All diagrams should be titled and include labels of materials used, along with their cost. Students follow their prototype diagram when building.

**Water Filter Prototype 1 Diagram** (example)



**NOTE**: It is recommended that student reserve an extra page in their lab notebooks for the prototype diagrams. Additional space will be needed as students modify or redraw the diagrams to incorporate improvements for each prototype. It may be helpful to remind teams that they do not have to use every available material. If teams cut materials (such as the felt, coffee filters, nylon, or burlap) to conserve, this will decrease the cost of that material accordingly. All water filters should be assembled inside the plastic container with hole.

**Checkpoint #3: After Diagram (Before Materials Are Collected to Build)**
As teams are ready, they should check in with the teacher to review their prototype diagram before accessing materials to build. Are the diagrams complete? Diagrams should be titled and materials labeled. Can you understand the diagram? Could you follow it to build the prototype? If not, clarify expectations. Students make corrections or any modifications and return to the checkpoint for the go-ahead. After meeting this checkpoint, students collect the materials they need and then build their prototype based on their diagram.

### Test
Teams test their prototypes using the prepared polluted water when their prototype is complete. Teams develop a simple test procedure for their water filter. An example test procedure is shown below:

1. Slowly pour 60 milliliters of polluted water into the prototype filter. Hold the prototype filter over the small plastic cup to collect the filtered water.

2. Transfer some of the filtered water to an empty test tube. Compare the water quality of the filtered water to the water quality in the prepared standard test tubes A-D.
3. Discard used filter materials and filtered water.
4. Repeat steps 1-3 with prototypes 2-3.

**<u>Checkpoint #4</u>: After Test Procedure**
As teams are ready, they should check in with the teacher to review their prototype test procedure. Can you follow each team's test procedure? Is it clear, concise, and specific? Will it test the prototype to see how well it solves the problem? If not, clarify expectations. Students make corrections or any modifications and return to the checkpoint for the go-ahead. Students pick up blank data tables and graphs (if applicable) to tape inside their notebooks at this checkpoint.

**Data**
Students record data for each prototype tested. Photocopy and distribute blank data tables to save time.

| **Table 1: Comparing Filter Prototypes** | | |
|---|---|---|
| **Prototype 1** | | |
| **Cost** | **Water Quality (A, B, C, or D)** | **Materials and Observations** |
| 1.12 | C | This prototype had small-, medium-, and large-pore materials arranged from large pore size to small inside the container. The filter did not trap oil and sediments. |

| Prototype 2 | | |
|---|---|---|
| **Cost** | **Water Quality (A, B, C, or D)** | **Materials and Observations** |
| 1.92 | C | The prototype had two large- and one medium-pore materials. The medium-pore material was at the top of the filter and large-pore materials were at the bottom. There was no improvement in water quality. |

| Prototype 3 | | |
|---|---|---|
| **Cost** | **Water Quality (A, B, C, or D)** | **Materials and Observations** |
| 2.35 | B | The prototype had two thick, small-pore materials, and one thin, large-pore material. The large-pore material was placed on top of the smaller-pore materials. The water quality improved. |

**NOTE:** Example data represent one possible outcome. Team Data will vary.

**Refine or replicate**

Teams use the data and observations from their first prototype filter to design successive prototypes with modifications and improvements to better meet the criteria of the problem, given the constraints. Teams can test and record results for up to three different prototypes. Teams can collaborate with other teams to share ideas if needed and revise their first prototype diagram to make the necessary changes. Students use their new diagram as a guide for building their second prototype and repeat this process with their third prototype.

When the prototype testing is complete, students should be prepared to explain how well their prototype solution solved the problem, given the criteria and constraints. This should include how their modifications positively or negatively affected their prototype's ability to filter pollutants out of the water at a low cost. This should be supported with data (evidence) from their data table.

If students have trouble evaluating their data to determine whether or not they would refine or replicate any of their prototype solutions, students can use a decision matrix to help them analyze their data. A decision matrix can be useful for making a choice when many factors are involved. For example:

| **Decision Matrix** | | | |
|---|---|---|---|
| | Is the filtered water B-grade or higher? (yes or no) | Is the cost less than $3? (yes or no) | Does the filter use only three types of materials? (yes or no) |
| **Prototype 1** | no | yes | yes |
| **Prototype 2** | no | yes | yes |
| **Prototype 3** | yes | yes | yes |

The information should then be used to explain if students would refine or replicate any of their prototype solutions based on the data.

For example: "We successfully engineered a prototype water filter device for the town of Little Stone to use in their storm drains. Our first two prototypes produced C-grade water quality. These prototypes had large- and medium-pore materials. These materials kept the cost low but they did not filter enough pollutants from the water. To improve the water quality in our final prototype design and to keep the cost under $3.00, we layered one large-pore material on top of two thick layers of small-pore materials in the filter. This filter design produced B-quality water. Based on our test data and filter design, we would recommend that Little Stone replicate our third prototype for the town's storm drains because it met the criteria given the constraints of the problem and the available materials."

**<u>Final Checkpoint</u>: After Data and Refine or Replicate**
As teams are ready, they should check in with the teacher to review the data and refine or replicate steps of their lab. One team member reads the team's refine or replicate conclusion aloud to you while you review the other team member's lab notebook. Do they restate the problem and describe the prototype technology? Did they make a claim about whether the technology should be refined or replicated? Look for key data points that students gathered from their test data to support their recommendation to refine or replicate. Is it clear? Is it persuasive? Do the data support the claim?

**<u>Wrap-Up</u>:**

**1.** Have a dialogue with students to review their engineering prototype results. For example:

- Ask a student from one team to present their prototype and conclusion to the class, describing how well their prototype met the criteria of the problem within the constraints. If students encountered any challenges, they should describe those challenges and how they addressed them.
- Ask a student from another team to describe how they went about solving the problem and addressing any challenges.
- Ask the first student how the need to factor in cost impacted their prototype. [*Answers may vary, but students would have had to take into account both the physical properties of the materials and their cost when designing their prototype. Students may have started out using the cheapest materials they could, but then discovered their prototype didn't effectively filter out the pollutants. Or students may have originally not paid attention to*

*cost and then realized their prototype was too expensive, failing to meet the constraints of the problem.*]
- Ask a student from another team why it was important to think about a material's porosity and permeability. [*The smaller the pore size is, the purer the water will be because everything that cannot fit through the pores will be filtered out. However, water flows more quickly through larger pore sizes, so any filtration technology would need to balance the need to filter out pollutants with the need for the water to move through it.*]

**2.** Continue the dialogue with students, reviewing how engineers can design solutions that help to maintain ecosystem services. For example:
- Ask one student why water filtration is an ecosystem service. [*It is a benefit to people because clean water is essential for all living things.*]
- Ask another student how they used scientific knowledge about the natural world to design their water filtration prototype. [*Answers will vary, but students have already worked through the scientific experiment into the porosity and permeability of different Earth materials to see how well water moves through them. They also observed how groundwater can become contaminated with pollutants.*]
- One at a time, provide multiple students with the chance to respond to this question.

# **Unit 7: Lesson 3** – Sample Laboratory Notebook

This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

Page

Engineering Water Filters, Date, Partner Name

## Lab #9: Engineering Water Filters

**Problem**: The residents of Little Stone are worried about the purity of the aquifer the town uses for drinking water because nonpoint-source pollution from the town washes into storm drains that flow into areas that eventually recharge the aquifer.

Criteria:

- The town needs lost-cost water filtration devices for their storm drains to filter runoff water.
- The filters must filter runoff water to a Grade B or higher.

Constraints:

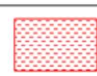
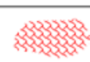
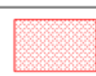
- The filters can only use three different types of materials to remove pollutants from the runoff water.
- Each filter must cost less than $3.00.

**Research**:

- Nonpoint-source pollution is a type of pollution discharged over a wide land area and comes from many different sources and locations.
- Examples of nonpoint-source pollution include fertilizers and pesticides, oil from vehicles, and animal waste.
- Porous materials can filter water through them. Materials with small pores can trap particles when water filters through them.

**Survey Available Materials**:

Materials Survey Chart

| Name | Cost (per item) | Quantity | Sketch | Made From | Properties |
|---|---|---|---|---|---|
| cotton balls | $.12 | 20 |  | cotton | small pores and thick |
| coffee filter | $.25 | 6 |  | paper | small pores and thin |
| nylons | $.15 | 3 |  | nylon | medium pores and thin |
| gravel | $.15 per cupful | 1 small cupful |  | rocks | large pores |
| felt | $1.50 | 1 |  | fabric | medium pores and thick |
| burlap | $.50 | 1 piece |  | plant fibers | large pores and thin |

# **Unit 7: Lesson 3** – Sample Laboratory Notebook

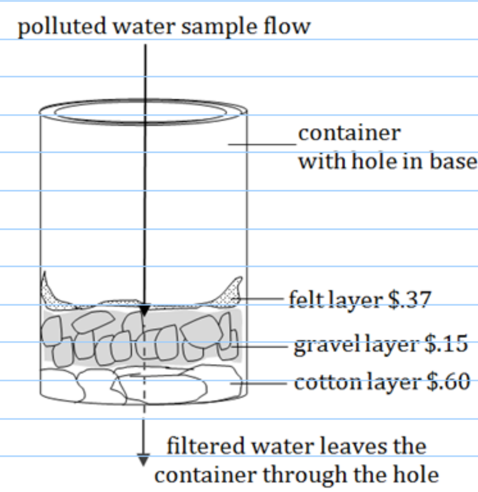
This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

**Possible Solutions**:

- Design a water filtration device with three different materials, each with a small pore size.
- Design a water filtration device with three different materials layered by decreasing pore size: large, medium, then small.
- Design a water filtration device with three different materials, two layers with medium pore size, and one with a small pore size.

**Diagram and Build Prototype**:

Water Filter Prototype 1 Diagram




**Test**:

1. Slowly pour 60 milliliters of polluted water into the prototype filter. Hold the prototype filter over the small plastic cup to collect the filtered water.
2. Transfer the filtered water to an empty test tube. Compare the water quality of the filtered water to the water quality in the standard test tubes A-D.
3. Discard the used filter materials and filtered water.
4. Repeat steps 1-3 with prototypes 2-3.

# **Unit 7: Lesson 3** – Sample Laboratory Notebook

This complete lab notebook entry is intended to be used as an exemplar for teacher use only. It is not intended for student use.

**Data:**

Table 1: Comparing Filter Prototypes

| Cost | Water Quality (A, B, C, or D) | Materials and Observations |
|---|---|---|
| **Prototype 1** | | |
| 1.12 | C | This prototype had small-, medium-, and large-pore materials arranged from large pore size to small inside the container. The filter did not trap oil and sediments. |
| **Prototype 2** | | |
| **Cost** | **Water Quality (A, B, C, or D)** | **Materials and Observations** |
| 1.92 | C | The prototype had two large- and one medium-pore materials. The medium-pore material was at the top of the filter and large-pore materials were at the bottom. There was no improvement in water quality. |
| **Prototype 3** | | |
| **Cost** | **Water Quality (A, B, C, or D)** | **Materials and Observations** |
| 2.35 | B | The prototype had two thick, small-pore materials, and one thin, large-pore material. The large-pore material was placed on top of the smaller-pore materials. The water quality improved. |

**Refine or Replicate:** We successfully engineered a prototype water filter device for the town of Little Stone to use in their storm drains. Our first two prototypes produced C-grade water quality. These prototypes had large- and medium-pore materials. These materials kept the cost low but they did not filter enough pollutants from the water. To improve the water quality in our final prototype design and to keep the cost under $3.00, we layered one large-pore material on top of two thick layers of small-pore materials in the filter. This filter design produced B-quality water. Based on our test data and filter design, we would recommend that Little Stone replicate our third prototype for the town's storm drains become it met the criteria given the constraints of the problem and the available materials.

**Unit 7: Lesson 3** – Blank Survey Chart

| Materials Survey Chart | | | | | |
|---|---|---|---|---|---|
| **Name** | **Cost** (per item) | **Quantity** | **Sketch** | **Made From** | **Properties** |
| cotton balls | $.12 | 20 | | | |
| coffee filter | $.25 | 6 | | | |
| nylons | $.15 | 3 | | | |
| gravel | $.15 per cupful | 1 small cupful | | | |
| felt | $1.50 | 1 | | | |
| burlap | $.50 | 1 piece | | | |

**<u>Unit 7: Lesson 3</u>** – Blank Data Table and Decision Matrix (optional)

| **Table 1: Comparing Filter Prototypes** | | |
|---|---|---|
| **Prototype 1** | | |
| **Cost** | **Water Quality (A, B, C, or D)** | **Materials and Observations** |
| | | |
| **Prototype 2** | | |
| **Cost** | **Water Quality (A, B, C, or D)** | **Materials and Observations** |
| | | |
| **Prototype 3** | | |
| **Cost** | **Water Quality (A, B, C, or D)** | **Materials and Observations** |
| | | |

## **Unit 7: Lesson 3** –Decision Matrix (optional)

| **Decision Matrix** | | | |
|---|---|---|---|
| | Is the filtered water B-grade or higher? (yes or no) | Is the cost less than $3? (yes or no) | Does the filter use only three types of materials? (yes or no) |
| **Prototype 1** | | | |
| **Prototype 2** | | | |
| **Prototype 3** | | | |

Name: ______________________________________________ Date: ________________

# Unit 7: Environmental Science

**Vocabulary Check**

**Part I:** Circle the best answer for questions 1-4 below.

**1.** Waste and gasoline runoff are both examples of ____________________ because they contaminate natural water bodies and can harm organisms and the environment.

A. water table B. aquifer discharge

C. water pollution D. aquifer recharge

**2.** Water filtration is an example of a(n) _______________________________ because it is a positive benefit that an ecosystem provides to people.

A. aquifer recharge B. nonpoint-source pollution

C. point-source pollution D. ecosystem service

**3.** ___________________________ helps to explain why sinkholes form because it is the study of geology focused on the distribution and movement of groundwater in the soil and rocks of Earth's crust.

A. Hydrogeology B. Geosphere

C. Hydrosphere D. Biosphere

**4.** A leak in an underground storage tank is an example of _________________________________ because it can be traced back to a single identifying incident.

A. nonpoint-source pollution B. point-source pollution

C. aquifer discharge D. aquifer recharge

**Part II:** Write the answers to questions 5-7 below.

**5**. How do **aquifers** provide an **ecosystem service**?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**6**. Why is **groundwater** important for human development?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**7**. How do humans contribute to **aquifer discharge**?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

Name: ________________________________________ Date: _______________

# Unit 7: Environmental Science

## Concept Check

**Part I:** Circle the best answer to each question.

**1.** Oysters are filter feeders. This means they strain nutrients, such as algae, from the water. As they feed, they also strain out pollutants. The result is that oysters help to make the water cleaner.

Which statement is **best** supported by the information provided above?

A. Oysters provide an ecosystem service by adding pollutants to the water, making it less clean.
B. Oysters provide an ecosystem service by filtering the water, making it cleaner.
C. Oysters damage ecosystems by straining water and eating algae and pollutants.
D. none of the above

**2.** In many parts of the world, oysters are disappearing. This disappearance has several causes, including water pollution, climate change, and overfishing by humans. As a result, many bodies of water are more polluted.

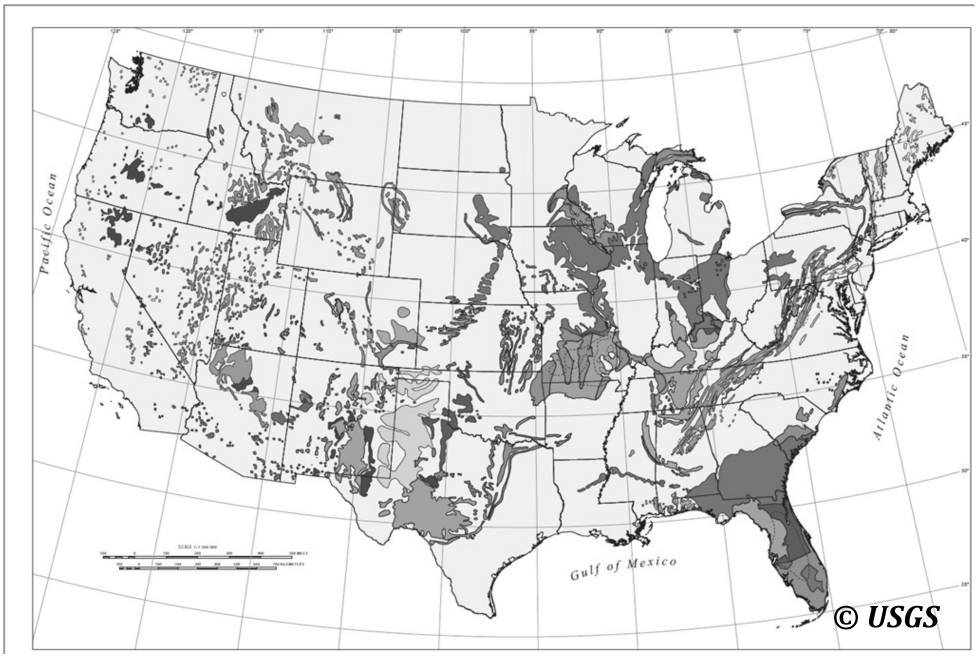
What is one way an engineer might solve this problem of water pollution?

A. The engineer could design a water filtration device to purify the water.
B. The engineer could conduct an experiment to answer the question of why oysters are disappearing.
C. The engineer could write a book that communicates with people about ways to purify the water.
D. none of the above

**Part II:** Use the space below the question for your answer.

**3.** The map below shows the distribution of different kinds of rocks that are easily dissolved by water and therefore prone to the formation of sinkholes.




***The dark-colored areas of the map show different kinds of rock that are easily dissolved by water.***

**3a.** How does the map support the argument that Florida is particularly prone to sinkholes?

______________________________________________

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______________________________________________

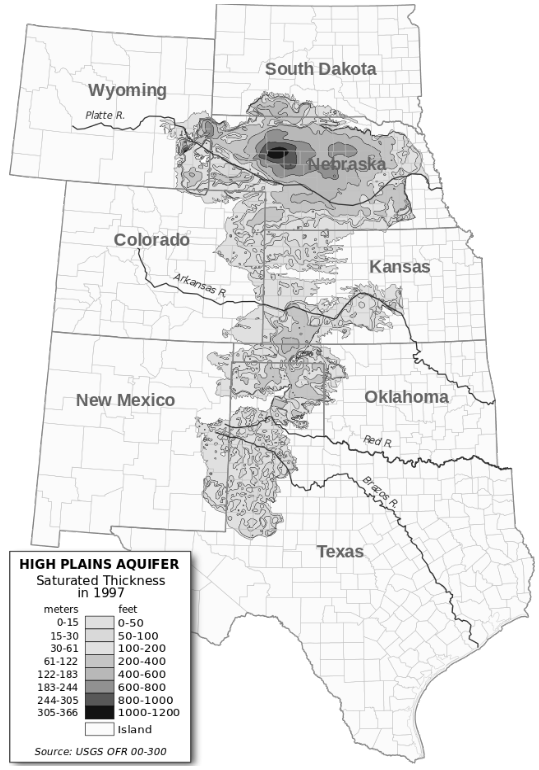
 

**3b.** Geologists in Florida are developing a map that shows where sinkholes could occur. The geologists began by marking where all existing sinkholes exist across the state. They have also used tools including photos from the air and historic maps. They hope that the map will allow them to analyze where a sinkhole might occur in the future.

Why is it important for people to be able to predict where a sinkhole might occur?

**4.** The largest aquifer in North America is called the Ogallala Aquifer or the High Plains Aquifer. It lies underneath seven western states: Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming.




The states above the aquifer grow large amounts of corn, wheat, and soybeans. Many of these states have a semi-arid climate, receiving little precipitation throughout the year.

**4a.** What is the **most likely** source of the water needed to grow crops in these states?

____________________________________________________________

____________________________________________________________

**4b.** In many locations, the Ogallala Aquifer is separated from the surface with a layer of almost completely impermeable rock. How might this rock layer make it more difficult to recharge the aquifer from precipitation?

____________________________________________________________

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**4c.** Using what you know about the Ogallala Aquifer, along with how aquifers become recharged or discharged, why do you think the Ogallala Aquifer is becoming depleted (losing more water than it gains)?

______________________________________________________

______________________________________________________

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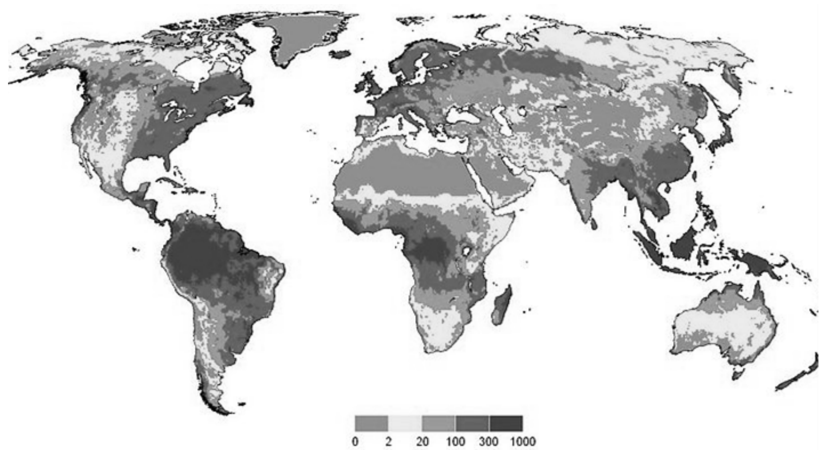
**5.** The map to the right shows groundwater resources around the world. The darkest areas show aquifers with large amounts of water. The lightest areas show aquifers with low amounts of water.




**5a.** How does the map support the argument that Earth's groundwater isn't evenly distributed around the planet?

______________________________________________________

______________________________________________________

______________________________________________________

**5b.** What factors might contribute to aquifers with large amounts of stored groundwater?

**5c.** What factors might contribute to aquifers with low amounts of stored groundwater?

**5d.** Aquifer depletion is a problem facing many regions around the world. This problem has many effects because many people depend on groundwater for clean drinking water, for watering crops and livestock for food, and many other applications.

How can people use engineering to mitigate (lessen) the harmful effects of aquifer depletion?

____________________________________________________________

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## Unit 7: Appendix 1
## Answer Keys

### Vocabulary Check

### Part I

1. C. water pollution [Waste and gasoline runoff are both examples of water pollution because they contaminate natural water bodies and can harm organisms and the environment. The water table is the highest point in an aquifer from which water can be obtained. Aquifer discharge refers to whenever water leaves an aquifer, while aquifer recharge refers to whenever water seeps into the ground and replenishes the aquifer.]
2. D. ecosystem service [Water filtration is an example of an ecosystem service because it is a positive benefit that an ecosystem provides to people. Aquifer recharge happens when water seeps into the ground and replenishes the aquifer, such as from precipitation. Point-source pollution is a source of pollution that can be traced back to a single identifying incident. Nonpoint-source pollution is discharged over a wide land area and comes from many different sources and locations.]
3. A. Hydrogeology [Hydrogeology helps to explain why sinkholes form because it is the study of geology focused on the distribution and movement of groundwater in the soil and rocks of Earth's crust. The hydrosphere is the Earth system that includes all of the water on the planet. The geosphere is the Earth system that includes the rocks, soil, landforms, and interior of the planet. The biosphere refers to all of the living things on Earth.]
4. B. point-source pollution [A leak in an underground storage tank is an example of point-source pollution because it can be traced back to a single identifying incident. Nonpoint-source pollution is pollution that is discharged over a wide land area and comes from many different sources and locations. Aquifer discharge refers to whenever water leaves an aquifer, while aquifer recharge refers to whenever water seeps into the ground and replenishes the aquifer.]

### Part II

5. [The answer should explain that aquifers are underground layers of rock, sand, or gravel that hold groundwater. They provide an ecosystem service by filtering water. An ecosystem service is the positive benefits that an ecosystem provides to people. Aquifers filter out pollutants as water moves through their layers, making the water cleaner.]

6. [The answer should explain that groundwater is the supply of fresh water found beneath Earth's surface in the pores of soil, sand, and rock. It is important for human development because it is the largest source of easily accessible fresh water, and all people need fresh water for survival.]
7. [Humans contribute to aquifer discharge by drilling wells and removing water from the aquifer. Aquifer discharge is the removal of water from an aquifer.]

**Concept Check**

**Part I**

1. B. Oysters provide an ecosystem service by filtering the water, making it cleaner. [Oysters provide an ecosystem service because filtering water and making it cleaner is a benefit to people. All living things need water to survive, and humans depend on clean, unpolluted water. Adding pollutants to the water, making it less clean isn't an example of an ecosystem service because it's not a benefit to people. Finally, oysters don't damage ecosystems by straining water and eating algae and pollutants.]
2. A. The engineer could design a water filtration device to purify the water. [In response to disappearing oysters, which are resulting in more polluted waters, an engineer could design a water filtration device to purify the water. Engineers solve problems such as polluted water by using scientific knowledge and math to design technologies. Scientists, not engineers, conduct experiments to answer questions. Writing a book that communicates with people about ways to purify water isn't an engineering solution.]

**Part II**

3. This question provides students with a map that shows the distribution of different kinds of rocks that are easily dissolved by water and therefore prone to the formation of sinkholes.

3a. [The map supports the argument that Florida is particularly prone to sinkholes because it shows that the entire state is made up of rock that is easily dissolved by water and therefore prone to sinkholes.]

3b. [It is important for people to be able to predict where a sinkhole might occur because sinkholes can be damaging, and sometimes catastrophic. Large sinkholes can swallow up homes, cars, and office buildings. People can plan ways to protect themselves if they know where a sinkhole is likely to occur.]

4. This question presents students with a scenario about the Ogallala Aquifer, also called the High Plains Aquifer. It assesses how well students understand

what aquifers are, how people use them, and what causes them to become recharged or discharged.

4a. [The most likely source of the water needed to grow crops in the states above the aquifer is the aquifer itself. This is because aquifers are the underground layers of rock, sand, or gravel that holds groundwater, and we know that many of the states receive little precipitation, so precipitation (rain or snow) isn't a likely source.]

4b. [This question asks students to apply what they know about rock permeability to aquifer recharge. Because the Ogallala Aquifer is separated from the surface with a layer of almost completely impermeable rock, it would be difficult for water to seep into it. This is because water doesn't move easily through impermeable rock.]

4c. [This question asks students to use what they know about the Ogallala Aquifer and aquifer recharge/discharge to explain why they think it is becoming depleted (losing more water than it gains). Aquifers are naturally balanced when the amount of water being added to the aquifer from precipitation is roughly the same as the amount of water leaving the aquifer. However, the regions above the Ogallala Aquifer don't receive a lot of precipitation. At the same time though, a lot of water is being withdrawn to grow crops. This will lead to the aquifer becoming depleted.]

5. This question provides students with a map that shows groundwater resources around the world. It assesses whether students can evaluate the map and draw conclusions about groundwater distribution around the planet.

5a. [The map supports the argument that Earth's groundwater isn't evenly distributed around the planet because it shows that some regions have very little groundwater and others have large amounts of groundwater.]

5b. [Factors that might contribute to aquifers with large amount of stored water include wet climates that receive high precipitation and permeable/porous rock underground that can store large amounts of water. Another factor would be low human development, where people aren't withdrawing large amounts of groundwater from the aquifer.]

5c. [Factors that might contribute to aquifers with low amounts of stored water include arid or semi-arid climates that don't receive much precipitation or areas where there is a lot of human development, with people using large amounts of the water from the aquifer.]

5d. [This question asks students how engineers can use engineering to mitigate (lessen) the harmful effects of aquifer depletion. There is no "correct" answer here. Possible answers include designing solutions that help to collect surface water when it rains, or conserve water such as energy efficient faucets and other appliances.]

## Lab Manual Answer Key

**Section 1 Review**

MC1. A. gravity [Gravity is the force most responsible for the movement of groundwater through an aquifer. Earth's gravity pulls everything on Earth toward Earth's center. As groundwater moves through rock and soil, gravity pulls it downward. Heat, friction (the force that slows motion when two objects rub against each other), and pressure are not the primary causes of groundwater's movement through an aquifer.]

MC2. D. all of the above [The rock cycle, weathering, and the movement of water are all processes that shape Earth's surface. The rock cycle refers to the processes that form, break down, and re-form rock from one category to another. Weathering is the breakdown of rock into smaller pieces from exposure to wind, water, and/or biological forces. The movement of water is one cause of weathering because as water travels, it constantly rubs against soil and rocks, eventually breaking down these surfaces.]

MC3. C. porosity [Porosity is a property that determines whether rock will make a good aquifer (the underground layer of rock, sand, or gravel that holds groundwater). Porosity refers to the amount of space between particles in a substance. Rock that is porous is able to hold water in its pores. Color, mass, and conductivity are unrelated to whether rock will make a good aquifer.]

CT1. [The answer should explain that it is useful for scientists to use systems when analyzing Earth's processes because Earth is so massive and has so many different parts that studying smaller sections (systems) allows them to better understand how everything works. For example, scientists can focus on just the interactions between all of the water on the planet (the hydrosphere) and the rocks, soil, landforms, and interior of the planet (the geosphere) to understand how these two systems influence one another.]

CT2. [The answer should explain that water plays a major role in the rock cycle because it is a primary source of weathering and erosion. If water did not exist on Earth, rocks on Earth's surface would not break down as much and would remain in the same place for much longer periods of time.]

CT3. [The answer should explain that erosion is the movement of sediment to new locations. Erosion is responsible for shaping Earth's surface by taking away matter from one location and moving it to new locations.]

CT4. [The answer should explain that sinkholes form in part because of weathering and erosion. They are common in areas where the land sits on top of rock that can naturally be dissolved by groundwater. Weathering and erosion create caverns and empty spaces within the rock. Over time, the rock erodes to the point where it can no longer support the land above it, and the surface land collapses.]

CT5. [Engineers are working to develop technologies that can predict when a sinkhole will occur because sinkholes can be devastating, especially because they can appear to occur with no warning. Knowing when a sinkhole will occur can help people prepare so they can minimize the damage that it causes.]

**Section 2 Review**

MC4. D. all of the above [Fertilizers, pesticides, and engine oil are all sources of water pollution. Water pollution is the contamination of natural water bodies by substances that harm organisms and the environment.]

MC5. A. pumping water from a well [Pumping water from a well can deplete an aquifer because it removes water from the aquifer. Flooding, heavy snowfall, and ice are all sources of water that can (eventually) recharge an aquifer by adding water to it.]

CT6. [All matter has gravity, and more massive objects have more gravity than less massive objects. A region that has more water on the ground has more water weight. Because of this, it has a slightly greater gravitational pull. This pull acts on the satellites, pulling them slightly closer to Earth. In contrast, a region that has less water has slightly less of a gravitational pull. This means the satellites float a little higher away from Earth's surface.]

CT7. [Answers will vary depending on student research. For example, the ability to access groundwater has allowed agriculture to flourish despite the region being mostly semi-arid and therefore receiving little precipitation. Additionally, as people moved west and began to pursue agriculture, there were no restrictions on who could drill wells or how much water they could access.]

CT8. [Surface water is very much connected to groundwater because of the water cycle. When surface water becomes polluted, it can seep into the ground, carrying pollutants with it as it mixes with groundwater.]

**Section 3 Review**

MC6. A. to separate different substances [The primary goal of filtration is to separate different substances. Filtration is the process of separating solid matter from a fluid by having the fluid pass through the pores of another substance, called a filter. Filtration does not join different substances, destroy harmful substances in another substance, or produce more of a particular substance.]

MC7. C. cells dividing to grow and reproduce [An ecosystem service is the positive benefits that an ecosystem provides to people. Cells dividing to grow and reproduce is not an example of an ecosystem service because this action doesn't benefit people. Tree roots preventing erosion, fungi returning nutrients to the soil, and bees pollinating fruits and vegetables are all examples of positive benefits that ecosystems provide to people.]

CT9. [The answer should identify that the team of students and engineers used engineering, not science, because they had a problem that they were trying to solve. Engineers use scientific knowledge to create technologies that solve problems.]

CT10. [The answer should describe how the team in Bolivia wanted to solve the problem of how to provide clean drinking water for two small villages in Bolivia. In order to solve the problem, the team needed to understand the principles of porosity and permeability related to different rock types, and the types of rocks found in aquifers, which naturally filter water. They then applied this information to select the best types of human-made or natural materials to filter contaminants from water in the villages.]

CT11. [The answer should explain that engineers who want to design a water filtration technology should evaluate materials based on their porosity and permeability. The smaller the pore size is, the purer the water will be because everything that cannot fit through the pores will be filtered out. However, water flows more quickly through larger pore sizes, so any filtration technology would need to balance the need to filter out pollutants with the need for the water to move through it.]

# Unit 7: Appendix 2
## Common Core Connections

KnowAtom units generally cover many Common Core ELA standards for reading informational texts and math standards in hands-on activities. The lab manual is designed to further connect science content to other disciplines with assignments that can be used as homework or in-class. This lab manual highlights one ELA standard:

**ELA** (page 9 of lab manual)
Reading Informational Text
**Key Ideas and Details**

- ELA-Literacy.RI.7.3: Analyze the interactions between individuals, events, and ideas in a text (e.g., how ideas influence individuals or events, or how individuals influence ideas or events).

Students read a news article announcing a new technology used by scientists to predict when and where sinkholes are likely to occur.

**Common Core Connection – ELA**

**Reading Informational Text – Key Ideas and Details**

Read the following news article about a technology for predicting sinkholes, and then answer the questions below.

**Can NASA predict where sinkholes might form and spread?**[1]

Unpredictable and scary, sinkholes swallow up the ground and everything above it. But NASA scientists believe they've discovered a way to predict where the holes might form and spread. Using a NASA plane with unique radar technology that transmits electronic pulses, scientists can map out how the earth's crust is shifting.

"We are taking a very precise measurement of the surface. By comparing the surface before and after, we can determine how much ground shift has happened," said Roger Chao, a NASA engineer aboard the plane.

Sinkholes typically occur when underlying rock is dissolved by water. Once eroded, the surface collapses.

In 2012 a whole line of trees in Assumption Parish, La., was sucked up in a sinkhole, and about 300 residents were forced to abandon their homes for good. By studying the radar images of the area recently, NASA scientists discovered that the sinkhole had shifted as much as 10 inches at least a month before the ground caved in. It's a finding that could in the future help track how sinkholes develop nationwide and possibly prevent people from being taken by surprise. NASA hopes to implement its research nationwide, especially in Florida.

**Questions:**
1. What is the main idea of this text?
2. How does engineering influence scientists in this text?
3. How could this technology influence people in a positive way?

[1] Adapted from a 2014 CBS News article by Vicente Arenas

Example Answer Key:
1. [*The main idea of this text is to introduce readers to a new technology being developed by scientists to predict when sinkholes are likely to occur.*]
2. [*Engineering influences scientists in this text because engineers developed the radar technology that scientists can use to analyze Earth's surface, looking for clues about when sinkholes might occur next.*]
3. [*According to the text, this technology could influence people in a positive way by preventing people from being taken by surprise when sinkholes do happen.*]

Students use the following Common Core standards in this unit.

| ELA Standards | Applying ELA Connections to the Unit |
|---|---|
| **Writing** | |
| W.7.1. Write arguments to support claims with clear reasons and relevant evidence. | • In Lesson 1, students write a conclusion (argument) to summarize their findings in the groundwater experiment, analyzing whether or not the data (evidence) supported their hypothesis (claim).<br>• In Lesson 3, students write a conclusion (argument) to summarize their results from the water filtration engineering lab, analyzing whether or not their prototype met the criteria and constraints of the problem, using data (evidence) to support their argument. |
| W.7.2. Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. | • In Lesson 1, students write out the groundwater experiment in their lab notebooks, including the question, research, hypothesis, experiment summary, materials, procedure, scientific diagram, data charts, graphs, and conclusion. They choose the relevant data points to use in their conclusion based on which data points best answer the question.<br>• In Lesson 3, students write out the water filtration engineering lab, including the problem, research, possible solutions, materials, testing procedure, diagram, and conclusion, using relevant data points in their conclusion to determine how their prototype solved the problem. |
| W.7.4. Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. | • In Lessons 1 and 3, students produce clear and coherent writing as they use their lab notebooks to work through the groundwater experiment and the water filtration engineering lab. The lab notebooks must be clear, concise, and specific enough that someone else could replicate the experiment and prototype. |

| | |
|---|---|
| W.7.9. Draw evidence from literary or informational texts to support analysis, reflection, and research. | • In Lessons 1, 2, and 3, students use the nonfiction reading from their lab manuals to support their analysis, reflection, and research during each lesson. |
| **Speaking and Listening** | |
| SL.7.1. Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly. | • In Lessons 1, 2, and 3, students engage in Socratic dialogue before beginning the experiment, investigation, and engineering prototype. Students apply what they have read in their lab manuals nonfiction reading, and personal experiences or observations to the dialogue. |
| SL.7.4. Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation. | • In Lessons 1, 2, and 3, students analyze what they have learned in the lesson in the wrap-up portion of class, coming together as a class to discuss important takeaways from the hands-on portion of the lesson. Student teams compare results, using their data and background knowledge to support their claims and evaluate other teams' claims. |

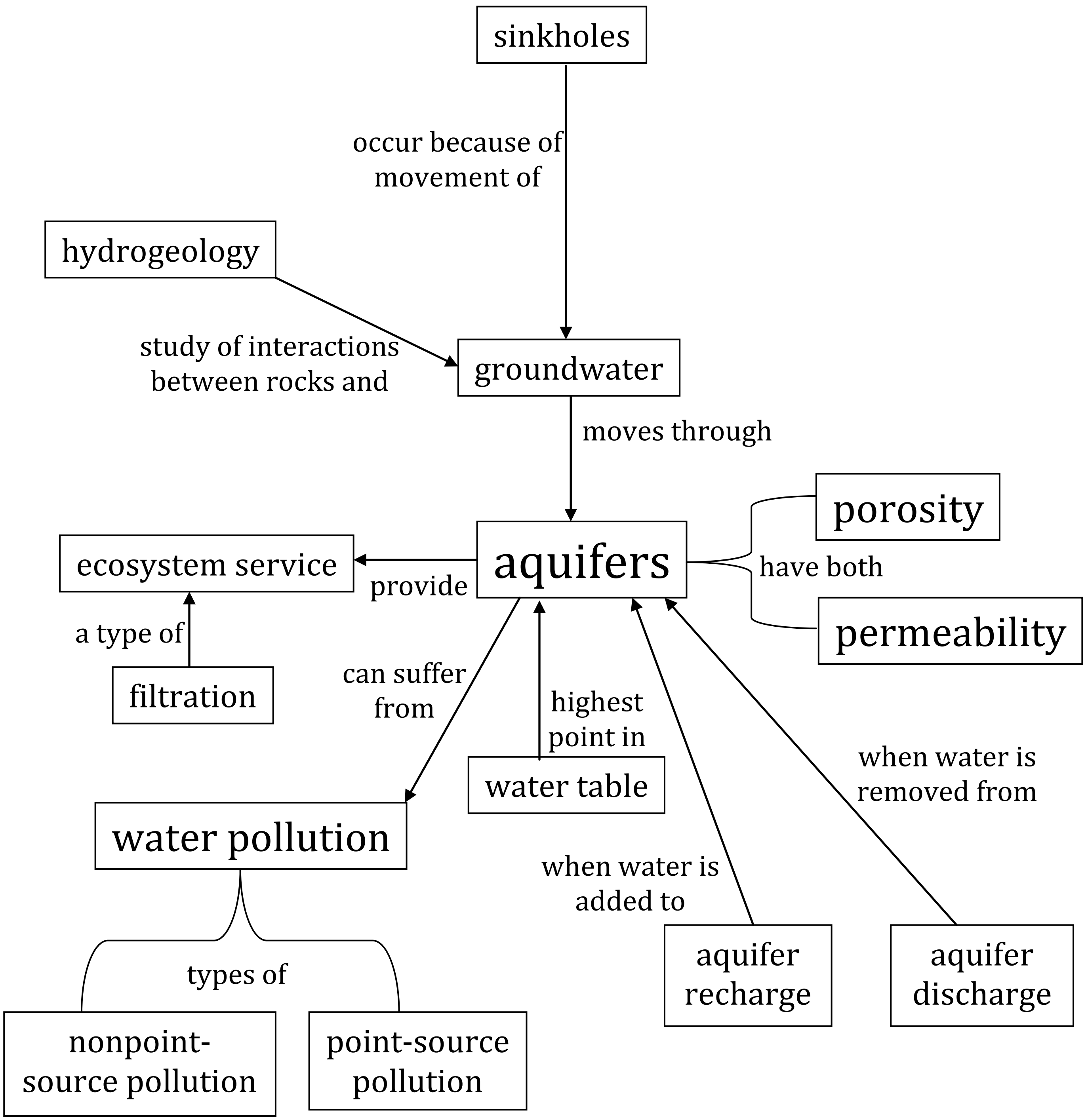
| Science and Technical Subjects | |
|---|---|
| RST.6-8.1. Cite specific textual evidence to support analysis of science and technical texts. | • In Lessons 1, 2, and 3, students use the information from their lab manuals to support their understanding of groundwater, water pollution, and how engineers can design technologies that solve the problem of water pollution. |
| RST.6-8.2. Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. | • In Lessons 1, 2, and 3, students read their lab manuals, determining the main ideas and conclusions of the text. They use this reading to inform and support the Socratic dialogue portion of the lesson. |
| RST.6-8.3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. | • In Lesson 1, students develop and then follow a procedure for testing the permeability of different Earth materials.<br>• In Lesson 2, students follow a multistep procedure to set up an aquifer model and then to test it.<br>• In Lesson 3, students develop and follow a multistep procedure to test their filtration prototypes. |
| 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. | • In Lessons 1, 2, and 3, students use evidence from their experiment, investigation, and engineering lab to support what they have read in their lab manual. |
| RST.6-8.10. By the end of grade 8, read | • In Lessons 1, 2, and 3, students work on developing their understanding of science/technical texts, using |

| | |
|---|---|
| and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently. | the unit vocabulary, context from the lab manual, and Socratic dialogue to support their comprehension of the nonfiction reading. |

| Math Standards | Applying Math Connections to the Unit |
|---|---|
| **The Number System** | |
| 7.NSA.3. Solve real-world and mathematical problems involving the four operations with rational numbers. | • In Lesson 1, students solve a real-world problem of Earth material permeability, calculating and then comparing the water filtration rate of three different substances. |

## Unit 7: Appendix 3
## Sample Concept Map



## Unit 7: Appendix 4
## Support for Differentiated Instruction

| Core Expectation | KnowAtom Assessment Strategies | Possible Primary Evidence |
|---|---|---|
| ***MS-LS2-5.*** Evaluate competing design solutions for maintaining biodiversity and ecosystem services. | Low Entry Point<br>• Describe a healthy ecosystem.<br>• Identify and describe examples of ecosystem services.<br>At Grade Level Entry Point<br>• Identify factors that affect the stability of a given ecosystem.<br>• Compare design solutions based on their ability to maintain ecosystem stability and biodiversity. | • student list of factors that contribute to a healthy ecosystem<br>• engineering lab notebook entry completed by student |
| ***MS-ESS2-1.*** Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. | Low Entry Point<br>• Explain that matter can only change with energy.<br>• Identify sources of energy that drive the cycling of Earth materials.<br>At Grade Level Entry Point<br>• Describe how Earth materials cycle from one form to another.<br>• Identify the processes that cause Earth materials to cycle. | • student diagram of the rock cycle and the water cycle<br>• groundwater experiment lab notebook entry completed by student |
| ***MS-ESS2-2.*** Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying times and spatial scales. | Low Entry Point<br>• Identify that Earth's surface has changed over time.<br>At Grade Level Entry Point<br>• Describe some of the geoscience processes that have changed Earth's surface over time. | • video of student describing how Earth's surface has changed over time<br>• student essay linking one geoscience process to a change it causes |

| Core Expectation | KnowAtom Assessment Strategies | Possible Primary Evidence |
|---|---|---|
| ***MS-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 geoscience processes. | <u>Low Entry Point</u><br>• Define groundwater.<br>• Recognize that groundwater is unevenly distributed around Earth.<br><u>At Grade-Level Entry Point</u><br>• Describe the processes that result in groundwater accumulating in particular locations.<br>• Describe how human use of groundwater depletes it, resulting in less available groundwater. | • photographs of student evaluating maps that show where Earth's aquifers are<br>• video of student explaining why some types of rocks are better able to store groundwater than other types of rocks |
| ***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. | <u>Low Entry Point</u><br>• Identify examples of natural hazards.<br>• Recognize that people can forecast future events using data from past events.<br><u>At Grade-Level Entry Point</u><br>• Identify patterns in data that can be used to predict future events.<br>• Describe how technologies can be used to mitigate the effects of different events. | • video of student contributing to a dialogue about catastrophic sinkholes and how engineers are designing technologies to predict when sinkholes are likely to occur |

| Core Expectation | KnowAtom Assessment Strategies | Possible Primary Evidence |
|---|---|---|
| ***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. | <u>Low Entry Point</u><br>• Identify a problem that needs to be solved.<br>• Recognize that scientific knowledge can be used to solve problems.<br><u>At Grade-Level Entry Point</u><br>• Define the constraints of a particular design problem.<br>• Describe how the solution will solve the problem. | • engineering lab notebook entry completed by student<br>• an engineering problem, along with its criteria and constraints, identified by student |
| ***MS-ETS1-2.*** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. | <u>Low Entry Point</u><br>• Recognize that for any problem, there exist multiple solutions that could potentially solve the problem.<br>• Recognize that some solutions will be more effective than others at solving the problem.<br><u>At Grade-Level Entry Point</u><br>• Use a systematic method for evaluating multiple solutions. | • engineering lab notebook entry completed by student<br>• decision matrix filled out by student that evaluates how well each of their prototype solutions meets the criteria and constraints of the problem |

| Core Expectation | KnowAtom Assessment Strategies | Possible Primary Evidence |
|---|---|---|
| ***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. | <u>Low Entry Point</u><br>• Test and collect data from multiple design solutions.<br><u>At Grade-Level Entry Point</u><br>• Identify relationships among the data collected to determine which characteristics worked well and which didn't. | • engineering lab notebook entry completed by student<br>• photographs of student testing water filtration prototype |
| ***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. | <u>Low Entry Point</u><br>• Identify what worked well and what didn't work well during the testing of the design solution.<br><u>At Grade-Level Entry Point</u><br>• Use collected data to improve the design solution.<br>• Identify limitations in the proposed solution. | • engineering lab notebook entry completed by student<br>• photographs of student building and then testing water filtration device prototype |

# Unit 7: Appendix 5
## Materials Chart

| | Lesson | Quantity | Notes | Used Again |
|---|---|---|---|---|
| Unit Kit Consumable | | | | |
| **Goggles** | all | 1 per student | safety equipment | ✓ |
| **Sand** | 1<br>3 | shared bags<br>teacher use | for permeability experiment<br>for creating polluted water | |
| **Large plastic cups** | 1<br>2 | 1 per team of 2<br>1 per team of 2 | for permeability experiment<br>for holding groundwater | |
| **small graduated cups (30 mL)** | 1<br>2<br>3 | 2 per team of 2<br>1 per team of 2<br>1 per team of 2 | for permeability experiment<br>for creating pond in aquifer<br>for pouring polluted water | |
| **Gravel (small)** | 1<br>2 | shared bags | for permeability experiment<br>for groundwater activity | |
| **Soil** | 1<br>3 | shared bags<br>teacher use | for permeability experiment<br>for creating polluted water | |
| **Small plastic cups** | 1<br>2<br>3 | 1 per team of 2<br>1 per team of 2<br>1 per team of 2 | for permeability experiment<br>for groundwater investigation<br>for water filtration lab | |
| **Gravel (large)** | 2<br>3 | shared bags<br>shared bags | for groundwater investigation<br>for water filtration lab | |
| **Food coloring (red)** | 2 | shared | for simulating contamination | |
| **Plastic spoons** | 3 | 1 per team of 2 | for engineering water filters | |
| **Cotton balls** | 3 | 20 per team of 2 | for engineering water filters | |
| **Coffee filters** | 3 | 6 per team of 2 | for engineering water filters | |
| **Felt** | 3 | 1 per team of 2 | for engineering water filters | |
| **Nylon** | 3 | 3 per team of 2 | for engineering water filters | |
| **Burlap** | 3 | shared roll | for engineering water filters | |
| **Baby oil** | 3 | teacher use | for polluting water | |
| **Corn starch** | 3 | teacher use | for polluting water | |
| Non-Consumable | | | | |
| **Stopwatches** | 1 | 1 per team of 2 | for timing experiment | ✓ |
| **Thumbtacks** | 1, 2 | 1 per team of 2 | for punching holes in cups | |
| **Graduated cups** | all | 1 per team of 2 | for measuring water | ✓ |
| **Grad. measuring containers** | all | shared | for pouring water | ✓ |
| **Bottle pumps** | 2 | 1 per team of 2 | for pumping water | |
| **Tubing** | 2 | 1 per team of 2 | for simulating a well | |
| **Test tubes (with covers)** | 3 | 1 per team of 2 + 4 extra | for observing water quality<br>for engineering lab | |
| **Containers with holes (no covers)** | 3 | 1 per team of 2 | for creating water filter prototypes | |
| Teacher Tool Kit | | | | |
| **Rulers** | 1, 2 | 1 per team of 2 | for measuring soil height | ✓ |
| **Invisible tape** | 2 | 1 per team of 2 | for taping tubing to container | ✓ |
| **Scissors** | 2,3 | 1 per team of 2 | for cutting materials | ✓ |

| Hand-outs | | | | |
|---|---|---|---|---|
| **Laboratory notebooks** | 1,3 | 1 per student | for "Lab 8" and "Lab 9" | ✓ |
| **Lab manuals** | 1, 2, 3 | 1 per student | for "Groundwater Contamination Investigation" | |
| Visuals | Download | | | |
| **Lesson 1** | Sinkholes Visual, Aquifers Visual | | | |
| **Lesson 2** | Aquifers Change Visual, Earth's Water Visual, Polluted Aquifers Visual | | | |
| **Lesson 3** | Water Filtration Visual | | | |