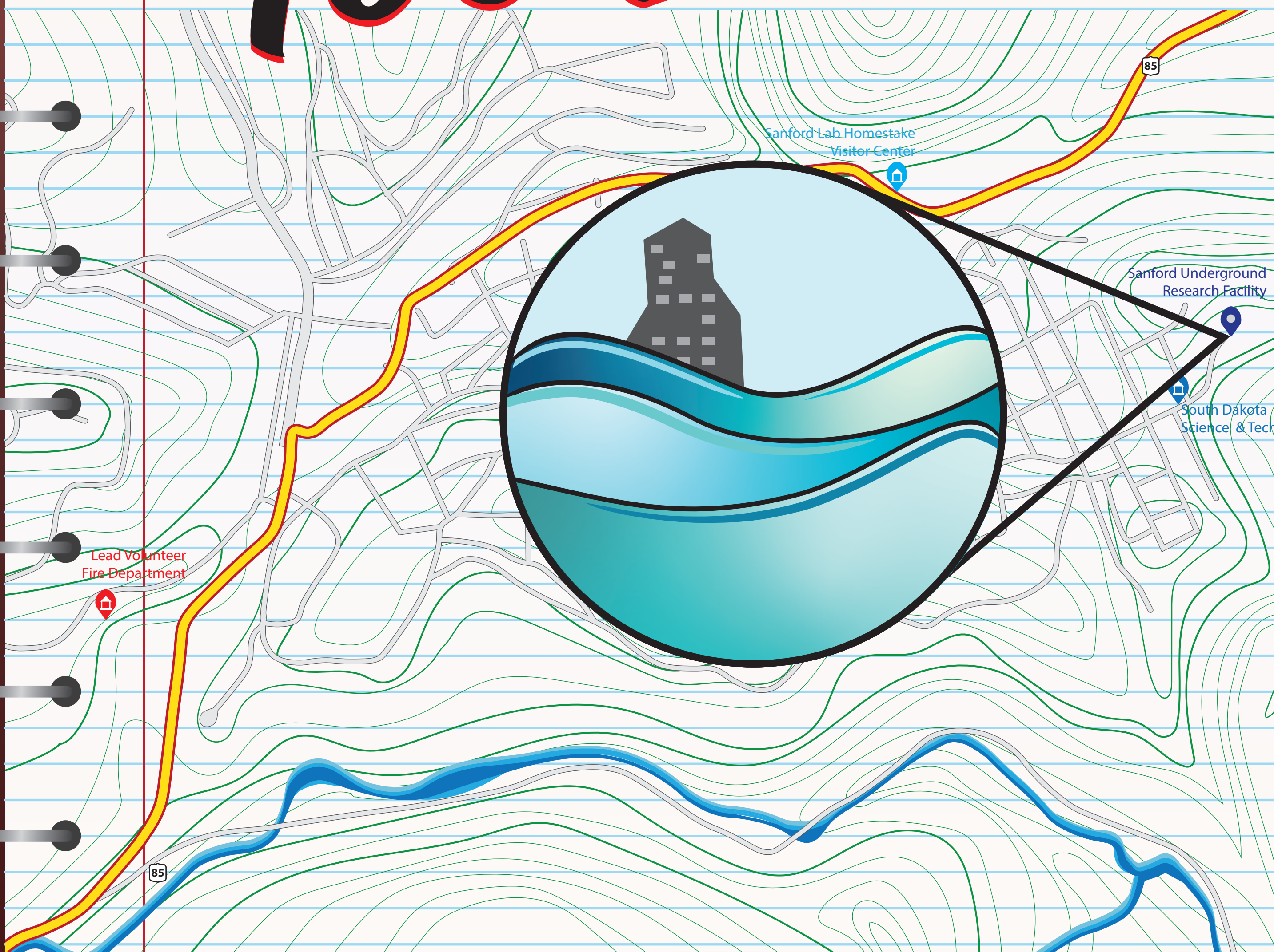
Too Much / Too Little



Education and Outreach

3 - 5

Curriculum Unit

Too Much, Too Little

Lesson #	Lesson Title	Suggested Time
1	What Is It? *What Do Flood and Drought Look Like?*	40 minutes
2	Where Does Flooding Occur? *Analyzing Patterns in Earth's Features*	40 minutes
3	When Does Drought Occur? *Using Graphs to Identify Weather Patterns*	45 minutes
4	Why Should I Be Concerned? *The Rapid City Flood of 1972*	55 minutes
5	How Can We Help? *Engineering Solutions for Water Issues*	45 minutes- Part A 90 minutes- Part B
6	Sanford Underground Research Facility Connections *How To Prevent Flooding A Mile Underground*	50 minutes

Too Much, Too Little- Grades 3-5 (Earth and Space Science)

Students explore the phenomena of flood and drought as they analyze maps, graph weather data, learn about the historic Rapid City flood of 1972, and examine current solutions to issues of too much and/or too little water. Students then generate and compare solutions to a local water issue of their choice. The unit concludes with an introduction to the Sanford Underground Research Facility (SURF), and the unique engineering challenge presented by pumping water a vertical mile in an effort to keep the deep underground laboratory dry for science.

Consider requesting a visit from an Education and Outreach team member for *Lesson Six*.
education@sanfordlab.org

Too Much, Too Little

Lesson One promotes student questioning and discussion focused around the phenomena of flood and drought, presented as images within a video montage. As students endeavor to comprehend the images presented, and the potential events leading up to what is depicted, they ask questions and define problems to focus their unit investigations. In the end, they discover that drought and flood are caused by amounts of precipitation in an area that are either much less than, or much greater than, respectively, what is considered “normal”.

After watching the *Lesson One* video montage, the first question students tend to ask is “can this happen where I live”. Therefore, in the second lesson, students investigate maps, ranging from their hometown to the entire contiguous United States, before analyzing and interpreting data (from maps) to discover patterns in Earth’s features that help identify where flood is most likely to occur.

Another question that students tend to ask is “what causes flood and drought to occur”. Therefore, in *Lesson Three*, students investigate the fact that drought can happen anywhere on land, though it is more likely in some regions than in others. After a brief introduction to graphs where they investigate the historic drought of the 1930’s in South-West South Dakota, students organize modern South Dakota weather data into graphical displays. Students then analyze these graphs to identify patterns that can be used to predict the weather conditions expected for any particular season. Since flood and drought are determined by comparison to the amount of precipitation that is considered “normal”, this analysis provides a baseline for the “normal” temperature and precipitation, by season, for central South Dakota.

Lesson Four requires students to utilize what they learned in *Lessons One* through *Three* to predict the likelihood of Flood in Rapid City, South Dakota. Then, students are presented with pictures and information about the historic 1972 Rapid City flood, which killed 238 people and injured 3,000…setting the stage for a deeper dive into causes of flood. Specifically, flash flood. Through the investigation of both 2D and 3D watershed representations, and precipitation data for June 9th and 10th of 1972, students construct explanations for why the 1972 Rapid City Flood occurred. Ultimately, students realize that even though some areas are more prone to flood than others, much like drought, flood can also happen just about anywhere on land.

Since flood and drought can both happen just about anywhere on land, it pays to be prepared! *Lesson Five* begins with an investigation into engineered solutions to issues of too much and/or too little water, and concludes with students generating and comparing multiple solutions for reducing the impacts of too much and/or too little water in their own hometown.

The unit concludes with an introduction to the Sanford Underground Research Facility (SURF) and its unique water challenge. Students engage in an engineering design challenge and construct explanations for why the lab uses a 5-step system for bringing water to the surface, as opposed to a single pump and mile long pipe.

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	Wonderment	Phenomenon	Practices	What We Figure Out	New Question(s)
LESSON 1 Unit Phenomenon	What are we going to investigate?	Unit Phenomenon - Video Montage	Asking questions, Scale proportion + quantity	What flood and drought look like	What caused this? Where? Are we safe?
LESSON 2 4-ESS2-2	Where do floods tend to occur?	News clip of house flooded for 4th time in under 2 years	Analyzing + interpreting data, Patterns	Regions of U.S. where floods are most likely	But what about drought? Where is drought most likely to occur?
LESSON 3 3-ESS2-1	Can we predict places prone to drought as well?	US Drought Declarations map (2000-2018)	Analyzing + interpreting data, Patterns	Drought can't be easily predicted, and can happen anywhere	What about flood? Can we predict when flooding is likely?
LESSON 4 Working toward 4-ESS3—2	What causes flood? Can it be anticipated?	Historic 1972 flood of Rapid City- Pictures and Information	Analyzing + interpreting data, Patterns	Flood can also happen just about anywhere!	Are we safe? What can we do to be prepared?
LESSON 5 4-ESS3-2	What can we do to lessen the effects of flood and drought?	*Act Now Save Later*- United Nations Video	Constructing explanations + designing solutions, Cause +Effect	Engineered solutions to our local water issues	What other engineering solutions exist?
LESSON 6 SURF Connection	What other innovative water solutions exist?	SURFwater issue and engineered solution	Constructing explanations + designing solutions, Systems	How to safely pump water from a mile deep science lab	What else can we do?

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Standards Addressed in the Unit

Lesson	Standards
1	Science and Engineering Practice (SEP): • Asking Questions and Defining Problems- Ask questions that can be investigated and predict outcomes based on patterns such as cause and effect relationships. Crosscutting Concept (CCC): • Scale, Proportion, and Quantity- Observable phenomena exist from the very small to the immensely large or from very short to very long time periods.
2	**4-ESS2-2** Analyze and interpret data from maps to describe patterns of Earth's features. Science and Engineering Practice (SEP): • Analyzing and Interpreting Data- Analyze and interpret data to make sense of phenomena using logical reasoning. Crosscutting Concept (CCC): • Patterns- Patterns can be used as evidence to support an explanation.
3	**3-ESS2-1** Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season. Science and Engineering Practice (SEP): • Analyzing and Interpreting Data- Analyze and interpret data to make sense of phenomena using logical reasoning. Crosscutting Concept (CCC): • Patterns- Patterns can be used as evidence to support an explanation.
4	Working Toward: **4-ESS3-2** Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans. Science and Engineering Practice (SEP): • Constructing Explanations and Designing Solutions- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation. Crosscutting Concept (CCC): • Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change.
5	**4-ESS3-2** Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans. Science and Engineering Practice (SEP): • Constructing Explanations and Designing Solutions- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem. Crosscutting Concept (CCC): • Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change.
6	Science and Engineering Practice (SEP): • Constructing Explanations and Designing Solutions- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem. Crosscutting Concept (CCC): • Systems- A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot.

Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science)
   Designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

***A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. (NRC, 2012)**

Crosscutting Concepts

1 **Patterns**

2 **Cause and Effect:
Mechanism and explanation**

3 **Scale, proportion, and quantity**

4 **Systems and system model**

5 **Energy and matter:
Flows, cycles, and conservation**

6 **Structure and function**

7 **Stability and change**

***A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. (NRC, 2012)**

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Materials List

- **Teacher-Provided**

Lesson	Materials Needed
1	For teacher: ➢ Projector and speakers For each student: ➢ Science notebook • Copy of *Drought, Flood or Neither* pictures
2	For teacher: ➢ Projector ➢ United States political map to project For each student: ➢ Science notebook ➢ *"What State Am I"* assessment (printed out) For each group of three students: • Set of 3 United States maps • (Optional) United States political map • Magnifying glass
3	For teacher: ➢ Projector and speakers For each student: ➢ Science notebook Each pair of student's needs: • U.S. Drought Declarations 2000-2018 (By County)" map • Set of Dust Bowl era graphs (precipitation + temperature) • (Optional) Transparency of Dust Bowl precipitation graph • Weather data card ➢ Materials/manipulatives for creating graphical displays
4 (continued next page)	For teacher: ➢ Projector and speakers • 3D models of Rapid Creek watershed (1 per 4 students) For each student: ➢ Science notebook

	Each group of 3 students will need (Launch): • Set of 3 *Lesson Two* maps labeled A-C Each pair of students will need (Explore): • 1972 Rapid City flood pictures and information • *Crumpled Watershed* instructions ➢ (1) Sheet copy paper • (2) Non-permanent dark colored markers ➢ Waterproof surface (cafeteria tray, desktop, lab bench) ➢ Tape • Spray bottle (each kit contains 10 for the class to share) • *Rapid City, SD Average Monthly Precipitation* data • *2D Black Hills Elevation Map* • *Total Storm Rainfall Map* for June 9-10, 1972 • Transparency of *Total Storm Rainfall Map*
5	For teacher: ➢ Projector and speakers For each student: ➢ Science notebook Each group of 4 students will need: • Set of engineered solution pages labeled A-D
6	For teacher: ➢ Projector and speakers • Tape measure • Painters tape For each student: ➢ Science notebook Each Pair of students (*Phenomenon*): • Diagram of SURF water pumping system Each group of 3 students will need (*Explore*): • (2) Tubes, one long and one short • (2) Hand pumps or “primer bulbs” • (2) Plastic buckets • Tee connector (T shaped) • Tube connector (identical ends) • (3) Tube-to-hand pump connectors (one end larger) • Absorbent pad • Flexible clip bent to fit on bucket and hold tube in place ➢ (Optional) timers

<table>
<tr><th colspan="2">Important Note</th></tr>
<tr><td>Science Notebooks</td><td>You may wish to have students set up their Science Notebooks prior to the first lesson.

Science notebooks are an important part of solidifying your students' learning. Student scientists record their observations, questions, evidence and ideas in a running record of their thinking. Science notebooks are also a great way to practice writing skills!

As students develop their understanding of science concepts, they may use drawings and other illustrations- such as charts, tables, models, and graphs. Additionally, the science notebook can be used by the teacher to assess the development of student understanding.

Science notebooks may be a printed booklet prepared by the teacher, a bound composition, or a spiral notebook.

A printable science notebook specific to this unit is available on the unit USB located in the front of the Teacher Guide (3-ring binder).

If your students are already utilizing bound science notebooks, consider projecting the printable notebook pages as a guide for students as they record their ideas. Or consider printing notebook pages for students to cut-and-paste (or fold and tape/staple) into their bound science notebooks.</td></tr>
</table>

Too Much, Too Little

<table>
<tr><th>Lesson 1</th><th>What Is It?</th></tr>
<tr><td>Overview
Standard(s) &
Objectives</td><td>Overview

This lesson promotes student questioning and discussion focused around the phenomena of flood and drought, presented as images within a video montage. As students endeavor to comprehend the images presented, and the potential events leading up to what is depicted, they ask questions and define problems to focus their unit investigations.

Standards

Science and Engineering Practice (SEP):

• Asking Questions and Defining Problems- Ask questions that can be investigated and predict outcomes based on patterns such as cause and effect relationships.

Crosscutting Concept (CCC):

• Scale, Proportion, and Quantity- Observable phenomena exist from the very small to the immensely large or from very short to very long time periods.

Objectives

Students

• Make observations about images of flood and drought
• Ask questions about flood and drought
• Discover that water, though necessary for life, can be present in amounts that are too large or too small
• Develop working definitions of flood and drought</td></tr>
<tr><td>Questions</td><td>Driving Question
• What happens when an area gets much more, or much less, water than is typical?

Probing Questions

• What is flood?
• What is drought?
• Why must we compare the amount of water in an area to the amount that is “typical”?
• What are the hazards associated with flood? With drought?
• What questions do you still have?</td></tr>
</table>

Too Much, Too Little

Background Information	**Flood** There are few places on Earth where people need not be concerned about flooding. Any place where rain falls is vulnerable, although rain is not the only cause of flood. A flood occurs when water overflows or inundates land that's normally dry. This can happen in a multitude of ways. Most common is when rivers or streams overflow their banks. Excessive rain, a ruptured dam or levee, rapid ice melting in the mountains, or even an unfortunately placed beaver dam can overwhelm a river and send it spreading over the adjacent land, called a floodplain. Coastal flooding occurs when a large storm or tsunami causes the sea to surge inland. Most floods take hours or even days to develop, giving residents ample time to prepare or evacuate. Others generate quickly and with little warning. These flash floods can be extremely dangerous, instantly turning a babbling brook into a thundering wall of water and sweeping everything in its path downstream. Moving water has awesome destructive power. When a river overflows its banks or the sea drives inland, structures poorly equipped to withstand the water's strength are no match. Bridges, houses, trees, and cars can be picked up and carried off. The erosive force of moving water can drag dirt from under a building's foundation, causing it to crack and tumble. When floodwaters recede, affected areas are often blanketed in silt and mud. The water and landscape can be contaminated with hazardous materials, such as sharp debris, pesticides, fuel, and untreated sewage. Potentially dangerous mold blooms can quickly overwhelm water-soaked structures. Residents of flooded areas can be left without power and clean drinking water, leading to outbreaks of deadly waterborne diseases like typhoid, hepatitis A, and cholera. But flooding, particularly in river floodplains, is as natural as rain and has been occurring for millions of years. Famously fertile floodplains like the Mississippi Valley in the American Midwest, the Nile River valley in Egypt, and the Tigris-Euphrates in the Middle East have supported agriculture for millennia because annual flooding has left millions of tons of nutrient-rich silt deposits behind. Adapted from https://www.nationalgeographic.com/environment/natural-disasters/floods/ **Drought** Drought is an extended period of unusually dry weather when there is not enough rain. The lack of precipitation can cause a variety of problems for local communities, including damage to crops and a shortage of drinking water. These effects can lead to devastating economic and social disasters, such as famine, forced migration away from drought-stricken areas, and conflict over remaining resources.

	Drought is a complicated phenomenon and can be hard to define. One difficulty is that drought means different things in different regions. A drought is dependent on the average amount of precipitation that an area is accustomed to receiving. For example, in Atlanta, Georgia, the average rainfall is about 127 centimeters (50 inches) a year. If significantly less rain falls, there may be water shortages and a drought may be declared. However, some arid regions, such as the deserts of the American Southwest, may receive less than about 25 centimeters (10 inches) of rainfall in a non-drought year. A drought in Atlanta could be a very wet period in Phoenix, Arizona! Most droughts occur when regular weather patterns are interrupted, causing disruption to the water cycle. Changes in atmospheric circulation patterns can cause storm tracks to be stalled for months or years. This disruption can dramatically impact amounts of precipitation that a region normally receives. Changes in wind patterns can also be disruptive to how moisture is absorbed in various regions. Trees and other plants have adapted to withstand the effects of drought through various survival methods. Some plants (such as grasses) will slow their growth or turn brown to conserve water. Trees can drop their leaves earlier in the season to prevent losing water through the leaf surface. However, if drought conditions persist, much vegetation will die. Many organisms, however, cannot adapt to drought conditions, and the environmental effects of extended, unusual periods of low precipitation can be severe. Negative impacts include damage to habitats, loss of biodiversity, soil erosion, and an increased risk from wildfires. Adapted from https://education.nationalgeographic.org/resource/drought/
Materials	For teacher: ➢ Projector and speakers For each student: ➢ Science notebook • Copy of *Drought, Flood or Neither* pictures
Prior Knowledge	Students should have some grasp of the necessity of water for living organisms.
Launch (5-10 minutes)	
Phenomenon	Explain that you are about to show the class a short video. During this video, they may find that they have many questions. While they watch they should write notes in their science notebook (pages 1 and 2) addressing: 1- What do you notice? 2- What do you wonder?

	Play the *Too Much/Too Little* video montage (3 min- found on the USB in the pencil pouch in the front of the 3-ring binder). After playing the video montage, ask students to share what they noticed. It is likely that students will ask to view the video again, and this is encouraged. *Note: you may want to pause the video occasionally for student discussion.* Next, facilitate a discussion about what students wonder. Encourage students to share their ideas and/or prior knowledge, and to utilize logical reasoning to draw conclusions about the pictures shown during the video montage. As the classroom teacher, facilitate the discussion as necessary, trying to avoid giving answers at this point. It may be useful to have students explain related phenomena they have experienced as they attempt to make sense of the pictures in the video montage.
Explore (20-25 minutes)	
Investigation	***Drought, Flood, or Neither*- Jigsaw Activity** Display the *Drought, Flood, or Neither* pictures (on the USB, in the *Lesson One* folder). Ask students to take a moment to silently make observations and decide whether they think each picture represents a drought, a flood, or neither. Form groups of 4 students. It is acceptable to have a few groups of 5, if necessary. These will be their "home" groups. Have students turn to page 3 of their science notebook. Each student in a home group will be responsible for analyzing a different picture. In this way, each home group will have an "expert" on each of the pictures, A-D. Once students have a picture to analyze, they should take 3-4 minutes to silently and individually complete page 3 of the science notebook. Next, form 4 "expert groups". Every student who analyzed picture "A" should gather for discussion, and every student who analyzed picture "B" should gather in a different location, etc. (*Expert group sizes of 4-5 students are optimal, but not always achievable. Consider forming two of each expert group if you have a large class)* Each expert group should attempt to come to consensus about whether their assigned picture represents flood, drought, or neither, as well as the reasoning behind their choice (page 4 of the science notebook). Circulate among the expert groups, listening for any that might need you to ask guiding or "probing" questions to help them draw logical, truthful, conclusions. *[A and D = Neither, B = Drought, and C = Flood]* Groups A and D may have trouble coming up with reasons their pictures represent neither flood nor drought. If necessary, try flipping the question around to ask, "How is this picture NOT flood" and "how is this picture NOT drought". *To facilitate equitable group discussion, we recommend using talking chips. Almost anything can be used for talking chips; pencils, erasers, poker chips, small colored pieces of paper, small craft pom-poms, etc.*

	Each student needs 3 talking chips. Any student may start the discussion. A talking chip is placed in the center of the table each time a student contributes to the discussion- 1 chip per statement/thought/question. When there are no more chips to be used in the group, students can refresh their chips to continue the discussion. This ensures that every group member contributes to the discussion, and no student is allowed to dominate. Reassemble the original “home” groups. Each student, in turn, should share what their expert group discussed concerning their assigned picture: flood, drought, or neither, and the reasoning. *To facilitate equitable sharing, consider the use of a talking stick. Any student may begin, but only the student holding the talking stick may speak… while the rest of the group listens. The talking stick is then passed around the table so that every student has a chance to share.* Pages 5 and 6 of the science notebook are for group members to record their learning (5 min). You may want to point out that students have already recorded their reasoning from their expert group discussion, and there is no need to record it again on pages 5 and 6. This is why there are only three places to record what they learn from the *other* 3 expert groups/pictures. As time permits, home groups should also consider the discussion question (using talking chips) on page 6 of the science notebook. *The most important conclusion at this point should be that flood and drought are determined by comparing the amount of water in an area to what is typically found there. Therefore, a desert with very little rainfall may not be in drought because the plants and animals of the desert are specifically adapted to (and accustomed to) that small amount of rainfall. In this way, organisms in a desert and in the ocean are considered to have something in common… they are all specifically adapted for the environments they live in!*
Summarize (5 minutes)	
Communicate	Have students turn to pages 7 and 8 of the science notebook to record what they have learned, what they are thinking, and what they are wondering about. Have students write “I Wonder” questions on pieces of paper that they tape to the board (or a wall). If time allows, ask students to begin grouping similar questions together. Tell students that they will have opportunities to answer some of their remaining questions over the next four lessons. Additionally, they will be looking at issues of too much and/or too little water in their hometown, and designing solutions for them, in *Lesson Five*.

Too Much, Too Little

Terminology and Concepts to Solidify	**Flood**-an overflowing of large amounts of water beyond its normal confines, especially over what is normally dry land. **Drought**- a prolonged period of abnormally low rainfall (as compared to typical or expected amounts) in a region, leading to a shortage of water.
Connection to Big Ideas (Phenomena)	Drought can happen anywhere, since it is a deviation from "normal" precipitation amounts over a long period. Working towards: Flood, technically, can also happen just about anywhere. However, flooding is much more likely in some areas due to weather patterns and topology.
(Optional) Follow Up/Practice	Drought and flood are often in the news. Ask students to bring information about current and/or historic drought/flood events from around the world. Alternatively, students could bring pictures of surprising places that are NOT in flood/drought. For instance, places where houses are built over water on stilts, etc. Another optional extension could be determining which of the posted student questions are testable (ie: scientific), and which are not. Then, students could suggest ways of testing the scientific questions.
Assessment	Science notebook pages 9 and 10.

Students often benefit from taking time to reflect upon their learning. As time allows, provide students time to consider how their ideas about flood and/or drought may have changed after each lesson. This can be shared with a partner, a small group, and/or recorded in science notebooks. Extra notebook pages can be taped or stapled into the printable unit notebook, as desired!

Lesson 2	Where Does Flooding Occur?
Overview Standard(s) & Objectives	**Overview** Students investigate maps, ranging from their hometown to the entire contiguous United States, before analyzing and interpreting data (from maps) to discover patterns in Earth's features that help identify where flood is most likely to occur. **Standards** 4-ESS2-2 Analyze and interpret data from maps to describe patterns of Earth's features. Science and Engineering Practice (SEP): • Analyzing and Interpreting Data- Analyze and interpret data to make sense of phenomena using logical reasoning. Crosscutting Concept (CCC): • Patterns- Patterns can be used as evidence to support an explanation. **Objectives** Students • Analyze and interpret information from maps • Describe patterns of Earth's features • Identify places prone to flooding
Questions	**Driving Question** • What patterns do you see that could be used to predict where floods are most likely to occur? **Probing Questions** • Are there any features of Earth's surface that tend to be found where floods most often occur? • Do floods tend to occur in the same sorts of places? • Could a flood occur anywhere in the U.S.? Are there any places where flood would be very unlikely?
Background Information	**Maps** A map is a symbolic representation of selected characteristics of a place, usually drawn on a flat surface. Maps present information about the world in a simple, visual way. They teach about the world by showing sizes and shapes of countries, locations of features, and distances between places. Maps can show distributions of things over the Earth, such as settlement

patterns. They can show exact locations of houses and streets in a city neighborhood.

Mapmakers, called cartographers, create maps for many different purposes. Vacationers use road maps to plot routes for their trips. Meteorologists—scientists who study the weather—use weather maps to prepare forecasts. City planners decide where to put hospitals and parks with the help of maps that show land features and how the land is currently being used.

Some common features of maps include scale, symbols, and grids.

Scale

All maps are scale models of reality. A map's scale indicates the relationship between the distances on the map and the actual distances on Earth. The most common type of graphic scale looks like a ruler. Also called a bar scale, it is simply a horizontal line marked off in miles, kilometers, or some other unit of measuring distance.

Symbols

Cartographers use symbols to represent geographic features. For example, black dots represent cities, circled stars represent capital cities, and different sorts of lines represent boundaries, roads, highways, and rivers. Colors are often used as symbols. Green is often used for forest, tan for deserts, and blue for water. A map usually has a legend, or key, that gives the scale of the map and explains what the various symbols represent.

Some maps show relief, or changes in elevation. A common way to show relief is contour lines, also called topographic lines. These are lines that connect points that have equal elevation. If a map shows a large enough area, contour lines form circles. A group of contour line circles inside one another indicates a change in elevation. As elevation increases, these contour line circles indicate a hill. As elevation decreases, contour line circles indicate a depression in the earth, such as a basin.

Grids

Many maps include a grid pattern, or a series of crossing lines that create squares or rectangles. The grid helps people locate places on the map. On small-scale maps, the grid is often made up of latitude and longitude lines. On maps showing greater detail, the grid is often given numbers and letters. The boxes made by the grid may be called A, B, C, and so on across the top of the map and 1, 2, 3, and so on across the left side. In the map's index, a park's location might be given as B4. The user finds the park by looking in the box where column B and row 4 cross.

Cartographers make many different types of maps, which can be divided into two broad categories: general reference maps and thematic maps.

	General reference maps show general geographic information about an area, including the locations of cities, boundaries, roads, mountains, rivers, and coastlines. Thematic maps display distributions, or patterns, over Earth's surface. They emphasize one theme, or topic. These themes can include information about people, other organisms, or the land. Examples include crop production, people's average income, where different languages are spoken, or average annual rainfall. Adapted from https://education.nationalgeographic.org/resource/map/
Materials	For teacher: ➢ Projector • Political map of United States to project For each student: ➢ Science notebook ➢ *"What State Am I"* assessment (printed out) For each group of three students: • Set of 3 United States maps (A-C) • (Optional) United States political map • Magnifying glass
Prior Knowledge	Students should have developed a basic understanding of what flood is during *Lesson One*. Part A of the *Lesson Two* investigation may be skipped if your students have already mastered basic map reading skills.
Launch (5-10 minutes)	
Phenomenon	Show the KPRC2 news clip (2 min 20 sec) "Meyerland home floods for 4th time in less than 2 years", or the shorter clip (35 sec) found on the USB in the *Lesson Two* folder. Ask students to think silently for a moment about what they think could cause a home to flood 4 times in less than 2 years. Allow students 2-3 minutes to discuss their ideas with a partner. Allow each pair to share their ideas with the class. Encourage appropriate student dialogue and generate a list of questions that students wish to investigate.

Explore (15-30 minutes)	
Investigation	Before students begin investigating why some areas are more prone to flooding than others, they will need some familiarity with reading maps. *Part A* of this investigation is included for introducing some very basic map-reading skills. **If your students have already mastered basic map reading skills, please skip to Part B.** **Part A** Project the Google Map for your school's location. *(If your school does not allow access to Google Maps, Bing Maps and MapQuest are acceptable alternatives, although MapQuest ads may be problematic. Alternatively, there are hard copy maps of Pierre, South Dakota, and the United States included in the kit.)* Ask students: • What information does this map display? • What do you see that helps us understand what is displayed? (key/legend/scale, etc.) • What would this map be useful for? • What additions would make this map even more useful? Select the "Satellite View" button displayed in the lower corner of the map. Ask students: • What is different about this map, as compared to the first? • What is the same? • What new information can we determine from this "satellite view"? Go back to the original version of the map and zoom-out until you can see your entire state. Toggle between the two views (satellite view and map view) again. Ask students: • Where are we located within our state? • What new information is displayed when we look at our state? • What can we learn about our hometown from this map? Finally, zoom-out until the entire contiguous United States is visible. Again, toggle between the satellite view and map view. Ask students: • Where are we located, within the contiguous United States?

- What can we learn about our state and/or nation from these two map views?
- Which map do you find most useful? *(answers should vary)*
- What additional information, on either map, would make them even more useful? *(again, answers should vary widely)*
- How should the new information be displayed? Would you add it to an existing map? Would it be better displayed using a third map? Why or why not?

(Optional) In preparation for Lesson 4, you may want to display and discuss the "terrain" option available with Google Maps. This option displays topographic contour lines as well as contour shading. You can select this option in the menu found at the upper left of the map. The symbol for the menu is 3 horizontal, parallel lines.

When you feel your students are "map-ready", move on to Part B.

Part B

Tell students that they are going to begin investigating floods. Specifically, they will be using maps to discover patterns that could be used to predict where floods are most likely to occur.

Form groups of 3 students. It is acceptable to have a few groups of 4, if necessary. These will be their "home" groups. Have students turn to page 11 of their science notebook and provide a set of three US maps (labeled A, B, and C) to each group. Each student in a home group will be responsible for analyzing a different map. In this way, each home group will have an "expert" on each of the maps, A-C.

There are magnifying glasses in the kit for students to use if they desire (1 per group, to share). There is also a political map of the United States on the USB to project during this activity, as students may desire help identifying states, rivers and other features that may not be well labeled on maps A-C. (*an optional hard copy for each group is also included*)

Once students have a map to analyze, they should take 3-4 minutes to silently and individually complete page 11 of the science notebook.

Next, form "expert groups" of 3-5 students. Unless you have a rather small class, you will likely need to form 2 expert groups for each map (2 expert groups for map A, 2 for map B, etc.). Each expert group should come to consensus (using talking chips) about what information their map displays, what the various colors represent, and the patterns they notice in the displayed information (page 12 of the science notebook). Circulate among the expert groups, listening for any that might need you to ask guiding or "probing" questions to help them draw logical conclusions.

	If students begin asking about the word "precipitation", you may want to interrupt for a quick discussion. Precipitation is more than just rain, it includes hail, sleet and snow as well… any form of water falling from the sky.
Summarize (10 minutes)	
Communicate	Reassemble the original "home" groups. Each student, in turn (using a talking stick), should share what their expert group discussed concerning their assigned map. Page 13 of the science notebook is for group members to record their learning. Then, expert groups should work collaboratively (using talking chips) on page 14 of the science notebook: What do you notice about areas that tend to flood, where would you choose to build a house to reduce the risk of flooding, and why. Provide guidance, as needed. Students should be looking for patterns of Earth's features that could be used to identify where floods are most likely to occur. For this lesson, features can be physical structures like mountains, lakes and rivers… but they can also be patterns found in climate and/or weather as displayed on the maps. A full explanation should require information from each of the three maps (flood prone areas, average annual precipitation, and topography). *(Optional) If time permits, have each group share where they decided to build their house to reduce the risk of flooding, and why. Encourage students to ask probing and clarifying questions of each other.*
Terminology and Concepts to Solidify	**Map-** a symbolic representation of selected characteristics of a place. **Scale-** indicates the relationship between the distances on a map and the actual distances on Earth. **Symbol-** pictures or shapes used to represent geographic features. **Key-** a table explaining the various symbols used on a particular map. **Topography-** the art of graphic delineation, usually on maps or charts, of natural and man-made features of a place/region to show relative positions and elevations. **Average annual precipitation-** an estimate of how much water (as rain, hail, sleet and snow) can be expected, over the course of a year, in any location/region.
Connection to Big Ideas (Phenomena)	Patterns found in Earth's features can be utilized in identifying where floods are most likely to occur.
(Optional) Follow Up/Practice	Consider having students create a map (including scale and legend) of something … their bedroom, their house, the school, a park, etc. Tabletop floodplains are a great way to experiment, discover, and visualize where flooding is most likely to occur. There is a .pdf document on the

	USB within the *Lesson Two* folder, or use this link: https://www.teachengineering.org/activities/view/cub_natdis_lesson07_activity1
Assessment	Play "What State Am I?" using the set of U.S. maps from **Part B** of this investigation and the same student groups of 3. Students work with a set of clues to determine the state with the characteristics that best match the clues. *Additionally, you will find a blank template in the print masters that can be used for making your own clue cards. Consider allowing student groups to create their own clue cards to challenge other groups!* **Note: You will need to print copies of the assessment for each student**. The files may be found in the *Print Masters* section of this facilitator guide, and also on the USB found in the binder pouch of the 3-ring binder.

Now that students have identified areas more prone to flood (Lesson Two), they will move to investigating drought (Lesson Three). Consider having students reflect upon what they have learned, which *Lesson One* "wonders" they are now able to answer, and if they have any new wonders. Most likely, students will be wondering if drought prone areas can be identified by patterns as well.

Too Much, Too Little

Lesson 3	When Does Drought Occur?
Overview Standard(s) & Objectives	**Overview** Students investigate the fact that drought can happen anywhere on land, though it is more likely in some regions than in others. After a brief introduction to graphs where they investigate the historic drought of the 1930's in South-West South Dakota, students organize modern South Dakota weather data into graphical displays. Students then analyze these graphs to identify patterns that can be used to predict the weather conditions expected for any particular season. **Standards** 3-ESS2-1 Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season. Science and Engineering Practice (SEP): • Analyzing and Interpreting Data- Analyze and interpret data to make sense of phenomena using logical reasoning. Crosscutting Concept (CCC): • Patterns- Patterns can be used as evidence to support an explanation. **Objectives** Students • Recognize that drought can happen anywhere. • Utilize graphical displays to organize weather data. • Analyze weather patterns to predict expected conditions during a particular season.
Questions	**Driving Question** • What patterns do you see that could be used to predict expected conditions for each season? **Probing Questions** • What are the typical weather conditions for spring in our hometown? Summer? Fall? Winter? • Is there any season(s) you think drought is more likely to occur? Why or why not? • Based on your <u>**class data**</u>, what month would be best for a vacation in or near your hometown (when should family visit from far away)? Why?

Too Much, Too Little

Background Information	*The following information was obtained from livescience.com:* https://www.livescience.com/21469-drought-definition.html Droughts occur in nearly all types of climate. Of all the weather-related phenomena that can cause severe economic impacts in the United States, droughts come in second only to hurricanes, according to the National Climatic Data Center. But unlike hurricanes, which are easily identified and straightforward to classify in terms of wind speeds, droughts are much tougher to define. **Definition of drought:** Most people think of a drought as a period of unusually dry weather that persists long enough to cause problems such as crop damage and water supply shortages. But because dry conditions develop for different reasons, there is more than one definition of drought. "Drought is caused by not only lack of precipitation and high temperatures but by overuse and overpopulation," said David Miskus, a drought expert and meteorologist at the National Oceanic and Atmospheric Administration's (NOAA) Climate Prediction Center. In the 1980s, two researchers uncovered more than 150 published definitions of drought which they published in the journal Water International. In an effort to bring some order to measuring drought, the scientists grouped the definitions into four basic categories: meteorological, hydrological, agricultural and socioeconomic. The first three descriptions track drought as a physical phenomenon. The last category deals with drought as a supply-and-demand problem, through the impacts of water shortfalls. These definitions usually specify the beginning, end and degree of severity of drought by comparing the precipitation over a certain time period to a historical average. Scientists include both rain and snow in precipitation measurements because some U.S. regions, such as the mountainous West, rely on winter snow for much of their yearly water. **Here are descriptions of the four main categories of drought:** **Meteorological drought** is specific to different regions, depending on the amount of yearly precipitation that's average for that area. For example, the southwest portion of the United States averages less than 3 inches (7.6 centimeters) of precipitation per year, while the Northwest gets more than 150 inches (381 cm) per year, according to the U.S. Department of Interior. A decrease in precipitation compared to the historical average for that area would qualify as a meteorological drought. **Agricultural drought** accounts for the water needs of crops during different growing stages. For instance, not enough moisture at planting time may hinder germination, leading to low plant populations and a reduction in yield.

	Hydrological drought refers to persistently low water volumes in streams, rivers, and reservoirs. Human activities, such as drawdown of reservoirs, can worsen hydrological droughts. Hydrological drought is often linked with meteorological droughts. **Socioeconomic drought** occurs when the demand for water exceeds the supply. Examples of this kind of drought include too much irrigation or when low river flow forces hydroelectric power plant operators to reduce energy production. **Tracking drought:** In the United States, the Palmer Drought Severity Index (PDSI, weekly index from CPC shown), devised in 1965, was the first comprehensive drought indicator. It is considered most effective for unirrigated cropland. The PDSI combines temperature, precipitation, evaporation, transpiration, soil runoff and soil recharge data for a given region to produce a single negative number that indicates drought conditions. The nationwide Drought Monitor categorizes drought into five levels of severity: • abnormally dry (category D0, PDSI between -1.0 and 1.9) • moderate drought (D1, PDSI between -2.0 and -2.9) • severe drought (D2, PDSI between -3.0 and -3.9) • extreme drought (D3, PDSI between -4.0 and -4.9) • exceptional drought (D4, PDSI between -5.0 and -5.9) **History of U.S. droughts:** In the United States, the most devastating drought on record occurred in the 1930s during the so-called "Dust Bowl" years. According to the National Climatic Data Center, the drought affected almost the entire Plains region and covered more than 60 percent of the country at its peak in July 1934. It caused the migration of millions of people from the Plains to other parts of the country, especially the West Coast. Researchers think a high-pressure ridge over the West Coast deflected moisture-bringing storms in 1934, causing the severe Dust Bowl droughts. This ridging pattern has been in place during some of the West's worst droughts, such as the 1976 and 2013 California droughts — two of the worst dry spells in the state's history. Persistent high pressure in the atmosphere curbs cloud formation and leads to lower relative humidity and less precipitation. In the West, prolonged droughts occur when large-scale high-pressure patterns persist for months or more, blocking storms carrying winter rains and snow. More recent U.S. droughts, such as those of the 1950s, 1988 and 2000, have also had serious economic and societal impacts. Between 1980 and 2014,

	16 drought events cost a combined $210 billion in the United States, and thousands of people died because of drought, according to NOAA.
Materials	For teacher: ➢ Projector and speakers For each student: ➢ Science notebook Each pair of student's needs: • Map- Official U.S. Drought Declarations 2000-2018 (By County) • Set of Dust Bowl era graphs (precipitation + temperature) • (Optional) Transparency of Dust Bowl era precipitation graph • Weather data card ➢ Materials/manipulatives for creating graphical displays
Prior Knowledge	Drought is a natural phenomenon caused by a significantly lower than expected amount of water in a particular location (from *Lesson One*).
Launch (5-10 minutes)	
Phenomenon	Hand out and display the "Official U.S. Drought Declarations 2000-2018 (By County)" map (available on the USB in the front zipper pocket of the teacher's guide, in the *Lesson Three* folder). Give students a moment to (silently) look at the map and analyze the information presented. Ask (*This might be a good place for a strategy like [think/pair/share]*) • What does this map tell us about drought? Where can drought happen? • Can we predict where drought is most likely to occur using patterns of Earth's features? Why or why not? • How is drought different from flood, considering where they are most likely to occur? • What questions do you have about drought? (Students could even check their questions posted from *Lesson One*)
Explore (30 minutes)	
Investigation	**Part A (5-10 minutes)** Tell students they are going to begin investigating events that contribute to drought. They are going to begin by analyzing information from one of the most severe droughts ever to occur in North America. It was a prolonged period in the 1930's referred to as the "Dust Bowl".

Show the short video clip (1 min 43 sec) about the Dust Bowl found here: http://www.pbs.org/kenburns/dustbowl/

If time permits, have students share what they noticed, and what they wondered, during the video.

Hand each pair of students a copy of the Dust Bowl era graph titled “July Precipitation for South-West South Dakota in the 1930’s”. Also, project the image of this graph (found on the unit USB). Ask students to silently analyze the graph, looking for anything useful in interpreting the information.

Ask students: (Another great place for a strategy like think-pair-share)

- What information is displayed in this chart? How do you know?
- What does each “bar” represent? How do you know?
- What pattern(s) do you see?
- Why is the height of each column important?
- What does the red dotted line represent? Why is it important?
- What would happen if the “labels” were not present?
- Can you think of any other ways to display this information? For instance, could we use something in place of the blue “bars”? Would it have to be on paper?

Hand each pair of students the second Dust Bowl era graph titled “Average July Temperature for South-West South Dakota in the 1930’s”. Student pairs should now have both Dust Bowl era graphs. Give students a moment to silently analyze this new graph.

Ask students:

- What information is displayed on this new graph?
- What pattern(s) do you see?
- How does the pattern for temperature (red bars) compare to the pattern for precipitation (blue bars)?
- Considering the information displayed on both graphs, which year do you believe was the worst for drought during the 1930’s Dust Bowl in South-West South Dakota? Why? What is your evidence?

(Optional) There are transparency copies of the Dust Bowl era precipitation graph to overlay onto the temperature graph, if desired.

When you feel your students are “graph-ready”, move on to Part B. If you feel that additional practice and support would be beneficial, consider the following (optional) activity:

(Optional) Graph Practice

Choose four or five students of various heights and create a data table consisting of name and height.

Tell your students that there are many ways to make data visual; the bar graphs they used in Part A are just one example. However, how do you go from numbers in a data table to a visual example, like a bar graph? Give students a few minutes to think about this and take suggestions.

Consider providing time for students to explore and give their ideas a try!

A fun suggestion for making a student height bar graph would be to have the named students line up in front of the dry erase board, or chart paper, and draw a line (a “bar” or rectangle) up one side of a student, across the top of their head, and down the other side. Do this for each student, and then have them step away from the board. What you have is the beginning of a bar graph of student heights!

Ask students what else could be added to make it more informational and useful. *Suggestions: axis labels, a title, a key or names on the bars, color code and shading-in the bars, etc.*

Part B (25 minutes)

Tell students that they will now investigate more recent trends in South Dakota weather. Specifically, they will be creating visual ways of displaying weather data that they can use to discover patterns. The goal is to use their visual representations of the data to predict conditions expected during any particular season.

Note: Though students may be familiar with bar graphs, this is an opportunity to expand their familiarity with the wide variety of visual representations available for displaying data. Consider showing students this infographic (also on the USB) to give their creativity a boost!

Ask students to think silently for a moment, then discuss this question with a partner: *(you might want to write the question on the board)*

- Why is it important to know and understand the expected conditions in any season (such as temperature, or precipitation)?

Student answers will be varied! Example responses are knowing what to pack for a trip and determining when to plant a garden. Determining whether or not a region is experiencing drought is another example.

Ask each pair to share one reason from their discussion.

Hand each group a data table (they are labeled A through P). The task card to guide their exploration is on page 15 of the science notebook. Every pair will have a different data set to work with. Make sure that half the class has precipitation data, and half receive temperature data.

	Aid groups as necessary. Each team should create and display a visual/graphical way of representing their data by month and season. Have students post all the temperature graphs in one location, and all the precipitation graphs in a separate location (for the gallery walk).
Summarize (5 minutes)	
Communicate	Once all groups have posted their graphical/visual representations, student groups should perform a "gallery walk" using page 16 of the science notebook. Pairs then collaborate on answering the questions found on page 17. If time permits, consider holding a full-class discussion addressing the *Putting It All Together* questions.
Terminology and Concepts to Solidify	**Pictograph-** a way of showing data using images. Each image stands for a certain number of things. **Bar Graph-** a diagram in which the numerical values of variables are represented by the height or length of lines or rectangles of equal width. **Drought-** a period of unusually dry weather that persists long enough to cause problems such as crop damage and water supply shortages. **Climate**- the weather conditions prevailing in an area in general or over a long period. **Weather**- the state of the atmosphere at a place and time as regards heat, dryness, sunshine, wind, rain, etc. **Season**- each of the four divisions of the year (spring, summer, autumn, and winter) marked by particular weather patterns and daylight hours, resulting from the earth's changing position with regard to the sun.
Connection to Big Ideas (Phenomena)	Though flood-prone areas can be determined based upon patterns found in Earth's features, drought is possible anywhere (on land).
(Optional) Follow Up/Practice Ideas	If your students are familiar with averages, consider having them represent their data by seasonal average (so only 4 data points). Or, have the class come up with a seasonal average for temperature and precipitation using all of the data provided (data tables A through P). Research and report on the Dust Bowl and/or the variety of factors that can contribute to drought occurrence. Watch "Stinging Dust and Forgotten Lives: The Dust Bowl" (2008) available on YouTube (~58 minutes). https://www.youtube.com/watch?v=Tzo9wtXfHGk
Assessment	The *Lesson Three Assessment* may be found in the science notebook on page 18.

<table>
<tr><th>Lesson 4</th><th>Why Should I Be Concerned?</th></tr>
<tr><td>Overview Standard(s) & Objectives</td><td>
Overview

Students utilize what they learned in Lessons One through Three to predict the likelihood of Flood in Rapid City, South Dakota. Then, students are presented with pictures and information about the historic 1972 Rapid City flood, which killed 238 people and injured 3,000. Through the investigation of 2D and 3D watershed representations, average monthly precipitation data, and precipitation data for June 9th and 10th of 1972, students construct explanations for why the 1972 Rapid City Flood occurred.

Standards

Working Toward:

4-ESS3-2 Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

Science and Engineering Practice (SEP):
Constructing Explanations and Designing Solutions- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation.
Crosscutting Concept (CCC):
Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change.
Objectives

Students

Investigate the Rapid Creek watershed.
Construct explanations for why the 1972 Rapid City Flood occurred.
Recognize that flood can happen just about anywhere.
Identify local features (man-made and natural) that might mitigate the effects of flood and/or drought.

</td></tr>
<tr><td>Questions</td><td>
Driving Question
What factors contributed to the historic 1972 flood of Rapid City?
Probing Questions

Based only on the maps from Lesson Two, how would you describe the likelihood of flood in Rapid City, SD?
How does the information presented about the 1972 Rapid City flood affect your understanding about where floods are likely?
How did the physical features of the Rapid Creek watershed contribute to the 1972 Rapid City flood?
How can the rate of rainfall contribute to flood?

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Background Information	The 1972 Rapid City Flood
	Adapted from https://www.usgs.gov/centers/dakota-water/science/1972-black-hills-rapid-city-flood?qt-science_center_objects=0#qt-science_center_objects On June 9-10, 1972, extremely heavy rains over the eastern Black Hills of South Dakota produced record floods on Rapid Creek and other streams in the area. Nearly 15 inches of rain fell in about 6 hours near Nemo, and more than 10 inches of rain fell over an area of 60 square miles. According to the Red Cross, the resulting floods left 238 people dead and 3,057 people injured. In addition to the human tragedy, total damage was estimated in excess of $160 million (about $664 million in 2002 dollars), which included 1,335 homes and 5,000 automobiles that were destroyed. Runoff from this storm produced record floods (highest peak flows recorded) along Battle, Spring, Rapid, and Boxelder Creeks. Smaller floods also occurred along Elk Creek and Bear Butte Creek. Although Pactola Reservoir was effective in storing runoff that originated upstream of Pactola Dam, the heaviest rainfall occurred downstream of the dam. Most of the flow that passed through Rapid City via Rapid Creek originated in the 51 square mile drainage between Pactola Dam and Canyon Lake. Flood waters that reached Rapid City above Canyon Lake Dam between 9:30 and 10:00 p.m. on June 9 carried large amounts of debris that clogged the spillway of Canyon Lake Dam. The dam at Canyon Lake failed at about 10:45 p.m. However, the effect of this dam failure on the subsequent flood wave into urban Rapid City has been difficult to assess because the amount of water coming down Rapid Creek and several tributaries (accounting for 86 percent of the peak flow) far over-shadowed the amount of water in the small lake (Swartz and others, 1975). The peak discharge of 50,000 cubic feet per second (ft^3/s) was carried through Rapid City via Rapid Creek at about midnight on June 9, while many people were asleep and unaware of the impending flood. The flood struck quickly and forcefully, but did not last long. Water in Rapid Creek was back within the banks of the stream by 5:00 a.m. on June 10. As the peak flows moved into less-steep terrain, the flows spread out over a wide area and much of the water was stored in the flood plains. The 1972 flood has an estimated recurrence interval of 500 years (Burr and Korkow, 1996), which means that a flood of this magnitude will occur on average once every 500 years. Every year there is a 0.2 percent chance (1 in 500) of experiencing a similar flood. Because of the short period of record for Rapid Creek gaging stations, the recurrence interval of 500 years may be revised substantially as additional data are collected. "Floods are natural and normal phenomena. They are catastrophic simply because man occupies the flood plain, the highway channel of a river (Bue, 1967)." In the aftermath of the 1972 flood, interim and long-range programs were initiated, and millions of federal dollars were spent in Rapid City and the

	surrounding stricken communities (Rahn, 1984). Rapid City approved a flood-plain management program, known as the "greenway" concept, whereby most of the flood plain was converted into large parks. However, Rapid City and the surrounding communities are susceptible to extreme flooding because of their location in and around the Black Hills. Most floods in the Black Hills area are caused by intense rainfall over very steep watersheds, which allows little time for warning residents of flood threats. In 1997, a flood-warning system was implemented by the USGS in cooperation with the Rapid City-Pennington County Emergency Management and the National Weather Service (NWS). Combination precipitation/streamflow-gaging stations monitor rainfall and subsequent rises in stream stage on a continuous basis during the flood season (April-October). This real-time information is relayed via a satellite network to the NWS, where forecasters can send warning to the public when streams rise to threatening levels. Rapid City-Pennington County Emergency Management can then coordinate emergency response, public safety services, and local governmental agencies as needed.
Materials	For teacher: ➢ Projector and speakers For each student: ➢ Science notebook Each group of 3 students will need (Launch): • Set of 3 *Lesson Two* maps labeled A-C • 1972 Rapid City flood pictures and information Each pair of students will need (Explore): • *Crumpled Watershed* instructions ➢ (1) Sheet copy paper • (2) Non-permanent dark colored markers ➢ Waterproof surface (cafeteria tray, desktop, lab bench) ➢ Tape • Spray bottle (each kit contains 10 for the class to share) • *Rapid City, SD Average Monthly Precipitation* data • *2D Black Hills Elevation Map* • 3D model of Rapid Creek watershed (1 per 4 students) • *Total Storm Rainfall Map* for June 9-10, 1972 • (optional) Transparency of *Total Storm Rainfall Map*
Prior Knowledge	Recognize what flood and drought look like, and how they differ from “normal conditions” in any specific area (*Lesson One*).

	Understand that the likelihood of flood can be predicted (to some extent) using patterns in Earth's features (*Lesson Two*). Explain that drought can happen just about anywhere on land (*Lesson Three*).
Launch (5-10 minutes)	
Phenomenon	Form groups of 3. Hand out the set of *Lesson Two* maps labeled A-C and give students a few minutes to look over the maps again. Ask students to turn to page 19 of their science notebook and, silently, answer the questions pertaining to how likely they believe flood is in Rapid City, SD. At this point, it is important that students write down their own, personal, initial thoughts before any peer discussion. A minimum of 5 minutes is recommended. Once everyone is finished recording their personal thoughts and reasoning, allow groups to share and discuss. Talking chips and/or a talking stick would be useful here. It is critical that every student share their initial ideas and reasoning before proceeding. Finally, hand out and display the historic 1972 Rapid City flood pictures and information (the lesson phenomenon). It is also available on the USB in the front of the facilitator guide for projecting. *Caution: The damage shown may be troubling for some students, especially if they have experienced trauma due to a flood, tornado, etc.* As time permits, play the montage of audio clips from flood survivors produced by SDPB: http://sdpb.sd.gov/newsite/shows.aspx?MediaID=60757&Parmtype=RADIO&ParmAccessLevel=sdpb-all Allow time for student groups to, equitably, address the questions on page 20 of the science notebook (ie: individual think time, then talking stick or talking chip discussion). Has their understanding of the likelihood of flood in Rapid City, SD changed? If so, in what ways? What might have caused this flood to occur? What questions do they have?
Explore (30 minutes)	
Investigation	**Part A: What is a Watershed? (15-20 minutes)** Tell your students that they are going to begin investigating the various factors that contributed to the 1972 Rapid City flood. First, they need to investigate Rapid Creek, the creek that flooded in 1972. Specifically, they are going to investigate what is called the Rapid Creek "watershed". But instead of telling them what a watershed is, you want them to discover it for themselves.

Form student groups of 2 (pairs) for this activity. Hand each pair a set of *Crumpled Watershed* instructions and direct them to page 21 of the science notebook for recording observations and ideas. Students may use any dark colored non-permanent felt-tip marker, such as Crayola brand.

Crumpled Watersheds may be taped to student desks, lab benches, or any waterproof trays available. Plastic cafeteria trays work particularly well, but even plastic shoeboxes can be utilized. Students can allow their watershed to dry, if desired, for later observation. Note that "lakes" may not dry with defined edges as the water tends to wick back up the slopes. Therefore, if students want to dry their watershed, they will need to outline any water bodies created with pencil or permanent marker.

Part B: Rapid Creek and the Flood of 1972 (10-15 minutes)

Hand each pair of students (and project) a copy of the *Rapid City, SD Average Monthly Precipitation* graph. Give students a moment to, silently, look at the data presented. This is a great opportunity to utilize the Think/Pair/Share strategy:

- What new information is presented on this graph?
- Based on the information presented, would you expect flood to be likely in Rapid City, SD in June? Why or why not?

Give each pair of students a copy of the 2D elevation map of the Black Hills region. Also, place a 3D model of the Rapid Creek Watershed between each pair of students, so that every 2 pairs share 1 model. Explain that the black box on the map represents what is shown on the 3D model. Students should compare the 2D elevation map of the Black Hills with the 3D model.

- What is similar when comparing the map with the model?
- What is different?
- Locate Rapid Creek on the Black Hills map *(enclosed within the black box)*. What information does this map and model tell you about Rapid Creek, as compared to the rest of the Black Hills?

Hand each group a copy of the *Total Storm Rainfall Map* for June 9-10. You might also want to project the map. Ask students to locate Rapid Creek *(enclosed within the black box)* and Rapid City. Note that the label "Rapid City" is placed far to the right of the city limits *(outlined)*.

- What new information is presented on this graph?
- What was the highest total storm rainfall found within the Rapid Creek watershed on June 9-10 of 1972?
- How does the highest total rainfall found within the Rapid Creek watershed compare with the average monthly precipitation for the entire month of June?

	(Optional) Hand each group a transparency of the *Total Storm Rainfall Map*. The transparency can be placed on top of the *2D Black Hills Elevation Map*, so that the black boxes align. Ask students how combining the information found on these two maps might be useful in figuring out what caused the 1972 Rapid City flood? Finally, have students spray the 3D model with water to simulate rain, just like in the crumpled watershed activity, and observe where the precipitation goes. Each group will then collaborate equitably (talking stick or chips) to generate an explanation of why the historic 1972 flood of Rapid City occurred (science notebook page 22). Explanations should address both rainfall and topography.
Summarize (10-15 minutes)	
Communicate	Direct students to page 23 of the science notebook. Groups should take a few minutes to discuss each question, one question at a time, at their own pace (this might be a good place to use talking sticks). If you are comfortable sharing your own experiences with too much and/or too little water, share them with the class before groups begin! As groups finish their discussion, prompt them to move on to the brainstorming activity on page 24 (talking chips suggested). The goal is for students to consider the man-made and/or natural features of their local landscape that might serve to mitigate the effects of flood and/or drought. This list will be utilized in *Lesson Five*. Encourage your students to look for more features to add to their brainstorming list on the way home. **They should also ask friends and family about their own experiences with too much and/or too little water.** Then, allow a few minutes before beginning *Lesson Five* for students to add to their science notebooks and share with group members.
Terminology and Concepts to Solidify	**Watershed-** the area of land that drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel. **Flash Flood-** a sudden local flood, typically due to heavy rain.
Connection to Big Ideas (Phenomena)	Though it is possible to predict areas that are prone to flooding based on patterns found in Earth's features, flood is, in actuality, possible just about anywhere.
(Optional) Follow Up/Practice Ideas	Weather.gov has a website dedicated to South Dakota Floods. It discusses 5 specific South Dakota Flood events, the typical types of flooding that occur in South Dakota, and flood safety. Check out this site for video footage of the July, 2016 flash flood that occurred in Old Ellicott City, Maryland: http://apps.npr.org/ellicott-city/

Too Much, Too Little

Assessment	Student explanations for why/how the historic Rapid City flood of 1972 occurred. (page 22 of the science notebook).

This is a great point for student reflection. What have they learned? How has their understanding of flood changed? What questions do they have? How are they feeling?

Too Much, Too Little

<table>
<tr><th>Lesson 5</th><th>How Can We Help?</th></tr>
<tr><td>Overview Standard(s) & Objectives</td><td>

Overview

Students investigate engineered solutions to issues of too much and/or too little water, then generate and compare multiple solutions for reducing the impacts of too much and/or too little water in their hometown.

Standards

4-ESS3-2 Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

Science and Engineering Practice (SEP):

- Constructing Explanations and Designing Solutions- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.

Crosscutting Concept (CCC):

- Cause and Effect- Cause and effect relationships are routinely identified, tested, and used to explain change.

Objectives

Students

- Discuss the purpose and process of engineering
- Investigate engineered solutions to issues of too much and/or too little water
- Generate and compare solutions to reduce the impact of too much and/or too little water in their hometown

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<tr><td>Questions</td><td>

Driving Question

- What can you do to reduce the impact of too much and/or too little water in your hometown?

Probing Questions

- What is the purpose of engineering?
- How do engineers generate solutions to problems?
- What engineered solutions to issues of too much and/or too little water do you observe in your hometown? How do they work? What problem are they addressing?
- What issues of too much and/or too little water remain unsolved in your hometown?

</td></tr>
<tr><td>Background Information</td><td>

Engineering

Engineers design, evaluate, develop, test, modify, install, inspect, and maintain a wide variety of products and systems. They also recommend and specify materials and processes, supervise manufacturing and

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</table>

construction, conduct failure analysis, provide consulting services and teach engineering courses in colleges and universities.

The field of engineering is divided into many specialty areas (Note that this is not an exhaustive list):

Mechanical engineering involves design, manufacturing, inspection and maintenance of machinery, equipment, and components as well as control systems and instruments for monitoring their status and performance.

Electrical engineering involves design, testing, manufacturing, construction, control, monitoring and inspection of electrical and electronic devices, machinery, and systems.

Civil engineering involves design, construction, maintenance, and inspection of large infrastructure projects such as highways, railroads, bridges, tunnels, dams and airports.

Aerospace engineering involves design, manufacturing and testing of aircraft and spacecraft as well as parts and components such as airframes, power plants, control and guidance systems, electrical and electronic systems, and communication and navigation systems.

Nuclear engineering involves design, manufacturing, construction, operation and testing of equipment, systems and processes involving the production, control, and detection of nuclear radiation.

Structural engineering involves design, construction and inspection of load-bearing structures such as large commercial buildings, bridges, and industrial infrastructure.

Biomedical engineering is the practice of designing systems, equipment, and devices for use in the practice of medicine.

Chemical engineering is the practice of designing equipment, systems, and processes for refining raw materials and for mixing, compounding and processing chemicals to make valuable products.

Computer engineering is the practice of designing computer hardware components, computer systems, networks, and computer software.

Industrial engineering is the practice of designing and optimizing facilities, equipment, systems and processes for manufacturing, material processing, and any number of other work environments.

Environmental engineering is the practice of preventing, reducing, and eliminating sources of pollution that affect air, water and land. It also involves detecting and measuring pollution levels, determining sources of pollution, cleaning up and rehabilitating polluted sites and ensuring compliance with local, state, and federal regulations.

	There is often considerable overlap among the different specialties. For this reason, engineers need to have a general understanding of several areas of engineering besides their specialty. For example, a civil engineer needs to understand concepts of structural engineering, an aerospace engineer needs to apply principles of mechanical engineering, and nuclear engineers need a working knowledge of electrical engineering. Particularly, engineers require in-depth knowledge of mathematics, physics, and computer applications such as simulations and computer-aided design. Therefore, most college programs include basic engineering courses in a wide range of topics before students choose to specialize in a particular area. Adapted from https://www.livescience.com/47499-what-is-engineering.html
Materials	For teacher: ➢ Projector and speakers For each student: ➢ Science notebook Each group of 4 students will need: • Set of four engineered solution pages labeled A-D
Prior Knowledge	Recognize what flood and drought look like, and how they differ from "normal conditions" in any specific area (*Lesson One*). Understand that the likelihood of flood can be predicted (to some extent) using patterns in Earth's features (*Lesson Two*). Explain that drought can happen just about anywhere on land (*Lesson Three*). Describe events that can produce flooding in a region where flood is unlikely and realize that flood can happen just about anywhere (*Lesson Four*).
Launch (10-15 minutes)	
Phenomenon	**This lesson is designed to take 2-3 class periods.** Ask students to think silently for a moment about what engineers do, as well as *how* they do it. Allow students 2-3 minutes to discuss their ideas with a partner. Allow each pair to share their ideas with the class. Encourage appropriate student dialogue, and generate a list of examples of engineering, as well as examples of how engineers go about "engineering". Show the video "Act Now, Save Later" (2 min 41 sec) Hyperlinked here, or on the unit USB. Students should take a few minutes to silently think about

	and answer the questions on pages 25 and 26 of the science notebook. These questions are used in the following “dyad discussion”. **Dyad Discussion:** Students pair up and take turns being the listener and the speaker. If time permits, each partner may address every question. To save time, you can have the first student address the first question while the second listens, then the other student addresses the second question while the first listens, etc. More information about dyad discussion is available here: https://ggie.berkeley.edu/wp-content/uploads/2019/11/PWI-Focused-Listening-in-Dyads.pdf • What did you notice? What questions do you have? • What “solutions” were shown in the video for protecting people, crops, and livestock? What were they being protected from? • Would any of the solutions shown in the video be useful in your hometown? Why or why not? • Where in your hometown is there a need for solutions dealing with either too much, or too little, water? Wrap-up: Engineers use what they know of science in the effort to solve problems. The work of engineers is never done, as there are always more and new problems to solve. As technology progresses, better solutions are sometimes possible. Next, we will take a closer look at some engineered solutions for dealing with too much and/or too little water. Page 31 of the science notebook shows a diagram of the engineering process. Notice that it is a circle. The more cycles, or “iterations”, the better the solution becomes!
Explore (60-90 minutes)	
Investigation	**Part A: Engineered Solutions** (~30 minutes) Since students may have questions about what constitutes an engineered solution to an issue of too much and/or too little water, they will first explore four solutions that may or may not be found in their hometown. Form groups of four and provide each group with a set of engineered solution pages (labeled A-D). Each student chooses one of the engineered solutions and takes 5 minutes to silently read, think, and record notes in their science notebook (page 27). Form “expert groups” of 3-5 students. Expert groups should begin by, one at a time, sharing what they noticed and wonder (talking stick recommended). Next, groups should discuss the questions on page 28 of the science notebook, considering one question at a time (talking chips recommended). When ready, have students return to their home group to share-out and record notes on pages 29 and 30 of the science notebook.

	Part B: Your Turn! (~30-60 minutes) Have students turn to page 31 of the science notebook. Students will be focusing on the *Plan* portion of the engineering process for this lesson. Engineers spend a great deal of time in the *Plan* portion of the design process. The more time spent on careful planning, researching, and brainstorming, the more successful the first design (or *Build and Test)* iterations tend to be! If time permits, you may certainly allow your students time to *Build*, *Test*, *Analyze*, and repeat, but it is not necessary. <u>Step One- Identify the Issue</u>: Have students look back at pages 23 and 24 of the science notebook (*Lesson Four*). These pages may be useful as students work to identify issues of too much and/or too little water they observe in their hometown. Record a list of all student ideas on the board. Next, ask students to begin analyzing the issues. Ultimately, each student should choose one issue to focus on. Students should consider the "stakeholders" that could be helped, or hurt, by solutions to each of the water issues they have identified. They may want to choose to design a solution to something that stands to benefit the most people in their community, or they may choose to solve a problem that specifically benefits themselves and their loved ones. Ultimately, any choice is fine, as long as students clearly articulate the reasons for their choice. Potential questions to utilize: • Do any issues have the potential to affect a majority of people in your community? • Would solutions to any problem potentially cause any harm? • Do any issues appear easier to solve than others do? • Would solutions to any of the problems benefit you and/or those you care about? Once students choose a water issue to work on, form groups of no more than 3 for collaboration. Even if an issue was chosen by only one student, there will most likely be others whose issues and solutions are related. <u>Step Two- Generate Solutions:</u> The most important step in brainstorming is most likely the portion done alone, in silence, before any group discussion. Therefore, ensure that students get at least 5-10 minutes of quiet "think time" before any group discussion about potential solutions. There is a *Brainstorming* space at the top of page 32 for notes that students may utilize. This would also be a great time for students to research potential solutions to their water issue. Though students are encouraged to be creative in developing novel solutions to their issue, it is acceptable to allow research on solutions already in place in other parts of the world. Ultimately, the solution that best fits for their community will depend on an analysis of the pros/cons of each potential solution, as well as the specific characteristics of their area. What matters most in the end is that students

	clearly explain the reasons <u>why</u> their chosen solution is the best fit for their local water issue. Have group members share their ideas and thinking, one student at a time (this is a great place for a talking stick). Once every student has shared their ideas, group members can start discussing, asking each other questions, and generally analyzing the pros and cons of the ideas presented (talking chips recommended). Then each student chooses three potential solutions to evaluate, the three *best* ideas, and records them on page 32 of the science notebook. Group members do <u>not</u> need to evaluate the same three solutions. *Note: If students seem to be choosing only solutions from the jigsaw activity in **Part A**, you might challenge them to try to come up with at least one novel solution of their own. Alternatively, challenge students to adapt/change at least one of the **Part A** solutions so it is better suited to their specific situation/place.* <u>Step Three- Evaluate Solutions:</u> Students should use page 33 and 34 of the science notebook for guiding their analysis, choosing the best solution, and explaining their reasoning.
Summarize (20-30 minutes)	
Communicate	Students should present their final analysis to the class. This could be done with posters and a gallery walk, or oral presentations. Invite community leaders and/or "stakeholders" to participate as audience members during student presentations (city council members, mayor, fire and/or police chief, business owners, city planner, wastewater personnel, parents, etc.). All final presentations should include the following: • Chosen issue and reasoning (why chosen) • Three potential solutions • Best solution and reasoning (why chosen) • What effect people will observe (evidence it is working)
Terminology and Concepts to Solidify	**Engineering-** any engagement in a systematic practice of design to achieve solutions to particular human problems. **Porous-** a substance with small spaces or holes through which liquid or air may pass. **Impervious-** any substance that does not allow fluid to pass through. **Flow-through Dam-** a structure created for the purpose of flood control. Small amounts of water, as from a stream, are allowed to pass through, but water levels above normal are restricted. **Water Tower-** an elevated water tank whose height creates the pressure required to distribute water through a piped system.

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	Detention Basin- excavated areas installed on, or adjacent to, rivers, streams, lakes, or bays to protect against flooding and, in some cases, downstream erosion by storing water for limited periods of time. **Stormwater-** surface water in abnormal quantity resulting from heavy rain or snow. **Stakeholder-** someone with an interest or concern in something. They may stand to benefit, or be harmed, in some way.
Connection to Big Ideas (Phenomena)	No place on Earth is free from issues of too much and/or too little water. It pays to think ahead and be prepared. Engineered solutions are all around us, but humankind still has work to do- and today's students will be tomorrow's problem solvers.
(Optional) Follow Up/Practice Ideas	Consider having students write letters to community leaders explaining the water issue they see, as well as their engineered solution and reasoning. Take your students on a tour of their hometown, looking specifically for examples of engineered solutions dealing with too much and/or too little water. Have students research additional engineered solutions (or go deeper with the four presented in this lesson), make models, and prepare/deliver presentations. *Water Blues, Green Solutions*, provided by Penn State Public Media, hosts a variety of free video and audio clips about water issues and solutions, as well as the full-length documentary of the same name.
Assessment	Choice of best engineered solution for chosen issue and reasoning (science notebook page 34).

At this point, students may be wondering what Sanford Underground Research Facility (SURF) has to do with this unit. *Lesson Six*, therefore, introduces the deep underground lab and its unique water issue. Students then engage in an engineering design challenge to figure out how SURF keeps the underground spaces dry for science.

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<table>
<tr><th>Lesson 6</th><th>Sanford Underground Research Facility Connections</th></tr>
<tr><td>Overview Standard(s) & Objectives</td><td>

Overview

Students learn about the Sanford Underground Research facility in Lead, South Dakota, as well as the unique water issues of running a mile deep science laboratory. Then, students engage in an engineering design challenge focused on pumping water 4 feet, vertically, with minimal effort. Finally, students make connections between their engineering solutions, and the pump system used at SURF. Ultimately; students learn why the lab utilizes a five-step system for bringing water to the surface instead of a single pump and mile long pipe.

Standards

Science and Engineering Practice (SEP):

- Constructing Explanations and Designing Solutions- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.

Crosscutting Concept (CCC):

- Systems- A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot.

Objectives

Students

- Predict whether a mile deep science laboratory has issues with too much, or too little, water.
- Develop and test potential solutions, using materials provided, to pump water 4 feet, vertically.
- Learn about the Sanford Underground Research Facility's solution to water in the underground laboratory spaces.
- Make connections between SURF's water solution, and the most efficient solutions to the engineering challenge.

</td></tr>
<tr><td>Questions</td><td>

Driving Question

- What would it take to pump water a vertical mile?

Probing Questions

- Is it easier to bring water up a short tube, a long tube, or is there really no difference? Why?
- What would it take to build, run, and maintain a pump capable of moving water a vertical mile?
- Is it easier to pull-up, or push-up, water in a tube? How can you tell?
- Which takes less effort, using 1 hand pump or using 2? Why?

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Background Information

Sanford Underground Research Facility (SURF)

Sanford Underground Research Facility, located in the former Homestake Gold Mine in Lead, South Dakota, was a science landmark long before being converted into a dedicated science facility. Nuclear chemist Ray Davis first recognized the potential for deep science in the mid-1960s when he built his solar neutrino experiment at Homestake. In 2002, his groundbreaking research earned him the Nobel Prize in Physics.

Why do scientists go so deep underground to study particles that come from the universe? Hold out your hand. On the surface, one cosmic ray passes through it every second. However, nearly a mile underground, it's about ten million times quieter! If you held your hand out underground, you would have to wait about 3 months for a cosmic ray to go through your hand. The rock acts as a natural shield, blocking most of the radiation that can interfere with sensitive physics experiments. It turns out SURF is particularly suited to large physics experiments for another reason—the hard rock is perfect for excavating the large caverns needed for big experiments.

SURF also hosts experiments in other disciplines—including biology, geology, and engineering. Experiments include the search for life underground, geothermal energy and seismic activity.

For more information about SURF, visit http://www.sanfordlab.org/

Water management at the Sanford Underground Research Facility

When it rains, water enters the underground spaces at SURF—every inch of precipitation on the surface is equal to roughly 4-5 million gallons of water entering the underground. It is estimated that around 650 gallons per minute comes in throughout the whole facility, which consists of 370 miles of tunnels referred to as *drifts*.

As water enters the facility, it collects in a deep pool and must be pumped out. The pumping system includes a deep well pump (6200 feet), and pumping stations on four levels—the 5000, 3650, 2450 and 1250.

The water level underground is currently at about the 5700 foot level; however, a recently completed water inflow project allows some of that water to be collected at higher levels. When more water is collected closer to the surface, less energy is required to pump it back out!

Having several pumps throughout the underground allows the lab to reduce pressure in vertical water pipes and provides more control over the amount of water pumped. A single pump to bring the water from 5700 feet below ground, all the way to the surface, would be impractical, costly, and nearly impossible considering the resulting pressure in the pipe.

	As water comes in, it is collected, stored and eventually pumped to the surface in stages (about 1200 feet at a time). Approximately 700 gallons of water per minute are pumped from underground, roughly equaling the inflow of water to the underground lab. This ensures a dry, safe, deep underground environment for the science and engineering taking place at the Sanford Underground Research Facility. Water pumped from the underground is treated before it is released. The main contaminant is iron, which stains the water a reddish-brown color but is otherwise non-toxic. Other, less prevalent, containments are removed using bioremediation. SURF's *Waterworks* unit focuses on its unique waste water treatment facility and is available for check-out as well. For more information about the Waste Water Treatment Plant, visit https://sanfordlab.org/features/wastewater-treatment-plant
Materials	For teacher: ➢ Projector and speakers • Tape measure • Painters tape For each student: ➢ Science notebook Each Pair of students (*Phenomenon*): • Diagram of SURF water pumping system Each group of 3 students will need (*Explore*): • (2) Tubes, one long and one short • (2) Hand pumps or "primer bulbs" • (2) Plastic buckets • Tee connector (T shaped) • Tube connector (identical ends) • (3) Tube-to-hand pump connectors (one end larger) • Absorbent pad • Flexible clip bent to fit on bucket and hold tube in place ➢ (Optional) timers
Prior Knowledge	Engineers use what they know of science in the effort to solve problems, including issues of too much and/or too little water. In addition, it pays to think ahead and prepare, as flood and drought can happen anywhere (*Lesson Five*).

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Launch (10 minutes)	
Phenomenon	**Driving Question: What is the Sanford Underground Research Facility, and does it have issues of too much, and/or too little water?** Introduce students to the Sanford Underground Research Facility. You may invite one of the SURF's Education and Outreach (E+O) specialists to visit your class or use the PowerPoint presentation and videos provided (available on the unit USB). The notes section of each PowerPoint slide contains information to assist in facilitating this lesson. Slides 1-3: General introduction to SURF Slide 4: Students predict- What is/are SURF's water issue(s) For more information about requesting a visit from an Education and Outreach team member: https://sanfordlab.org/educators/assembly-programs
Explore (30 minutes)	
Investigation	**Driving Question: What would it take to pump water a vertical mile?** Now that students have some familiarity with the water issue underground at SURF, instead of telling them how engineers solve the problem… we want them to investigate and learn for themselves. Form groups of three and display slide 5. The challenge is to pump water 4 vertical feet, from a container on the floor to a second container held 4 feet above, with as little effort as possible. After an initial silent student think time, have groups equitably share their ideas before discussing and deciding on three to test. Students may explore the supplies during silent think time and group discussion, as manipulating the supplies may aid in conveying thoughts and ideas. Students should use notebook page 35 for guidance. While students are working, measure and mark (with painters' tape) 4 feet vertically from the floor in multiple places around the room. Pay particular attention to areas you expect students to be actively testing ideas. Once you approve group plans, students may gather any remaining supplies, place ~350 ml of water in the container that will be on the floor (with the tubing clip/holder) and begin testing. Results and observations from the investigation should be recorded on page 36. Supplies provided: Long tube, short tube, 2 primer bulbs (or *hand pumps*), two plastic buckets (one with a clip to help hold the tubing in place), a variety of connectors and an absorbent pad. Be sure to advise students that this is a laboratory investigation, and they **should NOT drink the water**.

	Each group will designate a *Water Watcher*. It is the job of the *Water Watcher* to inform the team on their progress, as it can be difficult to simultaneously pump, ensure the materials remain connected and/or in the water, and watch the water's progress. Most importantly, the *water watcher* is responsible for keeping the classroom, students, and teacher as dry as possible. Once groups find a "most efficient" set-up, have them draw it on the board, or on large pieces of chart paper to hang in the classroom. (Optional) groups may use timers to collect data on how quickly water in the top bucket fills to a certain level. They can also calculate the rate of filling, if familiar with the math. These would provide quantitative data for analysis, in addition to qualitative. *Note: The hand pumps have a directionality and are labeled "in" and "out" on the hard plastic ends. You may allow students to discover this on their own if there is time. If time is limited, however, it can be helpful to point out the directionality to students before they begin. The "in" side should be directed toward the floor and/or the water-filled bucket.*
Summarize (5-10 minutes)	
Communicate	Wrap-up with a share/compare/discuss, displaying slide 6. Depending on time constraints, this could be done a variety of ways (see notes on slide 6 for ideas). As time allows, groups should share what they tried, what worked best, and why they think that solution worked the best. *Students should conclude that the taller the vertical tube, the harder it is to bring up water with a single pump. If any students attempt to bring water up the tall tube when it is held at an angle (not perfectly vertical), they should discover that it becomes easier (as compared to perfectly vertical). Therefore, it is the overall height, not the length of the tube, that matters most. At SURF, where water must be pumped a vertical mile, it is not only impractical to manufacture a pump capable of such a feat… it would be extremely dangerous due to the high pressures found in the lower parts of a mile long vertical pipe full of water.* **The SURF Solution** Ask students to think for a moment about what the word "system" means. They may want to write their thinking in their science notebook or on a scrap piece of paper. Then, have students pair-up to share their thinking (2-3 minutes). Another strategy is to have each student write their definition on a piece of paper, then everyone holds it up when you call "Show Me". Allow time for students to read the definitions of peers near them and think silently for a bit, then encourage group discussion. Finally, have pairs share-out.

	Tell students that they will now investigate the water pump system used at SURF. Share the lab's multi-pump system (slide 7) for bringing water up from the underground spaces. *There is an optional hard copy for each group in the kit, if desired.* Ask students to study the diagram silently for a few minutes, looking for connections to their engineering solutions. Then, allow groups to discuss (talking chips recommended) the following questions: • What do you notice? • What do you wonder? • How does this compare with your experiment? Hold a group share-out/discussion. *Much like the primer bulbs (hand pumps), the water pumps at SURF both push and pull. The Deep Water Pump mostly pushes water up toward the surface, but no pump is strong enough to push water a vertical mile… so it needs help along the way. Additionally, each pump has a large reservoir associated with it. These are big pools of water that act like insurance policies- If any one pump breaks down, the rest can continue pumping water out of the laboratory to keep it dry. Once on the surface, the water is treated to ensure it is clean (the main contaminant is iron, which though safe stains the water reddish-brown). Finally, the water is released to Gold Run Creek which flows to Whitewood Creek, and ultimately the Gulf of Mexico.* Display slide 8 and point out the pumps represented on the left-hand side of the computer screen shown (in the picture). This is Ken Noren, the Waste Water Treatment Plant foreman. He is in charge of keeping the deep underground spaces dry for science, but also making sure the water is cleaned before it is released. Ken is shown explaining the automated system that runs the entire operation. He can even control everything from his cell phone! Finally, play the slide 9 video (2 min 15 sec) introduction to the SURF's water issues and solutions. There are optional extra slides (10-14) containing additional information about the Waste Water Treatment Plant, or consider inviting an E+O Science Specialist to visit your classroom (virtually or physically).
Terminology and Concepts to Solidify	**SURF-** a nearly mile-deep science laboratory located in the former Homestake Gold Mine in Lead, South Dakota. **System-** a group of related parts that make up a whole and can carry out functions its individual parts cannot.
Connection to Big Ideas (Phenomena)	No place on Earth is free from issues of too much and/or too little water. Even the mile deep nearly underground research facility has issues with too much water and engineers are constantly looking at ways to improve how SURF deals with its water issue.

(Optional) Follow Up/Practice Ideas	**Bring the Sanford Underground Research Facility into your school or classroom!** Invite an Education and Outreach team member to visit your school (physically or virtually). They will talk about the facility, share pictures and video, as well as answer questions from students. Our programs are available to schools free of charge. https://sanfordlab.org/education/field-trips-presentations Challenge your students with *A Really Long Straw* from Scientific American: https://www.scientificamerican.com/article/a-really-long-straw/
Assessment	Conclusion in student science notebook (page 36). It may help to have students write responses on the back of page 36 or on a separate sheet of paper if they need more room. Extra notebook pages can be folded and taped (or stapled) into science notebooks as foldables.

Have students return to their *Lesson One* "wonders". Which questions are they able to answer, now? Are there as-yet unanswered questions they still wonder about? If so, consider having students explore these additional questions!

Print Masters

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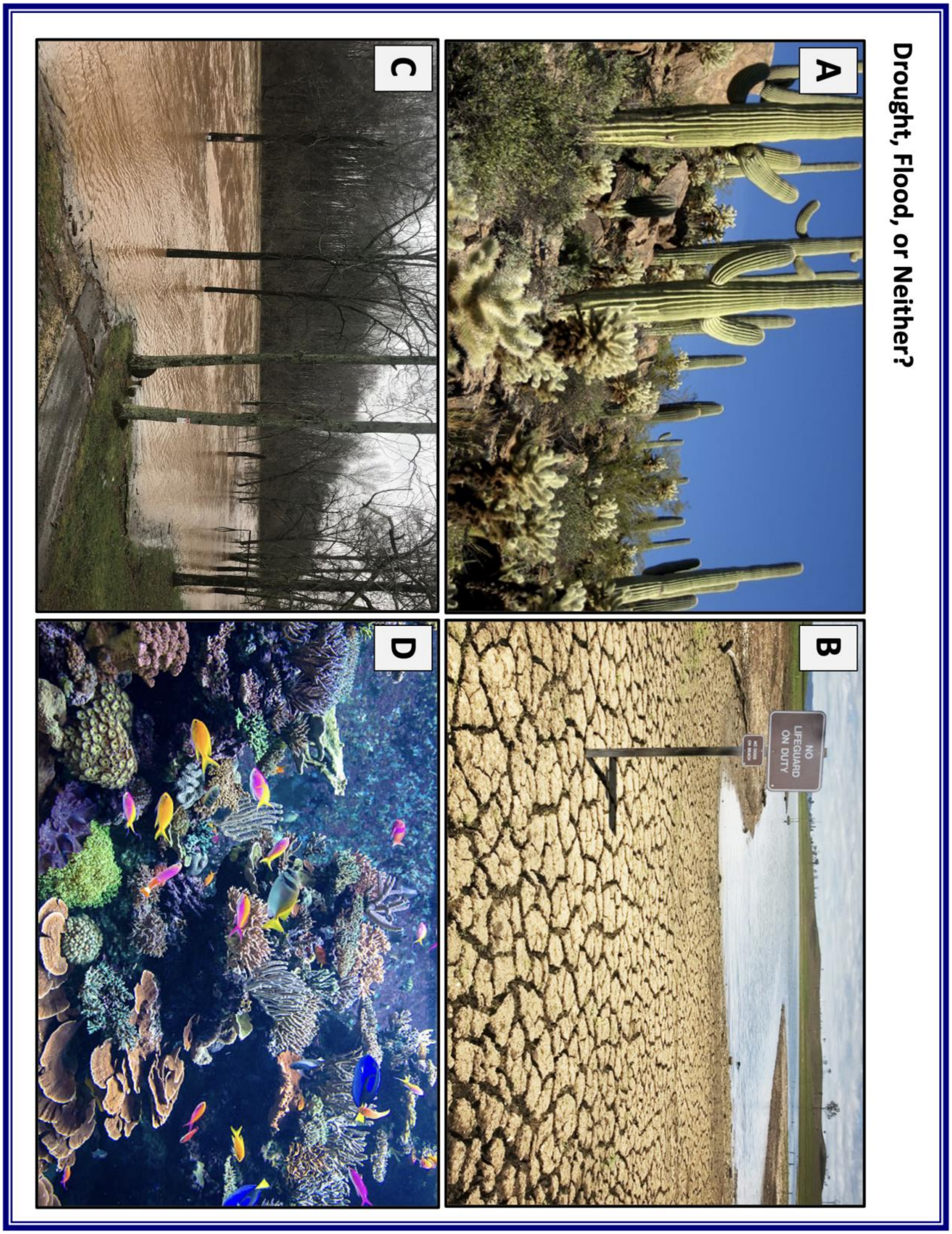

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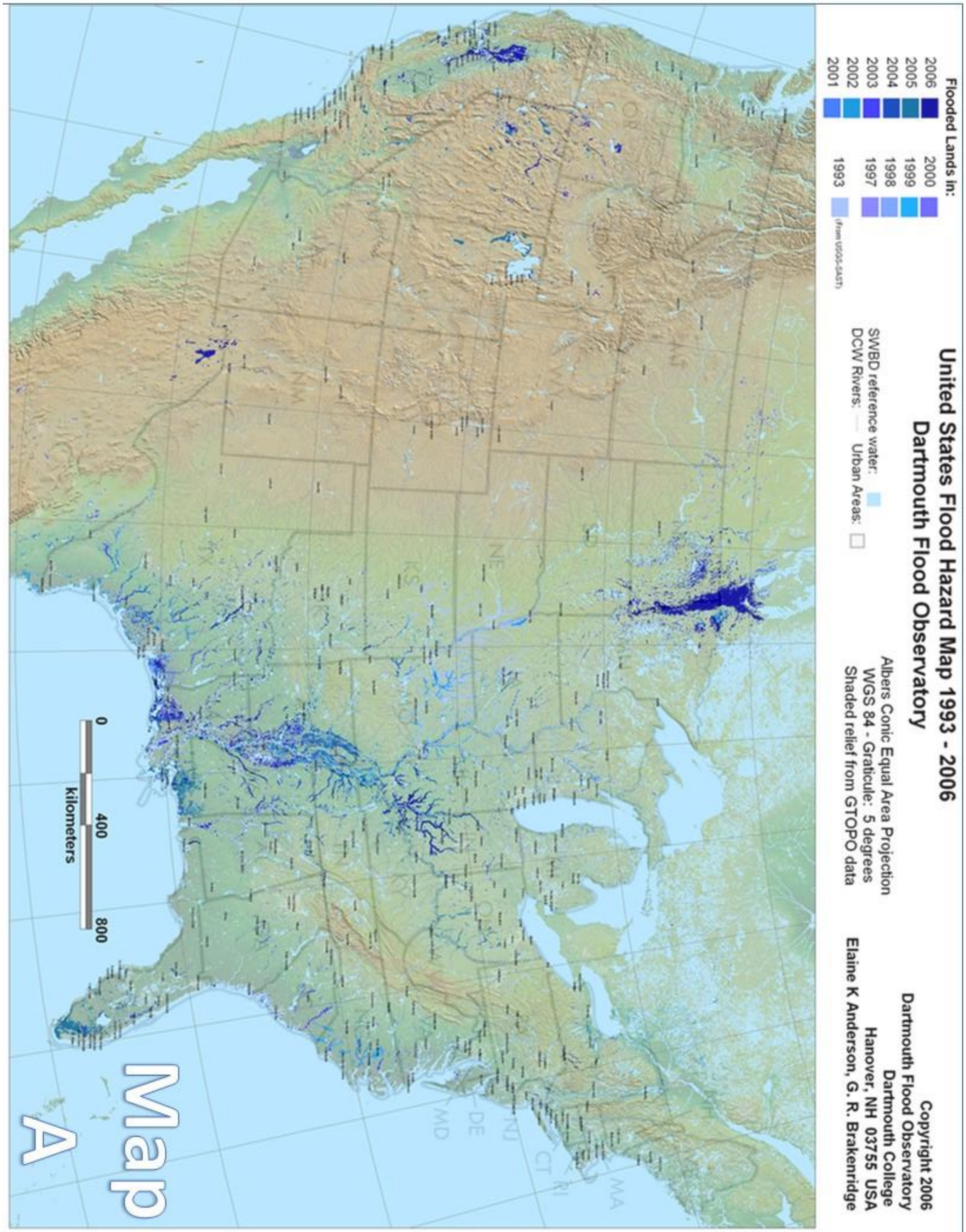

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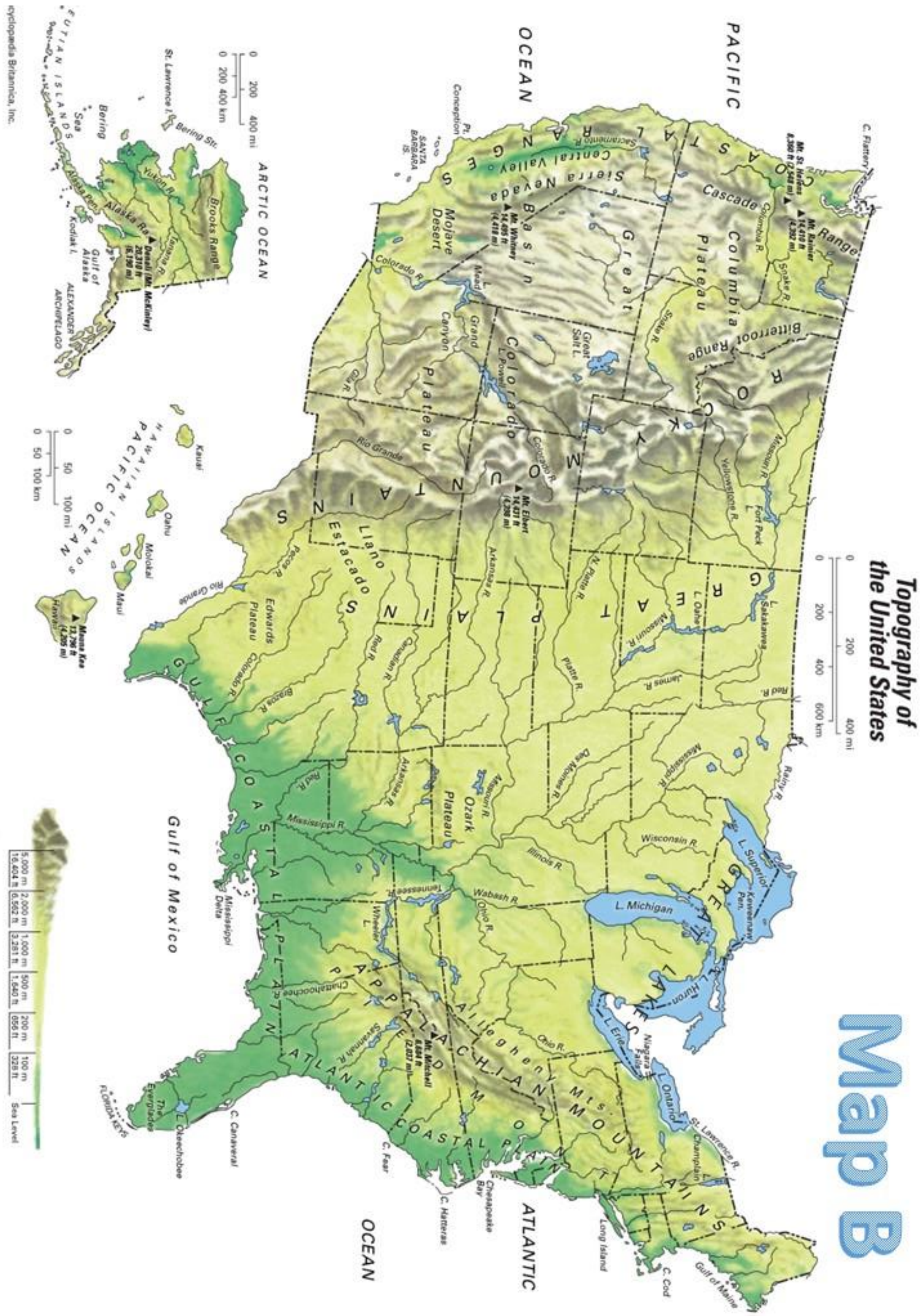

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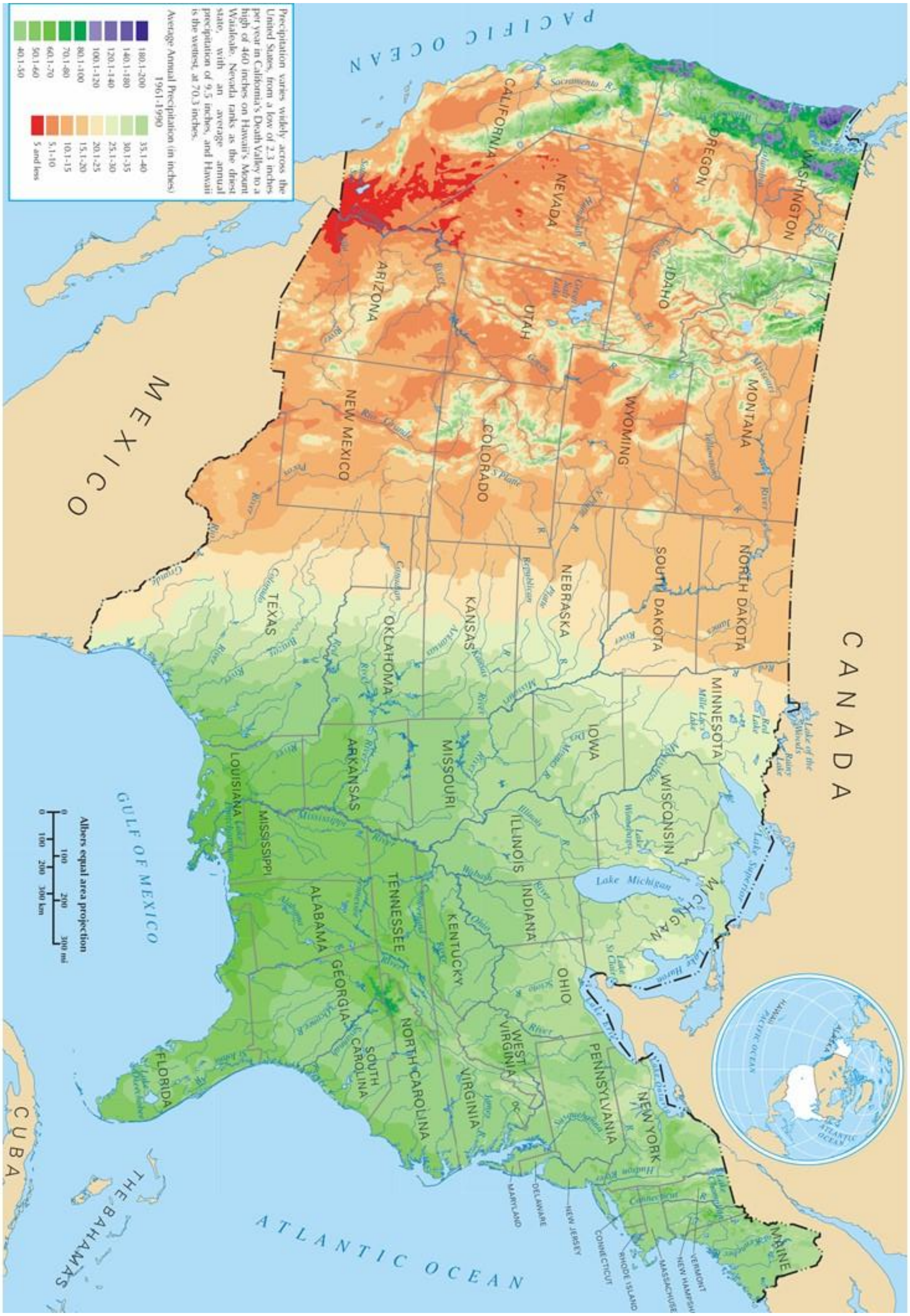
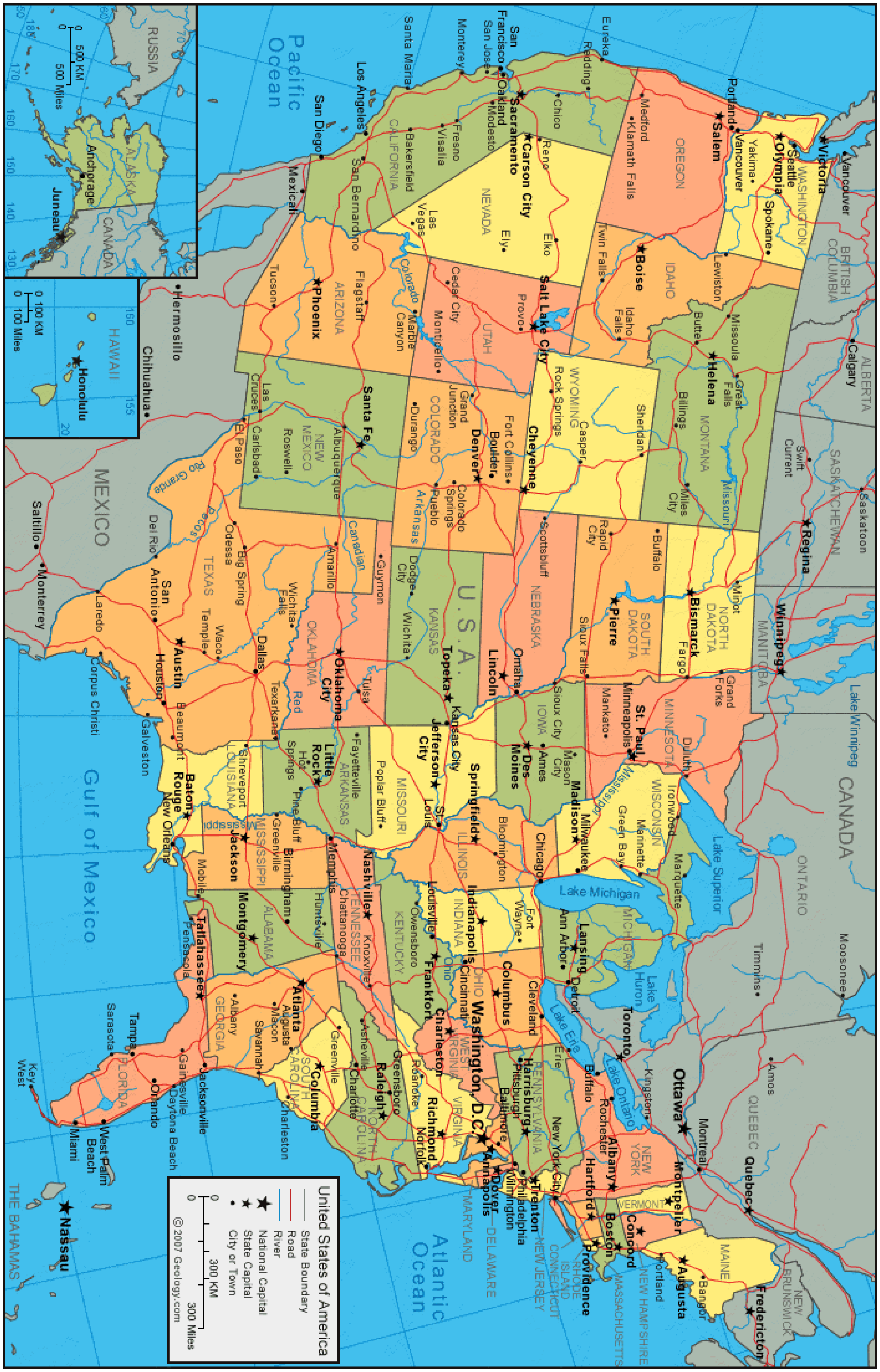


Map C

Too Much, Too Little



What State Am I? [1] **Map Used**

- Geographic Region: Great Plains _____
- Elevation: 500 to 1,000 meters _____
- Rainfall: Most of state = 15-20 inches _____
- Flooding: Lots! Especially on the right side _____

Which map was most helpful? _____

Why:

This is the State of ______________________________

What State Am I? [2] **Map Used**

- Geographic Region: Cascade Range _____
- Elevation: Up to 5,000 meters _____
- Rainfall: 5-10 inches on the right half, up to 200 inches in places on the left _____
- Flooding: None _____

Which map was most helpful? _____

Why:

This is the State of ______________________________

What State Am I? [3] **Map Used**

- Geographic Region: Great Plains _____
- Elevation: 500 to 1,000 meters _____
- Rainfall: Ranges from 15-20 inches on the left side, to 40-50 inches on the right _____
- Flooding: Some on the right side _____

Which map was most helpful? _____

Why:

This is the State of ______________________________

What State Am I? [4] **Map Used**

- Geographic Region: Lower half on Coastal Plain _____
- Elevation: Sea level up to ~2,000 meters _____
- Rainfall: Ranges from 40-50 inches in the middle, to 70-80 inches in the upper right _____
- Flooding: Almost none _____

Which map was most helpful? _____

Why:

This is the State of ______________________________

What State Am I?

- Geographic Region:
- Elevation:
- Rainfall:
- Flooding:

I am the State of ____________________

What State Am I?

- Geographic Region:
- Elevation:
- Rainfall:
- Flooding:

I am the State of ____________________

What State Am I?

- Geographic Region:
- Elevation:
- Rainfall:
- Flooding:

I am the State of ____________________

What State Am I?

- Geographic Region:
- Elevation:
- Rainfall:
- Flooding:

I am the State of ____________________

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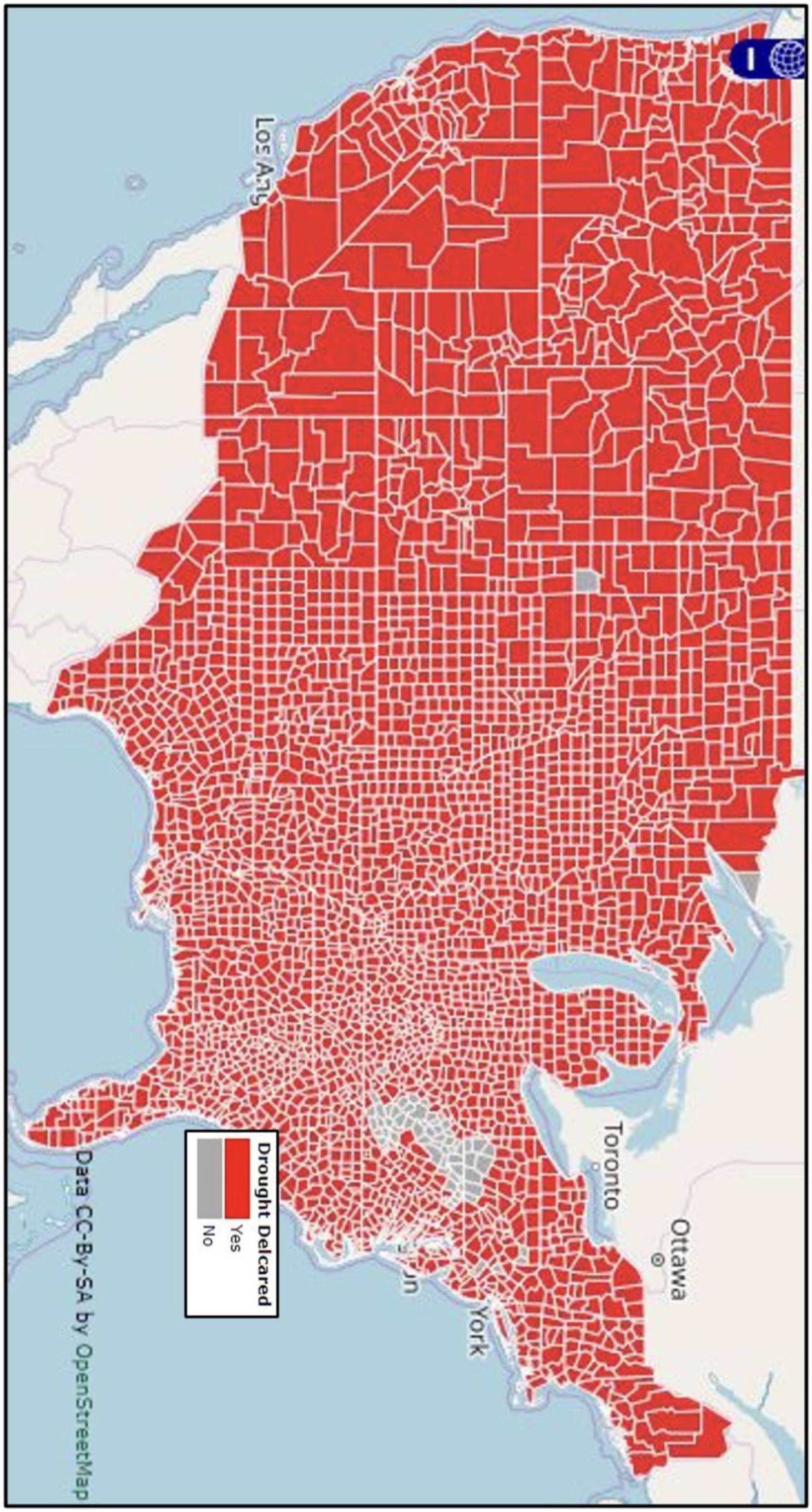

Official U.S. Drought Declarations 2000-2018 (By County)

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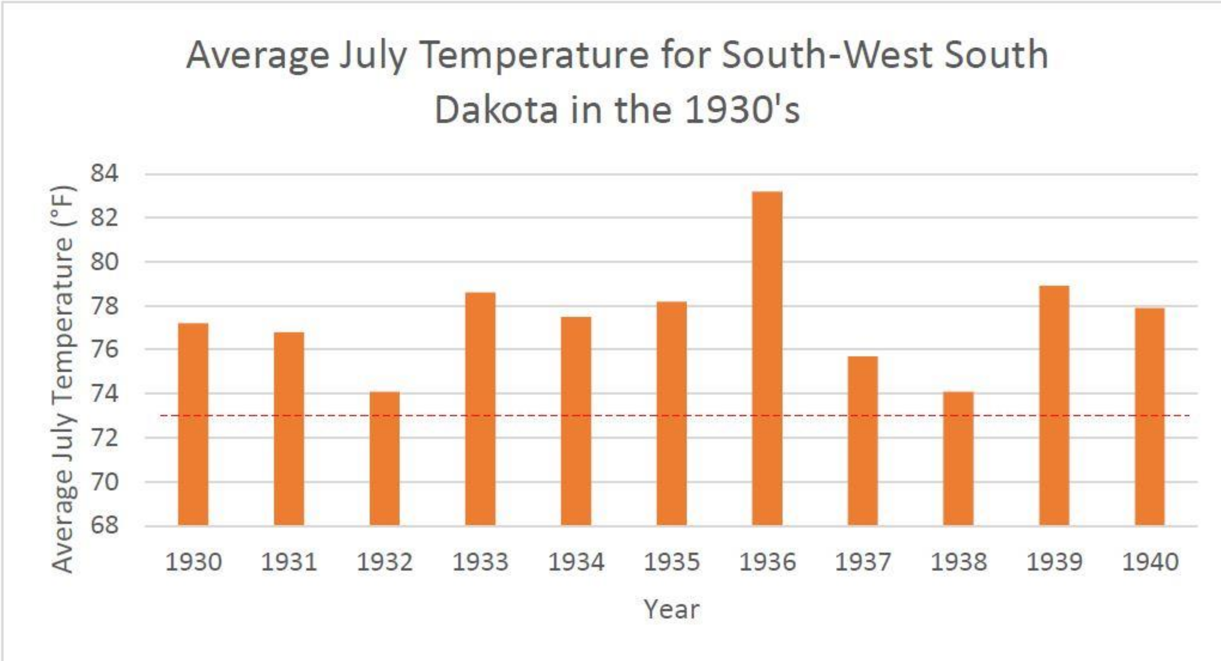

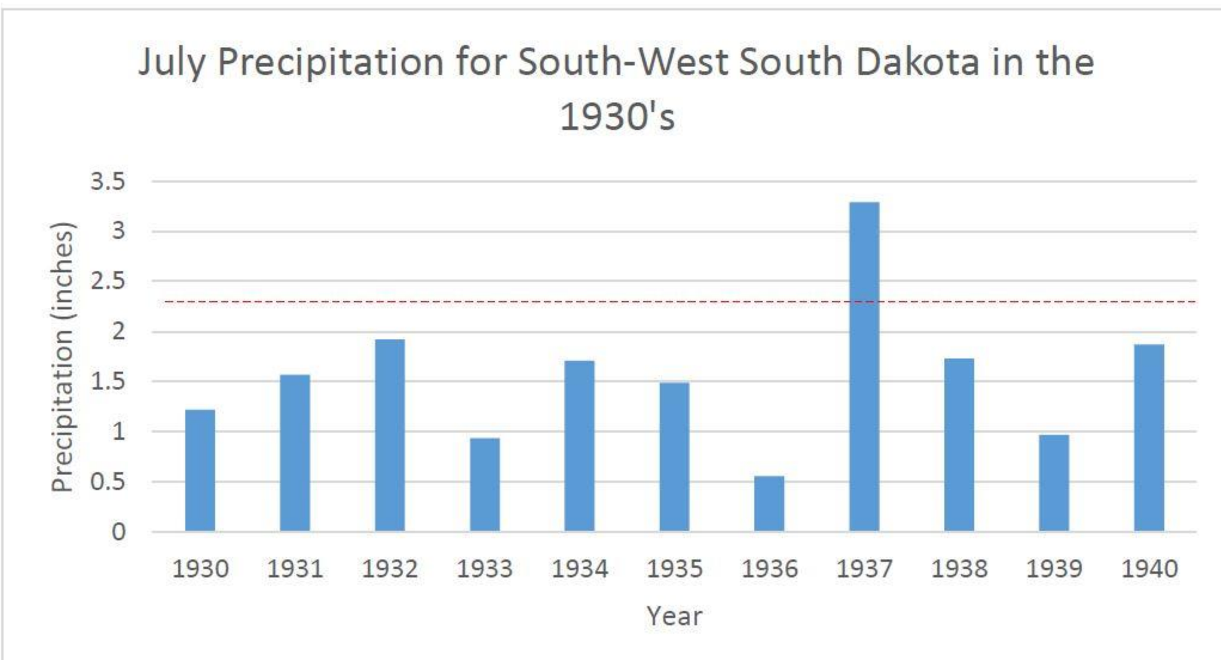

Too Much, Too Little

Too Much, Too Little
Lesson Three- When Does Drought Occur?
Central South Dakota Weather Data- A

Year	Month	Average Temperature (°F)
2000	March	40.1
2000	April	45.5
2000	May	58.9
2000	June	65.1
2000	July	74.4
2000	August	75.0
2000	September	64.0
2000	October	51.0
2000	November	24.7
2000	December	10.3
2001	January	23.4
2001	February	12.2

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Lesson Three- When Does Drought Occur?
Central South Dakota Weather Data- B

Year	Month	Precipitation (inches)
2000	March	1.15
2000	April	2.60
2000	May	2.84
2000	June	2.42
2000	July	1.87
2000	August	1.34
2000	September	0.25
2000	October	1.13
2000	November	1.04
2000	December	0.39
2001	January	0.78
2001	February	0.98

Too Much, Too Little
Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- C

Year	Month	Average Temperature (°F)
2001	March	29.7
2001	April	46.8
2001	May	58.3
2001	June	66.7
2001	July	75.8
2001	August	74.6
2001	September	63.7
2001	October	48.9
2001	November	41.2
2001	December	24.7
2002	January	25.1
2002	February	30.8

Too Much, Too Little
Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- D

Year	Month	Precipitation (inches)
2001	March	0.23
2001	April	3.66
2001	May	2.94
2001	June	2.57
2001	July	3.73
2001	August	0.38
2001	September	1.82
2001	October	0.91
2001	November	1.05
2001	December	0.05
2002	January	0.30
2002	February	0.08

Too Much, Too Little

Too Much, Too Little

Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- E

Year	Month	Average Temperature (°F)
2002	March	22.6
2002	April	45.6
2002	May	53.1
2002	June	71.9
2002	July	78.7
2002	August	71.9
2002	September	64.1
2002	October	39.9
2002	November	35.3
2002	December	27.7
2003	January	19.6
2003	February	19.5

Too Much, Too Little

Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- F

Year	Month	Precipitation (inches)
2002	March	0.80
2002	April	0.97
2002	May	1.11
2002	June	1.69
2002	July	1.68
2002	August	3.20
2002	September	1.67
2002	October	0.90
2002	November	0.02
2002	December	0.20
2003	January	0.53
2003	February	0.67

Too Much, Too Little

Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- G

Year	Month	Average Temperature (°F)
2003	March	33.3
2003	April	48.7
2003	May	55.8
2003	June	65.2
2003	July	75.7
2003	August	76.1
2003	September	61.7
2003	October	52.9
2003	November	27.8
2003	December	27.3
2004	January	16.3
2004	February	24.0

Too Much, Too Little

Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- H

Year	Month	Precipitation (inches)
2003	March	0.51
2003	April	2.71
2003	May	2.93
2003	June	3.13
2003	July	1.51
2003	August	0.89
2003	September	1.08
2003	October	0.76
2003	November	0.72
2003	December	0.11
2004	January	0.26
2004	February	0.24

Too Much, Too Little
Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- I

Year	Month	Average Temperature (°F)
2004	March	39.3
2004	April	48.8
2004	May	57.2
2004	June	62.7
2004	July	72.3
2004	August	67.7
2004	September	64.3
2004	October	49.7
2004	November	37.1
2004	December	27.8
2005	January	16.8
2005	February	30.1

Too Much, Too Little
Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- J

Year	Month	Precipitation (inches)
2004	March	2.17
2004	April	0.44
2004	May	3.35
2004	June	3.24
2004	July	2.61
2004	August	2.16
2004	September	4.36
2004	October	2.33
2004	November	0.27
2004	December	0.04
2005	January	0.32
2005	February	0.30

Too Much, Too Little
Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- K

Year	Month	Average Temperature (°F)
2005	March	35.6
2005	April	48.6
2005	May	54.5
2005	June	68.8
2005	July	76.0
2005	August	73.6
2005	September	67.4
2005	October	50.2
2005	November	37.0
2005	December	19.8
2006	January	34.0
2006	February	24.5

Too Much, Too Little
Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- L

Year	Month	Precipitation (inches)
2005	March	0.72
2005	April	2.41
2005	May	3.67
2005	June	4.50
2005	July	1.00
2005	August	1.31
2005	September	1.56
2005	October	0.60
2005	November	0.84
2005	December	0.52
2006	January	0.41
2006	February	0.25

Too Much, Too Little

Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- M

Year	Month	Average Temperature (°F)
2006	March	32.0
2006	April	50.9
2006	May	59.1
2006	June	70.8
2006	July	80.7
2006	August	73.9
2006	September	57.8
2006	October	45.1
2006	November	33.9
2006	December	27.3
2007	January	21.1
2007	February	15.4

Too Much, Too Little

Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- N

Year	Month	Precipitation (inches)
2006	March	1.37
2006	April	1.33
2006	May	0.66
2006	June	1.27
2006	July	0.71
2006	August	3.26
2006	September	2.81
2006	October	0.19
2006	November	0.33
2006	December	0.47
2007	January	0.13
2007	February	0.71

Too Much, Too Little
Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- O

Year	Month	Average Temperature (°F)
2007	March	41.7
2007	April	43.5
2007	May	60.8
2007	June	68.9
2007	July	78.0
2007	August	72.3
2007	September	64.0
2007	October	50.6
2007	November	35.6
2007	December	20.9
2008	January	17.8
2008	February	20.2

Too Much, Too Little
Lesson Three- When Does Drought Occur?

Central South Dakota Weather Data- P

Year	Month	Precipitation (inches)
2007	March	2.39
2007	April	1.77
2007	May	4.29
2007	June	3.70
2007	July	0.48
2007	August	3.89
2007	September	1.18
2007	October	3.41
2007	November	0.01
2007	December	0.45
2008	January	0.18
2008	February	0.29

Too Much, Too Little

Rapid City, South Dakota
June 9th, 1972

- 238 people killed
- 3,000 people injured
- 1,335 homes destroyed
- 5,000 automobiles destroyed
- 15 bridges destroyed

Crumpled Watershed Instructions

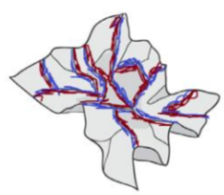
Adapted from "Crumple a Watershed" by *Expedition Northwest* ©2006, OMSI available here:
https://omsi.edu/sites/all/FTP/files/expeditionnw/4.E.1.Crumple.pdf

1- Take a sheet of copy paper and crumple it into a loose ball.

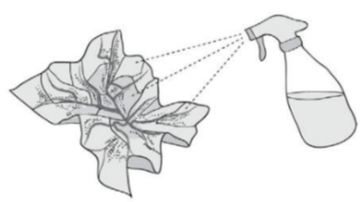
2- Uncrumple the paper a bit and set it on a horizontal, waterproof surface (Cafeteria tray, desktop, etc.)

3- Tape the edges of the crumpled paper onto the waterproof surface. Just enough so that it doesn't move, you do not have to tape the entire edge.

4- Use at least 2 different (dark) colored non-permanent markers to shade the ridges ("high points") of the crumpled paper. Each side of the ridge should be a different color.

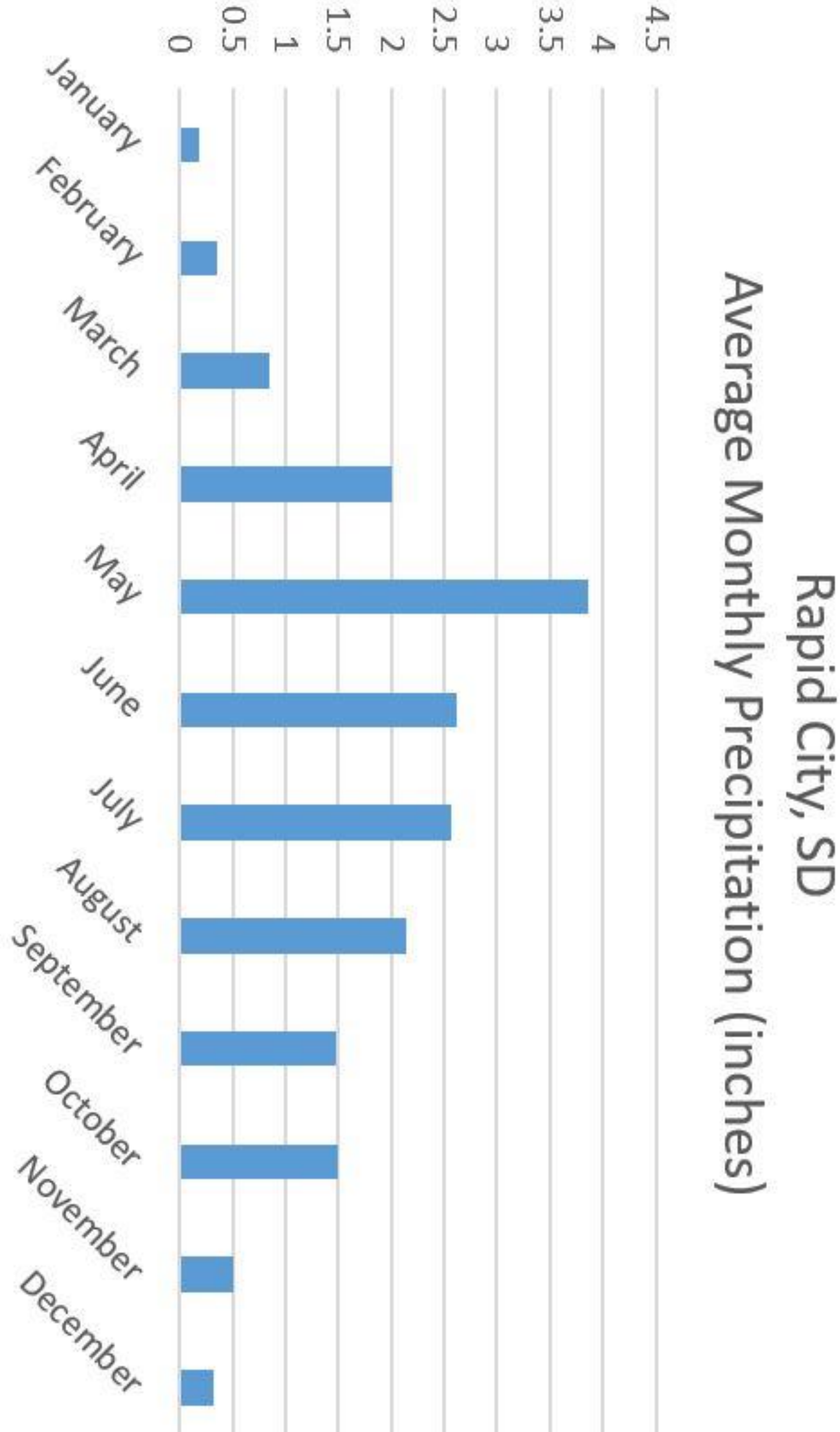


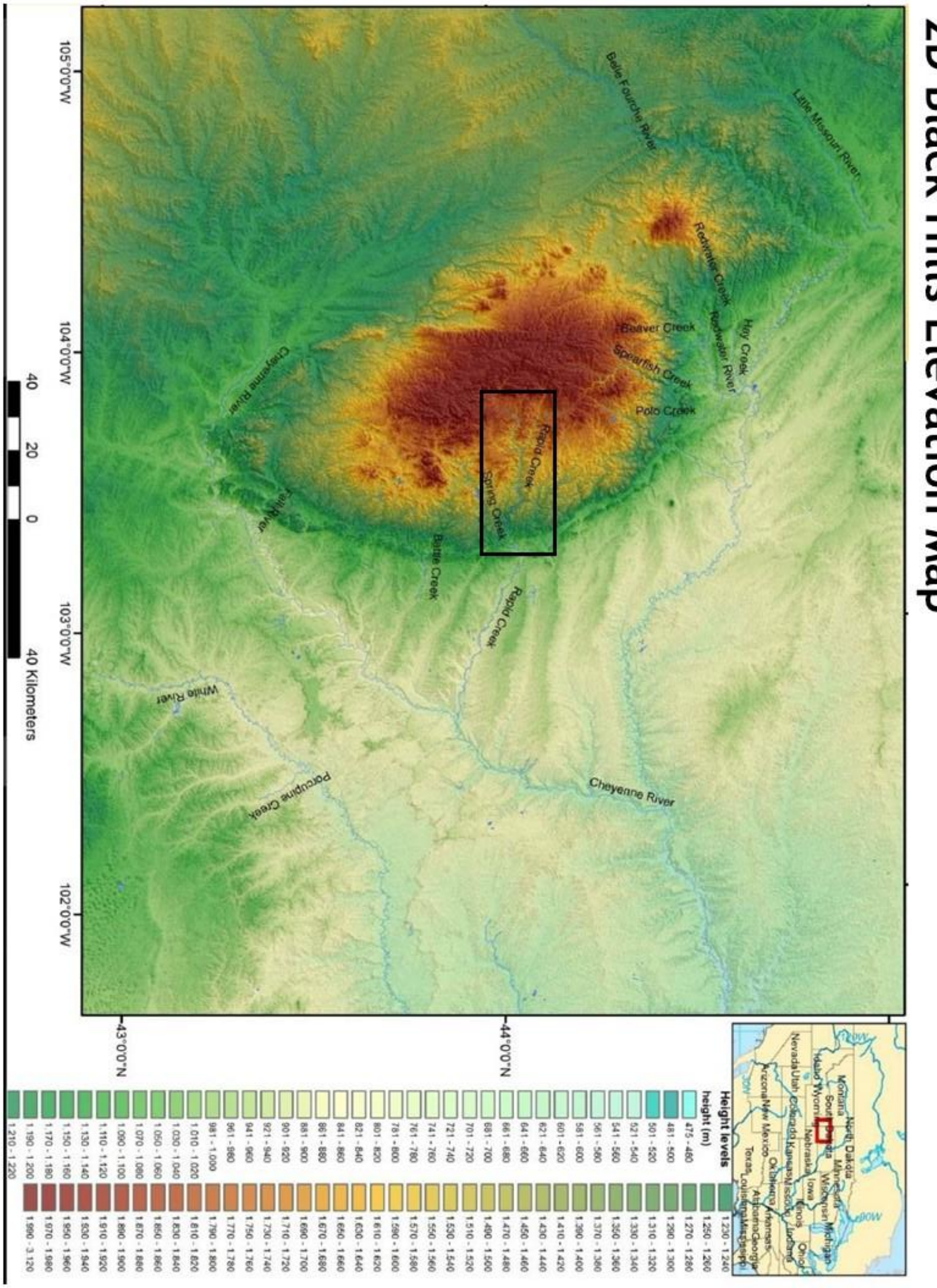
5- Spray the paper lightly with water using a spray bottle. This simulates rain.

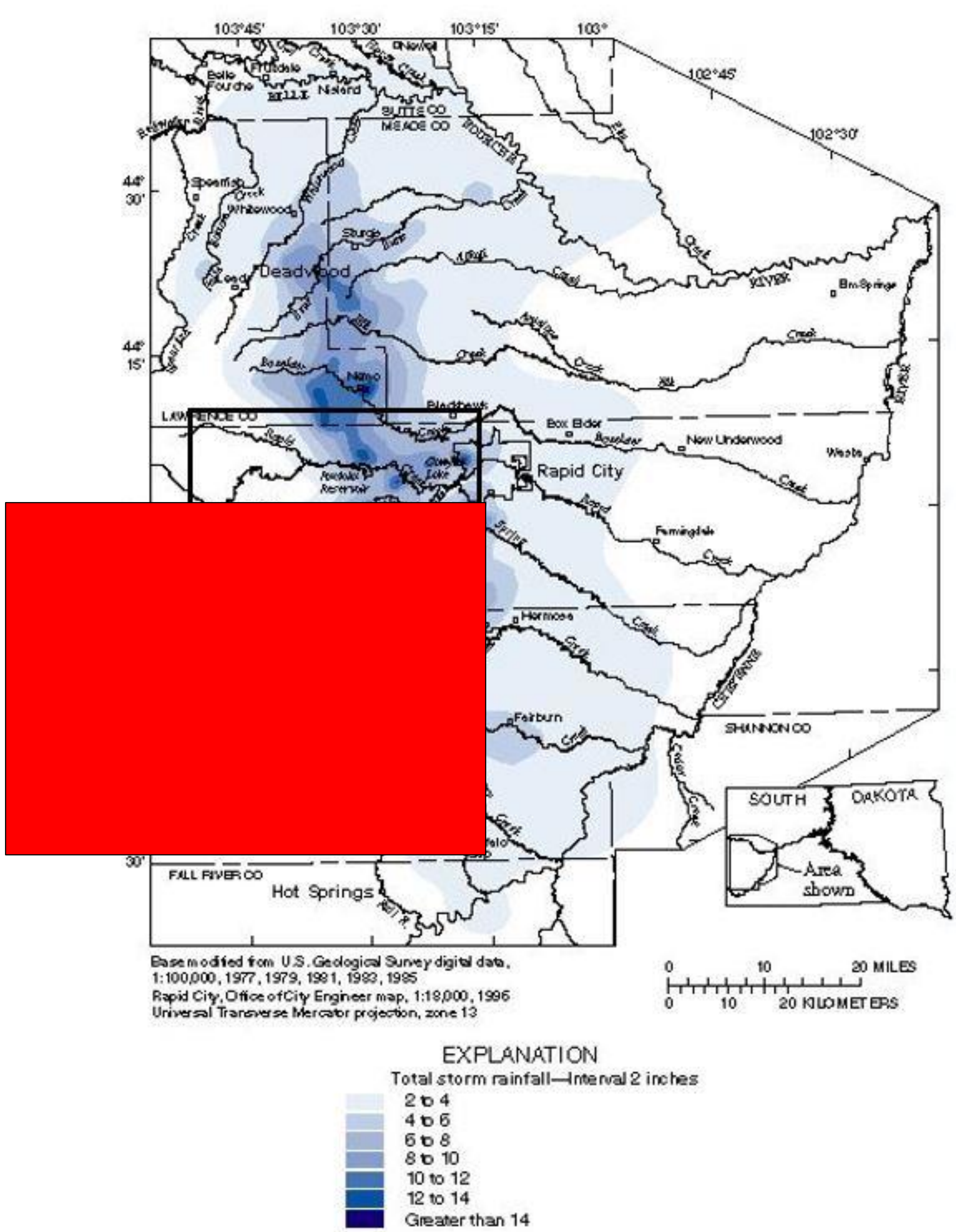


6- Record your observations in your science notebook.

Too Much, Too Little




2D Black Hills Elevation Map
Little Missouri River
Belle Fourche River
Redwater Creek
Hay Creek
Redwater River
Beaver Creek
Spearfish Creek
Polo Creek
Rapid Creek
Spring Creek
Battle Creek
Cheyenne River
Fall River
White River
Porcupine Creek
105°0'0"W
104°0'0"W
103°0'0"W
102°0'0"W
43°0'0"N
44°0'0"N
40 20 0 40 Kilometers
Height levels
height (m)



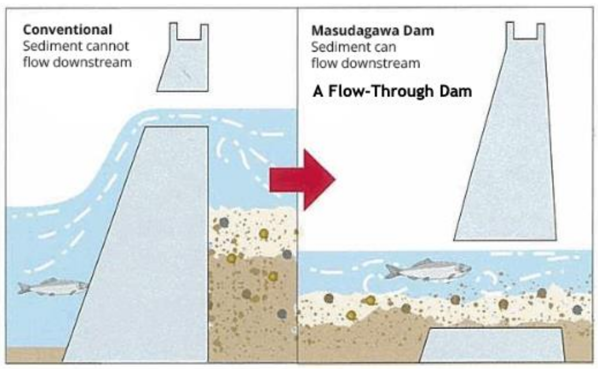
Total storm rainfall for June 9-10, 1972 (from Schwartz and others, 1975).

Modified from U.S. Geological Survey Fact Sheet FS-037-02

Flow-through dams for flood control

A

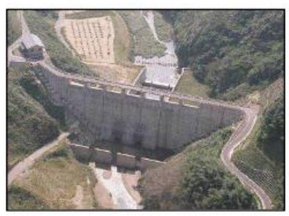
Adapted from https://www.ctc-n.org/technologies/flow-through-dam-flood control#targetText=The%20flow%2Dthrough%20dam%20(also,flow%20through%20during%20normal%20times.



Flow-through dams are constructed for the purpose of flood control, in areas at high risk for flooding. Unlike reservoir dams, which are built primarily for water storage or power generation, the spillway (opening) is built at the **same** height as the riverbed, allowing the river to continue its natural flow in normal conditions.

Conventional Dam

Flow-Through Dam



When water levels rise, the dam restricts the amount of water flowing through the opening. This helps reduce flood damage to areas downstream.

The Olmos dam in San Antonio Texas is an example of a flow-through dam. Under normal conditions, it allows Olmos creek to flow naturally through the dam. When precipitation leads to flooding, though, the dam holds a significant amount of water upstream of San Antonio, protecting homes and businesses from flooding. Instead, the water floods a public golf course and natural recreational areas, keeping damage to a minimum. Below are pictures of Olmos dam in normal conditions, as well as during a flood event.

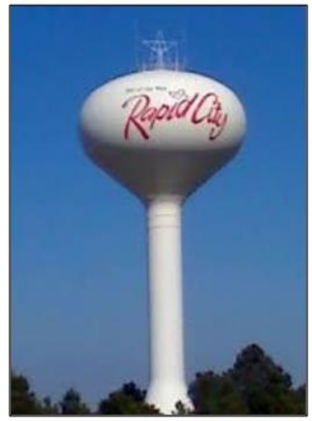
Normal conditions

Flooding

How Do Water Towers Work?

B

Adapted from: https://www.wonderopolis.org/wonder/how-do-water-towers-work/



Have you ever wondered why water towers exist? Are they really full of water? Why does anyone need a tower of water? Does it have a spigot so you can drink from it like a water fountain?

Water towers are indeed full of water. And, no, you can't drink from them like a water fountain. Every water system needs water towers to provide water in the case of an emergency.

You've probably noticed that other utilities may go out from time to time. In a storm, you may lose electric power. Your television or telephone service might also experience interruptions occasionally. But what about your water?

Do you remember a time recently when you weren't able to turn on the faucet to get water? If you can't, that's great. Most water systems are very reliable, and water towers play an important role in providing that reliability.

Water towers come in all sorts of shapes and sizes. However, they all work the same way. Water towers are nothing more than simple elevated tanks of water. However, unlike big ponds or underground tanks, water towers, due to their elevation, also supply water pressure!

When you turn on your water faucet at home, the water comes out because the water is under pressure. Your local water system pushes the water to your home. A typical water system supplies water at a pressure of somewhere between 50 and 100 PSI (pounds per square inch).

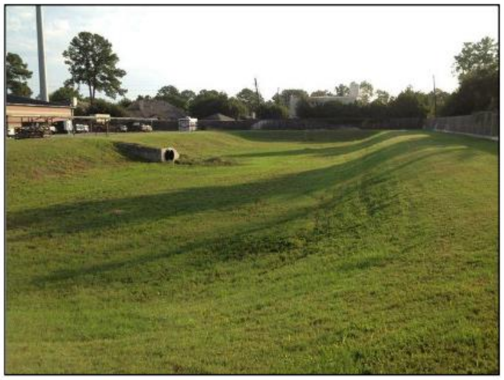
Water towers are tall and are often placed on high ground, so that they can provide sufficient pressure to deliver water to homes in case of an emergency. Scientists estimate that each foot of a water tower's height provides a little less than half a pound per square inch of pressure.

So how much water can most water towers hold? A lot! An average backyard in-ground swimming pool will hold over 20,000 gallons of water. Most water towers can hold 50 times that amount -- that's one million gallons! The exact size of a water tower tank can vary greatly, but most are built to hold approximately one day's water supply.

Stormwater Detention Basins

C

Adapted from: http://www.dupagerivers.org/detention-basin-basics/



A stormwater detention pond, or detention basin, is a man-made pond in residential and commercial areas that collects stormwater run-off from surrounding landscapes, roads, and rooftops. The detention pond temporarily holds stormwater until it slowly releases into a local waterway.

Depending on its design, some detention basins are dry-bottomed and all the water drains between storms. Some are more pond-like and hold open water all of the time. Finally, some are more wetland-like with a mix of water and vegetation.

All three types are designed to hold a specified amount of stormwater (storage capacity) based on the need of the development.

Detention basins **reduce the rate at which stormwater enters local waterways**. By temporarily storing stormwater, a detention pond can prevent flooding.

They also **prevent flooding in homes**. Since detention ponds capture stormwater run-off from surrounding landscapes and rooftops, stormwater collects in the basin instead of homeowners' properties.

Detention ponds help to **keep pollutants and sediment out of the streams and other waterways** by allowing them to settle at the bottom of the detention pond. However, pollutants and debris can degrade a detention pond's water quality, often leading to murky water and a thick layer of algae.

If properly maintained, detention ponds can regulate stormwater while being an attractive feature for residents in the area, providing opportunities to enjoy nature and increasing property value at the same time.

What is Porous Pavement?

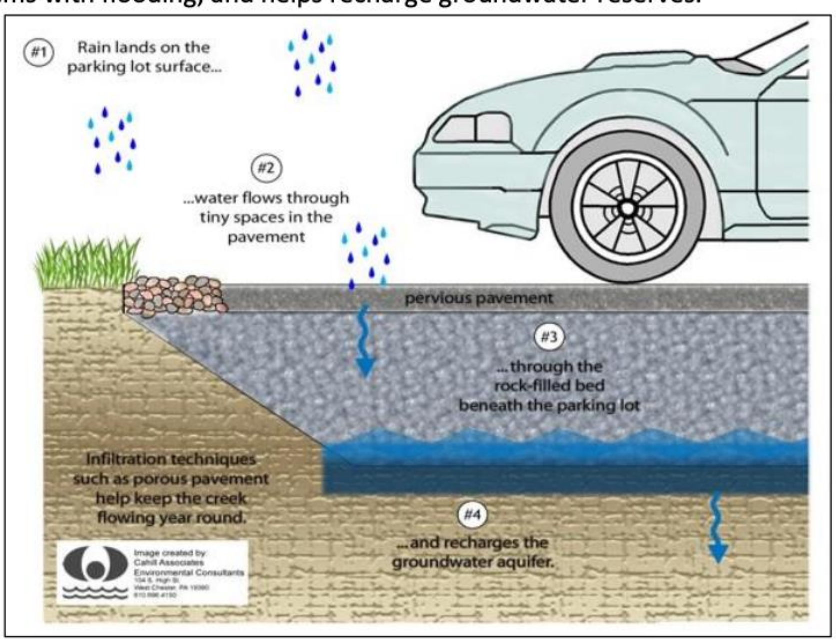
D

Adapted from: http://taschifsky.com/taschifsky.com/Eco_Paving.html and
https://watershedcommittee.org/our-publications/

The material we typically use for roads, sidewalks, parking lots and driveways does not allow water to soak into the ground. These surfaces are "impervious". Storm water runoff will flow from these impervious surfaces into nearby storm drains, then into our streams, lakes and rivers. The increased runoff can cause more severe flooding.

Porous pavement, or "pervious" pavement, however, contains open spaces that allow water to soak through the pavement into the ground below. It looks a bit like a sponge.

Instead of rainwater stopping when it hits traditional asphalt and becoming runoff (and contributing to flooding), porous pavement allows the rainwater to flow into a gravel layer below. After rainwater passes into the gravel layer, it is returned to the ground water system. This in turn reduces storm water runoff, lessens problems with flooding, and helps recharge groundwater reserves.



Too Much, Too Little