Waterworks

Lesson #	Lesson Title	Suggested Time
1	Distribution of Water on Earth *A Drop in the Bucket*	50 minutes
2	Why is Water So Important? *The Heart of Everything That is*	50 minutes
3	What's in the Water, Where Does it Go? *"Water" You Drinking?*	50 minutes
4	Bioaccumulation and Biomagnification of Pollutants *It's Deadly at the Top*	50 minutes
5	What's in YOUR Water? *What's Your Watershed?*	50 minutes
6	How Can We Remediate Our Water? *Clean It Up!*	50 minutes

Waterworks- 6-8 (Environmental Science)
Students will explore the water cycle, learn why water is so important for life as we know it, and investigate the fate of contaminants in a watershed. Bioaccumulation, biomagnification, water quality testing and bioremediation are specifically addressed. The unit culminates in an engineering design challenge focused on microbial remediation of an environmental pollutant, and the use of bioremediation at the Waste Water Treatment Plant at Sanford Underground Research Facility.

Waterworks

What is the worth of water?

In lesson one, students learn that water is essential to life as we know it. As the *universal solvent*, able to dissolve almost anything, liquid water is highly efficient at transporting nutrients into cells while carrying waste products away. Cells are comprised of about 70 percent water, and liquid water is important for facilitating the biochemical reactions that all living things depend upon for growth and metabolism. Here on Earth, where there is liquid water present, scientists can find living organisms (mostly microbial). So, it's no wonder that scientists searching for life on other planets say to "follow the water".

When looking at a picture of the Earth from outer space, Earth possesses vast water resources. Unfortunately, as students learn in lesson two, 97 percent of Earth's water is too salty for drinking or growing crops. Of the remaining three percent, approximately two percent is tied up in solid form within glaciers and the ice caps. Therefore, only about one percent of the Earth's water is fresh and available for drinking, as long as you consider all ground water (sometimes accessible through wells) as *available*. Students, after discovering how precious fresh water is, utilize their knowledge of the water cycle to discover the source of a fictitious water contamination event by utilizing contour mapping.

Considering how important fresh, available, water is to living organisms, water quality is of the utmost importance. Unfortunately, many human activities have a negative impact on water quality, and thus a negative impact on the health and well-being of living organisms. Some contaminants, like mercury, tend to accumulate in the tissues of living organisms that are, in turn, eaten by organisms higher up the food chain. You may have seen a fish consumption warning at your favorite fishing lake, or when you were buying fish at the supermarket. In this scenario, an environmental contaminant present at low levels in the air or water can be bioaccumulated and biomagnified to a level that is dangerous for consumers (like humans) at the top of the food chain. Students discover this phenomenon through game-based modeling.

Armed with a new understanding of the importance of water from the initial three lessons, students investigate the health of their local watershed. Students collaborate to choose and acquire samples, run water quality tests, and share results before discussing, debating, and writing an evidence-based analysis. Students are then introduced to the water contamination and superfund site caused by the historic Homestake Gold Mine, where the Sanford Lab now resides, and how it was remediated. The bioremediation methods utilized by the waste water treatment plant are highlighted, and a connection drawn to the bioremediation of pollutants. Students then engage in an engineering design challenge where they work together to discover the optimum ratio of microbes for the bioremediation of pollutants.

Standards Addressed in the Unit

Lesson	Science Standards	Oceti Sakowin Standards (2016 draft revision)	Literacy Standards
1	MS-ESS3-1 (working toward)		
2	MS-LS1-5	1.2	
3	MS-ESS2-4, MS-ESS3-3*		
4	MS-LS1-5, MS-LS2-3, MS-LS2-4	1.4	6-8.WHST.1, -.4, -.5
5	MS-ESS3-3*	1.4	6-8.WHST.1, -.4, -.9
6	MS-LS2-5*; 6-8-ETS1-2, -3, -4	1.2, 1.4	6-8.WHST.1, -.4, -.6

* Notates emphasis on engineering

MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS-LS2-5 Evaluate competing design solutions for maintaining biodiversity and ecosystem services. *

MS-ESS2-4 Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.

MS-ESS3-1 *Building Toward:* Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. (does not address mineral and energy distribution)

MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. *

6-8-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

6-8-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

6-8-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Oceti Sakowin Standard 1.2 Describe traditional and contemporary Oceti Sakowin perspectives on communal stewardship of land and natural resources (flora, fauna, geographic and sacred features).

Oceti Sakowin Standard 1.4 Identify and explain contemporary environmental issues facing Oceti Sakowin lands (i.e., Dakota pipeline, etc.).

For more information about the Oceti Sakowin Essential Understandings: http://www.wolakotaproject.org/introduction-to-the-oceti-sakowin-essential-understandings/

6-8.WHST.1 Write arguments focused on discipline-specific content.

a. Introduce claim(s) about a topic or issue, acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically.

b. Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.

c. Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), counterclaims, reasons, and evidence.

d. Establish and maintain a formal style. e. Provide a concluding statement or section that follows from and supports the argument presented.

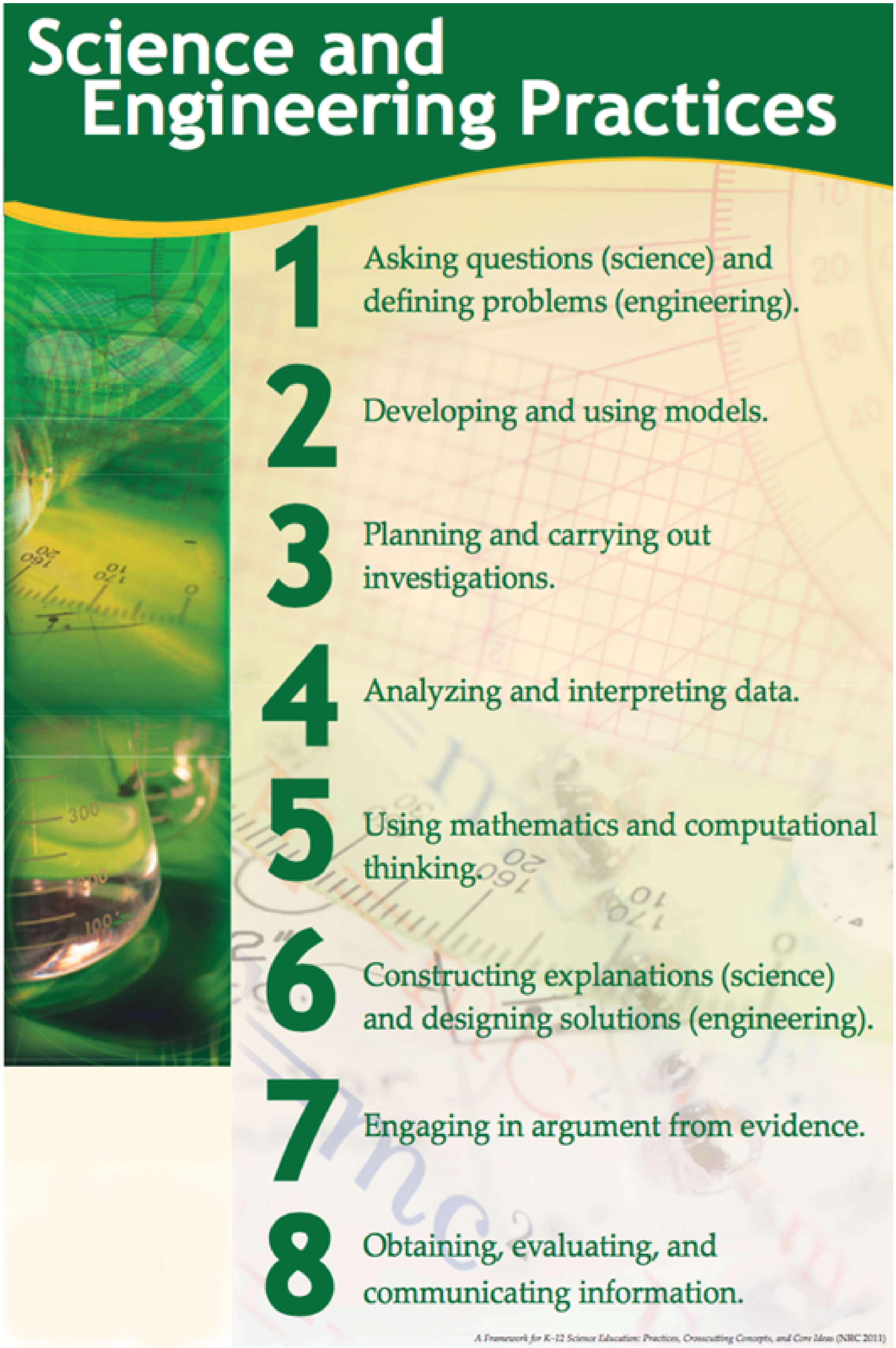
6-8.WHST.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

6-8.WHST.5 With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed.

6-8.WHST.6 Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently

6-8.WHST.9 Draw evidence from informational texts to support analysis reflection, and research.

Note: Specific science and engineering practices (SEP) and crosscutting concepts (CCC) for each lesson are indicated within the individual lesson overviews.


Science and Engineering Practices
1 Asking questions (science) and defining problems (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 (science) and designing solutions (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 2011)

Materials List

- *Teacher-Provided*

Lesson	Materials Needed
Prior to Lesson 1	➢ (optional) Materials to create science notebook

1	For teacher:
	• *Just a Drop to Drink* demonstration
	    • Clear, one liter measuring cup (containing 1 liter of tap water)
	    • 100 ml graduated cylinder
	    • 10 ml graduated cylinder
	    • Plastic dropper
	    • Small, blue metal bucket
	For each student:
	➢ Science notebook

2	For teacher: • 14.8 ml (1 tbsp.) tap water in a graduated cylinder • Quart size zip top baggie with 7.4 ml (0.5 tbsp.) baking soda (powder) • Quart size zip top baggie with 7.4 ml (0.5 tbsp.) calcium chloride (powder) • Goggles (one pair for teacher) ➢ (optional) DampRid moisture absorber refill, baking soda and quart size zip-top baggies For each student: ➢ Science notebook For each group of 3-4 student's: • Pack of 10 *Life Cards* • (optional) *Lesson 1 Optional Student T-Chart* For the classroom: ➢ Computer and projector with speakers
3	For teacher: • Video Display for students to watch NASA video • Look over Lesson 3 *Mystery in the Black Hills* teacher guide • Copies of Lesson 5 Water Sample Analysis Sheets (for students who volunteer to collect water samples for testing during Lesson 5) For each student: ➢ Science notebook

	• Full page copy of *Lesson 3 Student Riverville Contour Map* • (optional) *The Water Cycle* handout For each group: • Lesson 3 *Mystery in the Black Hills- A Hazardous Whodunit* activity sheet • Colored pencils
4	For the teacher: • PowerPoint *Lesson 4 Presentation* For each student: ➢ Science notebook • Copy of Table 6 from the *South Dakota Mercury TMDL (pg. 34)* • *Biomagnification Game* Activity Sheet • *Organism Card* for the *Biomagnification Game* • Lesson 4 *Assessment Prompt* ➢ Calculator *(recommended, but not required or provided)* For whole class: • Tokens of three colors, 100 of each color • 19 cloth *food bags* (one for each zooplankton) ➢ Computer and projector with speakers

5	For Teacher to set-up before class:
	• Four water testing stations (each with a bag of materials, two sets of instructions, and information sheets)
	  • pH (six test strips per class, one plastic cup)
	  • Nitrate and nitrite (six test strips per class, one plastic cup)
	  • Phosphate (six test strips per class, one 10 ml vial)
	  • Heavy metals (six test strips per class, one plastic cup)
	➢ Extra (teacher-supplied) water samples *(just in case any students forget to bring samples they agreed to acquire)*
	For each student:
	➢ Science notebook
	• Lesson 5 *A.C.E. writing* assessment prompt with rubric

	For each group: • Water sample analysis sheet (one per water sample, 6 per class) ➢ Water sample (group numbers 1-6) ➢ Supplies for creating large, detailed map (group #7 only) ➢ Computers for additional research (if desired) For the class: ➢ Computer with projector and speakers Only with teacher approval: Additional water testing supplies for ammonia, lead, cyanide, and mercury. Only to be used if a sample tests high for heavy metals, and/or any of these pollutants are strongly suspected. *(These tests are limited to only 3 per kit! If you have the time, let the class(es) debate, and come to a consensus on any samples they would like tested for these potential contaminants.)*
6	For each student: ➢ Science notebook ➢ Copies of Lesson 6 Activity Data Table For the teacher: • Quick rise yeast • Sugar • Vinegar • Dish Soap ➢ Hot water For the class: • Test Tube Stands, 10 per class + 1 for teacher • Test Tubes, 40 per class + 4 for teacher • Water Balloons, 50 per class • Measuring Spoons, 10 sets per class • 4 Pipettes w/ labeled cups to place them in • 6" Rulers • String ➢ Computer with projector and speakers Suggested items for optional extensions: ➢ Various acidic household items (ex: soda, coffee) ➢ Various basic household items (ex: baking soda, ant-acid tabs)
After Lesson 6	• *Post-assessment* and rubric

Science Notebooks	**You may wish to have students set up their Science Notebooks prior to the first lesson.** As students develop and refine their understanding of science concepts, it is helpful for them to reflect on and record what they have learned. A science notebook provides them with a record of their questions, ideas, experiences, and evidence. The science notebook can also 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 spiral notebook. Interactive science notebook support material can be found at the end of lesson 1. As students progress through this unit, the goal is for each student to develop more detailed, relevant science documentation in their notebook through explanations, diagrams, and terminology.

Lab Data Sheets	As the classroom teacher, you must consider how you want your students to document investigations (data sheets versus science notebook entries) and how you want them to organize and structure information from these explorations. Some instructors may prefer to receive individual lab sheets for scoring purposes. If this is the case, students may tape these into their science notebooks after instructor feedback is given. An alternative would be to have a sample data sheet (or two) at each station to help students develop skills for organizing the data collected during scientific investigations. In this case, all student data, observations, and questions would be recorded directly in the science notebook.

Post-Test	Please administer the post-test a day or two after concluding the unit. There is no time set-aside for these assessments within the five lessons.

A Teacher's Guide to the Interactive Notebook

IF you already have a science notebook (or journal) that students use during the class please continue to use that format. If you do not require a notebook for your classroom, try using an Interactive notebook for the duration of this unit.

The Interactive notebook should be kept in a composition (or spiral) notebook. The front side of the first piece of paper in the interactive notebook should be designated as a table of contents. The table of contents will be created as the pages of the notebook are created. Following the table of contents, all pages should be numbered, and the dates recorded.

The next front side page should be the title page. For this unit students should create a page that reads *Waterworks*. Students are free to decorate this page any way they choose – they may even choose to utilize both the left and right-handed side pages.

Beginning with the backside of the second sheet of paper the students begin to make entries into their interactive notebook.

- Student output goes on the left-hand pages.
- Input from other sources belongs on the right-hand pages.

Left Side – Output-Student Directed	**Right Side – Input- Teacher Directed**
RAP: Review and Preview or Reflect and Process Used for: ➢ Organize new information in creative formats ➢ Interact with information from the right page ➢ Lab Reflection questions ➢ Warm-ups ➢ Express opinions and feelings Explore ➢ new ideas ➢ Mind maps, Venn diagrams, Drawings, ➢ Vocabulary cards, Analogies, Creating Questions, Wanted posters, etc.	WOW – Words of Wisdom Used for: ➢ Class Notes ➢ Discussion Notes Handouts ➢ with new info Lab ➢ Procedures ➢ Answer questions from text ➢ Sample Problems Vocabulary ➢ words/book definitions ➢ Movie, video notes

At the end of the unit students will write a summary of what they learned during the unit. You may also have them select two items that represent their best work. Students should provide the dates of their chosen entries and then explain why they chose these two items, what they learned from these two items, and how these items reflect scientific thinking or skills. Students must use evidence to defend their choices and should not provide emotional responses such as “that is my best drawing” or “that activity was a lot of fun”. Encourage students to share their notebooks during parent teacher conferences, or other instances when they have special visitors in the classroom.

Lesson 1	A Drop in the Bucket

Overview Standard(s) & Objectives	**Overview** In this unit, students work to connect their understanding of water as a crucial element of life and why it is important to be good stewards of the resources around us, including water. In this lesson, students will be faced with the realization that, although much of our world consists of water, only a small percentage of it exists as clean, potable, drinking water. **Objectives** Students • Draw a conclusion that water is necessary for life • Analyze why/when there is too much of a good thing

Materials	For teacher:
	• *Just a Drop to Drink* demonstration
	  • Clear, one liter measuring cup (containing 1 liter of tap water)
	  • 100 ml graduated cylinder
	  • 10 ml graduated cylinder
	  • Plastic dropper
	  • Small, blue metal bucket
	  •
	For each student:
	  ➢ Science notebook

Prior Knowledge (for students)	Much of Earth's surface is covered by water. Water can be found in oceans, freshwater streams, lakes, and rivers, and in frozen polar ice caps. Students should also understand that not all freshwater is clean and drinkable.
Phenomenon	In groups of 2-3, ask students to take about five minutes to discuss, debate and come to a consensus on what percentage of water here on Earth is potable (drinkable) and available for use by living organisms. As necessary, remind students to support their arguments with evidence. One student from each group should write the group's proposed percentage on the board. If there is fierce disagreement, take time to discuss this in class. If students are lacking conversation in their groups, you might facilitate with asking thought-provoking questions such as: • Is all water on Earth fit to drink? Why or why not? • Is all water on Earth easily accessible? Why or why not? Proceed with the *Just a Drop to Drink* demonstration: • Explain that the clear measuring cup with the picture of the Earth on it contains one liter of water. This liter represents all the water on planet Earth.

- Proceed to pour 30 ml of this water into a 100 ml graduated cylinder. Explain that this 30 ml represents all the fresh (not salty) water on planet Earth.
- Next, pour 6 ml from the 100 ml graduated cylinder into the 10 ml graduated cylinder. This 6 ml represents the fresh water on Earth that is in the liquid state. The rest is frozen in glaciers, icebergs and the polar ice caps (and therefore *unavailable* for use by living organisms).
- Finally, fill the plastic dropper with water from the 10 ml graduated cylinder and hold up the small, blue metal bucket. Tell the class that you are about to demonstrate just how much of that original 1 liter of water is fresh, liquid, non-polluted, and available for use. Allow a single drop of water to fall (from about a meter above the bucket) from the plastic dropper into the metal bucket (holding it loosely by the metal handle so that it is free to vibrate) so that the class, if they are quiet and attentive, may hear the single drop of water hit the bucket. This single drop of water represents 0.005% of the original 1 liter of water… the percentage of Earth's water that is fresh, liquid, clean and available for use by living organisms!
- Write 0.005% on the board

Ask students if they have any prior knowledge of pollutants in water that make water undrinkable. Give students time to think. Ask them to share their ideas. (This could be done by giving students sticky notes that they can write on and bring to the board.) Group together common ideas from students. This will help the teacher and students see if many students are wondering the same thing.

Provide students with a sticky note and ask them to write one question they have so far about water on earth. They will use these questions to develop a Driving Question Board (DQB). Have one student come up to the board and read their question and place it somewhere on the board. Ask students if they have the same question as student 1. If they do, encourage students to write down another question to replace theirs. Tell them it is ok if they do not have one right away, as the continuing discussion will likely bring up new questions.

Ask students to raise their hands if they have a question related to Student 1's question (not the exact same) and have Student 1 choose a peer to come up and share their question. This will continue until all students have placed a question on the board or until 20 minutes. As students are placing their questions, guide them in the development of the DQB. Encourage them to look for patterns early and find any major themes or categories that the questions could be placed. (NOTE: If you teach multiple periods of the same course, you can choose to create a new DQB for each period or have each subsequent period continue with

	the work done in previous periods.) If there are students that have not placed their sticky notes on the DQB have them come up and place it on the board where they feel it fits best. Tell students that these questions are going to drive our work throughout this unit. **Note: The Driving Question Board can be done virtually using programs such as Padlet or FigJam.
Summarize	Wrap-up by facilitating a discussion about the actual percentage of water on Earth that is fresh, unpolluted, and available for drinking~ 0.005%. Ask students why so little of the non-salty, liquid water is available for safe use by living organisms. (Two important reasons are water pollution, and the fact that so much water is trapped in soil (like the water contained within a wet sponge) or is too far below ground to reach with wells. Since so little of our water is available and potable (drinkable), we need to take good care of it!)

Lesson 2	The Heart of Everything That Is
Overview Standards & Objectives	**Overview** In this lesson, students discover that water appears to be essential for life as we know it. As the *universal solvent*, water makes many chemical reactions possible. Since living organisms rely on chemical reactions for important biological processes (like deriving energy from food), they require the availability of liquid water. **Standards** MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. *(Note that genetic factors are not addressed in this lesson)* Oceti Sakowin Standard 1.2 Describe traditional and contemporary Oceti Sakowin perspectives on communal stewardship of land and natural resources (flora, fauna, geographic and sacred features). Science and Engineering Practices (SEP): • Developing and using models • Analyzing and interpreting data Crosscutting Concepts (CCC): • Patterns

	Objectives - Determine the characteristics shared by all living things. - Describe water as the *universal solvent*, essential for many chemical reactions to proceed efficiently. - Understand that life, as we know it, requires liquid water. Draw an analogy between the human circulatory system and the water cycle of the Black Hills of South Dakota.
Background Information (For Teachers)	**The typical characteristics of living things** - Homeostasis (Maintaining the *status quo*… temperature, etc.) - Organization (Cells) - Metabolism (Energy Transformations) - Response to Stimuli - Growth - Reproduction Adaptation Note that whether viruses qualify as living organisms is a matter of current scientific debate. In fact, the very definition of what it means to be *alive* is under debate! **What we know about water** - A *universal solvent* due to polarity (strong positive and negative regions capable of causing the separation of ionic compounds). - Appears to be essential for life as we know it. - The typical solvent facilitating chemical reactions involving ionic compounds. - Expected to be a key component in the search for extraterrestrial life. **Evidence of a Chemical Reaction** - Change in color - Change in energy (sound, light, heat, etc.) - Production of a gas (bubbles, odor) - Formation of a precipitate (solid formed from solution) - Change in pH Note that none of this evidence of a chemical reaction can be considered proof that a chemical reaction has occurred. To prove that a chemical reaction has occurred, one must demonstrate that the atoms. have rearranged to form a new substance(s).
Materials	For teacher: 14.8 ml (1 tbsp.) tap water in a graduated cylinder - Quart size zip top baggie with 7.4 ml (0.5 tbsp.) baking soda (powder) - Quart size zip top baggie with 7.4 ml (0.5 tbsp.) calcium chloride (powder) - Goggles ➢ (optional) DampRid moisture absorber refill, baking soda and quart size zip-top baggies For each student: ➢ Science notebook For each group of 3-4 student's: - Pack of 10 *Life Cards*

	• (optional) *Lesson 1 Optional Student T-Chart* For the classroom: Computer and projector with speakers
Prior Knowledge (For Students)	Students should be familiar with the idea that living organisms derive energy from the food that they eat and understand that this is a transformation of energy from one form to another. Students should understand the importance of blood, arteries/veins, and the human heart.
Launch (5-10 minutes)	
Engagement and Communication of Student Expectations	**Introduce lesson** Project the picture of the Black Hills next to a human heart as students enter the classroom. Begin by explaining that Native peoples revere the Black Hills and consider them *The Heart of Everything That Is*. Using the Think/Pair/Share strategy, ask students to contemplate how the Black Hills might be like a human heart. Record a list of student ideas for later use. *(At this point, students may not have many ideas… but that's OK. This exercise will set them up to better explore the idea at the end of the lesson.)*
Explore (30 minutes)	
Procedure	***Life Cards* Activity** **Each group of 3-4 students will need a pack of 10 *Life Cards*.** Explain to students that they will be observing pictures of a variety of organisms and attempting to figure out what they all have in common. 1. Student groups should look at their ten *Life Cards* and work together to create a T-chart of the organism shown (on the left-hand side) and all their observations (on the right-hand side). 2. Then, using their observations, students generate a list of everything the organisms have in common. 3. Next, student groups collaborate with a second group of 3-4 students with a different pack of *Life Cards* (every group's set of cards will be unique). Groups continue their original T-chart by adding observations of the second group's organisms. Students should have a total of 20 organisms and observations when their T- charts are complete. 4. Students should look back to their original ideas about what all organisms have in common (developed after observing only ten organisms) and decide if any characteristics of living things need to be added, deleted, or altered in any way. Students should work together, in their large groups of 6-8 students, to create a list of at three to five things that all twenty organisms they observed have in common. Students should write their list on the board, but without duplicating any that are already written on the board by another group.

6. Facilitate a quick class discussion and attempt to come to a consensus. Students should write their final class list of traits that all living things have in common in their science notebooks. *(Common traits may include the need for food, water, shelter, or an appropriate environment, etc.)*

Chemical Reactions Need Water **Demonstration**

1. Explain that the class has discovered the hallmarks of what it means to be *alive*. Now you are going to go deeper into what may be the number one most important component that all life requires. *(Don't tell them this, but we're looking into chemical reactions!).*

2. Put on a pair of goggles and hold up two clear, quart size, zip-lock plastic baggies, one with 7.4 ml (0.5 Tbsp.) baking soda and one with 7.4 ml (0.5 Tbsp.) calcium chloride. Each chemical is a dry white powder. Announce that you are going to perform an amazing demonstration *(play it up for dramatic emphasis and humor)*.

3. Open both baggies and carefully transfer the baking soda into the calcium chloride baggie *(the calcium chloride is an eye irritant, so take care to avoid aerosolization)*. Zip the top shut, mix the powders by shaking, and wait. You might want to say things like "Wait for it", "Any second now", and "You'll see, it's going to be amazing!". Eventually students will catch on that nothing is happening. You might play it up and say "Oh, I must have forgotten something. What could it be…".

4. Take student suggestions about what you might have *forgotten.*

5. Hopefully someone will suggest water, or even notice that you happen to have a graduated cylinder with liquid in it sitting nearby *(if not… smack your forehead and exclaim "I forgot the water!")*. At this point, pour the water into the baggie with the baking soda and calcium chloride. Quickly seal the top and allow the chemical reaction to proceed. Walk through the class allowing students to see and feel the chemical reaction proceeding in the baggie but be careful to not allow anyone to squeeze the baggie. If too much gas is produced, or the baggie is squeezed hard enough, the baggie can pop and make a mess! *(Optional) If you would like your students to do this activity themselves, you can use baking soda and DampRid moisture absorber Refill (which consists of calcium chloride flakes).*

6. Ask students what they believe is taking place within the baggie *(A chemical reaction)*. Ask students to state what evidence they must support their hypothesis.

7. Facilitate a quick class discussion that clears up any misunderstandings or misconceptions and focuses on the fact that water was necessary for the chemical reaction to proceed. Students

   might want to write a list of observations in their science notebooks, as these are evidence that a chemical reaction has occurred. *Note that students will be*

	able to observe most of the evidence of a chemical reaction EXCEPT for formation of a precipitate and change in pH. If you happen to have an indicator on hand, such as phenol red, you can also observe the pH change! ***Note for Teachers*** *Living organisms depend on water for many reasons, but most important may be the ability of water to facilitate the chemical reactions necessary for life. Living organisms, including humans, require chemical reactions for extracting energy from food. Humans, specifically, require energy to walk, run, talk, think, and learn. This is one reason that it's so important to eat a healthy breakfast in the morning before school… without fuel, your brain cells don't have enough energy to help you focus and pay attention!*
Questions	**Driving Question** • How are the Black Hills like a human heart? **Probing Questions** • What do all living organisms have in common? • Why is water essential to life? • Why didn't the two dry powders react before water was added? • Why did water cause the chemical reaction to proceed? • How are flowing waterways like our veins and arteries? What do blood and water have in common?
Summarize (10-15 minutes)	
Communicate	***Class Discussion*** Project *Streamer* on the board: http://water.usgs.gov/streamer/web/. Go to the map and zoom in to where you can see the convergence of the Cheyenne and Belle Fourche Rivers (just east of Rapid City, South Dakota). Click *upstream trace* in the upper right-hand corner, and then click on the Cheyenne River just east of where the Belle Fourche connects with it. You should now see, in red, all the streams coming out of the Black Hills that feed the Cheyenne and Belle Fourche Rivers. Ask students what this tells us about the importance of the Black Hills. Project the picture of the Black Hills next to a human heart again. Ask students to revisit their original list of ways the Black Hills are like a human heart. • Is there anything you would like to add? Delete? Revise? • Why do living things need the water that flows out of the Black Hills? • What is so important about our blood, and the heart that pumps it throughout our bodies? • Since blood plasma (the liquid component) is approximately 92% water, which is more important to our health: Blood or water? As students discuss their ideas, make sure everyone backs up their answers and responses with evidence and/or logical reasoning! Students should note this final class list of ways the Black Hills are like a human heart in their science notebooks.

	Wrap-up Look back at the questions that the students came up with at the beginning of the unit. Have any of the questions been answered? Are there new questions to add to this space? Show video clip of "Astrobiology: The Search for Life Begins with Water" (2 min 37 sec) http://bigthink.com/think-tank/astrobiology-the-search-for- life-begins-with-water and discuss the connection to the search for life deep underground at the Sanford Underground Research Facility in Lead, South Dakota. The more we learn about life living in extreme environments here on Earth (such as microbes living in hydrothermal vents, hot springs, or a mile underground in the rock at the Sanford Underground Research Facility), the more likely we will be able to find it (if it exists) beyond our planet. These organisms living in extreme environments are called "extremophiles".
Terminology and Concepts to Solidify	**Chemical Reaction-** a process that involves rearrangement of the molecular or ionic structure of a substance, as opposed to a change in physical form or a nuclear reaction. **Solvent-** a substance that can dissolve another substance, or in which another substance is dissolved, forming a solution. Water is the most common solvent. **Energy Transformation-** the process of changing one form of energy to another form of energy. Deriving the energy to walk or run from the food we eat is one example of how living organisms utilize energy transformations for life. **Living Organism-** an organism is any contiguous living system, such as an animal, plant, fungus, archaeon, or bacterium. All known types of organisms are capable of some degree of response to stimuli, reproduction, growth and development, and homeostasis.
Connection to Big Ideas (Phenomena)	Living organisms depend on energy transformations. Water is often referred to as the *universal solvent.* Life, as we know it, requires liquid water.
Optional Follow Up	Show the TED talk with Aomawa Shields "How We'll Find Life on Other Planets" (5 min 25 sec). https://www.ted.com/talks/aomawa_shields_how_we_ll_find_life_on_other_planets?language=en
Assessment	Students should explain (in their science notebooks, or as an *exit ticket*) the similarities and differences between the human circulatory system (blood and the human heart), and the water flowing within/from the Black Hills. Diagrams with labels are encouraged!

Lesson 3	"Water" You Drinking?
Overview Standards & Objectives	**Overview** This lesson Focuses on the water cycle and sources of water pollution. After an activity where students analyze data to determine the point source of an imaginary water contamination event, they brainstorm about potential water pollution sources in their own community. Students test actual water samples of their own choosing in Lesson 4. **Standards** MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. MS-ESS2-4 Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity. *(Note that this lesson asks*

	students to utilize a model instead of developing one and does not address effects due to energy from the sun). Science and Engineering Practices (SEP): • Analyzing and interpreting data • Developing and using models • Engaging in argument from evidence Crosscutting Concepts (CCC): • Systems and system models • Energy and Matter: Flows, Cycles, and Conservation. Objectives: • (Optional) Model the water cycle. • Understand how little water on Earth is fresh and available for drinking. • Utilize a model for determining the source of a ground water contamination event. • Identify potential sources of water pollution. • Design a plan for testing the water quality of their own community.
Background Information (For Teachers)	**The Water Cycle** The Water Cycle (also known as the hydrologic cycle) is the journey water takes as it circulates from the land to the sky and back again. The Sun's head provides energy to evaporate water from the Earth's surface (oceans, lakes, etc.). Plants also lose water to the air (called transpiration). The water vapor eventually condenses, forming tiny droplets in clouds. When the clouds meet cool air, precipitation (rain, sleet, or snow) is triggered and the water returns to the land (or sea) due to the pull of gravity. Some of the precipitation soaks into the ground. Some of the underground water is trapped between rock or clay layers; this is called groundwater. But most of the water flows downhill as runoff (above ground or underground), eventually returning to the seas. **Point Source Pollution** Point source water pollution refers to contaminants that enter a waterway from a single, identifiable source, such as a pipe or ditch. Examples include discharges from a sewage treatment plant, a factory, or a city storm drain. **Non-Point Source Pollution** Non-point source pollution refers to diffuse contamination that does not originate from a single discrete source. This type of pollution is often the cumulative effect of small amounts of contaminants gathered from a large area. A common example is the leaching of nitrogen compounds from fertilized agricultural lands, or nutrient runoff in storm water from *sheet flow* over an agricultural field or a forest. Sheet flow is an overland flow (or downslope movement) of water taking the form of a thin, continuous film over relatively smooth soil or rock surfaces that is not concentrated into channels. **Groundwater Pollution** Interactions between groundwater and surface water are complex. Consequently, groundwater pollution, also referred to as groundwater contamination, is not easily classified as surface water pollution. Ground water aquifers are susceptible to contamination from sources that may not directly affect surface water bodies. A spill or ongoing release of chemical or radioactive contaminants into soil (located away from a surface water body) may not create point or non-point source pollution but can contaminate the aquifer below, creating a toxic plume. **Contour Mapping** Contour lines help geologists (as well as hikers) understand the slope of the land. Each line represents an elevation at that line. If you were to walk across a line, you are

	changing elevation. The steeper the slope, the more lines you will cross in a short distance.
Materials	For teacher: • Video Display for students to watch NASA Video • Look over Lesson 3 *Mystery in the Black Hills* guide • Copies of Lesson 5 water sample analysis sheets (for students that volunteer to collect water samples) For each student: ➢ Science notebook • Full page copy of *Lesson 3 Student Riverville Contour Map* • (optional) *The Water Cycle* handout Each pair of students: • Lesson 3 *Mystery in the Black Hills – A Hazardous Whodunit* activity sheet • Colored pencils
Prior Knowledge (For Students)	The force of gravity pulls things down and causes raindrops to fall from the sky. Energy from the Sun heats objects and causes liquid water to vaporize. Human activity has an impact on the environment. Water is essential for life as we know it, and thus water quality is important for the health and wellbeing of all living things.
Launch (15 minutes)	
Engagement and Communication of Student Expectations	Have students watch the following video. While students are watching it, have them fill out a T-chart of their notices and wonders in their science notebook. After watching the video, take time to discuss common notices and wonders. Encourage students to share either one notice or one wonder as the teacher documents them in the similar format to the DQB from Lesson 1. Compare information collected from this activity with information obtained from the students on their DQB. DO any of the same questions exist? Have any of their questions been answered? (Optional) Project the water cycle activity (available here) on the board and hand out copies of the models to be filled in and added to student's science notebooks (if desired). Ask students to volunteer and work together to correctly identify where each label belongs. (This activity could also be used as a take home assignment for reviewing and reinforcing basic water cycle ideas and terminology, but it is not required for completion of this curriculum unit. This can be omitted for sake of time.) Finally, show the video *Causes of Water Pollution.*
Explore (25 minutes)	
Procedure	Arrange students into pairs. Distribute the *Lesson 2 Mystery in the Black Hills* Activity sheet (one per group) and full-page copy of the *Lesson 3 Student Riverville* Contour Map (one per student). Depending on the level of your students, two version of the *Student Riverville* Contour Map have been supplied in the print masters: one without the contour lines (so that students may draw them themselves) and one with the contour lines already provided.

	Depending on your preference, students may either write all answers on the student activity sheet for submission, or they may use science notebooks. If using science notebooks, students should keep notes and answer all questions in their notebooks, then staple their completed contour maps into their notebooks. It is recommended that every student have their own copy of the *Leson 3 Student Riverville* Contour Map for their science notebook. Students should still work together in pairs, even though each student has their own copy of the map. Read over the Lesson 2 *Mystery in the Black Hills* lab sheet introduction with the class. Ask students to predict which potential source of the contamination they think is most likely the actual source and why. If time permits, you might ask students if they can think of any methods for determining which business is the source of the pollution. Lead a short brainstorm session. Then tell students that they are about to learn a particular method for helping to determine the source of groundwater contamination that utilizes contour mapping. Contour maps help geologists understand the slope of the land. Each line represents an elevation at that line. If you were to walk across a line you are changing elevation. The steeper the slope, the more lines you will cross in a short distance. Assist students with the activity and analysis as necessary.
Questions	**Driving Question:** • How is the cycling of water through Earth's systems driven by energy from the sun and the force of gravity? **Probing Questions:** • What happens to pollutants introduced into the water cycle? • What are some of the sources of water pollution? • Are all sources of water pollution man-made? • Why is it important to protect our fresh drinking water? • How is energy from the sun involved in the water cycle? • How is the force of gravity involved in the water cycle? • How might the source of water contamination be discovered?
Summarize (10 minutes)	
Communicate	Have students discuss their results in large groups. Ask groups to share their final analysis on the source of the water pollution, and their prediction for which well will become contaminated next. Did everyone agree? *(You may wish to project the Student Riverville Contour Map during this discussion for students to utilize. Please note that the key supplied is only one potential solution. There could be other acceptable solutions depending on how students interpret their individual contour lines and additional factors such as the river, etc. What is most important is that students provide logical explanations supported with evidence from their maps).* Now as students to brainstorm any potential water pollution sources n their own community, and the water bodies that might be affected. Help guide the class towards choosing no more than six sites for sampling. Students should record final class list of sites in their science notebooks and draw a rough sketch of the area which points out the sites to be tested. The class will be testing these water samples in lesson 4.

	If anyone suggest a water source that is on private land, they/you will need to get permission from the landowner to sample the water. Additionally, if students have water on their own land, they will need to volunteer to bring in these samples. Work with your students to figure out how to collect all of their desired water samples! An interesting activity is sampling the water both above and below the wastewater treatment facility in your area. Sampling above/below any potential contamination source on a flowing waterway is a good idea for comparison. *For each water sample, obtain 400-500mls (about two cups) and fill out the 'observations' section of the sample analysis sheet. A clean, plastic, screw top beverage bottle can be used for sample collection and transport. IF multiple classes choose the same site, make sure you have enough for each class period. A two-liter screw -top beverage bottle may be useful in these instances. If possible, advise students to utilize an un-opened bottle of water. Upon reaching the water source to be sampled, the bottle may be opened, the contents dumped away from the sampling site, and then the clean, uncontaminated, water bottle filled with water from the sampling site. Screw the top back on immediately to avoid contamination until testing.*
Terminology and Concepts to Solidify	**Pollutant:** a substance or condition that contaminates air, water, or soil. Pollutants can be artificial substances or naturally occurring substances that occur in harmful concentrations in an environment. **The Water Cycle:** the cycle of processes by which water circulates between the earth's oceans, atmosphere, and land involving precipitation as rain and snow, drainage in streams and rivers, and return to the atmosphere by evaporation and transpiration. **Gravity**: the force that attracts a body toward the center of the earth, or toward any other physical body having mass. **Energy:** the capacity to do work, such as the capacity to move an object of a given mass by the application of force. Energy can exist in a variety of forms, such as electrical, mechanical, chemical, thermal, or nuclear and can be transformed from one form to another. It is measured by the amount of work done, usually in units of joules or watts. **Fresh Water:** water having a low salt concentration (less than 1%) and most frequently found in ponds, lakes, rivers, streams, and wetlands. The ice caps, icebergs, and glaciers are also composed of fresh water, in the solid state, and account for almost 70% of the total fresh water found on Earth. **Contour Map:** a topographic map on which the shape of the land surface is shown by contour lines, the relative spacing of the lines indicating the relative slope of the surface. **Precipitation:** rain, snow, sleet, or hail that falls to the ground. **Transpiration:** process by which moisture is carried through plants from roots to small pores on the underside of leaves, where it changes to vapor and is released to the atmosphere. **Percolation:** the movement and filtering of fluids through porous materials. **Absorption:** the process of assimilating a substance into a cell or across a tissue or organ, accomplished through diffusion. **Excretion:** the process of eliminating or expelling waste matter. **Respiration:** the action of breathing **Evaporation:** the process by which water changes from a liquid to a gas, or vapor. **Condensation:** the conversion of a vapor or gas to a liquid. **Sheet flow:** an overflow (or downslope movement) of water taking the form of a thin, continuous film over relatively smooth soil or rock surfaces that is not concentrated into channels.

Connection to Big Ideas (Phenomena)	The cycling of water through Earth's systems is driven by energy from the sun and the force of gravity. Human activities have an impact on the environment.
Optional Follow Up/Practice	Additional activities and resources are available here. **Optional Extensions:** **Make a terrarium:** DIY: How to make your own green terrarium to keep or give away for the holidays (inhabitat.com) With enough water and a little sunshine, students will be able to watch the water cycle…and you can introduce the concept of plan transpiration, too! Can be a large, single classroom terrarium, or encourage students to bring supplies and make their own. **Research and Report:** A) Students may choose to investigate a current/historic source of pollution in the Black Hills and report/present their findings in any format they choose. Suggested topics specific to the Black Hills include uranium and gold mining. Historically, these mining activities have been associated with the release of mercury, cyanide, arsenic, and radioactive material. B) Students might research and report on more general forms of water pollution found anywhere in the world: fecal bacteria, antibiotic compounds banned from soaps, industrial waste, acid rain, or prescription medication. C) The Rapid City flood of 1972 might also be an interesting topic of exploration, as the topography of the Black Hills has much to do with the danger of flooding.
Assessment	**Exit Card:** Have students predict which water samples the class chose to test will be contaminated and explain what they believe the cause of the pollution might be. **Formative Assessment:** Lesson 3 *Mystery in the Black Hills – A Hazardous Whodunit* Completed contour maps and answers to questions.

Lesson 3 – Teacher's Guide

Introduction:

This activity allows students to put their ideas on paper and gives them an opportunity to make those ideas visible to their peers.

Lesson 3 Phenomenon Optional Student T-Chart

Notices	Wonders

Lesson 3 – Teacher's Guide
Mystery in the Black Hills: A Hazardous Whodunit

Introduction:

This activity presents the student with a hypothetical problem often encountered in the real world and provides a simple, but not always accurate, tool for investigating the problem.

The problem is that a town's drinking water is contaminated. In many small towns like Riverville, every home and most businesses have a private well (or wells). Lab results from several wells show that the ground water has been contaminated with a fuel stored by three entities. Of the three possible suspected sources of contamination, each has a reasonable argument as to why they are not responsible for the problem.

1. The Gas Stations are the prime suspect as they store the most fuel in underground tanks. However, they recently had their tanks inspected and there were no leaks.

2. The Bus Barn for the school district claims that their tanks are new and shouldn't be leaking so soon after installation.

3. The Lonely Ghost Gold Mine is not as financially secure as they would like to be. They say that the expense of digging up and inspecting their tanks is more than they can bear without stronger evidence to back up the need.

The only way to find out who is responsible is to produce some sort of evidence that pinpoints which of these businesses is the actual source of contamination. Emphasizing the expense of cleaning up ground water contamination and the need for certainty before forcing a business to begin cleaning up lets students know that there is often a lot at stake in this kind of investigation.

Objective:

Students will develop a topographic (contour) map, use it to predict ground water flow, and determine the most likely source of a ground water contamination event.

Procedure:

1. Students work together in pairs. Each pair will need: Colored pencils, Student Activity Sheet, and two copies of the Student Riverville Contour Map
2. Tread over the introduction on the Student Activity Sheet with the class. Ask students to predict which of the three businesses they think the source of the contamination might be and why.
3. You might ask (depending on time constraints) whether anyone can think of a way of finding the source of the water contamination before beginning the activity. For instance, the wells nearest the source would have the highest levels of contamination, and those farthest away would have the lowest levels. Unfortunately, this can be rather expensive as lab tests can cost $200.00+ for each well.

Note:

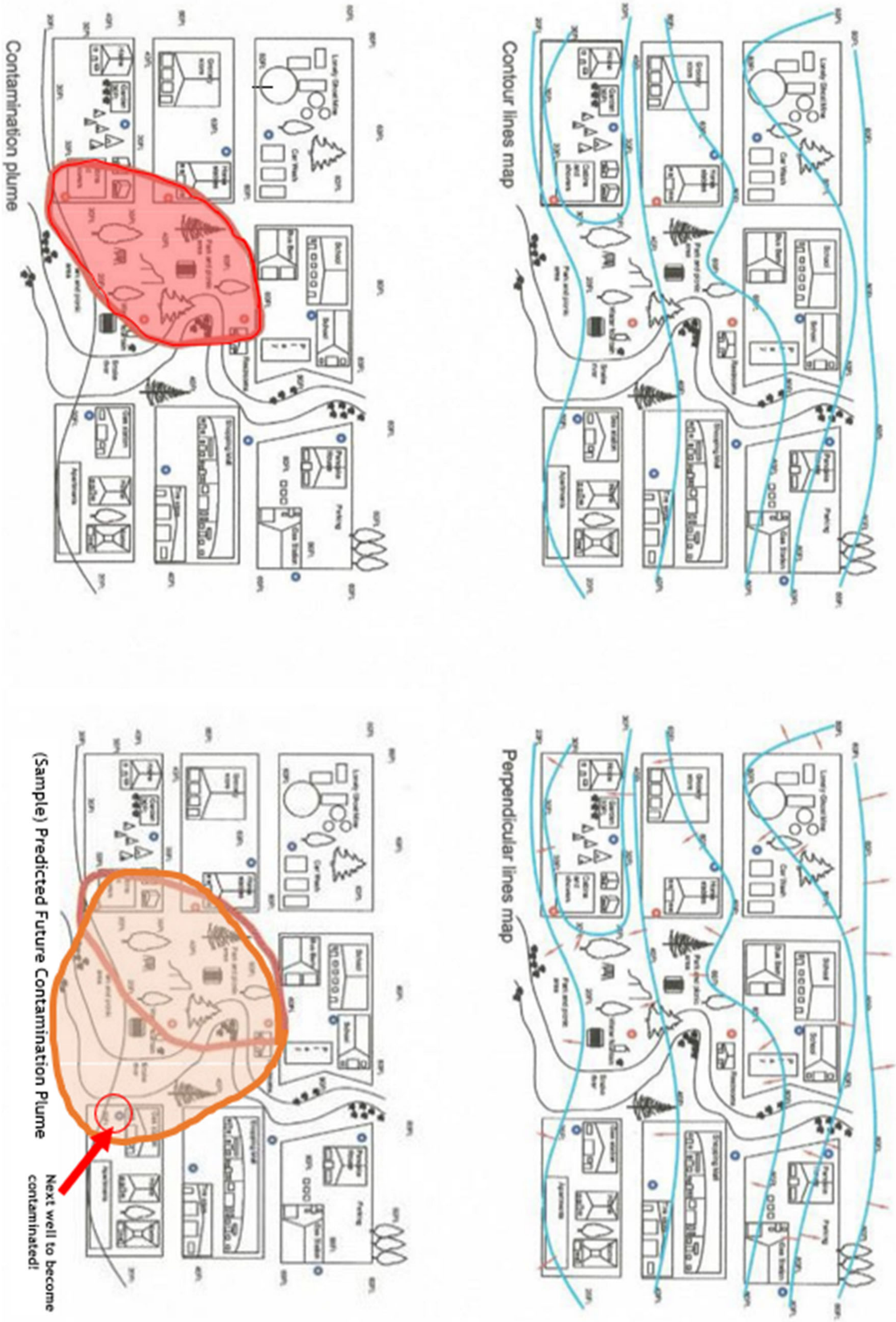
You may want to explain to your students that they are looking at a single section/segment of a contour map. Some may be confused by the fact that only one of the contour lines (at the 30-meter elevation) appears to make a complete circle.

Answers to Activity Questions:

1. The school bus barn is the most likely source of the contamination.
2. Only the bus barn is uphill from all the contaminated wells.
3. See (suggested) teacher key maps below.
4. See (suggested) teacher key maps below.
5. Accept any logical and supported answer. For instance, wells nearest the source would have the highest levels of contamination and those farthest away would have the lowest levels.
6. If either of the gas stations or the mine was leaking fuel, you would expect the wells just downhill from them to be contaminated…..but they are not.

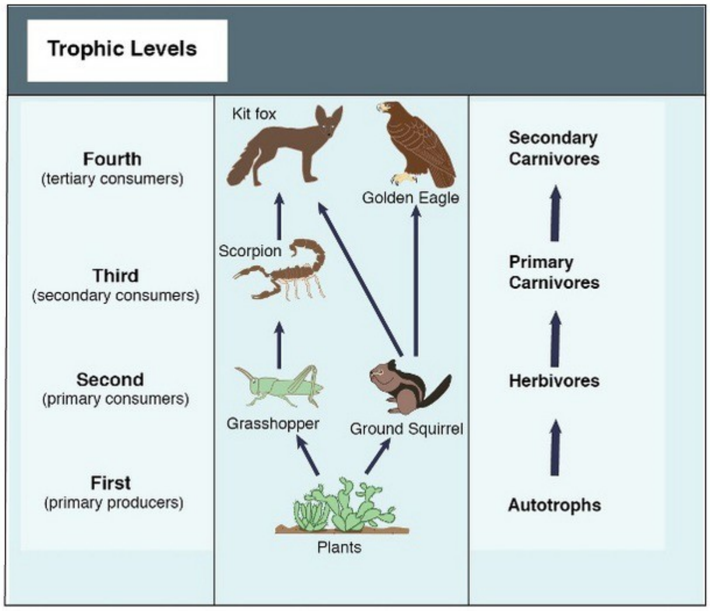
See Teacher Key Contour Map on the next page. Remember that this is only one potential analysis of the situation. Consider all logical analyses, as long as students back-up their viewpoints with evidence from their contour maps.

Lesson 3 Teacher Key Contour Maps



Lesson 4	It's Deadly at the TOp
Overview Standards & Objectives	**Overview** In this lesson, students will model the bioaccumulation and biomagnification of mercury in a food chain in order to develop an understanding of why some organisms accumulate dangerous levels of pollutants, while others do not. A direct correlation is made to the fish consumption advisories posted at many popular fishing lakes. **Standards** MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. Oceti Sakowin Standard 1.4 Identify and explain contemporary environmental issues facing Oceti Sakowin lands (i.e., Dakota pipeline, etc.). *(This standard is not explicitly addressed within the lesson but is implied and could be incorporated into class discussions.)* 6-8.WHST.1 Write arguments focused on discipline-specific content. a. Introduce claim(s) about a topic or issue, acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically. b. Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources. c. Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), counterclaims, reasons, and evidence. d. Establish and maintain a formal style. e. Provide a concluding statement or section that follows from and supports the argument presented. 6-8.WHST.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. 6-8.WHST.5 With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed. **Science and Engineering Practices (SEP):** • Developing and using models • Analyzing and interpreting data • Engaging in argument from Evidence **Crosscutting Concepts (CCC):** • Energy and matter: Flows, Cycles, and Conservation • Patterns

	Objectives • Model bioaccumulation and biomagnification of mercury. • Understand the basic concepts of a food chain and/or web. • Analyze data to determine the type of fish which tend to have higher levels of mercury in their flesh. • Explain why some toxins, typically present at low environmental levels, can be dangerous to apex predators in a food chain/food web.
Background Information (for Teachers)	**Food Chains** A food chain is a linear networks of links in a food web starting from producer organisms (such as grass or trees which use energy from the sun to make their food) and ending at apex predator species (like grizzly bears or killer whales), detritivores (animals like earthworms or woodlice that feed on dead organic material), or decomposer species (such as fungi and bacteria that breakdown organic material into essential nutrients for recycling). A food chain also shows how organisms are related with each other by the food they eat. Each level of a food chain represents a different trophic level. **Food Webs** A good web is an important ecological concept. Food webs represent feeding relationships within a community. They also demonstrate the transfer of food energy from its source in plants through herbivores to carnivores. Normally, food web s consists of several food chains meshed. Each food chain is a descriptive diagram including a series of arrows, each pointing from one species to another, representing the flow of food energy from one feeding group of organisms to another. There are two types of food chains: the grazing food chain, beginning with autotrophs, and the detrital food chain, beginning with dead organic matter. In a grazing food chain, energy and nutrients move from plants to herbivores consuming them, and then to the carnivores or omnivores preying upon the herbivores. IN a detrital food chain, dead organic matter from plants and animals is broken down by decomposers (e.g. bacteria and fungi) and moves to detritivores and then to carnivores. Here is an example of a food web showing the various trophic levels:



Bioaccumulation and Biomagnification of Pollutants

Bioaccumulation is the gradual build up, over time, of a chemical in a living organism. This occurs either because the chemical is taken up faster than it can be used, or because the chemical cannot be broken down for use by the organism (that is, the chemical cannot be metabolized). Bioaccumulation need not be a concern if the accumulated compound is not harmful. Compounds that are harmful to health, such as mercury, however, can accumulate in living tissues and cause disease or death.

Bioaccumulated chemical pollutants come from many sources. Pesticides are an example of a contaminant that bioaccumulates in organisms. Rain can wash freshly sprayed pesticides into creeks, where they will eventually make their way into rivers, estuaries, and the ocean. Another major source of toxic contaminants is the presence of compounds from industrial smokestacks and automobile emissions that return to the ground in rainfall. Deliberate discharge of compounds into water is another source of chemical pollutants.

Once a toxic pollutant is in the water or soil, it can easily enter the food chain. For example, in the water, pollutants adsorb or stick to small particles, including a tiny living organism called phytoplankton. Because there is so little pollutant stuck to each phytoplankton, the pollutant does not cause much damage at this level of the food web. However, a small animal such as zooplankton might then consume the particle. One zooplankton that has eaten ten contaminated phytoplankton would have ten times the pollutant level as the phytoplankton. As the zooplankton may be slow to metabolize or excrete the pollutant, the pollutant may build up or bioaccumulate within the organism. A small fish might then eat ten contaminate zooplankton. The fish would, therefore, now have 100 times the level of toxic pollutant as the original phytoplankton. This multiplication could continue throughout the food web until high levels of contaminants have biomagnified in the top predators. While the amount of pollutant might have been small enough to not cause any damage in the lowest levels of the food web, the biomagnification amount might cause serious damage to organisms higher in the food web. This phenomenon is known as biomagnification.

	Mercury and the Mercury Cycle Mercury in any form is poisonous, with mercury toxicity most commonly affecting the nervous system, digestive system, and kidneys. Poisoning can result from vapor inhalation, ingesting, injection, and absorption through the skin. Mercury has three forms: elemental mercury, inorganic salts, and organic compounds. Organic mercury compounds, specifically methylmercury, are the most dangerous. Though industrial mercury pollution is often in the inorganic form, aquatic organisms and vegetation convert it to the deadly methylmercury form. Fish eat these contaminated organisms, and the mercury becomes biomagnified in the fish. Fish protein binds more than 90% of the consumed methylmercury so tightly that even the most vigorous cooking methods (e.g., deep-frying, boiling, baking, pan-frying) cannot remove it. Mercury contaminates the environment through a cycle involving the initial emission (through natural processes or human activities), subsequent atmospheric circulation in the vapor state, and the eventual return of mercury to the land and water via precipitation. Mercury present in seas, lakes and rivers after methylation can contaminate fish, which in turn may be consumed by terrestrial predators including people. Human activities that can result in mercury emission and exposure include the burning of fossil fuels, mining, and the burning of waste. Natural sources of mercury include volcanic activity, earthquakes, erosion, and the volatilization of mercury present in the marine environment.
Materials	For the teacher: • PowerPoint Lesson 4 Presentation For each student: ➢ Science notebook • Copy of Table 6 from the South Dakota Mercury TMDL (p. 34) ➢ Calculator (recommended, but not required or provided) • Biomagnification Game Activity Sheet • Organism Card for the Biomagnification Game • Lesson 4 Assessment Prompt For the whole class: • Tokens of three colors, 100 of each color • 19 cloth food bags (one for each zooplankton)
Prior Knowledge (for students)	Students should have some prior knowledge about the organisms living in and around a freshwater lake. Students should have a basic understanding of the flow of energy through the trophic levels of a food chain/food web (from the primary producers to the apex predators). Water is essential for life as we know it, and thus water quality is important for the health and wellbeing of all living things. Students should have a basic understanding of the water cycle, and the fate of contaminants introduced into the water cycle.
Launch (5 minutes)	

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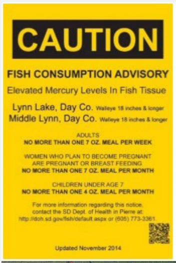
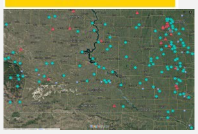
<td>Engagement and Communication of Student Expectations


</td>
<td>Project the yellow fish consumption advisory sign on the board as students enter the room (slide 1).

- Have any of you seen this sign before?
- What is it warning about?
- What does it mean?

Project slide 2 of the PowerPoint containing the electronic resources for lesson 4 or project the interactive web-based version. When using the interactive map, you can zoom-in on any area and click on the symbols for more information (such as lake name and contaminated fish species). Contaminated lakes include Bitter Lake, Coal Springs Reservoir, Elm Lake, Lake Hurley, Lake Isabel, Lake Minnewasta, Hazelden Lake, Lake Roosevelt, Lardy Lake, Long Lake, Lynn Lake, Middle Lynn Lake, New Wall Lake, Newell Lake, North Island Lake, Opitz Lake, Pudwell Dam, Reid Lake, Swan Lake, and Twin Lakes.

- Have any of you gone fishing in a lake with mercury-contaminated fish? (Lakes containing fish with elevated levels of mercury in their flesh are represented by the red triangles.)
- Do you think these contaminated lakes *look* contaminated?

Give each student a copy of Table 6 from the South Dakota Mercury TMDL (P. 34). Laminated copies can be found in the curriculum unit kit.
Facilitate a quick class discussion. If necessary, you should explain that there are some lakes in South Dakota where the water tests well below dangerous levels for the metal mercury (which is toxic), and yet there are fish living in those lakes with dangerous levels of mercury in their flesh.

The State Department of Health posts these warning signs when they find fish that have potentially dangerous levels of mercury. If a person ate enough mercury-containing fish, they could become very ill.

Table 6 is actual data from a 2015 South Dakota report.

- What could possibly be happening to cause the health warning if the level of mercury in the water itself is at safe levels?

Students should think/pair/share, and record ideas in science notebooks. *(Students will be discovering the answer to this question through modeling during the Biomagnification Game.)*</td>
</tr>
<tr>
<td colspan="2">Explore (25 minutes)</td>
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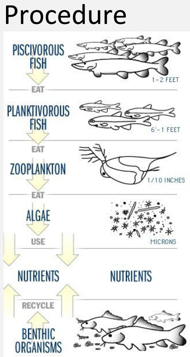
<tr>
<td>Procedure

</td>
<td>Show the free *BrainPop* video on food chains (3 min 19 sec). *Note that you will not find a copy of the US version of this video on the USB. There is a downloaded copy of the UK version on the USB, as well as embedded within slide 3 of the lesson 4 presentation (4 min 2 sec), and it is the same except for the voice of Tim and the addition of closed captioning.* https://www.brainpop.com/science/ecologyandbehavior/foodchains/

Watch the Food Chain Rap (3 min 4 sec) embedded in slide 4 of the presentation.
http://cashmancuneo.net/movieshtm5/fc/3.html

Tell students that they will now be modeling a freshwater lake/lake-side ecosystem, and what happens to some contaminants within these ecosystems. Ask students to think/pair/share what a basic fresh water (or *aquatic*) food chain might look like. Have</td>
</tr>
</table>

(and/or help) students sketch- out what they think a freshwater food chain/web might look like in their area (slide five of the *Lesson 4 Presentation* can be used for this purpose). Below are some questions you might use to help the class diagram their food chain or food web (interconnected food chains in the same ecological community):

- What organisms would you expect to find in/near a lake?
- Which organism(s) would form the base of the food chain (the *primary producers*)?
- Which organism(s) would be classified as primary consumers (these eat the primary producers)?
- Which organism(s) would be classified as secondary and/or tertiary (third tier) consumers (eating the primary and secondary predators)?
- Which organism(s) would be classified as apex (or *top*) predators?
- What direction does energy flow in your food chain/web?

Project the general freshwater food chain diagram on the board for the class to contemplate and discuss (slide 6). Ask students to decide which organisms should be labeled as plankton, zooplankton, planktivorous, piscivorous, and/or benthic. Encourage students to sketch their class food chain/web into their science notebooks, including specific terminology as labels where appropriate. For example, if the class included insect larva in their food chain/web, these would be appropriately labeled as *zooplankton*. If small pan fish (sunfish, crappie, bluegill) were a part of the class food chain/web, they would be labeled as planktivorous. If the class food chain/web is missing any particular category from this general freshwater food chain diagram, encourage them to add additional organisms so that every category is represented.

Hand each student an organism card. Each organism card is unique, though some will have identical instructions for feeding. Instruct students to quietly read the instructions on their organism card, and ask for clarification, if necessary. You will need to adjust the number of organisms to match the number of students in each class, ensuring that at least 53% of the class is zooplankton.

- The typical minimum number of students required for playing the *Biomagnification Game* is 17 (see below for how to run the game with less than 17). A class of 17 would utilize:
  - 1 apex predator game piece
  - 2 piscivorous game fish game pieces
  - 5 planktivorous small fish game pieces
  - 9 zooplankton game pieces
- For classes of less than 17 students, you may give as many zooplankton-modeling students (as required) TWO game cards each and allow them each to pick-up TWO colored phytoplankton tokens at a time… allowing you to run the game as if there are 17 students!
- For classes between 17 and 27 students, simply add more zooplankton to the game piece numbers shown above (for 17 students).
- Classes of 28 students should use:
  - 1 apex predator
  - 3 piscivorous game fish
  - 9 planktivorous small fish
  - 15 zooplankton

Determine the *ecosystem* boundaries where you plan to play the game. A large classroom is fine if students are free to move around, but a small gym or courtyard area is ideal. Scatter the 300 multicolored tokens around the ecosystem. These tokens represent the phytoplankton (primary producers).

Explain that the game will be played in four quick rounds. Students who are not actively participating yet are responsible for making sure the zooplankton don't cheat by picking up more than one token at a time. Students are to walk quickly (no running!) and need to be gentle with each other when *tagging* a prey species' elbow. Food bags should be willingly given to a predator after being tagged on the elbow, and predators are not allowed to try to grab and/or snatch food bags away from others. And finally, adjust the time for each round as necessary so that all predators *catch* the appropriate number of prey (as determined by their game card). The optimal time for each round will depend upon class size, and the boundaries of the *ecosystem* game play area. It is best to call time in each round *before* all individuals of a trophic level are tagged. It is optimal to have at least one representative of each trophic level with a food bag for data analysis at the end of the game.

Round one:

- All zooplankton will enter the designated game play area (the *ecosystem*) and have about ten seconds to *eat* as many phytoplankton (tokens) as possible. Each zooplankton may only eat one phytoplankton at a time by: bending over, picking up one token, standing up straight, and placing the token into their food bag (stomach).
- Once time is called, zooplankton will stop and wait while the planktivores (small fish) enter the ecosystem.

Round two:

- When given the signal, everyone may begin *eating*. Zooplankton continue placing food tokens in their food bags, and small fish begin *catching* zooplankton by gently tagging them on the elbow.
- Anyone tagged on the elbow must give their food bag(s) to the predator who caught them.
- When time is called, all zooplankton sit down (with food bags if untagged), small planktivorous fish remain in the game area, and piscivores (large game fish which prey on smaller fish) enter the ecosystem.

Round three:

- Large (piscivorous) game fish have about ten seconds to catch their prey (the small planktivores) and take their food bags.
- When time is called, planktivores sit down (if untagged) and the apex predator enters the ecosystem.

Round four:

- The apex predator should be allowed about 10 seconds to catch the appropriate number (listed on apex predator's game card) of piscivorous fish before time is called, collecting the food bags of each prey fish tagged on the elbow.

	Once time is called, everyone with a food bag(s) should count the number of each token color and record these numbers in their science notebook. Students without a food bag should help those with tokens to sort and count.
Questions	**Driving Questions** • How can changes to physical or biological components of an ecosystem affect populations? • How does matter cycle among the living and nonliving parts of an ecosystem? **Probing Questions** • What is the fate of an environmental contaminant, like mercury? • How does mercury affect different trophic levels of an ecosystem? • Why are apex predators at most risk of mercury poisoning? • What is the role of bioaccumulation in biomagnification? • How is a food chain different from a food web? • What is an ecosystem?
Summarize (15-20 minutes)	
Communicate	**Class Discussion** Announce which token color represents the toxic pollutant, mercury. It is a good idea to change the color representing mercury each class period so that *word of mouth* does not affect results later in the day. Have students with a food bag(s) at the end of the biomagnification game record the number of tokens representing mercury in their food bag under the appropriate trophic level on the board. There should be four areas for recording: zooplankton, planktivores (small fish), piscivores (large game fish), and the apex predator (slide 8 of the presentation has a chart you can project on the board for this purpose). Students should record the class data in their science notebooks. Ask a student volunteer to average the number of the token color representing mercury for the organisms in each trophic level and record this as well. Facilitate a class discussion focusing on the level of contaminants in the individual organisms of each trophic level during the Biomagnification Game. • Why was there a difference in the contaminant levels of certain species? • Which species had the greatest contaminant levels? • What do the species with the highest contaminant levels have in common? • What does this suggest might be happening to cause officials to post the yellow warning signs we looked at when class began? **Wrap-up** Students should form groups of 2-3 and look at Table 6 from the *South Dakota Mercury TMDL (pg. 34)* again (provided on slide 8 for projection, if desired). Suggest that they work together to determine the percentage of each fish species testing above the 0.3 mg/kg threshold for methylmercury. • Which fish species had more than 40% of the population testing positive for excessive methylmercury levels? • What do these fish species have in common? *(they are apex predators)* **Teachers Note** *The way this game models the biomagnification of mercury is not completely accurate, though it is a useful analogy. Since none of the food in this game is metabolized, the*

	actual ratio of mercury-representing tokens to all tokens will not increase as you move up the trophic levels of the food chain. In real life, much of the food consumed would be metabolized, and thus cause an even more dramatic biomagnification. *Therefore, for this game you need the students to focus only on the average number of mercury-representing tokens in the organisms of each trophic level.* **Connection to the Sanford Lab** *(slides 10 and 11 of the presentation)* Historically, mercury was used to recover small bits of gold from crushed rock (called *ore*), and mercury is still used today in many developing countries. This process was called *amalgamation*. During amalgamation an alloy (mixture involving two metals) is formed, in this case an alloy of gold and mercury. The gold is literally dissolved into the mercury. This allows the collection of very small particles of gold, increasing the recovery rate and efficiency of the mining operation. At the end of the process, the mercury and gold are separated, and the mercury is recycled for reuse. After amalgamation, the left-over ore (also called mine *tailings*) was typically washed downstream as waste. Trace amounts of mercury in these left-over tailings were an historical source of mercury pollution until an even more efficient method of gold extraction was developed called *cyanidation*. The former Homestake Gold mine in Lead, SD was closed in 2001 and eventually repurposed for the current Sanford Underground Research Facility. The old Homestake gold mine was no different from other mines of the day, and was a source of environmental mercury contamination until the 1970's. In addition to no longer utilizing mercury in the processing of gold ore, the Grizzly Gulch Tailings Dam was constructed to prevent mine tailings from washing downstream. These two actions helped speed the process of environmental remediation downstream of the former Homestake Gold Mine. Gold mining isn't the only source of mercury in the environment, though. Other sources include the burning of fossil fuels and the burning of waste, volcanic activity, earthquakes, and natural erosion. Though most mercury contamination (from both natural sources and human activity) is inorganic, it can be naturally converted in the environment to a much deadlier, organic form called methylmercury. Methylmercury is efficiently concentrated in the food chain through bioaccumulation and biomagnification. Though mercury in any form is poisonous, methylmercury is the most toxic. Mercury toxicity most commonly affects the nervous system, digestive system, and kidneys. The most severe side effects include uncontrollable shaking, inability to walk well, blindness and double vision, memory problems, seizures and even death (with large exposures). **Remind students who may have volunteered to collect water samples that they need to bring those for the next lesson.**
Terminology and Concepts to Solidify	**Ecosystem-** a biological community of interacting organisms and their physical environment. **Food Chain-** an arrangement of the organisms of an ecological community according to the order of predation in which each uses the next usually lower member as a food source.

	Food Web- a system of interlocking and interdependent food chains. **Bioaccumulation-** the accumulation of substances, such as pesticides, or other chemicals in an organism. **Biomagnification-** the concentration of toxins in an organism as a result of its ingesting other plants or animals in which the toxins are more widely disbursed. **Neurotoxin-** a poison that acts on the nervous system. **Apex Predator-** also known as an alpha predator or apical predator, is a predator residing at the top of a food chain upon which no other creatures' prey. **Trophic Level-** each of several hierarchical levels in an ecosystem, comprising organisms that share the same function in the food chain and the same nutritional relationship to the primary sources of energy. **Primary Producer-** organisms in an ecosystem that produce biomass from inorganic compounds (autotrophs). In almost all cases these are photosynthetically active organisms (plants, cyanobacteria, and a number of other unicellular organisms. **Primary Consumer**- the living organisms that eat the producers, which are the plants. All organisms that are classified as herbivores, also called plant-eaters, fall into the category of primary consumers. **Secondary Consumer-** these eat primary consumers. They are carnivores (meat-eaters) and omnivores (animals that eat both animals and plants). **The Mercury Cycle-** a biogeochemical cycle involving mercury. **Methylmercury-** toxic compounds of mercury containing the complex CH_3Hg^- that often occur as pollutants which accumulate in living organisms (like fish) and are especially dangerous to higher levels of a food chain due to biomagnification. **Decomposer**- an organism, often a bacterium or fungus, that feeds on and breaks down dead plant or animal matter, thus making organic nutrients available to the ecosystem. **Detritivore**- an organism (such as an earthworm or a fungus) that feeds on dead and decomposing organic matter. **Plankton**- the small, microscopic organisms drifting and/or floating in the sea or fresh water. They consist of diatoms, protozoans, small crustaceans, and the eggs and larval stages of larger animals. Many animals are adapted to feed on plankton, especially by filtering the water. **Phytoplankton**- Free-floating algae, protists (single celled microorganisms), and cyanobacteria. Phytoplankton form the beginning of the food chain for aquatic animals and fix large amounts of carbon. **Zooplankton**- plankton consisting of small animals and the immature stages of larger animals. Zooplankton consume phytoplankton. **Planktivore**- animal which feeds on plankton. **Piscivore**- Animal which feeds on fish.
Connection to Big Ideas (Phenomena)	Both environmental and genetic factors influence the growth of organisms. Environmental contaminants can cycle among the living and nonliving parts of an ecosystem. Changes to the physical or biological components of an ecosystem affect populations. Human activities have a direct impact on the environment.
Optional Follow Up/Practice	More about the fish consumption advisory https://danr.sd.gov/OfficeOfWater/SurfaceWaterQuality/waterqualitystandards/fishflesh.aspx Mining and pollution in Indonesia http://www.bbc.com/news/ magazine-

	24127661 BrainPop Game (Free) https://www.brainpop.com/games/foodchaingame/ Images of lake food webs http://www.waterontheweb.org/under/lakeecology/11_foodweb.html Mercury info https://people.uwec.edu/piercech/Hg/mercury_water/index.htm Food chain activity http://sciencenetlinks.com/tools/food-chains/
Assessment	Students should respond to the lesson #4 assessment writing prompt using the *A.C.E.* format (student assessment prompt cards, with rubric, are available in the print master's section). If time permits, allow students to peer review and revise before submission for teacher comment. Ideally, students would also be allowed time to revise and resubmit after teacher comments. You may choose to utilize this assessment as a take home assignment, but if time permits it is advisable to set aside class time for peer-review before submission. There is time in the final days of this unit, while students are optimizing experimental conditions during lesson 5, for students to focus on written responses, peer review, and even resubmission after initial teacher comments. Prompt: *Why are some toxins, typically present at extremely low levels in the environment, particularly dangerous to apex predators like northern pike, eagles, bears and humans?*

Lesson 5	What's Your Watershed?
Overview Standards & Objectives	**Overview** In this lesson, students learn what a watershed consists of and test local water samples (identified by the students in lesson 3) for contaminants and overall water quality. Students share results for all water samples tested, and a classroom debate focusing on the overall health of the local watershed ensues. Students are then asked to produce a logical, well- supported, written analysis of the health of their local watershed, including any remediation efforts they believe would be useful in fixing any identified issues. **Standards** MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. Oceti Sakowin Standard 1.4 Identify and explain contemporary environmental

	issues facing Oceti Sakowin lands (i.e., Dakota pipeline, etc.). 6-8.WHST.1 Write arguments focused on discipline-specific content. a. Introduce claim(s) about a topic or issue, acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically. b. Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources. c. Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), counterclaims, reasons, and evidence. d. Establish and maintain a formal style. e. Provide a concluding statement or section that follows from and supports the argument presented. 6-8.WHST.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. 6-8.WHST.9 Draw evidence from informational texts to support analysis reflection, and research. Science and Engineering Practices (SEP): • Analyzing and interpreting data • Engaging in argument from evidence *(writing prompt)* Crosscutting Concepts (CCC): • Energy and Matter: Flows, Cycles, and Conservation • Scale, Proportion, Quantity **Objectives** • Identify the components of a watershed. • Trace the local watershed both upstream and downstream. • Evaluate the health of the local watershed. • Discuss the implications of point source contamination. • Produce a well-supported, clear and coherent, written argument. • Connect to Lesson 1 Phenomenon – importance of taking care of water
Background Information (for Teachers)	**Components of a Watershed** A watershed is a landform defined by highpoints that descend into lower elevations and stream valleys. Water *shed* from the land after rain falls and snow melts is channeled into soils, groundwaters, creeks, and streams into larger rivers, and eventually the sea. Water, the universal solvent, is affected by all that it encounters the land it traverses, and the soils through which it travels. What we do on land affects the water quality for all communities downstream. Therefore, a watershed includes not only the water in any individual drainage basin, but everything existing and living there as well.

Materials	For teacher to set-up before class:
	Waterworks Testing Guide
	• Four water testing stations (each with a bag of materials, two sets of instructions, and information sheets).
	    • pH (six test strips per class, one plastic cup)
	    • Nitrate and nitrite (six test strips per class, one plastic cup)
	    • Phosphate (six test strips per class, one 10 ml vial)
	    • Heavy metals (six test strips per class, one plastic cup)
	➢ Extra (teacher-supplied) water samples *(just in case any students forget to*

	bring samples they agreed to acquire) For each student: ➢ Science notebook • Lesson 5 *A.C.E. writing* assessment prompt with rubric For each group: • Water sample analysis sheet (one per water sample, 6 per class) ➢ Water sample (groups numbers 1-6) ➢ Supplies for creating large, detailed map (group #7 only) • Computers for additional research (if desired) For the class: ➢ Computer with projector and speakers Only with Teacher approval: • Additional water testing supplies for ammonia, lead, cyanide, and mercury. Only to be used if a sample tests very high for heavy metals, and/or any of these other pollutants are strongly suspected. *(These tests are limited to only 3 per kit! If you have the time, let the class(es) debate, and come to a consensus on any* • *samples they would like tested for these potential contaminants.)*
Prior Knowledge (for students)	Water is essential for life as we know it, and thus water quality is important for the health and wellbeing of all living things *(addressed in Lesson One)*. Students should have a basic understanding of the water cycle, and the fate of contaminants introduced into the water cycle *(reviewed in Lesson Two)*. Environmental pollutants may undergo bioaccumulation and biomagnification within the organisms of a food web *(Lesson Three)*.
Launch (10 minutes)	
Engagement and Communication of Student Expectations	Ask students to think/pair/share what the word *watershed* means. Show the video "What is a Watershed?" (1 min 17 sec) https://www.youtube.com/watch?v=QOrVotzBNto Project *Streamer* on the board: http://water.usgs.gov/streamer/web/. Find your school's location on the map (you will have to zoom in so that you can see all the local waterways). Click the "Trace Upstream" button located at the top of the page. Click on the river, stream or creek that is closest to your school, and observe the watershed which supplies your school's region. This is where surface water comes from on its way downhill to your location. (Note that if you are located on the Missouri River, you may want to choose the nearest tributary that flows into the Missouri. Otherwise, the upstream trace is a little large.) Next, click the "Clear Map" button at the top of the page, and then the "Trace Downstream" button. Facilitate a class discussion about the water you drink and where it comes from… as well as where that water goes. Questions for thought: • What ultimately happens to the water we pour on the ground, or into the nearby creek/stream/river? • What happens to every other liquid that we pour onto the ground? • What happens to things that can be dissolved into solution (in water) that are left out in the elements? • What happens to solid objects that can float in or on water?

	• What happens to these things when someone dumps them upstream of us? OR Project *River Runner* on the board: https://river-runner- global.samlearner.com/. Either type your location into the search window or use your mouse to find your location on the map. Watch the geographical view of a rain drop traveling from your location to the ocean. Discuss the *Proper Laboratory Procedures* found on the lower half of the *Water Sample Analysis Sheet* with your students before allowing groups to begin water sample testing!
Explore (25 minutes)	
Procedure	1. Have one group of 2-4 students (group #7) sketch out (on large paper, or electronically) your area with the locations of all water samples being tested clearly indicated. Include all major waterways and water bodies, as well as visual landmarks like well-known stores, parks, and factories. Be sure to include all potential sources of pollution identified in Lesson 3. 2. All other groups of 3-4 students (group numbers 1-6) should distribute water samples (one per group) and cycle through the four lab stations: Phosphorous (Phosphate), nitrogen (nitrate/nitrite), pH, and heavy metals. All testing observations, information and results should be recorded in student science notebooks, as well as on the sample analysis sheet. 3. At each station, two students should work collaboratively to make sure water testing is performed safely and correctly. The rest of the group should be looking into what type of pollution each test is an indicator of, and what can be done to remediate a site with that particular issue. Students may utilize computers for research, and/or the information pamphlets supplied at each station. Working collaboratively, the group should collect the information specified on the *Water Sample Analysis Sheet*. Information may be recorded in science notebooks, or directly on the *Sample Analysis Sheets* (teacher discretion). group should then report their water testing results on the large class map. Green check s indicate that all five tests were within acceptable ranges. Red question marks indicate here was at least one test indicating an unacceptable level of contaminant. All red ion marks should have the unacceptable test(s) (and level) indicated on the map.
Questions	**Driving Questions** • How can changes to physical or biological components of an ecosystem affect populations? • How does matter cycle among the living and nonliving parts of an ecosystem? **Probing Questions** • What is the fate of an environmental contaminant, like mercury? • How does mercury affect different trophic levels of an ecosystem? • Why are apex predators at most risk of mercury poisoning? • What is the role of bioaccumulation in biomagnification? • How is a food chain different from a food web? • What is an ecosystem? **Driving Question** • How are we affected by the actions of those upstream in our watershed, and how do our own actions affect those downstream?

	Probing Questions • What ultimately happens to the water we pour on the ground, or into a nearby creek, stream, or river? • What happens to every other substance that we pour onto the ground? • What happens to things that can be dissolved into solution (in water) that are left out in the elements? • What happens to solid objects that can float in or on water? • What happens to these things when someone dumps them upstream of us? • What can we do to help prevent water contamination? • What can we do to clean-up (or remediate) contaminated waters? • Why should we care?
Summarize (10 minutes)	
Communicate	As a class, discuss what the water sample testing results tell you about the health of your watershed. If there are any red question marks on the map, discuss what the potential causes might be, as well as possible ways to clean-up, or "remediate", the issue. • Are there any potential problems that might need to be addressed, or is the water in your area in good shape? • If there are issues, what can you do to help fix them? • Does everyone agree about the health of your watershed? • If there is disagreement, can you see any reasons behind the various viewpoints? Why might different people interpret these results in different ways? The class should then discuss if any of the water samples are likely to be contaminated with ammonia, mercury, cyanide, or lead. There are only three test strips in the curriculum unit kit for each of these additional contaminants. Students should lobby you, the teacher, about why they believe any of the water samples should be tested for ammonia, mercury, lead, and/or cyanide. If you decide it is worthwhile, allow the tests you feel likely to produce a positive result. *(Keep in mind how many class periods you plan to run this lesson, and what samples the later classes have that might also have these contaminants. Use the three test strips for each of the extra 4 potential contaminants carefully! This limitation of resources actually models issues with water quality testing that states, including South Dakota, deal with every year. Even though many officials would like to test every water body for contaminants every year, there simply isn't enough money in the budget to pay for it. Therefore, the most contaminated water bodies get the most frequent testing (once every five years or so in South Dakota), and the typically uncontaminated bodies are tested less frequently.)* As time permits, allow students to begin crafting their written responses to the *Lesson 4 Assessment Prompt* (available in the print masters with rubric): *"What is the overall health of your watershed?"*
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. **Solution-** a liquid mixture in which the minor component (the solute) is uniformly distributed within the major component (the solvent).

Connection to Big Ideas (Phenomena)	Human activities have a direct impact on the environment. Scientific principles can be used to monitor human impact on the environment. Science and engineering practices can be used to minimize human impact on the environment.
Optional Follow Up/Practice	Here is another short video about watersheds and the water cycle http://sciencenetlinks.com/videos/surfrider-foundation-explains- watersheds-101/ Other great watershed resources can be found at http://water.usgs.gov/edu/watershed.html
Assessment	Students should respond to the lesson #5 assessment writing prompt using the *A.C.E.* format (student assessment prompt cards are available in the print master's section). If time permits, allow students to peer review and revise before submission for teacher comment. Ideally, students would also be allowed time to revise and resubmit after teacher comments. Prompt: *What is the overall health of your watershed?*

WATER TESTING GUIDE

There are enough of these testing strips to perform analysis with your class in groups of four.

PH

- Pour 50ml of water sample into snack cup
- Submerge lower half of pH strip in water sample
- Keep test strip in water sample for 2 seconds
- Remove test strip and shake off excess water
- Compare the 4 colored squares to the chart

PHOSPHORUS

- Fill tube to 10 ml line
- Gently bend test strip in half, pads inwards (do not fold)
- Cap tube and invert slowly and fully 5 times
- Remove cap and discard test strip
- Match color to the chart

NITRATE/NITRITE

- Pour 50 ml of water into snack cup
- Submerge lower half of strip in water for 2 seconds
- Do NOT move test strip while in water
- Remove test strip from water
- Wait 1 minute
- Compare test strip to color chart within 1 minute

HEAVY METALS

- Pour about 50 ml of water into snack cup
- Dip lower third of strip into sample for 30 seconds
- Gently move stirp back and forth in water
- Remove strip from water and briskly shake once.
- Wait 2 minutes
- If colors vary use color intensity to match.

There are NOT enough of these test strips included to perform analysis with the whole class. you may utilize these as the teacher to test any samples that test high for heavy metals.

CYANIDE

- Plate 2ml of water in clean microcuvette
- Dip Reagent Strip 1 slowly up & down for 30 seconds.
- Repeat for Reagent Strip 2.
- Shake Strip 2 and immediately match color using "Reagent Strip Colors" chart.
- Let microcuvette sit for 15 minutes before matching color using "Microcuvette Colors" color chart.

AMMONIA

- Fill tube to top line with water sample
- Dip both pads of test strip into water
- Vigorously move pads up & down in water for 30 seconds
- Remove test trip and shake off excess water
- Hold strip level with pads for 30 seconds
- Turn strip over so pads face away from you
- Compare small pad to the chart

LEAD

- Place 5ml of water sample into test vial
- If pH was not 2-5 during original test, add 3 drops of reagent Pb-1 and swirl carefully to mix
- Recheck pH to ensure it is now between 2 and 5
- Dip lower third of test strip into sample for 1 second
- Shake off excess water and wait 2 minutes
- Match test strip to color chart

MERCURY

DO THIS TEST LAST – Requires 200ml of sample
- Dip lower third of strip into sample for 1 minute while moving strip back and forth in water
- Remove strip from water and briskly shake once
- Wait 30 seconds
- Match color on strip to chart

Lesson 6	Clean it Up!
Overview Standards & Objectives	**Overview** In this lesson, students will learn how microbial bioremediation is utilized at the Sanford Underground Research Facility's waste water treatment plant. Additionally, students will engage in an engineering process design challenge, working collaboratively, to optimize conditions for microbial bioremediation of bacteria (yeast). **Standards** MS-LS2-5 Evaluate competing design solutions for maintaining biodiversity and ecosystem services. 6-8-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. 6-8-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. 6-8-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved. Oceti Sakowin Standard 1.2 Describe traditional and contemporary Oceti Sakowin perspectives on communal stewardship of land and natural resources (flora, fauna, geographic and sacred features). Oceti Sakowin Standard 1.4 Identify and explain contemporary environmental issues facing Oceti Sakowin lands (i.e., Dakota pipeline, etc.). 6-8.WHST.1 Write arguments focused on discipline-specific content. a. Introduce claim(s) about a topic or issue, acknowledge and distinguish the claim(s) from alternate or opposing claims, and organize the reasons and evidence logically. b. Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources. c. Use words, phrases, and clauses to create cohesion and clarify the relationships among claim(s), counterclaims, reasons, and evidence. d. Establish and maintain a formal style. e. Provide a concluding statement or section that follows from and supports the argument presented. 6-8.WHST.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. 6-8.WHST.6 Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently. **Science and Engineering Practices (SEP):** • Planning and carrying out investigations • Analyzing and interpreting data • Obtaining, evaluating, and communicating information *(final project and*

	presentation) **Crosscutting Concepts (CCC):** • Scale, proportion, and quantity • Stability and change **Objectives** • Understand the role of microbial bioremediation at the Sanford Lab's waste water treatment plant. • Collaborate to optimize conditions for microbial bioremediation (yeast) of sugar (pollutant) contamination in water. • Present final results and analysis in a clear, coherent, format. Discuss humanities role as stewards of the environment, and what students can do to have a positive impact on the health and well- being of our precious freshwater resources.
Background Information (for Teachers)	**Bioremediation** "Remediate" means to solve a problem, and "bio-remediate" means to use biological organisms to solve an environmental problem such as contaminated soil or groundwater. In a non-polluted environment, bacteria, fungi, protists, and other microorganisms are constantly at work breaking down organic matter. What would occur if an organic pollutant such as oil contaminated this environment? Some of the microorganisms would die, while others capable of eating the organic pollution would survive. Bioremediation works by providing these pollution-eating organisms with fertilizer, oxygen, and other conditions that encourage their rapid growth. These organisms would then be able to break down the organic pollutant at an increased rate. In fact, bioremediation is often used to help clean up oil spills. Bioremediation of a contaminated site typically works in one of two ways. In the case described above, ways are found to enhance the growth of whatever pollution-eating microbes might already be living at the contaminated site. In the second, less common case, specialized microbes are added to degrade the contaminants. Bioremediation provides a good cleanup strategy for some types of pollution, but as you might expect, it will not work for all. For example, bioremediation may not provide a feasible strategy at sites with high concentrations of chemicals that are toxic to most microorganisms. These chemicals include metals such as cadmium or lead, and salts such as sodium chloride. Nonetheless, bioremediation provides a technique for cleaning up pollution by enhancing the same biodegradation processes that occur in nature. Depending on the site and its contaminants, bioremediation may be safer and less expensive than alternative solutions such as incineration or landfilling of the contaminated materials. It also has the advantage of treating the contamination in place so that large quantities of soil, sediment or water do not have to be disturbed for

treatment.
This is important because when contaminated substances are disturbed, they often mobilize small, contaminated particles which move the pollution into previously unpolluted areas.

Sanford Lab's Waste Water Treatment Plant

In order to operate as an underground research facility, about 400,000,000 gallons of water must be pumped up and out of the old mine tunnels each year… otherwise the lab would flood. Pumping must at least match the rate of infiltration to keep the level constant, and it is estimated at approximately 700 gallons per minute of water coming in from rain, snow, or other surface sources. The water is a rusty color full of particulates due to high levels of iron naturally present in the rock.

This iron is leached out of the rock by sitting in the old mine tunnels for long periods of time. Iron oxidizing bacteria also help precipitate or pull the iron (III) from the water, giving it a characteristic rusty, red color. There is also toxic, inorganic, arsenic (As) leaching out of a mineral called arsenopyrite which is in the rock and naturally present in the area. The current water level at the Sanford Lab is at approximately 5,900 feet below the surface. The science laboratory spaces are located 4,850 feet below Earth's surface. Since the deepest tunnels reach to about 8,000 feet below the surface, there's a LOT of old, rusty, arsenic laden, water down there.

Mine tailings are the crushed-up rock and chemicals left-over from extraction of precious metals from ore. Tailings from gold mining at the former Homestake Gold Mine in Lead historically contained mercury (Hg) until the 1970's, though the amount of mercury was greatly reduced in the early 1900's when a more efficient method utilizing cyanide (CN), called cyanidation, was developed. Both cyanide and mercury are potent toxins… and of course the tailings contain the naturally occurring, toxic arsenic as well. Until the EPA stepped in around 1970, these tailings were being released into nearby Whitewood creek, washing downstream for many miles, damaging water quality, and posing health risks to people and animals. At one point, contamination from the Homestake Gold Mine could be traced all the way to the Gulf of Mexico. The EPA required Homestake to construct the Grizzly Gulch Tailings Dam and Waste Water Treatment Plant (WWTP) to prevent the downstream pollution due to gold mining. The tailings dam kept all the contaminated, left-over material in one place, and the waste water treatment plant was used to clean up the run-off so that there wasn't any cyanide or arsenic released downstream (mercury was no longer being utilized by the time the tailings dam was constructed).

Though cyanide was a component of the tailings contained by the Grizzly Gulch dam, it was discovered that naturally occurring bacteria were converting the cyanide to ammonia. These microbes were cultivated by Homestake and utilized to bioremediate the water at the waste water treatment plant. Unfortunately, ammonia is also toxic, and so bacteria able to convert ammonia into harmless substances are also utilized at the waste water treatment plant. Sanford Lab currently treats water coming from the underground spaces, as well as from the historic tailings contained in Grizzly Gulch. Water from both sources is mixed together before entering the waste water treatment

	plant, but not just because they both need remediation, it is also to cool down the water coming from the deeper tunnels of the underground lab. The rock at the 8,000-foot level is very hot, estimated to be about 135 degrees Fahrenheit. Therefore, the water being pumped up from the lower levels of the Sanford Lab must be cooled before being released into the watershed area around SURF. Pollution comes in many forms, and so the elevated temperature of uncooled water coming from the waste water treatment plant could harm aquatic life downstream!
Materials	For each student: ➢ Science notebook ➢ Copies of Lesson 6 Activity Data Table For the teacher: • Quick rise yeast • Sugar • Vinegar • Dish Soap ➢ Hot water For the class: • Test Tube Stands, 10 per class + 1 for the teacher • Test Tubes, 40 per class + 4 for the teacher • Water Balloons, 50 per class • Measuring Spoons, 10 sets per class • Pipettes w/ labeled cups to place them in • 6” Rulers • String • Quick Rise Yeast • Sugar • Dish Soap • Vinegar ➢ Computer with projector and speakers Suggested items for optional extensions: ➢ Various acidic household items (ex: soda, coffee) ➢ Various basic household items (ex: baking soda, antacid tabs) For teacher to set-up prior to class: • Lab station with balloons, conical tubes, supplies, and a marker for labeling conical tubes. • Safe area for test tube holders
Prior Knowledge (for students)	Water is essential for life as we know it, and thus water quality is important for the health and wellbeing of all living things *(addressed in Lesson One)*. Students should have a basic understanding of the water cycle, and the fate of contaminants introduced into the water cycle *(reviewed in Lesson Two)*. Environmental pollutants may undergo bioaccumulation and biomagnification within the organisms of a food web *(Lesson Three)*. Water, the universal solvent, is affected by all that it encounters the land it traverses, and the soils through which it travels. What we do on land affects the water quality for all communities downstream. (Lesson Four) Human activities have a direct impact on environment. (Lesson Five)

Launch (25-30 minutes)	
Engagement and Communication of Student Expectations	Project pictures of Sanford Lab water (untreated) as students enter the room. There is a file on the USB you can run as a slideshow. Allow students time to see all pictures and comment amongst themselves as you take attendance, etc. Present the PowerPoint Lesson 6 Presentation 1: Bioremediation and the WWTP (15minutes; available as a PowerPoint for you to present or as a video file of the recorded presentation) detailing the contamination caused by the former Homestake Gold Mine, what was done to remediate the contamination, and what SURF is doing today to continue these remediation efforts. The final slide of the initial PowerPoint presentation displays a quote of Wallace Black Elk, a Lakota Sioux medicine man, in answer to the question "How can we save the Earth?". He responds "We don't need to save her. She can save herself. We just have to stop making her sick." Ask students to *think/pair/share* about what Wallace Black Elk meant by his statement. Facilitate a quick class discussion, reminding students to support their proposals with evidence. Continue to the Lesson 6 Presentation 2. **Teacher Notes:** If you have trouble playing the video embedded within the Lesson 6 Presentation 2, you can find it on the USB within Lesson 6 Resources, or show it using the following link. If you play the recorded presentation, you will need to show this video at the conclusion. At the end of Lesson 6, it is advisable to stress to students that they will begin development, testing, and refinement of a bioremediation procedure for cleaning-up pollutants in collaboration with their classmates. Everyone will work together like a start-up company, trying to optimize conditions for a bacterium that eats pollutants. Pollutants, like the Deepwater Horizon oil spill in the Gulf of Mexico in 2010, threaten wildlife, health, and business. Your company wants to market an efficient, safe, biological remedy for these catastrophic events. By quickly and efficiently degrading the oil from these spills, wildlife, health, and jobs in and around these spills might be protected. Additionally, by collaborating and communicating you will be modeling the actual behavior of scientists. Science is a very collaborative endeavor, and it takes many minds and many hands working on a variety of tasks to efficiently advance scientific knowledge. No model is perfect. This lab demonstrates a process of cellular respiration. Your students may or may not have a background in cellular respiration, which will not impact the lab. The purpose of the lab is NOT to look at the process of cellular respiration happening in the balloon, but instead to think about the model of sugar as the pollutant and yeast (even though it is a fungus) as the "bacteria" used to clean up the pollutant.
Explore (20 minutes)	
Procedure	Students should work in groups of 3. Student Group

Assignments:

- Materials Collector – collect all supplies for experiment
- Set Up Coordinator – collaborates with group members to determine quantity of supplies in the experiment
- Data Collector – marks ratios of water, pollutant

Give each group the *Lesson 6 Clean It Up! Task Card*. Students will need time to brainstorm/develop questions, design an experimental plan with appropriate controls, and set-up their experiment. Students should have a minimum of 15 minutes to set up experiment and experience results. Remind students that they should only be testing one variable in their experiment. Allow student 5 minutes of private think time before coming together with their group.

(Time fillers: While students wait for their results, you will want to keep them close to their tube stand and conical tubes, so they do not miss results happening in *live time*. While at their workstations, you could encourage them to research the Sanford Lab's Waste Water Treatment Plant at https://sanfordlab.org/feature/waste-water-treatment-plant)

The groups will try to find the best ratio of bacteria, to pollutant, to water. Each group will have four test tubes and a test tube holder for their experiments. We will be using sugar to simulate a pollutant, like oil pollutant in water. We will be using yeast to simulate bacteria to clean up the pollutant in water. As yeast combines with sugar, carbon dioxide will be released which allows us to measure the effectiveness of removing the sugar pollutant from our water. **Students will need to mark their ratios of pollutant (sugar) to bacteria (yeast) to water on their test tubes. *1 test tube from each group needs to be a control of just water and yeast.*** Once all groups have set-up their experiments, place the test tube stands in a safe location.

Each group will observe and record results from their four test tubes (in their science notebooks), share results with the full class (you could have each group write their best and worst results on the board for easy comparison and discussion), and discuss which results were best and the reasons for better results.
Students will be comparing the size of the balloon on their test tubes. The larger the balloon, the more carbon dioxide was released, indicating bacterial metabolism. (*It is important to note that this may not be the absolute truth if students add additional energy sources – more sugar. Therefore, proper controls are very important!)* The main goal of this engineering design process challenge is for the students to collaborate to figure out how to get the largest carbon dioxide release (largest balloon).

Student groups can decide the best way to measure their results. Rulers and string are included. They may come up with other ideas.

Students will be evaluating competing design solutions, combining a variety of successful conditions, and working to find the optimal combination of conditions that support bacterial (yeast) metabolism. Each successive day, for as long as time and supplies are available, students should design new experiments and record results in their science notebooks, share results with other students/classes, design, and set-up another set of tests. If all classes share results and data, as well as attempt to replicate each other's findings and collaborate to test a wide variety of variables, optimal conditions for the most efficient bacterial metabolism of pollutants should occur fairly quickly. Allow students to bring and test whatever they believe may work, as long as they clear it with you, and you believe it will be safe.

Teacher Notes

This activity can take as few as 1 class period, but it is strongly recommended that students continue exploring and refining their methods for at least 2-3 class periods to fully model the engineering design process. Students might even upload their results to a class/school spreadsheet (Google Sheet's and/or Google Doc's suggested) for viewing by other students/classes. Remember that science is never done in isolation, and results are only generally accepted after repeated testing with consistent results.

Extension: Students can calculate the rate of change

After the initial lesson introduction and lab activity set-up, this activity may be continued using only 15-20 minutes of each subsequent class period (for noting results in notebooks, planning next steps, and setting- up subsequent trials/tests). Allow students to continue exploration as long as they continue making suitable progress, have continued interest, and you feel the time is well spent. Consider encouraging especially interested students to work before or after school, during lunch, etc.

This activity can become a wonderful science fair project. The rest of these class periods can be utilized for wrapping-up the writing activities of lessons 4 and 5 (peer-review, revision, resubmission), some of the optional extension suggestions, or your typical course curriculum.

Though students should be discovering *optimal* conditions for bacterial (yeast) metabolism of pollutant (sugar) for themselves, here are a few tips about the microbes that you might like to know as you facilitate this engineering design process challenge:

- Changing the temperature of the water will impact metabolism. Encourage students to use water that has been, for example, sitting at room temperature, is set to the warmest faucet setting, etc.)
- Concentration matters. Students may want to try different amounts of bacteria, pollutant, and water. In addition to changing concentration, students may also test changing the water temperature.
- Combinations of different factors can work together to increase bacterial metabolism more than any individual factors.
- On each round of testing (4 test tubes in test tube holder), students should always keep a control in their experiment.
- Hint: combinations that we tested:
- Bacteria (yeast) & Water (equal parts)
- Bacteria (yeast), Pollutant (sugar), & Water (equal parts)
- Bacteria (yeast) X2, Pollutant (sugar) X1, & Water X1
- Bacteria (yeast) X2, Pollutant (sugar) X2, & Water X1
- Bacteria (yeast) X1, Pollutant (sugar) X1, Acid (vinegar) X1, & Water X1

	• Bacteria (yeast) X1, Pollutant (sugar) X1, Base (Dish Soap) X1, & Water X1 If needed, e-mail education@sanfordlab.org for additional assistance or with questions.
Questions	**Driving Question** • How can humans design solutions to maintain biodiversity and ecosystem health? **Probing Questions** • How can microorganisms be utilized to remediate environmental contamination? • What are the optimal conditions for oil-degrading bacteria remediating contamination in surface water?
Summarize (10 minutes)	
Communicate	*Save this summary activity for when you are ready to bring lesson 6 to a close, or whenever you feel like it's time to begin bringing this unit to a close.* Ask students to share what worked well, and what did not work well, during their engineering design challenge. Include a discussion about the process, collaborating, and how both success and failure are integral parts of the engineering design process. *(Failure is often considered more important than success.)* Find out if students agree on the optimal conditions for bacterial metabolism of pollutants. If there is disagreement, initiate a debate where each side must support their stance with evidence (data). There may be no over-all class consensus, and that is acceptable as long as every group can back up their argument with evidence and logic. Set a final date for presentations with help from your students. Answer any questions about the final project that students may have. Revisit the image of the human heart next to the Black Hills, as well as the Black Elk quote about Mother Earth being able to 'save herself'. Ask students: • Why is fresh water and water quality so important? • What are the most important things we can do to help protect our precious freshwater resources? • Do you think that the Earth can really "save herself" if we just stop "making her sick"? **Remember to ask students to support their statements with evidence.** You may also want to allow students time to work on written responses to lesson three and four writing prompts, peer review and revision for resubmission before bringing the *Waterworks* unit to an end. **Optional Extension** Have students read about one (or both) of the Native American Indian scientists helping to remediate environmental damage. Dr. Robin Kimmerer is a plant ecologist working to restore black ash trees on native Iroquois land, and Dr. Jani Ingram is a chemist looking for better clean- up strategies for radioactive metals (both short essays are available in the *Print Masters* section found after this lesson). Students might want to research other

	scientists and the challenges they may face in the pursuit of their passion for science. Or students may want to write their own personal essay from a point of view 20 years into their future (what do they think they will be doing in 20 years, and how do they think they will get there from this point in present time?).
Terminology and Concepts to Solidify	**Bioremediation-** the use of either naturally occurring or deliberately introduced microorganisms or other forms of life to consume and break down environmental pollutants, in order to clean up a polluted site. **Microorganism** – a life form that is so small, it can only be seen with a microscope. **Pollutant –** a chemical that causes harm to the environment. **Precipitate** –a substance deposited in solid form from a solution.
Connection to Big Ideas (Phenomena)	Human activities have an impact on the environment. Science and engineering practices can be used to minimize human impact on the environment.
Optional Follow Up/Practice	*Deep Thoughts* 2014 on cyanide utilizing bacteria- http://www.sanfordlab.org/sites/sanfordlab.org/files/newsletters/deep_thoughts/2014/140428-Deep-thts.pdf **Other useful links:** https://www3.epa.gov/safewater/kids/gamesandactivies.html http://sciencenetlinks.com/tools/microbial-life-educational-resources/ http://nationalgeographic.org/activity/simulate-oil-spill-cleanup/ http://coseenow.net/blog/2010/08/oil-spill-resources/
Assessment	Final group product and presentation of results and analysis of laboratory investigations. See *Lesson 6 Clean It Up! Task Card* with rubric. You will notice that the task card and rubric leave the format of the final group project and presentation very open. This is so that you, the classroom teacher, can facilitate/suggest/require whatever formats you prefer. It is suggested that you allow students to be creative and propose formats for approval… at which point you may give feedback and suggestions before students put too much effort into their final projects.
Optional Extension	Join us for a tour of the Sanford Underground Research Facility's Waste Water Treatment Plant (WWTP). Either plan a field trip to visit the facility OR contact us (education@sanfordlab.org) to set up a virtual 360* tour with one of our education specialists.

Waterworks Task Card

Lesson #6- Clean It Up!

The Challenge

Work collaboratively with other students as a start-up company determining the optimal conditions for inexpensive, safe, and efficient bioremediation of an oil spill in water. Then, prepare and present 5-minute sales pitch convincing investors to support your company's efforts.

The Engineering Design Process

In order to design the best possible process or tool, this cycle must be repeated many times. Each cycle brings you closer to your goal! Remember that engineers and scientists don't work alone and comparing your data with that of your fellow researchers is encouraged.

Student Group Assignments

Materials Collector - collect all supplies for experiment
Set Up Coordinator - collaborates with group members to determine quantity of supplies in the experiment
Data Collector - marks ratios of water, pollutant, bacteria, and any additional substances

Safety Notes

- *Wash your hands after handling all lab supplies and/or equipment*
- *Do not eat or drink anywhere near the lab stations*
- *Wash hands thoroughly after handling*

Day One

- *Your group will use a conical tube stand and four tubes*
- *Your group will need to change the amounts of one of the items added to the tube (ex. Sequentially add more to each test tube)*
- *Brainstorm/develop questions, then design an experimental plan with appropriate controls that addresses one of your questions*
- *Set-up your experiment (using the four tubes provided)*
- *Once all solutions have been added, place a balloon over the top of the tube and place the tube in the tube stand. Wait 15 minutes to collect results.*
- *Your teacher will provide materials for measuring/collecting your results.*
- *Share results and brainstorm next steps (as a class)*

Day Two and Beyond

- *Repeat steps from Day One*
- *Design, re-delegate responsibilities, and carry-out the next round of tests*
- *Repeat as necessary*
- *Be creative! What other conditions might increase bacterial metabolism? What about combinations?*
- *If you have an idea, share it with your classmates and teacher... you may bring supplies to test!*

Print Masters

Waterworks Unit Pre-/Post-Assessment
Answer the following. You may include illustrations to help with your explanations.

Scenario	Question	Explanation
Walleye and northern pike in a local lake have dangerous levels of mercury in their flesh, so a fish consumption advisory has been posted. The lake water was tested and found to have measurable, but acceptable mercury levels. Help resolve the disagreement between Bob and Brenda.	Circle the most scientifically correct statement. **Bob** Since the lake water was tested and found to have acceptable mercury levels, the fish must have become contaminated through some other means. **Brenda** Even though the lake water has acceptable mercury levels, it is still the most likely source of the mercury contaminating the fish flesh.	Explain why this statement is correct.
Wells in a town are becoming contaminated with fuel. Since there are two gas stations with buried fuel tanks near the contaminated wells, there are two potential sources of the contamination. Help Jenny and Tom decide what should be done.	Circle the most scientifically correct statement. **Jenny** Since both gas stations have underground fuel storage tanks, both businesses need to have their tanks dug up and inspected. **Tom** It is unlikely that both businesses have leaking fuel tanks. It would be better to use contour mapping to determine the most likely contamination source.	Explain why this statement is correct.

Waterworks Post-Assessment Rubric

		2 pts.	1 pts.	0 pts.	Score
Fish Consumption Advisory Scenario	Most scientifically correct statement circled	Brenda's statement circled		Bob's statement circled	
	Explanation of how the mercury in the water is biomagnified in higher trophic levels of the food chain	Clear explanation of the fact that mercury is biomagnified in higher trophic levels of the food chain	Incomplete or unclear explanation of the fact that mercury is biomagnified in higher trophic levels -or- Simply stating "biomagnification" and/or "bioaccumulation"	No explanation of the fact that the fish is not actually where it appears to be	
	Explanation of how apex predators are where pollutants are most likely to concentrate in harmful amounts	Clear and complete explanation of how apex predators are where pollutants are most likely to concentrate in higher amounts	Incomplete or unclear explanation of how apex predators are where pollutants are most likely to concentrate in higher amounts	Incorrect, or lack of any, explanation about how apex predators are where pollutants are most likely to concentrate in higher amounts	
Well Contamination Source Scenario	Most scientifically correct statement circled	Tom's statement circled		Jenny's statement circled	
	Explanation of the time and money wasted by digging up tanks for inspection without clear evidence	Clear and complete explanation of the time and money wasted by digging up tanks for inspection without clear evidence	Incomplete or unclear explanation of the time and money wasted by digging up tanks for inspection without clear evidence	Incorrect, or lack of any, explanation about the time and money wasted by digging up tanks for inspection without clear evidence	
	Explanation of how contour maps can help determine a source of contamination due to water's tendency to flow downhill following the contours of the land	Clear and complete explanation of how contour maps can help determine a source of contamination due to water's tendency to flow downhill following the contours of the land	Incomplete or unclear explanation of how contour maps can help determine a source of contamination due to water's tendency to flow downhill following the contours of the land	Incorrect, or lack of any, explanation of how contour maps can help determine a source of contamination due to water's tendency to flow downhill following the contours of the land	
				Total	**/12**

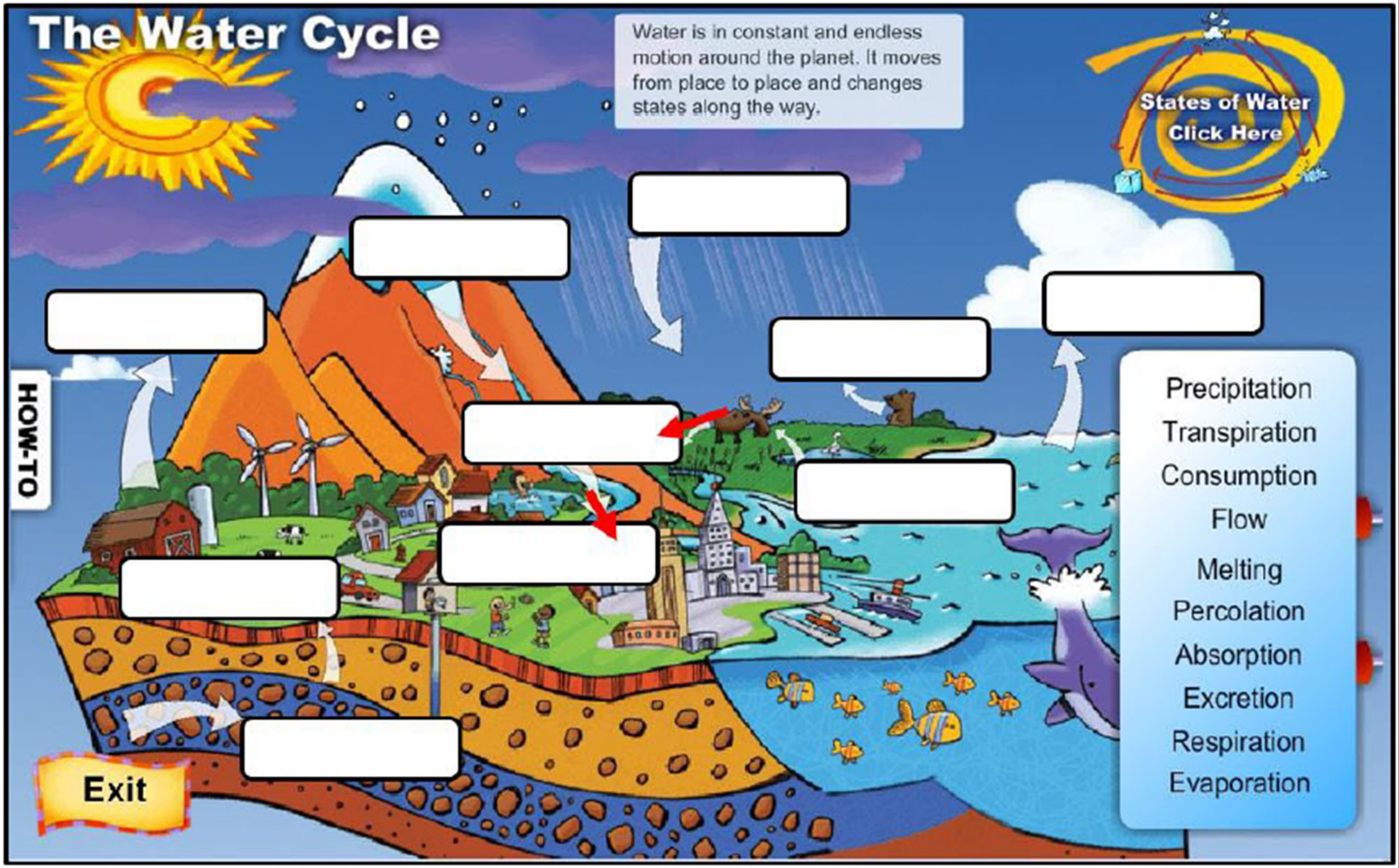
Lesson 2 ***Life Cards*** **Optional Student T-Chart**

Organism	Observations

Conclusions: *What do all living organisms have in common?*

Lesson 2 Student Activity Sheet The Water Cycle

Using the applet available at http://www.discoverwater.org/water-cycle/, and the vocabulary terms in the lower right, fill-in the empty bubbles. Turn this page over to define each vocabulary term in your own words.



Define each of the following vocabulary terms in your own words.

Vocabulary Term	Definition	Vocabulary Term	Definition
Precipitation		Percolation	
Transpiration		Absorption	
Consumption		Excretion	
Flow		Respiration	
Melting		Evaporation	

Lesson 3 Phenomenon — Optional Student T-Chart

Notices	Wonders

Lesson 3 STUDENT ACTIVITY

Mystery in the Black Hills: A Hazardous Whodunit

Adapted for use in grade 6-8 classrooms from Office of Water activity, available at www.epa.gov/safewater.

Introduction:

Riverville is a fictional town with a real problem. Each week, more and more citizens are complaining that their drinking water tastes bad. In many small towns like this one, there is no central water supply. Every home, and most businesses, have a private well. The town's mayor tested the water from several wells and found that the ground water has been contaminated with some kind of fuel. The wells that have been contaminated are marked on the town map with red stars. Unaffected wells are indicated by blue circles.

The mayor suspects that one of the gas stations is responsible for this contamination, and wants them to start checking their buried fuel storage tanks for leaks. The gas station insists that their tanks were recently tested, and that they are not the cause of the contamination. The gas station has suggested that it is actually the Lonely Ghost Gold Mine, which also has fuel storage tanks, that is the source of the pollution. The Lonely Ghost Mine, not happy about the potential expense of a costly inspection, says the source could just as likely be the school district's "bus barn". Since all three locations (school bus barn, gas station, and Lonely Ghost Gold Mine) have underground tanks for storing the same kind of fuel, all three seem likely candidates.

Therefore, Riverville has a serious problem. No one is sure who is responsible, and nobody wants to spend the money necessary to dig-up and inspect all the buried fuel tanks. The mayor needs some way of determining who is responsible for the contamination, and who should therefore clean it up. **You will be the "detective" who helps determine where the pollution is coming from!**

Cleaning up ground water contamination is a very expensive job. You need to be certain that your determination of the responsible business is accurate. If you are wrong, both time and money will be wasted and the plume of contamination will continue to spread to more and more wells. It is up to you to solve the mystery.

Objective:

You will make a topographic map, use it to predict ground water flow, and choose the most likely source of the ground water contamination.

Procedure:

To decide which of the suspected businesses is the most likely source of contamination, the easiest thing you can do is figure out the direction that ground water flows in the area. Since ground water generally flows downhill, following the slope of the surface of the land, you can be fairly certain that the actual source of the contamination is the suspected source located farthest "upstream".

This activity will show you how to estimate ground water flow by making a contour map. The contour lines on a contour map help geologists (as well as hikers) understand the slope of the land. Each line represents the elevation at that line. If you were to walk across a line, you are changing elevation. The steeper the slope, the more lines you will cross in a short distance. To make a contour map, it helps to know the elevation of as many places as possible. The supplied map shows elevations for several locations in the town. Follow the directions (below) for drawing in the contour lines, determining the flow of ground water, and observing the contamination plume. Once you have completed the activity, use your contour map to answer the questions.

Directions:

1. Connect all the elevations that are the same with a smooth curved line. One contour line (at an elevation of 20 meters) is already drawn for you. Use colored pencils so that the contour line for each elevation is its own unique color. These are your maps contour lines.

2. Every 2-3 centimeters or so, along each contour line, draw a short arrow perpendicular from one contour line, out towards the line having the next lowest elevation. For instance, draw a perpendicular arrow from the 40 meter elevation contour line towards the 30 meter elevation contour line. Ground water flows in the directions that the arrows point.

3. Find all the contaminated wells and draw a loop around them that encompasses <u>only</u> the contaminated wells. Be sure your loop does not encompass any areas of elevation higher than the elevations of the contaminated wells. The area inside this loop shows how far the contamination has spread through the ground water, and is called the *contamination plume*. Lightly shade (color or fill-in) the plume of contamination with a red colored pencil.

Questions:

1. If the flow of ground water (and the pollutants in it) follows the contour of the land, which is the most likely source of the Riverville contamination? Choose one:

   ☐ Lonely Ghost Mine ☐ school bus barn ☐ Gas Station

2. Explain why you chose the source of contamination that you selected in question 1. Include in your explanation any evidence you have to back-up your claim, and how this evidence supports your conclusion.

3. The contamination plume will continue to slowly spread through the ground, much like smoke from a chimney drifting in the wind. Go back to your contour map and draw a new loop (in a new color) that represents what you predict the contamination plume might look like in another year. Shade (color or fill-in) the new region of contamination with an orange-colored pencil.

4. Which currently uncontaminated (blue) well is most likely to become contaminated in the near future? Indicate this well clearly on your map.

5. Is it possible that you could be wrong in assuming that ground water flow follows the contour of the land in all cases? What else could you investigate to be certain?

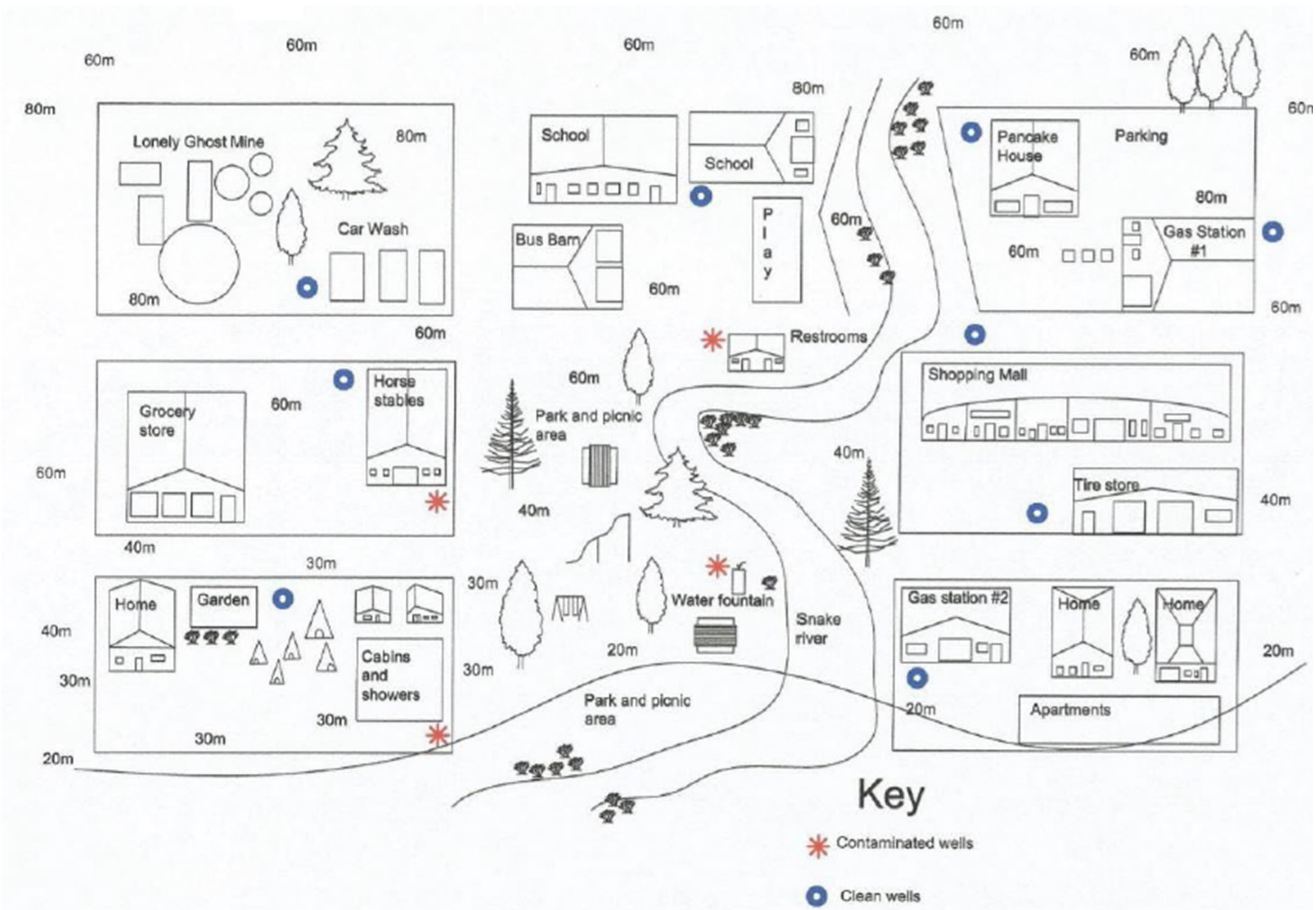
6. Assuming that ground water does follow the contours of the land, is it possible that there could be multiple sources of contamination? What would you expect to observe if either, or both, of the other suspected sites had leaking fuel storage tanks and were additional sources of contamination?

EXTENSION IDEAS:

1- The fictional town of Riverville does not have a communal source of water. Citizens of the town are looking at the possibility of digging a deep well to supply the community with safe water, and hopefully encourage more people to settle in the area. Go back to your contour map of Riverville. Where would you locate a community well so that the water is most likely to remain safe and uncontaminated for many years to come? Be certain to include evidence in your explanation, and how that evidence supports your choice for the best location of a new town well.

2- Obtain a Chamber of Commerce map of your local community. Use the map to chart the most likely directions of ground water flow. You may need to get elevations from a local source. If your community has a shared source of municipal water, show its location on your map as well. Using what you have learned from this activity, determine the "safest" location for a communal water source in your area. Compare your chosen location, if possible, to your community's actual water source. If you chose a location far away from your community's actual water source, explain why your community might have chosen another location. There are many considerations, in addition to the direction of ground water flow, for determining where a water source should be located! If your community does not have a communal water source, write a brief paragraph explaining why the location you chose would be the best position for creating a communal water source in your area.

Lesson 3 Student Riverville Contour Map



Lesson 3 Student Riverville Contour Map

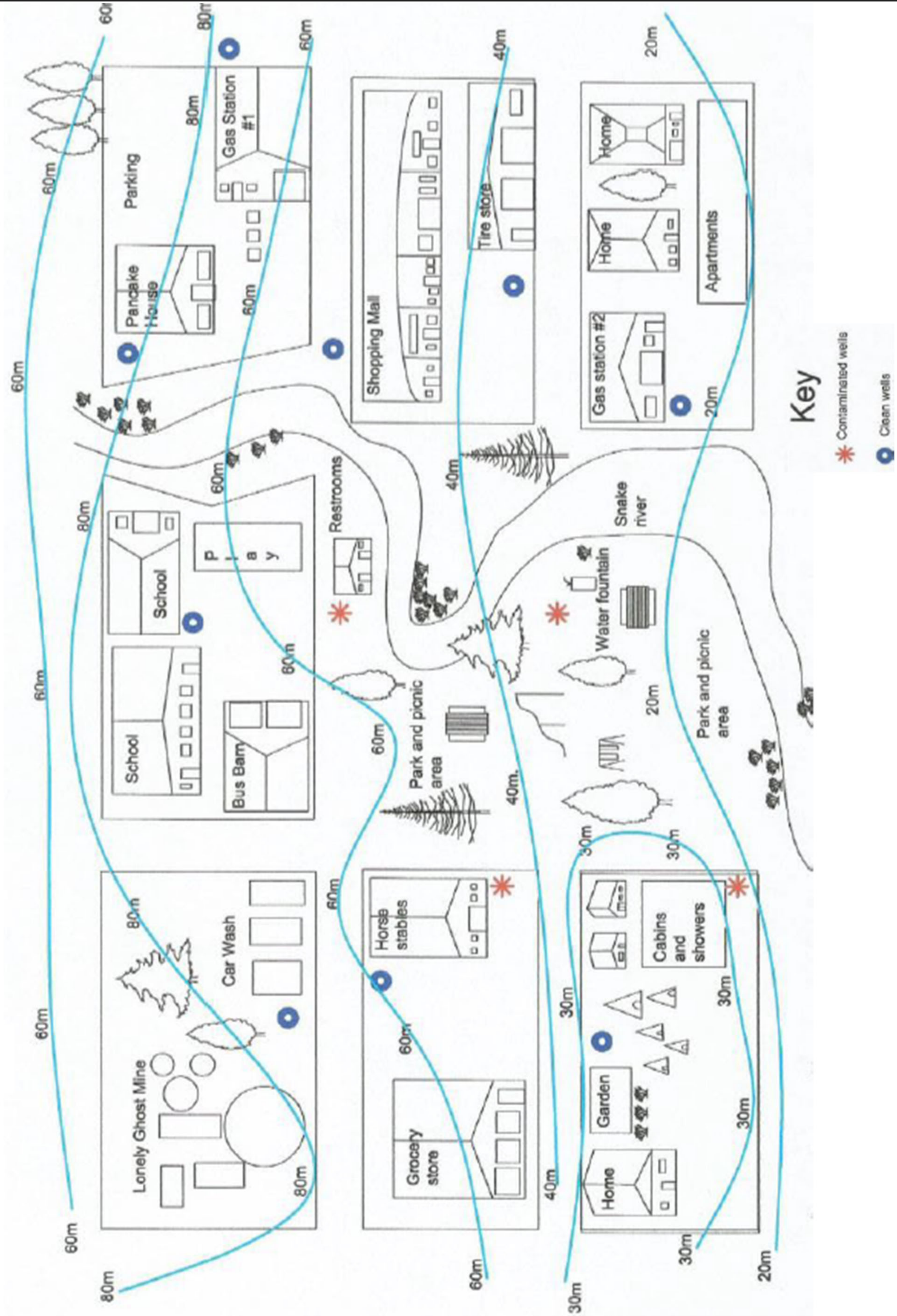


Table 6. Number of fish samples with methylmercury concentrations above 0.3 mg/Kg 1994-2014 and mean length of population (mm).

Species	Total N	N>0.3 mg/Kg MeHg	Length (mm)	Species	Total N	N>0.3 mg/Kg MeHg	Length (mm)
Bigmouth Buffalo	2	1	*Insf*[1]	Northern Pike	1034	761	615
Black Bullhead	687	25	274	Shorthead Redhorse	25	2	*Insf*[1]
Black Crappie	401	86	242	Smallmouth Bass	108	27	299
Bluegill	285	34	189	Walleye/Sauger	2637	1238	384
Channel Catfish	472	68	446	White Bass	215	118	350
Common Carp	177	7	472	White Crappie	22	6	244
Freshwater Drum	12	4	*Insf*[1]	White Sucker	204	10	417
Goldeye	20	4	*Insf*[1]	Yellow Perch	690	139	232
Largemouth Bass	503	372	373				

1 –Insufficient sample size: Population variance of walleye (highest), northen pike (lowest), and largemouth bass indicated a minimum sample size of 60 -135 individuals is required to calculate a mean with an accuracy of 95%. Other species are expected to have a similar variance and a minimum N of 100 was set for calculating mean lengths.

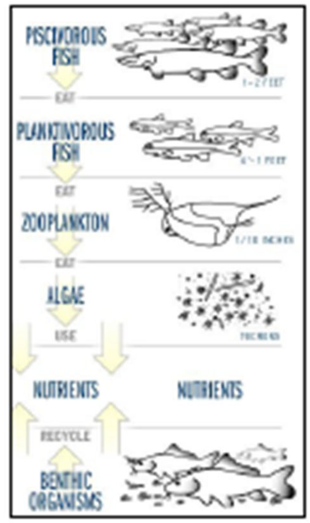
Lesson 4 STUDENT ACTIVITY

The Biomagnification Game: Fresh Water Ecosystems

Adapted from *Food Web and Bioaccumulation* activity, available at
http://www.dec.ny.gov/docs/administration_pdf/ifnyfdwebbioacclp.pdf.

Introduction:

A food chain is a linear network of links in a food web starting from producer organisms (such as grass or trees) and ending at apex predator species (like grizzly bears, killer whales, or even humans). A food chain shows how the organisms are related by the food they eat. Each level of a food chain represents a different trophic level. Food webs consist of a number of interconnected food chains.



A typical aquatic food chain

Toxic pollutants, once introduced into an ecosystem, can easily enter a food chain. For example, in the water, pollutants stick to tiny photosynthetic organisms called phytoplankton (which include algae). Because there is so little pollutant stuck to each phytoplankton, the pollutant isn't dangerous at this trophic level. However, small animals called zooplankton eat the phytoplankton. Once a zooplankton has eaten ten contaminated phytoplankton, the zooplankton has ten times the pollutant. As the zooplankton may be slow to metabolize or excrete the pollutant, the pollutant tends to build up or *bioaccumulate*. If a small fish then eats ten contaminated zooplankton, the fish could have 100 times the level of toxic pollutant as the original phytoplankton! This multiplication continues up the food web until high levels of contaminants are biomagnified to dangerous levels in the top predators. This phenomenon is known as *biomagnification*.

Mercury is a pollutant typically biomagnified in aquatic food webs. Mercury in any form is poisonous, with mercury toxicity most commonly affecting the nervous system, digestive system, and kidneys. Poisoning can result from inhalation, ingestion, injection, and absorption. The most dangerous form of mercury, methylmercury, is often found in low levels in aquatic ecosystems. Fish protein binds more than 90% of the methylmercury that a fish consumes so tightly that even the most vigorous cooking methods cannot remove it!

Objective:

You and your classmates will model the bioaccumulation and biomagnification of mercury in a fresh water ecosystem.

Procedure:

Every student will be given a game card. Make sure to read the instructions on your game card very carefully. Every game card is different!

The small multicolored tokens represent the primary producers (phytoplankton/algae).

Follow your teacher's directions, and the instructions on your card, as you play the game!

Directions:

- All zooplankton will enter the designated game play area (the ecosystem) and have about ten seconds to *eat* as many phytoplankton (tokens) as possible. Each zooplankton may only eat one phytoplankton at a time by bending over, picking up one token, standing up straight, and placing the token into their food bag (stomach).
- Once time is called, zooplankton will stop and wait while the planktivores (small fish) enter the ecosystem. When given the signal, everyone may begin *eating*. Zooplankton continue placing food tokens in their food bags, and small fish begin *catching* zooplankton by gently tagging them on the elbow.
- Anyone tagged on the elbow must give his or her food bag(s) to the tagger.
- When time is called, all zooplankton sit down (with food bags if untagged), and piscivores (large game fish which prey on smaller fish) enter the ecosystem.
- Large game fish have about ten seconds to catch their prey (the small planktivores).
- When time is called, planktivores sit down (if untagged) and the apex predator enters the ecosystem for about ten seconds.
- When time is called, everyone with a food bag(s) should count the number of each token color and record in their science notebook.

Data:

Token color representing mercury:	
Average number of mercury-representing tokens in zooplankton:	
Average number of mercury-representing tokens in planktivores:	
Average number of mercury-representing tokens in piscivores:	
Number of mercury-representing tokens in the apex predator:	

Questions to consider:

1. Why was there a difference in the contaminant levels of certain species?
2. Which species had the greatest contaminant levels?
3. What do the species with the highest contaminant levels have in common?

Waterworks Assessment Prompt

Lesson #4- *It's Deadly at the Top*

Driving Question
Why are some toxins, typically present at extremely low levels in the environment, particularly dangerous to apex predators like northern pike, eagles, bears and humans?

What You've learned (Evidence)
- Food chain video's
- Biomagnification game
- Table 6 from South Dakota TMDL (pg.34)
- Class discussion

A.C.E. Your Response!
Use this format for your response to the Driving Question

Answer the driving question
Use a complete sentence(s).

Cite your evidence
Incorporate at least three forms of evidence.

Explain your reasoning
How the evidence supports your answer.

Waterworks Assessment Prompt

Lesson #4- *It's Deadly at the Top*

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Use this format for your response to the Driving Question

Answer the driving question
Use a complete sentence(s).

Cite your evidence
Incorporate at least three forms of evidence.

Explain your reasoning
How the evidence supports your answer.

Waterworks
Assessment Rubric

Lesson #3- *It's Deadly at the Top*

	1	2	3	Points
Answer	No answer stated	Answer stated unclearly	Answer stated Clearly and logically	
Cite (Evidence)	No evidence cited	Minimal evidence cited (only 1 or 2 forms), and/or stated in an illogical manner/unclear	Adequate evidence (at least 3 forms) cited in a clear and logical manner	
Expand/Explain	No explanation of how the evidence cited supports the answer	Minimal or unclear explanation of how the cited evidence supports the answer	Clear and logical explanation of how each form of cited evidence supports the stated answer	
Content	No clear understanding of the applicable science content evident in the response	Minimal or incomplete understanding of the applicable science content evident in the response	Clear and complete understanding of the applicable science content evident in the response	

Score: _____ /12

Feedback for revision:

Waterworks
Assessment Rubric

Lesson #3- It's Deadly at the Top

	1	2	3	Points
Answer	No answer stated	Answer stated unclearly	Answer stated Clearly and logically	
Cite (Evidence)	No evidence cited	Minimal evidence cited (only 1 or 2 forms), and/or stated in an illogical manner/unclear	Adequate evidence (at least 3 forms) cited in a clear and logical manner	
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Content	No clear understanding of the applicable science content evident in the response	Minimal or incomplete understanding of the applicable science content evident in the response	Clear and complete understanding of the applicable science content evident in the response	

Score: _____ /12

Feedback for revision:

Lesson 5 Water Sample Analysis Sheet

Complete these five questions when collecting the water sample.

Location:

Date and Time of sampling:

Identity of sampler(s):

Suspected source(s) of pollution: *(if any)*

Observations during sampling: *(color, clarity, odor, objects in/on water, etc...)*

Proper Laboratory Procedures:

- Never eat, drink, or apply makeup at a lab station.
- Wash your hands after handling laboratory supplies.
- Clean-up before leaving any lab station (wipe up spills, throw away trash, etc.)
- Dump-out, rinse and drain wet test vials/cups upside down on a paper towel after use. *(This ensures supplies are clean and ready for the next group!)*
- If no sink is available in the classroom, dump used liquids into a large container for disposal down a sink at the end of testing. You may rinse vials/cups with tap water poured from a small container (beaker, bottle, etc.) when finished with each test.
- Used test strips may be disposed of in the trash.
- Do not use the same water for more than one test. Each test should be performed with a fresh *aliquot* (portion) of your water sample.

Water Testing Results:

pH: Test Result (with unit!) ☐ Acceptable? (Y/N) ☐

Why should we care?

What can be done to remediate unacceptable levels?

Nitrate + Nitrite: Test Result (with unit!) ☐ Acceptable? (Y/N) ☐

Why should we care?

What can be done to remediate unacceptable levels?

Phosphate: Test Result (with unit!) ☐ Acceptable? (Y/N) ☐

Why should we care?

What can be done to remediate unacceptable levels?

Heavy Metals: Test Result (with unit!) ☐ Acceptable? (Y/N) ☐

Why should we care?

What can be done to remediate unacceptable levels?

Waterworks Task Card

Lesson #6- *Clean It Up!*

The Challenge

Work collaboratively with other students as a start-up company determining the optimal conditions for inexpensive, safe, and efficient bioremediation of an oil spill in water. Then, prepare and present 5-minute sales pitch convincing investors to support your company's efforts.

The Engineering Design Process

In order to design the best possible process or tool, this cycle must be repeated many times. Each cycle brings you closer to your goal! Remember that engineers and scientists don't work alone and comparing your data with that of your fellow researchers is encouraged.

Student Group Assignments

Materials Collector - collect all supplies for experiment
Set Up Coordinator - collaborates with group members to determine quantity of supplies in the experiment
Data Collector - marks ratios of water, pollutant, bacteria, and any additional substances

Safety Notes

- *Wash your hands after handling all lab supplies and/or equipment*
- *Do not eat or drink anywhere near the lab stations*
- *Wash hands thoroughly after handling*

Day One

- *Your group will use a conical tube stand and four test tubes*
- *Your group will need to change the amounts of one of the solutions added to the test tube (ex. Sequentially add more bacteria to each test tube)*
- *Brainstorm/develop questions, then design an experimental plan with appropriate controls that addresses one of your questions*
- *Set-up your experiment (using the four test tubes provided)*
- *Once all solutions have been added, place a balloon over the top of the tube and place the tube in the tube stand. Wait 15 minutes to collect results.*
- *Your teacher will provide materials for measuring/collecting your results.*
- *Share results and brainstorm next steps (as a class)*
- *Wash well-plates with soap and water **VERY WELL** to remove **ALL** residual*

Day Two and Beyond

- *Repeat steps from Day One*
- *Design, re-delegate responsibilities, and carry-out the next round of tests*
- *Repeat as necessary*
- *Be creative! What other conditions might increase bacterial metabolism? What about combinations?*
- *If you have an idea, share it with your classmates and teacher... you may bring supplies to test!*

Assessment

Since you are modeling the activities of a start-up company trying to "make it big", each group will prepare and present a 5 minute sales pitch (or "elevator talk") at the conclusion of this lesson. The goal of your presentation is to convince "wealthy investors" (the teacher and your classmates) that you have figured out how to save the world from the devastating effects of oil spills. In order to do this, you will have to be creative and convincing... which means you'll have to back up all your statements with evidence!

Rubric

	1	2	3	Points
Content	No evidence of understanding of the applicable science content	Minimal evidence of understanding of the applicable science content	Clear and complete evidence of understanding of the applicable science content	
Clarity	Unclear and/or illogical	Logical arguments made, but some still unclear and/or illogical	Entire presentation clear and logical	
Creativity	No evidence of creativity	Minimal creativity evident	Entire presentation creative and engaging	
Evidence	No evidence presented to support statements	Minimal evidence presented to support statements	Clear and logical evidence provided in support of every statement	
Persuasiveness	Unconvincing and lacking in persuasiveness	Minimally convincing and/or persuasive	Completely convincing... the investors have been persuaded to fund your efforts!	

Score: _____ / 15

Feedback:

SACNAS
BIOGRAPHY PROJECT

M Middle School Level

Dr. Robin Kimmerer – Plant Ecologist

The legend goes that the first black ash tree grew from the ashes of the Anishnabe leader Black Elk. Before his death, Black Elk had a vision of how to pound the growth rings of the black ash into strips for basket weaving. Making the baskets, which people could use for trading or selling, was a long process. The tree had to mature, be harvested, prepared, and then finally woven. Thus, Black Elk saw how weaving baskets from the black ash would both provide for his people and teach them patience. (Legend of the Black Ash Basket: http://susinuss.tripod.com/legend.htm)

Since those ancient times, black ash baskets have become an important part of many Native American communities, including the Onondaga people of upstate New York. For the Onondaga, who are part of the Iroquois nation (http://www.iroquois.net/), basket weaving is an expression of art, history, and religion. Unfortunately, due to human pollution, wildfires, and natural diseases, the numbers of black ash are greatly declining. As a professor at the State University of New York in Syracuse (SUNY) (http://www.esf.edu/), I am working to restore forests of black ash trees on native Iroquois land.

To successfully restore the black ash, I have to think about the eco-system of the forest. For the black ash, the eco-system includes all of the other plants, insects, birds, and animals in the forest. The Onondaga people are also part of this eco-system and they have a lot of traditional knowledge about the forest. In my work, I strive to make a bridge between their native culture and the culture of academic science, so that together we can solve environmental problems.

I often feel like a bridge between cultures myself because I am part Potawatomi (http://www.potawatomi.org) and part Caucasian. Although the Potawatomi are originally from the Oklahoma area, I was born in Schenectady, New York in 1953. My grandfather and great-uncles were the first of my family to come to New York when they were taken from the Potawatomi reserve and placed at the Carlisle Indian School (http://home.epix.net/~landis/) in Pennsylvania.

As a child, I had the sense of living in two worlds. I was familiar with the native world and mainstream society, but I didn't feel like I belonged in either one of them. One place I truly felt comfortable was outside. Although my family was removed from their natural homeland, they instilled in me a deep respect for the land of the northeast. My sister and I grew up with a lot of knowledge about edible and medicinal plants, and a deep sense of being rooted to the earth. It was this love of the land that made me know from a very young age that I wanted to be an ecologist.

I majored in Forest Botany at SUNY, the same university where I am now a professor. I then went on to graduate school at the University of Wisconsin, Madison (http://www.wisc.edu/) where I received my Ph.D. in Botany in 1983. Earning a Ph.D. has given me the credentials to show people that Native Americans and scientists can work together and share knowledge. In this way, I have finally joined my two worlds together.

Through my experiences, I have tried to bring to life the Anishnaabe saying, "Use your gifts and dreams for good." It is my hope that my work with the Onondaga and SUNY teaches people to appreciate all forms of knowledge. It is also my hope that people of two cultures, will rather than feeling out of place, create a place for themselves. I have learned that ultimately, like the black ash, we must depend on our communities/eco-systems for survival.

 www.sacnas.org

SACNAS
BIOGRAPHY PROJECT

H High School Level

Dr. Jani Ingram – Chemist

I was born in 1962 in Kingman, Arizona. Kingman is a very multi-cultural community, and has a large mix of Hispanics, Native Americans, and Anglos. I am a mix myself: my mother is Navajo and my father is Caucasian.

During the time I was raised, Kingman was such a little town that there were not a lot of career opportunities for women, and girls didn't see examples of women who were doctors, lawyers, engineers, and scientists. Many girls, including myself, struggled with this lack of role models. However, I received a tremendous amount of encouragement from my parents who were both teachers. They showed me that an education could take me far.

Growing up in Kingman had its advantages too. In a smaller community you can really excel, even if you aren't the smartest person in the whole world. I was a good athlete and I was the valedictorian of my high school class. The confidence I gained in my hometown gave me courage through my entire education.

After high school I went to Yavapai College in Prescott, Arizona where I played basketball. It was at Yavapai where I first fell in love with chemistry. I had always loved math and had decided to study engineering. While taking my standard science requirements, I took my first chemistry class. I had an incredibly enthusiastic chemistry professor that really made the lectures and labs come alive. Even though I loved chemistry, the class was still very hard for me. I actually went to my professor to tell him I needed to switch classes to take something easier. He said, "Oh no you don't!" He was able to show me how to take a step back and ask for help, instead of saying, "I quit!"

As I continued with my education, however, I learned there are times when you truly have to give some things up. For example, when I went to New Mexico State University (www.nmsu.edu) to get my B.S. in chemistry, I thought I would continue playing basketball. I quickly saw that basketball, on top of my classes and labs, was going to be impossible. Quitting basketball was a hard decision to make, but it was an important step in preparing for graduate school, where science had to be my entire focus.

Although I stopped playing competitively, basketball was still a part of my life, and in fact, taught me a lot about being a chemist. All of the discipline, determination, and patience that it takes to learn a sport are the same things it takes to succeed in science. The bottom line is that it takes hard work and focused time to improve. Neither science nor basketball is something that you can do haphazardly and succeed.

That determination was necessary when I started graduate school in chemistry at the University of Arizona (U of A - www.arizona.edu). Graduate school was truly a test of perseverance, not just because the material was challenging. As I advanced into higher-level math and science classes, I noticed that there were fewer and fewer women and people of color. I got used to saying to my lab partners, "You know, a woman can actually do the same things as you!"

While at U of A, I found myself struggling, like when I was a girl, to find a female role model. There was a woman chemistry professor that I greatly admired. However, while she was very brilliant and successful, it seemed like she was "married" to science. I realized that for me to be happy, I needed to have another life besides chemistry. I am now married and have three children. Times have changed. People realize that

Dr. Jani Ingram – Chemist 2

having a family doesn't make you less productive. In fact, having a family helps me stay more focused at work because I know I can't waste time!

After earning my Ph.D. in 1990, I spent twelve years as a research scientist at the Idaho National Engineering and Environmental Laboratory (INEEL), which is operated by the Department of Energy. I study surface chemistry, which is the chemistry right where air or liquid meets a solid. At INEEL, I studied how waste metals like uranium and plutonium that were used in weapons production interact with the environment, mostly at the surface. Our research tries to understand all of these interactions so that better clean-up strategies can be developed.

Currently I am a professor of chemistry at Northern Arizona University (www.nau.edu). Teaching provides me with a way of interacting with students who are just getting started in science. Hopefully I am able to show students that a Navajo woman can be a mother, athlete, and scientist. I try and give my students the same advice my chemistry teacher gave me a long time ago, "Don't sell yourself short, test your limits and try the impossible!"

Waterworks Refurbishment Inventory

Lesson	*Quantity*	*Item*	
All	1	Facilitator Binder w/ USB	
	1	Shipping Tote	
	1	100ml Graduated Cylinder	
	1	10 ml Graduated Cylinder	
	1	Teacher Goggles	
	Optional	Student Goggles (If Requested)	
	12 packs	Colored Pencils	
Lesson 1	1 per class	Quart baggie w/ .5 tbsp Baking Soda	
	1 per class	Quart Baggie w/ .5 tbsp Calcium Chloride	
Lesson 2	1	Clear 1L Measuring Cup	
	1	Plastic Dropper	
	1	Small Metal Bucket	
	10 packs of 10	Life Cards	
Lesson 3	1	Full Page Student Riverville Contour Map	
	Optional	Water Cycle Handout	
	1	Mystery in the Black Hills Sheet	
Lesson 4	30	Laminated Copies of Table 6	
	1 Set	Organism Cards	
		1 Apex Predator	3 Piscivores
		9 Planktivores	19 zooplankton
	100	Purple Tokens	
	100	Green Tokens	
	100	Pink Tokens	
	19	Cloth Food Bags	
Lesson 5	6 per class	pH Test Strips (cup, instruction, info sheet)	
	6 per class	Nitrate Test Strips (cup, instruction, info sheet)	
	6 per class	Phosphate Test Strip (vials, instruction, info sheet)	
	6 per class	Heavy Metal Test Strip (cup, instruction, info sheet)	
	3 per kit	Ammonia Test Strips (vial, instruction, info sheet)	
	3 per kit	Lead Test Strips (vial, solution, instruction, info)	
	3 per kit	Mercury Test Strips (cup, instruction, info sheet)	
	3 per kit	Cyanide #1 Test Strip (microcuvette, pipette)	
	3 per kit	Cyanide #2 Test Strip (instruction, info sheet)	
Lesson 6	11	Conical Tube Rack	
	1 bottle	Vegetable Oil	
	1 jar	Quick Rising Yeast	
	1 bottle	Vinegar	
	1 bottle	Dish Soap	
	1 tub	Sugar	
	50 per class	Balloons	
	10	Tall Plastic Cups	
	10	Pipettes	
	10 sets	Measuring Scoops	
	40	Conical Tubes	
	4	Extra Conical Tubes	

NOTICE: THE HEADER/FOOTER AND REVISION HISTORY OF THIS ATTACHMENT IS NOT INCLUDED IN THE PRINTED DELIVERABLE.ANY BLANK PAGES ARE LEFT SO INTENTIONALLY.

Revision History

Rev	Date	Section	Paragraph	Summary of Change	Authorized by
01	2/27/2024	NA	NA	Initial Release	CCR 911