Community Waters Science Unit

Grade 4 Teacher Manual

This stormwater engineering unit incorporates Next Generation Science Standards* and the Ambitious Science Teaching framework. In addition to this manual, there are maps, videos, and additional school specific support materials available on our website: www.islandwood.org or www.communitywaters.org.

This curriculum was developed by IslandWood in collaboration with Seattle Public Schools and adapted for Tacoma Public Schools in 2022.

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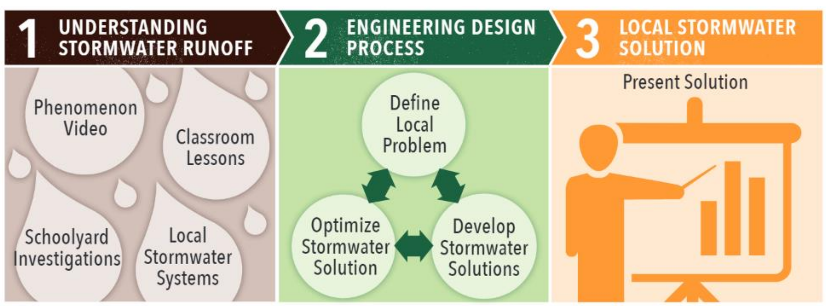
Unit Overview

The unit invites teachers to engage students in science and engineering to understand and develop a solution for a real world stormwater runoff problem in their community. Students begin the unit trying to understand why stormwater can cause flooding in an urban setting. Then they use an Engineering Design Process to come up with a proposal towards solving a specific local stormwater problem:



- **Understanding Stormwater in the City:** In the first part of this unit, teachers use an Ambitious Science Teaching approach as they elicit student's ideas, support changes in thinking, and press for evidence-based explanations. The students watch a video showing short clips of problems caused by stormwater and then add their personal understanding of stormwater to an "explanatory model". Classroom lessons and outside investigations help them refine their understanding and revise their explanatory model.
- **Using Engineering to Solve a Stormwater Problem:** Once their understanding is built, students apply it towards coming up with a solution for a stormwater runoff problem at a specific site (likely in their schoolyard). During this part of the unit, an Engineering Design Process is used to define the problem, develop solutions, and optimize the solution they select.
- **Sharing their Solution:** At the end of the unit, the students share their solutions with their classmates and/or local stakeholders.

Lands and Waters Acknowledgement

Concepts of how land has been shaped by water and water has shaped land over time are embedded throughout this unit. Since time immemorial through today, Indigenous people have observed, learned about, depended upon, changed and cared for these lands and waters. Specifically, the Puyallup Tribe continues to have a vital role in stewarding the water bodies of the Puyallup River watershed and beyond, from Tahoma (Mt. Rainier) to Commencement Bay on Puget Sound.

> "In our Lushootseed language we are known as the spuyaləpabš. The literal translation of this word means "people from the bend at the bottom of the river." This refers to the many dispersed villages that spanned outward from the mouth of the Puyallup River, near the present day site of the Tacoma Dome."
>
> (Source: http://www.puyallup-tribe.com/ourtribe/)

The Puyallup Tribe participates in ongoing scientific and cultural stewardship of Tacoma's water resources and hold both traditional and contemporary expertise in caring for salmon, the Salish Sea, and the vibrant urban ecosystems all around us. For more on this work related to habitat restoration, fish projects, water quality monitoring and more, check out: http://puyallup-tribe.com/fisheries/

For more information about the Puyallup Tribe history and current projects, check out their website (www.puyallup-tribe.com) and the video here: http://www.puyallup-tribe.com/ourtribe/

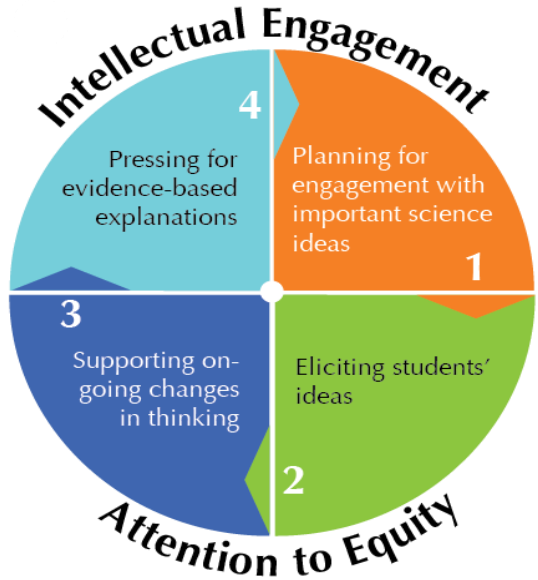
Also, please view the **Puyallup Tribe Land Acknowledgement** in Lushootseed and English (2 m): https://youtu.be/KGnac8x-SIM.

Consider connecting your **Since Time Immemorial** and Washington State history lessons with this unit as students learn about how water moves through the city, the impacts of polluted stormwater on salmon and humans, and how people rely on nature as they develop solutions to some of the problems with stormwater.

Specifically, the "Salmon Recovery and the Boldt Decision" lessons in Since Time Immemorial relate closely to the unit's connections to salmon and how salmon are affected by human activities:

https://www.k12.wa.us/student-success/resources-subject-area/time-immemorial-tribal-sovereignty-washington-state/elementary-curriculum/elementary-unit-3-washington-state-history

Incorporation of the Ambitious Science Teaching Framework



This curriculum leverages the Ambitious Science Teaching (AST) Framework as developed by the University of Washington. For more details about see **Appendix 1 and 2** in this manual and their website: http://ambitiousscienceteaching.org/

The graphic on the right is used throughout this manual to highlight when each of the four AST practices are being addressed. To highlight those connections here:

1) **Planning for engagement with important science ideas** starts with the unit being framed around the phenomena of stormwater flooding in urban communities, and the problems it can cause. To assist teachers in the planning for engagement, the Unit Overview section includes the unit's goals, the Next Generation Science Standards addressed, background information for the teacher, and a storyline outline of the lessons in the unit.
2) **Eliciting students' ideas** occurs in the first lesson including students representing their ideas in an "explanatory model" that they can continue to update as their thinking changes.
3) The remainder of the first half of the unit focuses on **supporting ongoing changes in thinking** with each lesson providing opportunities to dig deeper into students' understanding of the urban stormwater phenomena. Most lessons provide teachers "Back Pocket Questions" to use with students to support their changes in thinking, and there are also a variety of tools provided in Appendix 2 of this curriculum.
4) **Pressing for evidence-based explanations** is important as students explain their changes in understanding throughout many of the lessons. This process is particularly highlighted when students add to and/or redo the explanatory models they created in lesson 1 to show how their thinking has changed, and at the end of the unit when students are making claims about what solution will best address the stormwater problem at their site. (see also AST web page: https://ambitiousscienceteaching.org/pressing-evidence-based-explanations/)

Unit Goals

1. Students will develop an understanding of stormwater runoff and the problems it can cause in an urban setting.
2. Students will apply an Engineering Design Process towards solving stormwater related problems in their schoolyard or neighborhood.
3. Students that might not otherwise be interested in science will be motivated and engaged by applying science and engineering on a real problem in their own community. (*See the "Engineering Design in Relation to Student Diversity" excerpt below)*

What students figure out by the end of the unit:

- Water moves rocks, soils, and sediments.
- Plants affect the physical characteristics of their region by reducing the movement of soils (erosion) and slowing, using and storing water.
- Flooding is a natural hazard that is made worse in an urban setting.
- Humans can take steps to reduce the flooding and its impacts, specifically, pollution entering waterways.
- The criteria and constraints for a specific stormwater problem in their community.
- Certain solutions will work better than others to solve a problem.
- A solution can be improved to work better in a specific situation.

Put another way:

If students understand…		then, students can explain…
…how water moves across and through the land and how plants and different surfaces affect it,	→	…what happens to stormwater in an urban environment and how people's actions can change the amount of stormwater runoff.
…what happens to stormwater in an urban environment and the problems caused by too much stormwater runoff in their community,	→	…what is happening to cause a specific local stormwater runoff problem and why they want to fix it.
…what is happening with their problem and the desires of those who care about their problem,	→	…the criteria and constraints of their problem.
…the criteria and constraints of their problem and the advantages and disadvantages of different possible solutions,	→	…why they picked a certain solution as the best one for their specific problem.
…why they picked a certain solution and whether a model of it meets their criteria for success,	→	…how well it works and what they would change to make it work better.
…why the solution they designed will help with stormwater runoff in their local community.	→	…how science and engineering can be relevant to their lives.

Next Generation Science Standards

The Next Generation Science Standards that this unit is focused on are included below. The relevant standards are also listed within each lesson with the components of the performance expectation that are a part of that lesson underlined. The Practices, Disciplinary Core Ideas, and Crosscutting Concepts listed in a lesson are ones used during that lesson - they are not limited to the dimensions that are a part of that lesson's performance expectation(s).

Targeted NGSS Performance Expectations	
4-ESS2-1.	**Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.** [Clarification Statement: Examples of variables to test could include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.] [*Assessment Boundary: Assessment is limited to a single form of weathering or erosion.*]
4-ESS3-2.	**Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.** [Clarification Statement: Examples of solutions could include designing an earthquake-resistant building and improving monitoring of volcanic activity.] [*Assessment Boundary: Assessment is limited to earthquakes, floods, tsunamis, and volcanic eruptions.*]
3-5-ETS1-1.	**Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.**
3-5-ETS1-2.	**Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.**
3-5-ETS1-3.	**Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.**

Dimensions from the targeted NGSS Performance Expectations		
Science and Engineering Practices (SEP)	**Disciplinary Core Ideas (DCI)**	**Crosscutting Concepts (CC)**
Asking Questions and Defining Problems • Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (4-ESS2-1) • Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1) ***Planning and Carrying Out Investigations*** • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-5-ETS1-3) ***Constructing Explanations and Designing Solutions*** • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem. (3-5-ETS1-2) • Apply scientific ideas to solve design problems. (4-ESS3-4)	***ESS2.A: Earth Materials and Systems*** • Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. (4-ESS2-1) ***ESS2.E: Biogeology*** • Living things affect the physical characteristics of their regions. (4-ESS2-1) ***ESS3.B: Natural Hazards*** • A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts. (4-ESS3-2) ***ETS1.A: Defining and Delimiting Engineering Problems*** • Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5-ETS1-1) ***ETS1.B: Developing Possible Solutions*** • Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (3-5-ETS1-2) • At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (3-5-ETS1-2) • Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3) • Testing a solution involves investigating how well it performs under a range of likely conditions. (secondary to 4-ESS3-2) ***ETS1.C: Optimizing the Design Solution*** • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3)	***Cause and Effect*** • Cause and effect relationships are routinely identified, tested, and used to explain change, (4-ESS2-1 & 4-ESS3-2) ***Connections to Engineering, Technology, and Applications of Science*** **Influence of Engineering, Technology, and Science on Society and the Natural World** • People's needs and wants change over time, as do their demands for new and improved technologies. (3-5-ETS1-1) • Engineers improve existing technologies or develop new ones to increase their benefits, to decrease known risks, and to meet societal demands. (4-ESS3-2, 3-5-ETS1-2)

Disciplinary Core Idea Progressions

These progressions show what students are expected to know as they advance through the grade bands. From http://nextgenscience.org.

DCI	K-2	3-5	6-8
ESS2.A Earth materials and systems	Wind and water change the shape of the land.	Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around.	All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.
ESS2.E: Biogeology	Plants and animals can change their environment.	Living things affect the physical characteristics of their regions.	
ESS3.B Natural hazards	In a region, some kinds of severe weather are more likely than others. Forecasts allow communities to prepare for severe weather.	A variety of hazards result from natural processes; humans cannot eliminate hazards but can reduce their impacts.	Mapping the history of natural hazards in a region and understanding related geological forces.
ESS3.C Human impacts on Earth systems*	Things people do can affect the environment but they can make choices to reduce their impacts.	Societal activities have had major effects on the land, ocean, atmosphere, and even outer space. Societal activities can also help protect Earth's resources and environments.	Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

* This DCI is in a 5th grade performance expectation (5-ESS3-1) but is relevant to this unit.

Engineering Disciplinary Core Idea Progressions

These progressions show what students are expected to know as they advance through the grade bands

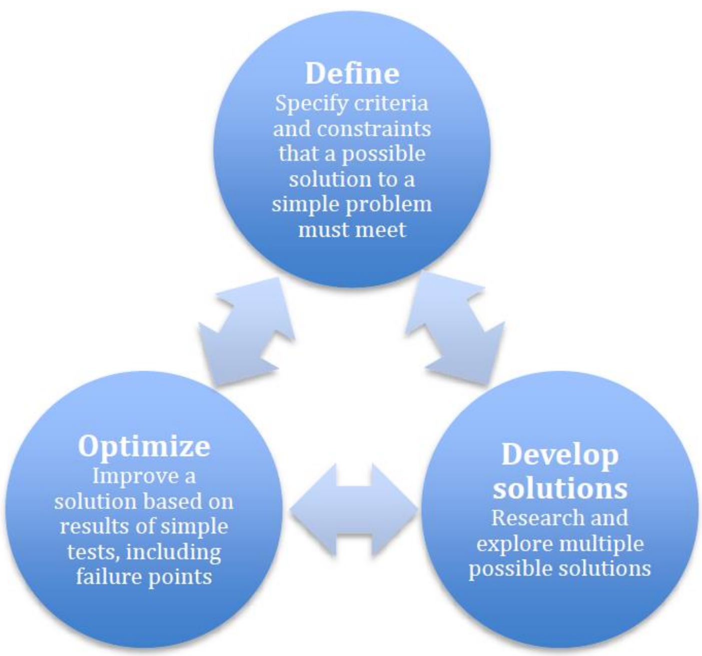
DCI	K-2	3-5	6-8
ETS1.A Defining and Delimiting Engineering Problems	• A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. • Asking questions, making observations, and gathering information are helpful in thinking about problems. • Before beginning to design a solution, it is important to clearly understand the problem.	• Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared based on how well each one meets the specified criteria for success or how well each takes the constraints into account.	• The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.
ETS1.B: Developing Possible Solutions	• Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people	• Research on a problem should be carried out before beginning to design a solution. • At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. • Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. • Testing a solution involves investigating how well it performs under a range of likely conditions.	• A solution needs to be tested, and then modified based on the test results in order to improve it. • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. • Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. • Models of all kinds are important for testing solutions.
ETS1.C: Optimizing the Design Solution	• Because there is always more than one possible solution to a problem, it is useful to compare and test designs.	• Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	• Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process - that is, some of the characteristics may be incorporated into the new design. • The iterative process of testing the most promising solutions and modifying what is proposed based on the test results leads to greater refinement and ultimately to an optimal solution

Grades 3-5 Engineering Design

From: http://ngss.nsta.org/3-5-engineering-design.aspx

Students' capabilities as problem solvers build on their experiences in K–2, where they learned that situations people wish to change can be defined as problems than can be solved or goals that can be achieved through engineering design. With increased maturity, students in third through fifth grades can engage in engineering in ways that are both more systematic and creative. As in earlier and later grades, engineering design can be thought of as three phases. It is important to keep in mind, however, that the lively process of design does not necessarily follow in that order, as students might think of a new solution during the testing phase, or even re-define the problem to better meet the original need. Nonetheless, they should develop their capabilities in all three phases of the engineering design process.

Defining the problem in this grade range involves the additional step of specifying criteria and constraints. Criteria are requirements for a successful solution and usually specify the function that a design is expected to perform and qualities that would make it possible to choose one design over another. Constraints are the limitations that must be considered when creating the designed solution. In the classroom, constraints are often the time and materials that are available.



Developing possible solutions at this level involves the discipline of generating several alternative solutions and comparing them systematically to see which best meet the criteria and constraints of the problem.

Improving designs involves building and testing models or prototypes using controlled experiments or "fair tests" in which only one variable is changed from trial to trial while all other variables are kept the same. This is the same practice as in science inquiry, except the goal is to achieve the best possible design rather than to answer a question about the natural world. The broader message is that "failure" is an essential and even desirable part of the design process, as it points the way to better solutions.

Engineering Design in Relation to Student Diversity

From Appendix I – Engineering Design in the NGSS:
http://www.nextgenscience.org/sites/default/files/Appendix%20I%20-%20Engineering%20Design%20in%20NGSS%20-%20FINAL_V2.pdf

The NGSS inclusion of engineering with science has major implications for non-dominant student groups. From a pedagogical perspective, the focus on engineering is inclusive of students who may have traditionally been marginalized in the science classroom or experienced science as not being relevant to their lives or future. By asking questions and solving meaningful problems through engineering in local contexts (e.g., watershed planning, medical equipment, instruments for communication for the deaf), diverse students deepen their science knowledge, come to view science as relevant to their lives and future, and engage in science in socially relevant and transformative ways. From a global perspective, engineering offers opportunities for “innovation” and “creativity” at the K-12 level. Engineering is a field that is critical to undertaking the world’s challenges, and April 2013 NGSS Release Page 3 of 7, exposure to engineering activities (e.g., robotics and invention competitions) can spark interest in the study of STEM or future careers (National Science Foundation, 2010). This early engagement is particularly important for students who have traditionally not considered science as a potential career choice, including females and students from multiple languages and cultures in this global community.

Social Studies and English Language Arts Standards

Social Studies. Science and society are intertwined, and very clearly so in urban settings. This unit supports multiple Common Core Social Studies standards (Skills and Geography) and Since Time Immemorial lessons.

> SSS1: Uses critical reasoning skills to analyze and evaluate claims. Enduring Understanding: Knows that there are many points of view to an argument and can share one's own position with evidence.
>
> SSS2: Uses inquiry-based research. Enduring Understanding: Knows how to ask a variety of quality questions and find appropriate materials to find the answers to those questions.
>
> *(see also SSS3 and 4)*
>
> G1: Understands the physical characteristics, cultural characteristics, and location of places, regions, and spatial patterns on the Earth's surface. Enduring Understanding: Knows that the use of tools (e.g., maps, globes, charts, graphs) is important to understanding the world around us. Different cultures may use different tools, and have different names and different perspectives, when looking at the world around us.
>
> G2: Understands human interaction with the environment. Enduring Understanding: Knows that the human-environment interactions are essential aspects of human life in all societies and that they occur at local-to-regional scale. Human actions modify the physical environment, and, in turn, the physical environment limits or promotes human activities.

English Language Arts. Throughout this unit, students are asked to read informational text, write explanations using evidence, and discuss their ideas with others. Some examples of engagement in ELA include: students read a couple short "just-in-time" texts, read about stormwater solutions, and write a "Claim-Evidence-Reasoning" (CER) statement by the end of the unit. For further detail and support on CERs, check out "What's Your Evidence: Engaging K-5 Children in Constructing Explanations in Science" (2013), which may be available in your building.

Several grade 4 ELA Standards from Common Core are supported through these practices:

> CCSS.ELA-LITERACY.RI.4.1
> Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.
>
> CCSS.ELA-LITERACY.RI.4.3
> Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.
>
> CCSS.ELA-LITERACY.RI.4.4
> Determine the meaning of general academic and domain-specific words or phrases in a text relevant to a *grade 4 topic or subject area*.
>
> CCSS.ELA-LITERACY.RI.4.7
> Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, timelines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears.
>
> CCSS.ELA-LITERACY.RF.4.4
> Read with sufficient accuracy and fluency to support comprehension.

CCSS.ELA-LITERACY.W.4.9
Draw evidence from literary or informational texts to support analysis, reflection, and research.

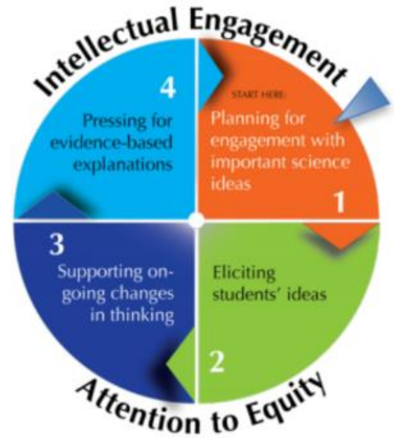
CCSS.ELA-LITERACY.SL.4.1
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 4 topics and texts*, building on others' ideas and expressing their own clearly.

CCSS.ELA-LITERACY.SL.4.4
Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

CCSS.ELA-LITERACY.SL.4.5
Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes.

CCSS.ELA-LITERACY.L.4.6
Acquire and use accurately grade-appropriate general academic and domain-specific words and phrases, including those that signal precise actions, emotions, or states of being (e.g., quizzed, whined, stammered) and that are basic to a particular topic (e.g., *wildlife, conservation,* and *endangered* when discussing animal preservation).

Teacher Background Information



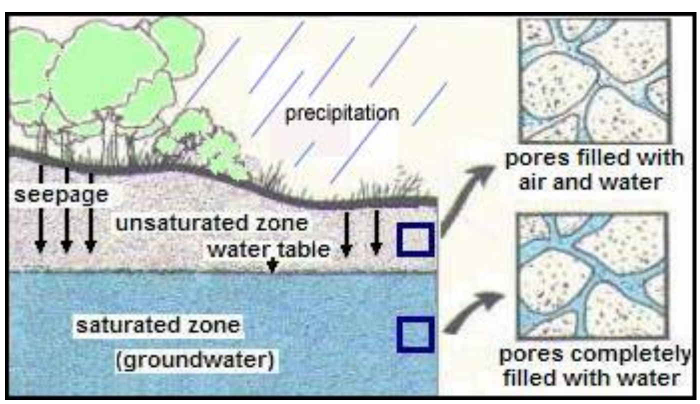
This section provides science content knowledge and explanations to understand the general phenomenon of how water affects land. The last part of the section provides information from *A Framework for K-12 Science Education* describing knowledge corresponding to each Disciplinary Core Idea featured in this unit.

Hydrosphere – The world of water

Information for this section is from:
http://www.geography4kids.com/ and
http://water.usgs.gov/edu/watercyclesummary.html

Earth's water is always in movement and is always changing states, from liquid to vapor to ice and back again, cycling for billions of years. The sun heats water in the oceans and other places. Some of it evaporates as vapor into the air. Rising air currents take the vapor up into the atmosphere along with water transpired from plants and evaporated from the soil. The vapor rises into the air where cooler temperatures cause it to condense into clouds. Air currents move clouds around the globe, and cloud particles collide, grow, and fall out of the sky as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Snowpacks in warmer climates often thaw and melt when spring arrives, and melted water flows over land. Most precipitation falls back into the oceans or onto land, where, due to gravity, the precipitation flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with streamflow moving water towards the oceans. Runoff, and groundwater seepage, accumulate and are stored as freshwater in lakes. Not all runoff flows into rivers, though. Much of it soaks into the ground. Some of the water infiltrates into the ground and replenishes aquifers, which store vast amounts of freshwater for long periods of time. Some groundwater stays close to the land surface and can seep back into surface-water bodies and the ocean as groundwater discharge, and some groundwater finds openings in the land surface and emerges as freshwater springs. Yet more groundwater is absorbed by plant roots. Over time, though, all this water keeps moving.

More on groundwater. Groundwater starts on the surface. When it rains and the water moves through the soil, it's called infiltration. There are spaces between the dirt and rocks that allow the water to flow through. Different soil types have different porosities.



Video on water movement in soil:
https://www.youtube.com/watch?v=vmo0FRAVgkM

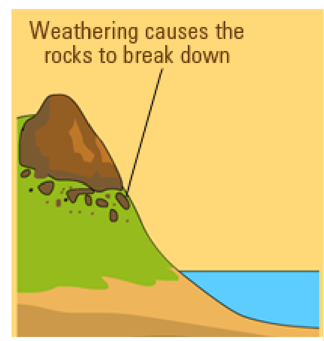
Eventually it percolates deeper into the Earth. Under the soil layer, the zone of saturation has very small spaces between the rocks. The spaces are so small they may even be the size of large molecules. When the water can go no deeper (because of impermeable rock layer), it creates an aquifer. An aquifer is an underground reservoir inside the rocks. Pollution seeps into the groundwater. Buried waste and landfills all let hazardous material seep into the groundwater. It happens naturally when water drains through the waste and seeps into the land. Eventually the groundwater will return to normal through natural filtration processes, but it will take several decades.

More on runoff. When rain hits saturated or impervious ground it begins to flow overland downhill. It is easy to see if it flows down your driveway to the curb and into a storm sewer, but it is harder to notice it flowing overland in a natural setting. During a heavy rain, water will flow along channels as it moves into larger creeks, streams, and rivers. As with all aspects of the water cycle, the interaction between precipitation and surface runoff varies according to time and geography. Similar storms occurring in the Amazon jungle and in the desert southwest of the United States will produce different surface-runoff effects. Surface runoff is affected by both meteorological factors and the physical geology and topography of the land. Only about a third of the precipitation that falls over land runs off into streams and rivers and is returned to the oceans. The other two-thirds is evaporated, transpired, or soaks into groundwater. Surface runoff can also be diverted by humans for their own uses.

- USGS: Effects of Urban Development on Floods, (Fact Sheet 076-03)
- USGS: Surface-water data for the Nation
- USGS: Real-time streamflow data
- USGS: Surface-water information

Weathering

Information for this section from www.kidsgeo.com/geology
(site no longer exists)



http://pixgood.com/weathering-and-erosion-of-rocks.html

Weathering takes place as rocks are broken down into progressively smaller pieces. A large chunk of bedrock many hundreds of feet long is broken down into smaller and smaller pieces, until finally there are many tens of thousands of small rocks. Often rocks are broken down so much that they become part of the soil.

Forces of weathering. Water is an important force that greatly effects weathering, but it is not the only force. Other forces include the atmosphere, and plant and animal life. Plant roots, microscopic animals and plants, and digging animals also help to break down rocks. To better understand the different forces that cause weathering, geologists separate them into three categories. These categories are mechanical, chemical, and biotic. This unit does not explore weathering, but details are provided here since so you can discuss it further with students if it becomes relevant to their thinking.

a. **Mechanical Weathering**. Mechanical weathering takes place when rocks are broken down by physical force, rather than by chemical breakdown. The forces that break rocks can be numerous, and include such things as pent up energy as the Earth's crust slowly moves. When great amounts of pressure build up, the resulting mechanical effect can be that very large joints, or faults are created.

i. **Frost wedging**. In liquid form, water can penetrate the many holes, joints, and fissures within a rock. As the temperature drops below 32° F, this water freezes. As water freezes, it expands, becoming about 9% larger than it was in liquid form. The result is that the holes and cracks in rocks are pushed outward. Even the strongest rocks are no match for this force. As the water thaws, it is then able to penetrate further into the widened space, where it later freezes again. The expansion of holes and cracks is very slow. Month after month, year after year, water freezes and thaws over and over, creating larger holes and cracks in the rocks.

Urban Frost Wedging
In an urban setting, we often see this in the form of cracks in concrete. Potholes form when frost wedging is combined with the repeated pounding from cars. A quick video explains the process: https://www.youtube.com/watch?v=rg5Hwety4RU

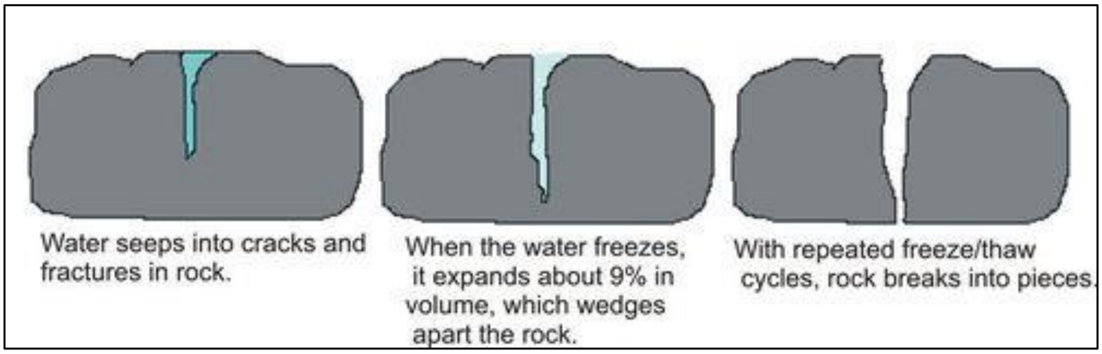


Image Source: http://www.ck12.org/user:richb/book/Earth-Science-for-St.-Marys-School-Aiken/section/5.2/

ii. **Salt wedging**. As water enters the holes and cracks in the surface of rocks, it often carries salt with it. As the water later evaporates, the salt is left behind. Over time, these salt deposits build up, creating pressure that causes rocks to split.

iii. **Temperature**. As temperatures rise, rocks expand slightly. As temperatures cool, rocks contract slightly. The effect of expanding and contracting over time weakens rocks, eventually causing cracks.

b. **Chemical Weathering**. Chemical weathering takes place in almost all types of rocks. Smaller rocks are more susceptible, however, because they have a greater surface area. Chemical reactions break down the bonds holding the rocks together, causing them to fall apart into smaller and smaller pieces. Chemical weathering is more common in locations where there is a lot of water. This is because water is important to the chemical reactions that can take place. Warmer temperatures also speed up the rates of reactions. Warm and wet places have lots of chemical weathering.

c. **Biotic Weathering**. Biotic weathering is any type of weathering that is caused by living organisms. Most often the culprit of biotic weathering is plant roots. These roots can extend downward, deep into rock cracks in search of water and nutrients. In the process, they act as a wedge, widening and extending the cracks. Other causes of biotic weathering are digging animals, microscopic plants and animals, algae, and fungi. Though plant roots do widen cracks and break rocks, roots are also good at holding onto soil and preventing erosion.

Erosion

Information for this section from: www.kidsgeo.com/geology
(site no longer exists)

http://pixgood.com/weathering-and-erosion-of-rocks.html

Erosion takes place when materials in the landscape are moved from one location to another. This might happen as dust is blown off the side of a cliff face by wind, or as silt is carried downstream by a river. In the context of this unit, water erosion is our main focus.

Erosion due to gravity*:*

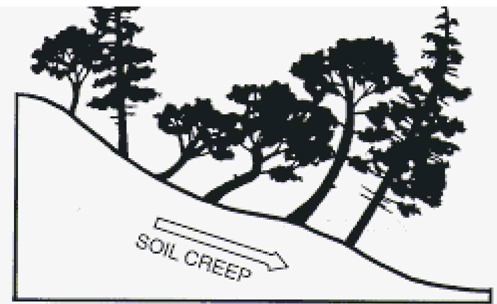
Mass Wasting. The power of gravity on Earth is inescapable. Gravity pulls a rock lower and lower towards the lowest surface possible. Rocks, dirt, and soil lie on the side of a mountain or hill, apparently unmovable. For many hundreds or even thousands of years the rocks and dirt change very little. Over time, however, as small amounts of dirt and additional rocks are added to the pile, the weight and mass of the pile build up. Then, suddenly, the entire pile might move several hundred feet within only a couple of minutes or seconds, only to once again come to rest on the side of the mountain or hill, waiting for the next event.

a. **Rock falls**. The most common type of mass wasting is falling. Rocks, boulders, pebbles, and dirt loosened by freezing, weathering, and other forces, simply fall downward, until they hit something that stops their descent. Often a pile of rocks forms at the bottom of a cliff or mountain. We call a pile of rocks, boulders, and dirt a talus. Often, taluses form a cone shape, as they ascend the side of the mountain.

b. **Landslides**. Landslides take place when dirt, pebbles, rocks, and boulders slide down a slope together. Sometimes these landslides are small, and hardly noticeable. Other times however, they can be substantial, involving the entire side of a mountain. These destructive slides can be triggered by several different causes. Often rain, which adds additional weight to the side of a slope, can cause slides. Other times they might be caused by erosion, as the base of a slope is slowly removed by a stream, weakening the entire side of the mountain. As a slide progresses down a mountain slope, it can pick up tremendous speed and energy. Some slides have been reported to travel at speeds approaching 200 miles per hour. The resulting winds can be so forceful that they are known to strip the leaves off surrounding trees. The momentum of falling material has been known to cause some of the materials to roll several hundred feet back up the other side of a valley. The amount of material moved in a landslide can be tremendous. In some cases, this material is so substantial that it is measured in cubic miles. This much material falling across a stream can be the cause for the formation or a new natural lake.

c. **Flows**. Flows take place much more slowly than do slides, and usually involve great amounts of water. After a heavy rainstorm, the ground can become too wet to absorb any additional water. The result is that the water is forced to run off on the surface, gathering dust, dirt, rocks, and in some cases, even boulders as it builds up. The leading edge of a flow gathers the most debris, causing it to be thicker and slower moving. This acts as a slow-moving dam. Eventually, such as in a wide area on a slope, the more liquid mud from behind breaks through the dam and rushes outward creating a muddy plain.

d. **Creeps**. The slowest type of mass wasting is referred to by geologists as a creep. The grass-covered slope seems to ooze downhill forming little bulges in the soil. This heaving of the soil occurs in regions subjected to freeze-thaw conditions. The freeze lifts particles of soil and rocks (because water expands when it freezes) and when there is a thaw, the particles are set back down, but not in the same place as before. Gravity always causes the rocks and soil to settle just a little farther downslope than where they started from. This is the slow movement that defines creep. Creep can also be seen in areas that experience a constant alternation of wetting and drying periods, which work in the same way as the freeze/thaw. Since the process is so slow, it can only be monitored in terms of flow over long periods of time. A creep takes place when the entire side of a hill or mountain moves downward under the weight of gravity, very slowly, usually much less than one inch per year. The rate of creep depends on the steepness of the slope, slope material and water absorption properties, and amount of vegetation. (Source: http://earthsci.org/flooding/unit3/u3-03-03.html) Site inactive.



Soil creep causes districtive curved form of tree trunks over time.

Illustration 5:
Indications of Soil Creep

: http://www.ecy.wa.gov/programs/sea/pubs/93-31/chap2.html

Erosion due to water

Many types of erosion described above are, at the core, caused by how water interacts with land causing the land to move. Here are ways water more directly moves soil and rocks.

a. Rain. As rain drops begin falling in a rain storm, they are first absorbed by the landscape. As the ground becomes saturated, the drops begin moving across the landscape above the surface. As this happens, small amounts of dust and dirt are carried with the water. This is known as splash erosion. As more and more water falls, the sheet of moving water becomes larger and larger. Large amounts of rain that cannot be absorbed into the ground either because the ground is supersaturated from prior rains or the land has been altered by pavement or deforestation, this rainwater carrying particles of silt and sediment runs off downhill into streams and rivers.

b. Streams & Rivers. Because of their strength, streams and rivers can cause a great amount of erosion. Dirt and dust is carried away in the water of the river, leaving only pebbles and rocks. The rocks are constantly smacking into one another, as the force of the river moves them about. This causes them to be continually breaking into smaller and smaller pieces. Rivers have been known to carve deep canyons in the bedrock in only a few hundred thousand years (e.g. the Grand Canyon). As rivers carry dust, pebbles, and rocks downstream, this material is eventually deposited at some location further down. These deposits form at bends in a river, as well as in locations where rivers dump water into lakes, seas, and oceans. The effect of deposits is that new land is created using materials from other locations upstream.

Land use, infiltration, and runoff

Information taken from: http://omp.gso.uri.edu/ompweb/doee/teacher/pdf/act10.pdf

(site no longer exists)

Changes in how we use and change the land affects our watersheds. Water may flow in a different direction, more water reaches the rivers, lakes, and oceans, and the water gets to these bodies of water faster without sediments and pollutants being removed by slow infiltration into the soil. The amount of nutrients, sediments, and toxic materials from increased runoff and soil erosion can seriously harm ponds, streams, and groundwater resources. Infiltration is when water seeps into the soil and rock and recharges an aquifer. Currently, aquifers are being depleted due to the huge water demand of American industries, farms, and families.

Forests have less runoff because leaves and trees slow down the rain before it hits the ground, giving plant roots time to absorb water and time for the water to soak into the earth. When land is paved or cleared for buildings, the vegetation is removed and the land is covered by blacktop or concrete. There is no longer any vegetation to slow down the rain hitting the ground and since the ground is covered, no water can soak into the soil. Instead, the water runs over the surface, often causing flooding and erosion. Our aquifers are also not being recharged with surface water as fast as they used to be.

Rates of infiltration for various land uses

<-Greatest--Smallest->

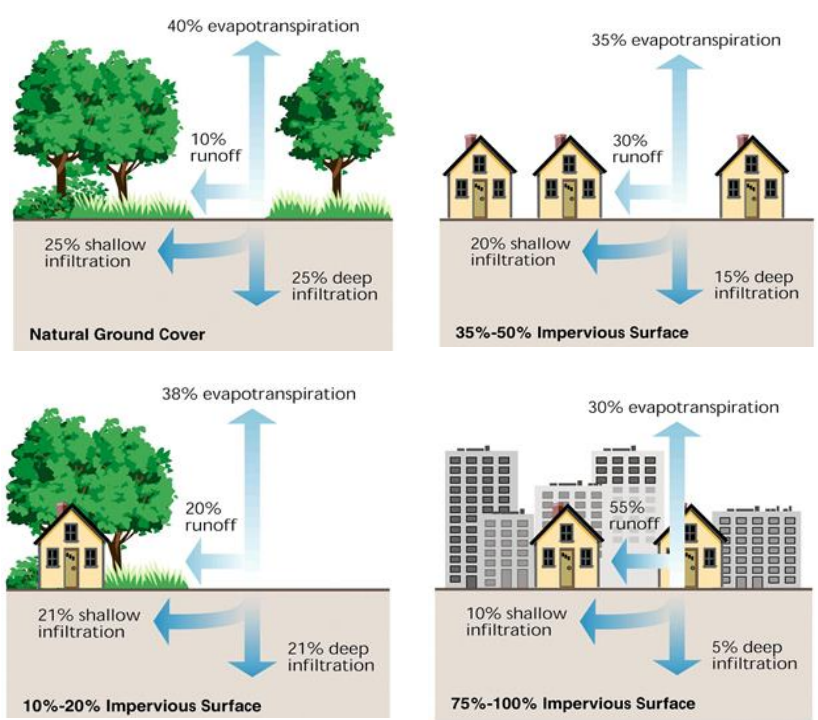
forest > pasture > crop land > bare earth > buildings > pavement

Rates of runoff for various land uses

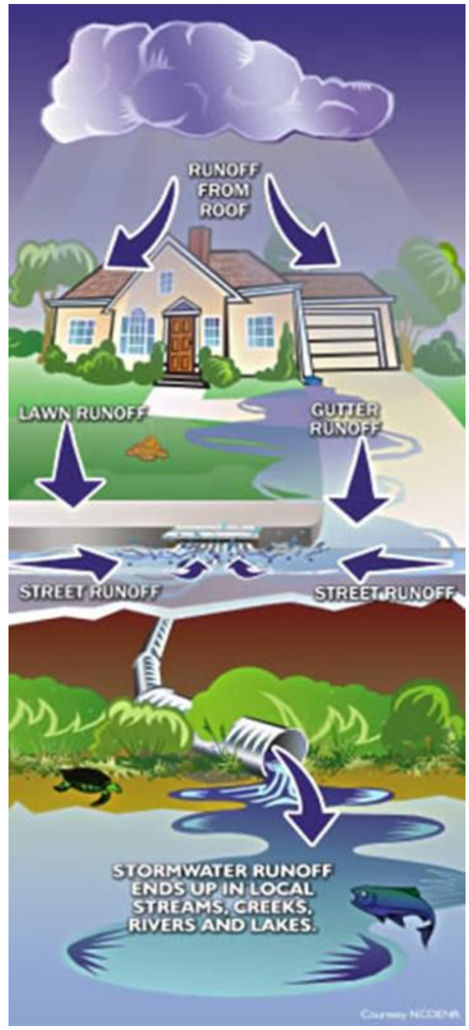
<-Greatest--Smallest->

pavement > buildings > bare earth > crop land > pasture > forest

Figure 1: U.S. Environmental Protection Agency



Stormwater Runoff



Stormwater runoff is water from rain or melting snow that "runs off" across the land instead of seeping into the ground. In build/developed areas, the water that falls on hard surfaces like roofs, driveways, parking lots, or roads cannot absorb into the ground. These "impervious surfaces" create large amounts of runoff that can cause problems both locally and where it ends up. The runoff flows from gutters and storm drains to streams (and other bodies of water), sometimes causing flooding and erosion of stream banks, which can make the stream banks and areas around the stream unstable. Unstable streams can be problematic for the animals that depend on the stream for habitat, as well as humans that live near or depend on the stream. Flooding of streams and other bodies of water may also damage property and be dangerous to people.

Cities often control stormwater runoff by channeling stormwater through pipes. In most cities, stormwater runoff goes into storm drains, through pipes and into a nearby body of water (see graphic on right), eventually ending up in Puget Sound. The stormwater does not get treated before entering waterways. Often, stormwater goes into larger underground vaults or above ground "catch basins" that can collect trash and leaves before going into a body of water, and in some places, runoff goes into detention ponds to then be slowly released to prevent flooding.

Polluted stormwater runoff is a major concern for our region, and the number one source of pollution of Puget Sound (source: https://ecology.wa.gov/Water-Shorelines/Puget-Sound/Issues-problems/Toxic-chemicals). Stormwater runoff in urban settings picks up pollution, such as chemicals, bacteria, sediment, tire and brake dust, and trash, and washes these things into ditches and storm drains, and then into creeks, rivers, ponds, and lakes. Much of the "behavior change" efforts of cities and other agencies and organizations is aimed at decreasing the amount of pollutants that enter stormwater runoff by encouraging people to pick up dog waste, wash cars at carwashes instead of on driveways, and use fewer chemical yard care products.

While most regional efforts involve BOTH reducing the amount of stormwater runoff and the pollutants in the stormwater runoff, the focus of this unit is on the amount. This helps keep the focus on things the students can easily see and measure, and addresses fourth grade NGSS Earth Science standards. Reducing the amount of stormwater runoff helps with pollution concerns; pollution will likely come up in discussions, it just may not be among the students' criteria for success.

Stormwater Runoff Solutions

Larger scale solutions to problems associated with stormwater (beyond behavior change) often fall under what is termed "green stormwater infrastructure" (GSI) or more generally "low impact development" (LID). GSI involves some degree of engineering to address stormwater issues in ways that utilize nature (soils, vegetation) and natural processes. "Gray stormwater solutions" that do not utilize nature are also an option to solve stormwater problems. According to the Environmental Protection Agency, “green infrastructure reduces and treats stormwater at its source while delivering environmental, social, and economic benefits” (https://www.epa.gov/green-infrastructure/what-green-infrastructure). Treating water “at its source” involves features that slow down stormwater and spread it out to allow it to soak into the ground.

Low-impact development (LID) is a stormwater and land use management strategy that strives to mimic pre-disturbance hydrologic processes of infiltration, filtration, storage, evaporation, and transpiration by emphasizing conservation, use of on-site natural features, site planning, and distributed stormwater management practices that are integrated into a project design.

Stormwater “solutions” shared in this curriculum:

- rain gardens
- soil improvements such as mulch and incorporating compost
- bioretention (includes bioswales)
- tree planting
- pervious surfaces (also called permeable pavement, or permeable surfaces)
- rainwater collection (specifically, rain barrels and cisterns).

Climate Change and Stormwater

As the intensity and frequency of storms increases in the northwest due to climate change, so does the need for solutions to prevent flooding and other stormwater runoff problems.

Climate change in the Pacific Northwest leads to wetter fall/winter seasons and drier spring/summer seasons; therefore, more water needs to be absorbed into the ground (especially in cities) in winter so it doesn't cause flooding. This increases the need for GSI and fewer impervious surfaces.

Search your city’s or county’s websites for more information on their plans for managing stormwater.

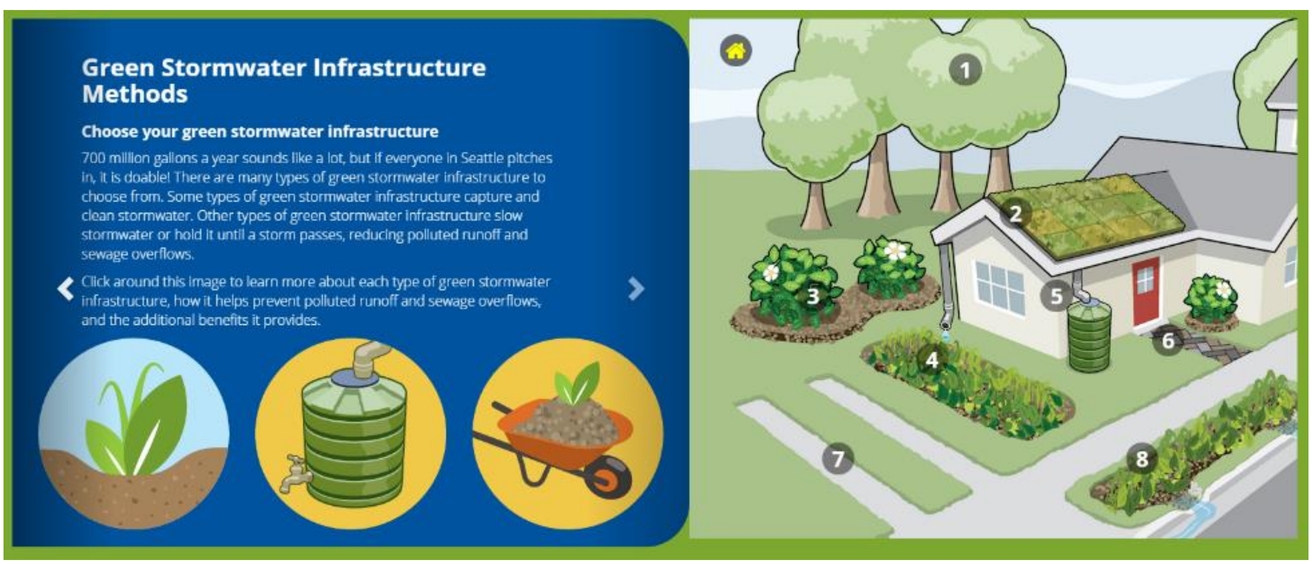


Figure 3: Image from ***[http://www.700milliongallons.org/types-of-gsi/; image no longer available on website.](http://www.700milliongallons.org/types-of-gsi/)***

As stormwater runoff becomes increasingly understood by scientists (for example, that polluted runoff has deadly effects on salmon) and green stormwater infrastructure is developed to manage runoff in our cities, education is needed for adults and youth to better understand the challenges and solutions. In schools around the country, especially in urban areas, stormwater is a "hot topic." Students in many places are not only learning about stormwater, pervious and impervious surfaces, and green infrastructure, they are also seeing and helping with stormwater projects in their schoolyards.

Involving students in green stormwater infrastructure (GSI) projects at schools has many benefits beyond the ecological value that these projects provide. These projects can serve as models for other schools, school districts, and government agencies. Stormwater solutions that are at least partially engineered (designed) and/or implemented by students have a variety of benefits, such as:

- school beautification and creating habitat and outdoor learning spaces
- empowerment in learning through relevant, hands-on team-based projects
- skill-building and career development
- experiential learning in STEM (specifically engineering)
- fostering engaged, knowledgeable citizen stewards.

See also:
Video from "Engineering is Elementary": "Engineering Everywhere Special Report: Runoff" on stormwater engineering solutions: https://www.youtube.com/watch?v=3zmp4UXomaU
12,000 Rain Gardens site about rain gardens in our region: http://www.12000raingardens.org/
Orcas Love Raingardens project at Tacoma schools: http://orcasloveraingardens.org/
Green infrastructure projects with other strategies like depaving: http://www.soundimpacts.org/en/

Please refer to your School Guide for more details about where **your** stormwater goes!

Strategies for Outside Learning

Outside spaces provide tremendous learning opportunities but can also present challenges that are very different from teaching in a classroom. This section includes things for a classroom teacher to think about both before and during the students' outside learning experience.

Setting Yourself up for Success

Planning

- **Scout the Site:** Any safety issues? What will your student boundaries be if you are letting them wander? What are potential distractions for the students? When is recess happening and can you avoid that time period? Do you need to plan for any mobility or other accessibility needs?
- Set aside time the day before and just before you head out to prepare the students for the experience. Which portions of your lesson need to happen outside? Are there things you could do in the classroom before or after the outside time?
- Create a detailed schedule that includes time for students to use bathrooms and to walk to the location.
- Check the weather report and make a contingency plan for inclement weather.
- If the field study requires finding specific organisms, consider having pictures or pre-collecting organisms to be sure to have some on hand.
- Divide students into groups that will work well together. Do you have any students that need a specific job to keep them focused?
- If you are leaving the school grounds, get permission and permission slips for a walking field trip.

Arranging for Support

- Arrange for at least one Chaperone to be with you outside (3-5 is better). If parents aren't available, can your principal, student teachers, or other school staff assist?
- If you have students with special needs, will they need their own assistant?
- Assign a chaperone to bring up the rear of the group.
- Make sure the office knows where you will be.

MATERIALS

- ❑ Whistle, megaphone or other noise maker
- ❑ Plastic sheet protectors for your notes
- ❑ Student Writing Surfaces (Clipboards or cardboard with binder clips)
- ❑ Teacher Writing Surface (Clipboard & a mini white-erase board)
- ❑ Extra pencils
- ❑ First Aid Kit
- ❑ Overhead sheets or sheet protectors can be clipped on top of student work to shed water on a drizzly day.
- ❑ Back up rain gear: Borrow items from your school's lost and found? Garbage bags with head and arm holes can also function as ponchos in a pinch.

Preparing Students

Most students think outside means recess-time and all students find more to distract them when outside. You can overcome this by setting up an expectation for learning and front loading as much as possible in the classroom before you head out.

1. Remind students the day before to bring rain gear and seasonally appropriate clothing.
2. Make it clear students will be outside for learning, not recess. Some teachers leave the building through a "science door" that is different than the door students use for recess.
3. Create and practice ground rules for going outside including an attention signal. A loud call-back is helpful amidst outside distractions.
4. Explain the outside plan in detail. Are there things you can practice inside?
5. If you anticipate distractions (like a recess or construction), prep the students to ignore them.

Outside with Students

During Talk Time

- Gather students in a circle for group sharing.
- Sit students down (if dry) to focus them on you.
- Review what you went over inside including expectations and what they will be doing.
- Put the sun in your eyes to keep it out of the student's eyes.
- Establish student boundaries (trees, sidewalks, fences, and posts all make good edges).

Adapting to the situation

- **Animals** are exciting! Let students focus on them and then segue back to the lesson.
- **Weather**'s impact depends on the students, amount of rain, and temperature. Can the students keep going? Do they need temporary shelter? Are you going to need to reschedule?
- **Lawnmower** noise can be overwhelming: relocate temporarily or provide open exploration time and then continue once it has moved away.

Adapting to the students

- High energy students might benefit from running to a location and back.
- Moving students might be focused by sitting down.
- Shade, shelter, and location can all be changed to meet student needs.

STUDENT BARRIERS

Student's outside experiences vary, and concerns interfere with their involvement:

- Modeling your comfort and excitement helps!
- Students could sit on plastic squares or garbage bags.
- Avoiding muddy areas can help with shoes.
- Garden kneel pads are great if you want the students to kneel on the ground.
- Check the ground for moisture, mud, and animal scat before asking students to sit.
- Gloves, plastic spoons, and/or yogurt lids are helpful for those who are worried about touching things.

Unit Vocabulary

Vocabulary in this list is called out as “new terms” listed in each lesson. We have **translated most of these terms** into six languages (Amharic, Arabic, Chinese, Somali, Spanish, Tagalog, Tigrinya and Vietnamese). They are available at https://communitywaters.org/translations/. There are also printable **“Word Wall” cards** available in the curriculum section of the website.

Stormwater Terms

Erosion:	When rocks and soil are picked up and moved to a different place by ice, water, wind, or gravity.
Groundwater:	Water that is in the soil, in the spaces between soil particles.
Impervious surface:	A hard surface that does not allow water to pass through or into the ground.
Pervious surface:	A surface that allows water to pass through or absorb into the ground.
Pollution:	The presence or introduction of a harmful substance into the environment (excess of a non-harmful substance can also become harmful; for example: too much noise = noise pollution).
Runoff:	Water that is not absorbed into the ground, and instead runs off the ground (usually off impervious surfaces) and into storm drains or bodies of water.
Slope:	Slope is a measure of steepness. (Water moves quickly down a hill with a steep slope and might form puddles if there isn't a slope.)
Soil:	Soil is a mix of minerals, water, air, organic matter, and micro-organisms. Often, soil includes various amounts of sand, rock, clay, and humus (or broken-down plant material).
Storm drain:	A drain that carries away excess water from a street, parking lot, or other surface during times of heavy rain.
Stormwater:	Water that falls onto the ground in significant amounts. Usually from heavy rain or melting snow.
Urban:	Having to do with a city or town.

Engineering Terms

Constraints:	Limitations on possible solutions, including cost, materials, and time.
Criteria for success:	Requirements that a solution must meet to be successful.
Engineer:	Somebody who solves problems using science and an engineering design process.
Engineering Design Process:	A series of steps to follow to solve a problem.
Failure point:	A part of a system that will cause it to stop working if it fails. Finding a failure point in a solution permits changes to improve the solution.
Optimize:	Testing solutions to make a solution as effective as possible in meeting the criteria and constraints.
Problem:	What we are trying to fix or develop a solution for.
Solution:	Something that meets a problem's criteria for success and stays within its constraints.
Stakeholder:	People (or other beings, like salmon!) who care about a problem and/or would be affected by its solution.

Other Science Terms

Changed Variable:	Factor that is intentionally changed during an experiment to affect the outcome (also called an "independent variable").
Controlled Variable:	Factors that are kept the same each time an experiment is run.
Fair Test:	An experiment with one changed variable and all other variables controlled.
Measured Variable:	Factor that is measured to determine the outcome of the experiment (also called a "dependent variable").
Model:	a dynamic representation of an event, system, or process; models can be diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. (source: NSTA)
Variable:	Factor that can affect the outcome of an experiment.

Unit Storyline

Phenomenon: Stormwater flooding in the city. What causes the flooding? What problems does the flooding cause?

Lesson *Focus Question*	Overview	**Page** Time	What should students be able to explain?	How does this add to their explanatory model?
Pre-unit **Take-home Interview**	Students interview a family member or other adult in their community about their experiences with rain/stormwater.	**p. 37** 30 min At home	• Experiences that their family member(s) have had with rain	• This activity surfaces student and family funds of knowledge and prior experiences that may appear on the explanatory model.
1: Flooding in Our Community *"Why does flooding happen in our community?"*	Students watch a video about flooding in their region and flesh out their understanding of what is going on.	**p. 41** 60 min	• Their current understanding of stormwater and why they think it might form a puddle in a parking lot (the explanatory model).	• Students fill in the explanatory model with their initial explanation.
2a: Investigating Effects of Stormwater **&** **2b: Analyzing and Interpreting our Data** *"What happens when rain falls on our schoolyard?"*	Students conduct an investigation of the school grounds, then analyze and interpret their data, to figure out where the (storm)water goes and find evidence of erosion.	**p. 53** **2a:** Part I – 15 m Part II – 45 m Part III – 45 m **2b:** 30 m	• Water moves through the schoolyard. • Water flows across impervious surfaces and soaks into pervious surfaces. • Rain can cause erosion by picking up soil and moving it to a new place. • Stormwater causes local problems, including erosion. • Plants slow down and soak up water.	• The flooding water was coming from somewhere. • Some water soaks into and moves through the soil. • Water flowed to the flooding area from the rooftops, sidewalks, and/or parking lot. • Impervious surfaces are the likely cause of the flooding • Plant roots help hold onto soil
3: Local Stormwater Systems *"Where does our stormwater runoff go and what problems does it cause?"*	Students analyze maps to determine where their stormwater goes and watch a video about the problems it causes.	**p. 77** 60 min	• There is a stormwater pipe (or ditch) system that carries the water away from our area. • Stormwater that leaves our site can cause problems where it ends up.	• Stormwater pipes could be drawn in underground sections in the model. • Water is affecting areas outside of where we are modeling.

Optional take-home: Stormwater in our Community *"What happens to stormwater in our neighborhood?"*	Students investigate what happens to stormwater in their neighborhood either on a walking field trip or with a take home assignment.	**p. 85** at home optional	• All the things we have been studying that happen with stormwater in our schoolyard also happen in our neighborhood. • Various features in our community affect how stormwater moves and/or soaks in.	• Stormwater flows through other areas beyond the school grounds. • Storm drains and other features could be added to the model.
Assessment of Understanding	A new copy of the Explanatory Model from Lesson 1 is used to assess student understanding of urban stormwater runoff.	**p. 97** 30-45 m	• How their understanding of stormwater runoff has changed over time.	• n/a

Engineering Challenge: Too much stormwater runoff is causing problems at our site and where it ends up (in the Puget Sound). What is the best solution?

Lesson *Focus Question*	**Overview**	**Page** Time	**What should students be able to explain?**	**How does this help solve the problem?**
4: Choosing A Problem Site *"Where do we want to solve a stormwater runoff problem?"*	The class chooses a local site with a stormwater problem and explains what is happening through a model.	**p. 105** 60 min	• Why the class chose the spot and what problems stormwater causes there. • What is happening with stormwater at their site.	Students understand what is causing the problem they are trying to solve. ***Engineers use science to understand*** *the problems they are trying to solve.*
5: Defining our Problem *"What do we need to know before we research solutions for our site?"*	Students define the criteria for success and constraints on possible solutions for their problem.	**p. 113** 60 min	• The Engineering Design Process and how it applies to solving their problem. • Why their criteria for success are important and what constraints will limit their possible solutions.	The criteria and constraints will be used to choose among possible solutions for their problem. ***Engineers define the problem*** *they are trying to solve.*
6: Modeling the Site *"How do we best model stormwater at our site?"*	Students build a model of their site on their existing models, and class runs a baseline test for later comparison.	**p. 123** 60 min	• How the model represents their site. • Improvements they made to their model to better represent their site. • Ways in which the model does not represent their site.	Creates baseline data they can use later when optimizing their solution. ***Engineers use models*** *as a part of their work.*

(continued on next page)

7: Researching & Evaluating Solutions *"Which solution will best meet our criteria and constraints?*	Students brainstorm and research possible stormwater runoff solutions, then evaluate the solutions to decide which one to test.	**p. 133** 60 min *(ELA option)*	• The advantages and disadvantages of each solution they research. • Why the solution they chose best fits their criteria for success and constraints. • Which solution they are going to test.	Students research possible solutions and choose a solution to test. ***Engineers research possibilities*** *as a part of developing a solution.*
8: Modeling Solutions *"How do we model our solution?"*	Students add their solution to the model of their site and add some water to it.	**p. 145** 60 min+	• How the model represents their solution. • That testing a solution can be used to improve it and to compare it to other ideas.	It will provide a model they can test. ***Engineers test their solutions*** *both to help choose one and to optimize the one they choose.*
9: Testing Solutions *"How can we improve our solution?"*	Students adjust their solution model and tests impact on stormwater runoff.	**p.153** 60 min	• Why any adjustments were made to their model. • The variables they controlled and measured. • How well their solution worked.	The data can be used to improve their solution. ***Engineers test their solutions***
10: Comparing Solutions *How effective is the solution my group modeled?*	Students revise and refine their solution and analyze how effective it is.	**p.161** 60 min	• Whether the testing was a "fair test." • Whether their solution meets the criteria and constraints for their site.	Students decide whether their solution would work ***Engineers use data to evaluate their solutions.***
11: Communicating Our Results *"How will we share what we have learned with others?"*	Students communicate about their solutions to peers and/or stakeholders.	**p.171** 60 min+	• Whether their solution is a good choice and their evidence for their claim.	Ideas need to be shared by students *and* ***Engineers*** if they are going to be put into action.
End-of-Unit Assessment: Take-Home Interview & 3D Summative Assessment	Final opportunities for students to demonstrate their learning.	**p.179** 45 min	Summative assessment focuses on Engineering Design standard (ETS1-2) and 4-ESS3-2.	n/a

Planning and Support

Unit Support

All digital materials and additional supports can be found on communitywaters.org.

Among other things, these include:

- Links, Powerpoints, and handouts for each lesson.
- School-specific Guides and information about how to schedule a planning session at your school and/or support with a field investigation in your neighborhood.
- Short training videos focused on materials set up and for specific lessons.
- Translations of many of the student worksheets into Amharic, Arabic, Chinese, Somali, Spanish, Tagalog, Tigrinya and Vietnamese.
- Additional resources, contacts for field trips and curriculum extensions including ideas towards implementing a project with your students.

Stakeholders in Your Community

This unit is greatly enhanced by connecting with local experts and stakeholders. Which groups or individuals do work related to stormwater or water systems in your area? Are there people you know of that have experienced flooding first-hand? Who might be affected by flooding and polluted water in your community? Early in this unit, begin reaching out to people or groups that might be good guest speakers or people to talk to when students are asked to consider the perspectives of stakeholders later in the unit (lesson 5).

- Some ideas: local water utility, Puget Sound stewardship groups, engineering companies that build stormwater infrastructure, land, water or salmon stewardship groups.
- For specific ideas, please see your School Guide.

Timing & Checklists

Unit Planning:

- ✓ See the Unit Storyline (above) for an outline of all lessons in the unit. This unit includes 11 lessons requiring 30 to 60-minute sessions, plus a mid- and end-of unit assessment and a couple of take-home options.
- ✓ Send home the take-home interview several days in advance of Lesson 1 if possible.
- ✓ Prepare models at least 3 days before Lesson 6.

If Receiving IslandWood Support, go to **Teacher Support** section on communitywaters.org to schedule:

- ❑ **Planning Session** with IslandWood at your school to occur before you start the unit (or at least ahead of doing the schoolyard investigation in Lesson 2).
- ❑ **Schoolyard Investigation –** The outdoor investigation in lesson 2 can be led by an IslandWood educator.
- ❑ Be sure to reply to any emails from IslandWood to confirm your dates!

Arrange Chaperones and/or extra help

- ❑ At least one chaperone (2 or more is best!) for when you take students outside on to the school grounds.
- ❑ If you have them, volunteers can also assist with materials management (see below) and when students are working on their site and solution models.

Other Communications:

- ❑ Arrange for stakeholders to interview or experts to consult with if you want to do so as a class when defining the problem in Lesson 8 and/or presenting your solutions in Lesson 15.
- ❑ Prepare to send home the Take Home Interview for students to do with an adult before Lesson 1 and at the end of the unit.

Materials and Set-up

(see also Materials section in each lesson)

Printed or other Items	Amount	Purpose
Butcher/chart paper		To create class Summary Table, Data Tables, etc.
Clipboards or hard surface to write on	1 per student	For outdoor investigations with students
Colored pencils and/or markers		For explanatory model drawing (optional) and share-out projects
Paper towels and/or rags		Clean-up
Miscellaneous materials (for example, milk cartons, math manipulatives, etc.**)**		modeling solutions
Student Packet with worksheets **<u>And</u>** **Explanatory model 11x17" paper (2 double-sided)**	1 per student	This contains all student worksheets and is available to order from TPS Printing Dept. Worksheets are also included in this Teacher Manual with their associated lesson.
School Guide PPT (for TEACHER)		Supports lessons with school-specific details
Word Wall cards	1 per class	Vocabulary visuals

Item in Kit	Amount	Purpose
Absorbent pads, large (1 sheet = 2 pieces)	7-8 sheets / 32 sections	protect desks and floor during modeling
Aluminum foil	1 (full roll)	create "impervious surfaces"
Container, gray, plastic, .5 gal	8	collect water from model
Bottle, spray	1	mist/water seeds
Crafts sticks	1 package	site and solutions models
Cup, Graduated, Plastic, 1 oz	8	rain barrel model
Cup, Plastic, 9 oz	8	collect water from model
Cylinder, Graduated w/base, 100 mL	8	collect water from model
Masking Tape	1 roll	mark edge of land block, group # on model, cover drain hole if missing stopper
Measuring Cup, 1 L	1	Measure soil into models, measure water
Plastic "Rain Jar" with lid (w/ 1/8th" holes)	8	"rain" on models
Potting soil (for "solutions") – optional	~32 oz	use in solutions modeling
Rubber stoppers, (size 000)	8	for tray models
Rulers (wood or plastic)	8	measure depth and size of earth mix in tray
Seed, Radish and grass mix	20 mL x 8	growing on some models
Soil mix - sand, gravel, potting soil*	2.5L x 8	model earth in trays
Sponge pieces	16-20	model pervious surfaces (trees, rain garden, etc.)

Spoons, metal	8	stir/move soil in tray
Toothpicks	1 pkg	use in solutions modeling
Tray (black, plastic) w/drain hole	8	hold earth mix/models
Trowel	1	distribute earth mix into trays
Wood angles	8	prop up end of tray to create slope

Model Preparation – do before Lesson 6

Physical models will be used by students in the later part of the unit to practice engineering design. Students build a model of the site that they are focused on, then build and test solutions to help with the runoff problem there.

The models can be set up without help, but parent or student volunteers might make the job easier. If you decide to set up with students, we suggest doing the first two steps ahead of time and using the provided student-friendly instruction sheet.

Student Groups

Students will work in small groups with their models. The unit is designed to work with 7 small groups (later called "engineering teams") of 4-5 students per group. The materials have been calculated for 7 groups PLUS one model for the teacher.

- **Video:** watch the "Setting up your Stormwater Tubs" video (on communitywaters.org under Teacher Supports) if you want a visual walk through of the setup (described below). (***Please note:*** *the materials used in Tacoma are slightly different than what is shown in the video, but the process is the same*).
- **Don't want to grow plants in the models?** If you have access to grass you can remove, we encourage you to dig up sections instead of growing plants. When you dig up the grass, remove as much of the dirt from the roots as you can so the clumps don't break loose during the Lesson 4 investigation. Don't forget to use the spray bottle to water the grass frequently after you add it to the models!
- **No Sinks?** If you are in a portable or classroom without sinks, materials management is more challenging. Some things that can help:
    - A large container that can hold and dispense water.
    - A big tub to rinse off materials in.
    - Extra towels and hand wipes for cleaning up.
    - Planning enough time to take the class to the bathrooms for handwashing.

Materials Cleaning

It is important to keep sand and gravel out of classrooms sinks so they don't get clogged. Outside hose spigots are great, but otherwise, rinse materials into a larger bucket to empty outside.

At the end of the unit, dispose of soil mix by dispersing it under bushes and/or under wood chips, not in grass as that can interfere with lawnmowers.

PROCEDURE FOR SETTING UP MODELS

Materials For Stormwater Models

- 8 black trays with drain holes
- 8 rubber stoppers
- 8 “Rain Jars” with holes in lids
- Masking tape & Sharpie
- Ruler
- Soil Mix
- Measuring cup
- Water (200ml per model)
- Trowel(s)

1. **Set Up a Materials Area:**

   Prepare a materials distribution table or countertop area where students can store and access materials throughout the unit.

   If you plan to have students set up the models, see “Student Directions for Model Set Up” next page, otherwise, proceed as follows:

2. **Mark where soil and water will go:**
   - In **ALL** trays, measure 15 inches or 38 centimeters from the side that does not have a hole. Mark that distance on both sides of the tray with masking tape.
   - On the outside of the 8 containers with holes in lids (“Rain Jars”), **make a line at 500mL** or halfway; 1000 ml (1 liter) is when it is filled to the top.

3. **Add Soil to trays** - Into **ALL trays (mix in each tray)**:
   - Put a rubber stopper into the hole (from the inside).
   - Use measuring cup to measure and add ~90 oz or 2.5 liters of pre-mixed soil into EACH tray. The soil is a mix of approximately 32 oz sand, 24 oz small-medium gravel and 24 oz humus or potting soil per model. DO NOT COMPACT SOIL MIX when measuring.
   - Add ~200 mL of water to each tray.
   - Mix soil and water together with trowel.
   - Shape the soil in each tray into a block of “land” between the line you made and the side with no drain hole. This block should be 15 inches/38 cm long & 1-2 inches deep). The land blocks should have a square cliff-like edge.

Drain hole

Student Directions for Model Set Up

Soil in Trays

1. Use a ruler to measure 38 centimeters (cm) from the short side of the tray that does NOT have a hole.
2. Mark that 38 cm with a piece of tape.
3. Put a small rubber stopper in each tray's hole (from the inside).
4. Use the measuring cup to measure and add **2.5 Liters of soil and 200 mL of water in tray. Do not push down on the soil when measuring.**
5. Mix the soil and water together in the tray.
6. Move all the soil in each tray away from the hole so it is past the mark on the sides of your tray. Shape it into a block with a smooth top and a cliff-like edge.

Tray with soil and tape that marks 38 cm (centimeters) from the back.

Lesson Details

Pre-unit / Lesson 0: Take Home Assignment

OVERVIEW

This "lesson" is an opportunity to connect the unit phenomenon and concepts with experiences of families and students through a home interview. It is important to send this home ahead of time so students have time to complete it with an adult. If a family member is not available, the student could interview another older person in their community.

Take-Home Assignment: Students interview a family or adult community member about personal and cultural experiences with stormwater.

Focus Question: What experiences have others in your community had with water?

New Terms: stormwater

MATERIALS

Website

communitywaters.org

For each lesson in this curriculum all worksheets, links, and graphics can be found on the communitywaters.org website. *There is a separate webpage for each lesson in the curriculum. Find them under the "Lesson Specific Materials" menu choice at the top of each page.*

Print for each student:

- **Pre-Unit Take Home Interview** worksheet – one per student (there are Amharic, Arabic, Chinese, Somali, Spanish, Tagalog, Tigrinya and Vietnamese versions available on communitywaters.org).

PREPARATION – 10 minutes

TEACHER DECISION POINTS

This symbol will be used throughout the curriculum when there are options for you to consider as a teacher.

- **IMPORTANT NOTE:** Please review the **Planning and Support AND Materials and Set-up** sections of manual. You will find directions for signing up for IslandWood support, checklists to help you anticipate upcoming needs, and directions for the setting up of stormwater models and planting of seeds. (These things are not included in the preparation time listed for this lesson).
- Review the **Pre-Unit Take Home Interview** (designed for students to ask questions of an adult in their home or community). Decide if you want to dedicate any classroom time to have students practice it with each other and how much time you can give students to bring it back before you start teaching the unit.

- Determine if you'll want to send translated versions home with students, and/or if you need to make your own edits to the document to make it more relevant to your students.
- ALTERNATELY, decide if you want to provide the option for students to video or record the interview and submit in an alternate format, for example via Flipgrid or Schoology or another platform your class uses.

PROCEDURE

Engage and Encounter

This unit is all about "stormwater runoff" in our city. "Stormwater" is water that falls onto the ground as rain or snow. "Runoff" is water that travels across the surface of the land (not soaking in).

During this unit, the students will be examining the problems caused by too much stormwater runoff in their city, neighborhood, and schoolyard. Once they understand what causes the problems and what helps solve them, they will pick a specific problem site in their schoolyard or neighborhood and design a solution for it.

The students will have an opportunity to go outside to investigate what happens with stormwater, work with models with soil in them to build an understanding of what is happening and create (and improve) their own models for solutions they come up with.

For this Take-home Interview, students will talk to an adult, fill out the worksheet with them, and bring it back. Read through instructions and help with vocabulary as needed.

EXAMINING STUDENT WORK

Review returned Take Home Interviews: Consider what you learn about your students' and families' cultural and personal experiences with water.

- Is there anything you could tie into the unit to inform understandings or increase engagement?
- Are there students who have experienced flooding and may either WANT to share, or be uncomfortable due to a traumatic experience with flooding?
- Are there experts (via job or experience) that could speak to students?
- What commonalities surface from students?
- Do any students identify particular local problems with stormwater that you can reference?

Community Waters Pre-Unit Take Home Interview Date: ___________

Student's Name: _______________________ Adult's Name: _________________________

Interview an adult in your household to see what they know about stormwater in your neighborhood.

Student reads to adult and records answers:

At school we are going to be studying what happens to rain after it falls in our city. Rain water that flows across the ground is called "stormwater runoff." My class will be investigating where stormwater goes in our schoolyard and neighborhood and the problems it can cause. Then our class will be choosing a location with a stormwater runoff problem and designing a solution for it.

I want to learn more about your experience with rain <u>when you were my age</u>. Can I ask you some questions?

1. What did you like to do when it rained? Did you like the rain? Why?

2. Where did the stormwater runoff go where you lived? Where did it end up?

3. What is a story about the rain you experienced or were told when you were my age? Do you remember rain causing any problems?

4. Does our family or culture have any traditions or stories that connect to water?

After recording your adult's answers, flip the page over and have them ask you the questions on the back.

Adult asks student:

1. What do you like to do when it rains?

2. What have you noticed happen to rain on the ground?

3. Do you go outside when it rains during recess at school? Does the rain every cause any big puddles or other problems around your school?

4. How are my experiences with rain the same or different than yours? Why do you think so?

Lesson 1: Flooding in Our Community

OBJECTIVES & OVERVIEW

Students examine some of the effects of too much stormwater runoff in urban settings and apply prior knowledge towards developing an explanation of the phenomenon.

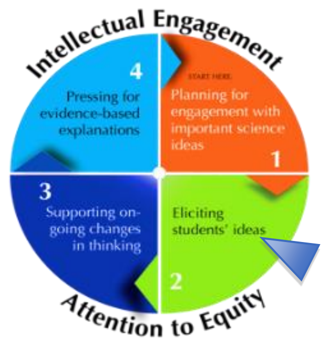
- Students will make and share observations about the effects of stormwater in an urban setting.
- Students will access prior knowledge to begin building an understanding of what is causing the stormwater runoff problem.

Focus Question: Why does flooding happen in our community?

Learning Target: I can create a model to share what I know about stormwater.

New Terms: stormwater, runoff

Ambitious Science Teaching: Eliciting students' ideas



Information gathered by eliciting all students' initial hypotheses about a scientific idea, and making a public record of these can inform instructional decisions for upcoming lessons. For more about this practice of eliciting students' ideas, visit http://AmbitiousScienceTeaching.org

NEXT GENERATION SCIENCE STANDARDS

The students will address these standards in more depth later:

PE 3-5-ETS1-1. <u>Define a simple design problem reflecting a need or a want</u> that includes specified criteria for success and constraints on materials, time, or cost.

PE 4-ESS3-2. Generate and compare multiple solutions to reduce the **<u>impacts of natural Earth processes on humans.</u>**

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
Asking Questions and Defining Problems. • Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. • Use prior knowledge to describe problems that can be solved.	**ESS3.B Natural Hazards.** • A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts. (4-ESS3-2) **ESS2.A Earth Materials and Systems.** • Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. (4-ESS2-1)	**Cause and Effect.** • Cause and effect relationships are routinely identified, tested, and used to explain change. (4-ESS3-2)

MATERIALS

For each lesson in this curriculum, all worksheets, links, and graphics can be found on the communitywaters.org website. *There is a separate webpage for each lesson in the curriculum. Find them under the "Lesson Specific Materials" menu choice at the top of each page.*

For the class:

- Butcher/chart paper for Hypotheses and Questions ("Public Records" named in lesson)
- Markers
- Word Wall cards

Per student:

- Copy of the **Explanatory Model Worksheet** on 11x17" paper; the larger paper will provide more space for student explanations and later additions. Ideally, you print the same worksheet on both sides of the paper so you can have them make a revised version after Lesson 6.
- Colored pencils (optional) for students to use on their explanatory model.

PREPARATION – 20 minutes

IMPORTANT
Have you set up the models?
Flooding trauma?

DECISION POINT

Which Explanatory Model is best for your class?

- Please review the **Planning and Support AND Materials and Set-up** sections of manual. You will find directions for signing up for IslandWood support, checklists to help you anticipate upcoming needs, and directions for the setting up of stormwater models and planting of seeds. (These things are not included in the preparation time listed for this lesson).
- **Flooding Sensitivity:** You may have students in your class that have experienced trauma related to flooding or landslides. It may be useful to review the video students will watch in lesson 1 and consider if students may find any of the footage concerning so that you can talk to the student ahead of time.
- **Decision Point:** Decide which version of the explanatory model you prefer for your class. In addition to the one provided at the end of this lesson, we have a version *without* any drawing/scaffolding. You can find all versions on communitywaters.org (in the Lesson 1 page from the "Lesson Specific Materials" menu option).
- **Video:** Queue up and test the phenomenon video (from communitywaters.org on the Lesson 1 page or at https://vimeo.com/644125228). If you feel it's appropriate, consider warning your students that they will be watching a video that includes flooding, but

Your Stormwater Problem

An option during Lesson 1 is to introduce students right away to the problem with stormwater they will address later in the unit. This can increase student buy-in to focus on the actual problem at or near their school, not just the general phenomenon of stormwater flooding.

Website

All worksheets, links, and graphics are on communitywaters.org

that no one was harmed in these situations, and that it is unsafe to walk or drive through flooding/high water.

- **Optional:** Later lessons ask for more preparation time – if you have time now you could create your summary table (PPT and Excel templates on website) (see Lesson 2 preparation).

PROCEDURE

Engage and Encounter

- **Introduction to Unit (whole class)**

  This unit is all about "stormwater runoff" in our city. "Stormwater" is water that falls onto the ground as rain or snow. "Runoff" is water that travels across the surface of the land (not soaking in).

  During this unit, the students will be examining the problems caused by too much stormwater runoff in their city, neighborhood, and schoolyard. Once they understand what causes the problems and what helps solve them, they will pick a specific problem site in their schoolyard or neighborhood and design a solution for it.

  The students will have an opportunity to go outside to investigate what happens with stormwater, work with models with soil in them to build an understanding of what is happening and create (and improve) their own models for solutions they come up with.

  When appropriate, introduce **Word Wall cards for stormwater and runoff**.

Turn-and-Talk

What have you observed after a big rainstorm?

- **Activate prior knowledge and experiences (whole class)**

  Ask the students to talk with a partner about what they have observed after a big rainstorm in their neighborhood or the schoolyard. "What have you noticed when it rains a lot around here?"

Video Clip

"Flooding in Tacoma"

- **Introduce and watch the video (whole class)**

  Tell students they are going to see a video showing some effects of too much stormwater runoff (and warn students that might be sensitive to flooding). While watching, they should be making observations: what problems are being caused in the video? What problems might be happening that we CAN'T see?

  Direct link: https://vimeo.com/644125228

Turn-and-Talk

What effects did you observe in the video?

- **Share observations about the problem (whole class)**

  Start with a turn-and-talk to have students share observations about what they saw and heard with a partner. Then have individuals share what they noticed with the whole class (as you write them down on the board).

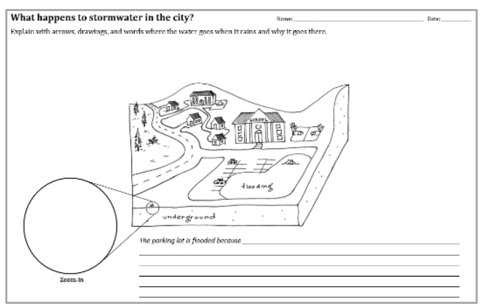
  Has anybody in the class experienced any of these things themselves?

Reflect and Explain

Present visual

- **Develop initial models to explain the phenomenon (individually)**

  To be able to solve flooding like what they saw in the video, students (and engineers) need to understand what is causing the problem. They need to understand how water flows through a city and what could increase or decrease the amount of flooding.



Project the "What happens to stormwater in the city?" model scaffold and explain the various pictures as needed for your class. Make sure students notice the hills and the flooding in the school's parking lot.

> **Intent of explanatory model**
>
> The explanatory model scaffold is intended to help students explain **their** understanding of stormwater. It is a working recording that they can add to or start over as the unit progresses and their understanding builds.
>
> It is important they have enough time working on this model to accurately represent their thinking.

Explanatory Model

Initial Explanation

Students will use arrows, drawings, and writing to explain what they think happens to the rainwater when it falls on the area shown. The "zoom in" can be used to show more detail or how something (like roots or soil parts) might be working.

This is to show THEIR understanding of what is happening; they won't be graded on how "right" or "wrong" it may be and will be able to change their understanding as they learn more during this unit.

Different colors of pencils could be used to show differences in their model.

Back-Pocket Questions

Observations & Modeling

These questions are provided for use with individuals or small groups while circulating

- **Pressing students for further explanation**

  As students work on their explanatory models, circulate and ask them neutral questions (without judgement or correction) about their thinking. How could they show their thoughts in a picture or words on their worksheet?

Back Pocket Questions

Observations

- What did you observe happening with the water in the video?
- What have you observed water doing when it rains around your neighborhood?
- You said you have seen water (insert student's observation). Why do you think it did that?

Modeling

- How can you show that on your model?
- How could you describe it in words on your model?

The YIELD symbol is used in this manual to suggest a spot you could stop for the day if you are out of time. We will leave it to you to reframe and review as needed when you return to the lesson later.

Explanatory Model

Gallery Walk

- **Pressing for possible explanations (whole class)**

Gallery Walk: Have students either place their models to be visible on their desks or tape them on the wall.

All students then circulate and look at each other's models. While circulating, they should be noticing what they see that is representing something they showed in their own model and what they see that is showing something different.

Public Record

List of Hypotheses

What hypotheses do students have about what kinds of things happen to stormwater in the city and why flooding occurs?

Discuss as a class and add ideas to the List of Hypotheses as you do so.

Apply and Extend

Public Record

List of Questions

- **Students generate questions (individuals)**

  On sticky notes, have students write at least one question they have about stormwater runoff in their community. Have students place the sticky notes on the Questions sheet.

  You can then either sort and consolidate them as a class, or after class for later reference.

EXAMINING STUDENT WORK

Review the **Explanatory Model Scaffolds** the students created. They are intended to help you see what your students do and do not know.

What understandings are students showing they already have?

Understandings desired:	How it might be shown by student	Lesson intended to help with this understanding
Water flows downhill	Arrows pointing downhill	Could be made explicit in many lessons
Water soaks into soil and moves through it.	Arrows or description of water "soaking in" or being "absorbed"	2a: Investigating Effect of Stormwater
Rainwater causes flooding	Arrows converging on parking lot or rain described as part of the problem	2a: Investigating Effect of Stormwater
Water moves across the surface of the land (runoff)	Arrows showing water movement	2a: Investigating Effect of Stormwater
Urban surfaces often prevent water from soaking in (impervious surfaces)	Listing concrete, rooftops or "impervious surfaces" as part of why the flooding might be happening	2a: Investigating Effect of Stormwater
Water can move soil and other things like pollutants (erosion).	Mentioning "erosion" or "pollution" as a part of the problem	2a: Investigating Effect of Stormwater & 3: Local Stormwater Systems
Plants reduce erosion and increase infiltration	Zoom out of plant roots or mention of water soaking in where plants are present	2a: Investigating Effect of Stormwater
Storm drains move water into pipes	Adding in storm drains or presenting a clogged drain as a possible part of the problem	3: Local Stormwater Systems
Water that goes into storm drains causes flooding and/or pollution problems elsewhere	Adding in stormwater pipes with a destination or a description in margin	3: Local Stormwater Systems

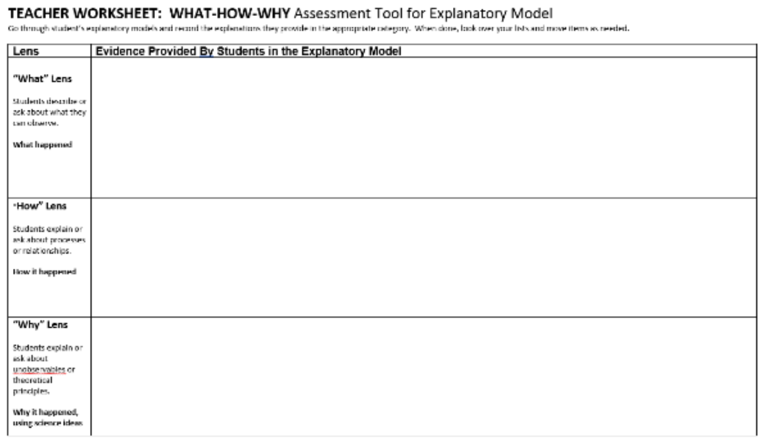
Are there alternative conceptions students have that you will want to make sure they think about further during the unit?

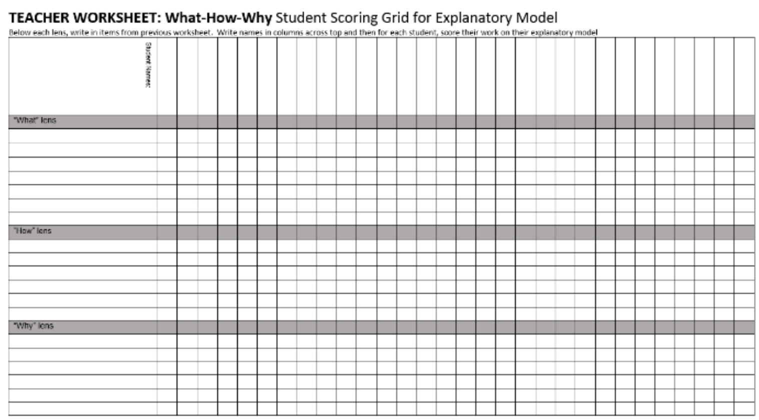
Common Alternative Conceptions	How it might be shown by student	Lesson intended to help revise this conception
The whole problem is too much rain	Describing only rain as the problem (not including mention of it not soaking in)	2a: Investigating Effect of Stormwater
We need more storm drains [this could solve flooding but does not address that storm drains cause other problems]	Listing lack of storm drain as the problem or adding storm drains into the picture without saying where they end up.	3: Local Stormwater Systems

We have also provided a “**What-How-Why Assessment Tool”** designed to help you look at each individual student’s thinking and track how it changes between Lesson 1 and Lesson 7 of the unit. You can download a PDF or spreadsheet from Communitywaters.org. We suggest legal paper if you print either document. Using the spreadsheet for the scoring grid will make it easier to add evidence and compare results when you use it again in Lesson 7. The spreadsheet also has a tab with examples on it.

Fill in the first part as you go through student work. Sort what you find into each row.

- **What** = objects that students label or descriptions of what is shown. Examples: “flooding here,” “rain,” “impervious surface,” or “tree.”





- **How** = when students are naming a process and/or explaining how something is happening. Examples: “Soaking In,” arrows showing movement of water, “Erosion here,” or “plugged storm drain causes flooding”
- **Why** = students incorporating scientific concepts that explain what is happening. Examples: Students drawing a Zoom-In that shows water moving between particles or being taken up by roots, writing “water flowing downhill,” “fast water is eroding here,” or “impervious surfaces won’t let water soak in.”

When done, revisit your sorting to see if any categories need to change, then transfer key points from each category onto the **What-How-Why Scoring Grid** (2nd page of teacher worksheet). Write student names across the top and revisit each student’s explanatory model to check the boxes for what each student has represented in their model. There may be student representations you will want to follow up on with students to see what they were thinking when they wrote or drew them.

PLANNING NEXT STEPS

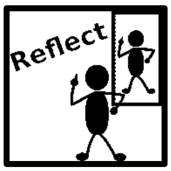
Fill in the **Teacher Reflection Worksheet** (below) to consider how well the tasks, talk, and tools worked for your students in this lesson and any equity issues that came up. Are there changes in approach you want to make going forward to address any concerns?

Consider the Understandings and Alternative Conceptions of your students (identified above)**:** It is not important that your students have certain understandings at this stage, but it is helpful to see how their understandings might inform future lessons. It may also be that certain concepts are clear enough already for you to shorten or skip upcoming lessons. Are there understandings students clearly have in their explanatory models? Are there things missing that you want to make sure to highlight in the appropriate lesson? Are there alternative conception that students will need to explore in more detail before they can consider other explanations?

Review the **Public Records**. Do the students' hypotheses and/or questions lead naturally into the lessons to come? If so, they could become the focus question of the lesson and make the unit more student driven.

TEACHER REFLECTION WORKSHEET

Teacher Reflection



Task, Talk, Tools & Equity

Use the prompts to reflect on the lesson in order to track student thinking and make changes to improve future lessons.

Keep a record of these reflections for your professional portfolio.

1. **TASK, TALK, & TOOLS.**

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load? How does the task relate to students' lived experiences or funds of knowledge?

Talk. What was the nature of talk in this lesson? What structures and routines supported student participation in talk?

The students talked to each other during (name particular parts of lesson) which allowed students to...

During turn-and-talks, I observed ______ which makes me wonder if/how…

Tools. Tools scaffold student thinking and can house student ideas. Tools in this lesson included the explanatory model scaffold and public records/charts. How did tools support students in communicating and capturing their ideas/thinking?

The explanatory model allowed students to...

Overall, reflecting on task, talk, and tools together:

Talk, task, and tools supported students to share their thinking because...

Overall, this combination of talk, task and tools, allowed most/all students to...

EQUITY.

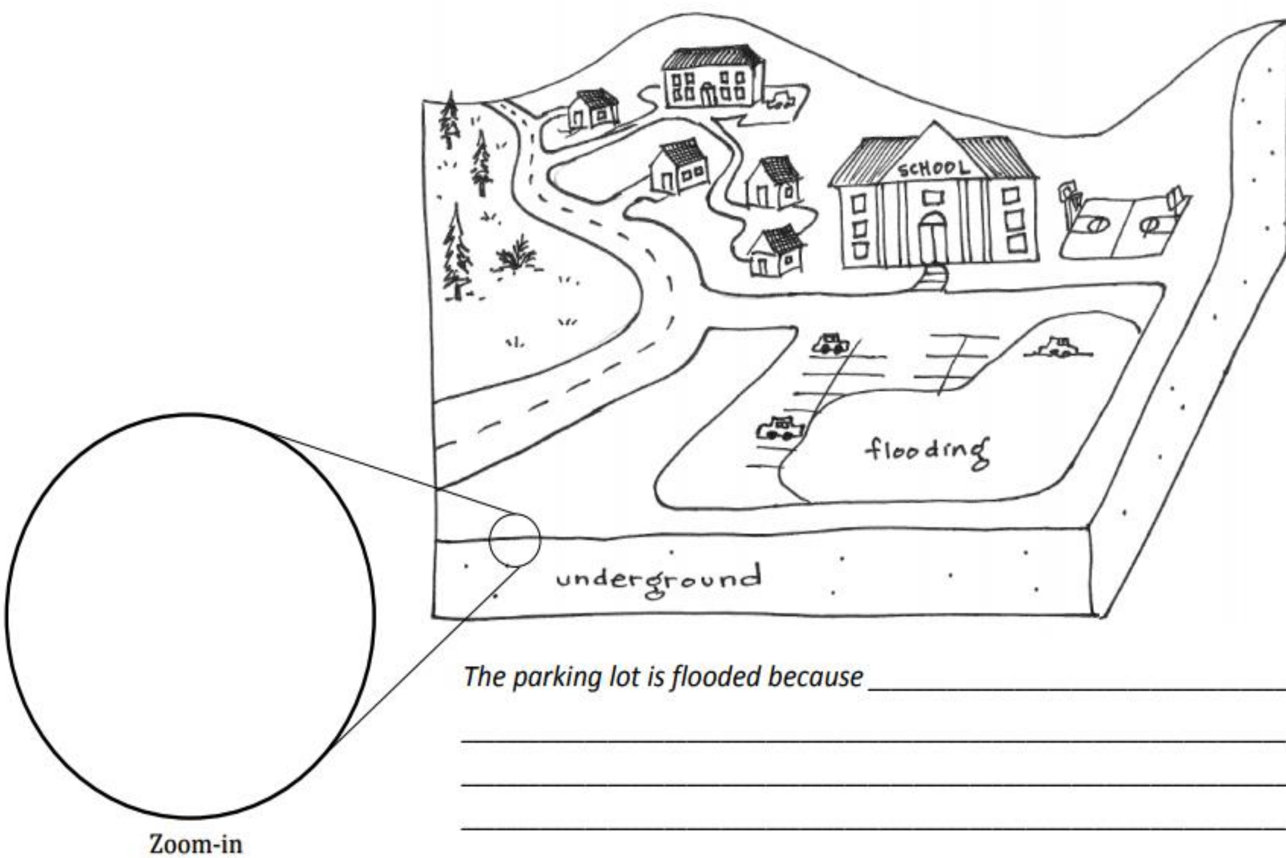
Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. Here are some categories to help you name a specific issue of equity:

- Developing relationships & forming an inclusive, trusting community
- Scaffolding for full participation in the culture and language of science
- Recognizing our own and others' worldviews & developing critical consciousness about our own assumptions and beliefs
- Addressing power dynamics (how a person is seen and responded to by others) to disrupt stereotypes and privilege

What happens to stormwater in the city?

Name: ____________________ Date: __________

Explain with arrows, drawings, and words where the water goes when it rains and why it goes there.



The parking lot is flooded because ____________________

Lesson 2a: Investigating Effects of Stormwater

IMPORTANT NOTE: If you are teaching this lesson for the first time and would like the outside field investigation and mapping portion ("Part III") modeled for you, please contact IslandWood.

OBJECTIVES & OVERVIEW

Students have many experiences with rain without necessarily thinking about what is happening to cause the mud, puddles, and water flow that they see. This lesson (consisting of three parts) gives them the opportunity to explore what happens when rain falls on land in their schoolyard and build understanding of where it goes and what it does.

This lesson is split into three parts:

Part I: In an initial short, outside encounter, students will pour water on the ground and observe the results.

Part II: In the classroom, they share what they saw, learn key terms that can help their thinking, and plan an investigation to figure out what happens to rain when it falls on different sloped surfaces in their schoolyard.

Part III: Back outside, students conduct their investigation and record stormwater features on a schoolyard map and their investigation results on a data sheet.

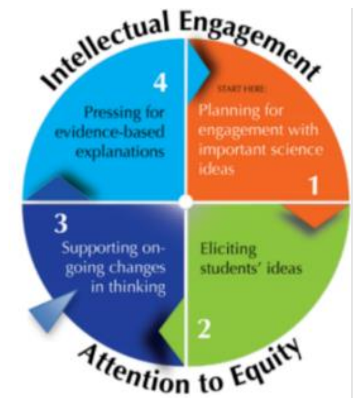
Focus Question: What happens when rain falls in our schoolyard?

Learning Target: I can make observations in an investigation to understand what happens when rain falls on various surfaces.

New Terms: erosion, groundwater, pervious surface, impervious surface, slope, storm drain, changed variable, controlled variable, measured variable, fair test

Ambitious Science Teaching Framework:

SUPPORTING ONGOING CHANGES IN STUDENT THINKING



This practice supports ongoing changes in student thinking by (1) introducing ideas to reason with, (2) engaging with data or observations, and (3) using knowledge to revise models or explanations. For more visit http://AmbitiousScienceTeaching.org

NEXT GENERATION SCIENCE STANDARDS

PE 4-ESS2-1. Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. [Clarification Statement: Examples of variables to test could include **angle of slope in the downhill movement of water, amount of vegetation…**]

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
Planning and Carrying Out Investigations. Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (4-ESS2-1)	***ESS2.A: Earth Materials and Systems*.** Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. (4-ESS2-1)	***Cause and Effect* -** Cause and effect relationships are routinely identified, tested, and used to explain changes. ***Patterns:*** Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

Common Core Connections:
CCSS.MATH.CONTENT.4.G.A.1
Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures.
CCSS.MATH.CONTENT.4.G.A.2
Classify two-dimensional figures based on the presence or absence of parallel or perpendicular lines, or the presence or absence of angles of a specified size. Recognize right triangles as a category, and identify right triangles

MATERIALS

For classroom:

- Word Wall cards
- Class Summary Table (see preparation section below)
- Lesson Powerpoint
- Just in Time readings (see end of lesson)

For outside:

- Water bottles, rain jars or other containers with water***** – ideally one per person .
- Bucket: If *possible*, have one or more buckets of water (or convenient hose spigot) available for students to refill their water containers
- **Mapping the Schoolyard Worksheet** for each student– version specific to your school found in School Guide – you will need to print these
- **Surface Investigation Data Sheet** - (in student packet)
- Clipboard or cardboard with rubber band to hold the paper in place & pencil
- OPTIONAL: Digital camera or smart phone with photo capabilities

*****If you have the opportunity, it would be helpful to collect 1 gallon milk jugs and/or 2 liter soda bottles for pouring during the outside investigations. Being able to pour a larger amount of water is helpful when looking for erosion. If you do this, you will need to adjust the amount poured in the investigation and make markings in the bottles to keep the amount poured consistent.

PREPARATION – 60 Minutes

- **Read through this lesson.** Consider the details and timing of each part and take note of how the lesson uses various school ground locations. If you have time, consider looking through Lesson 2b also to see what you will be doing with the data gathered.

Website

All worksheets, links, and graphics are on communitywaters.org

SAFETY ALERT

Are there areas (or roads) to establish boundaries or avoid?

DECISION POINT

Where will you be doing this lesson's investigation?

Do you want support from IslandWood?

- Review **Lesson 2 notes in your School Guide** provided for your school (can be found on communitywaters.org if you don't already have it from your Planning Session). Your School Guide includes a map of the schoolgrounds with suggestions about places and features around the school to visit during this lesson. Pictures are accompanied by short descriptions of the feature and questions you might pose to your students to encourage further thinking or connection-making.
- **Watch the 5-minute "Leading an Investigation of your Schoolyard"** video available on Communitywaters.org (under Teacher Support). The video is for an earlier form of this lesson but can still be helpful in thinking about the mapping students will do.
- **Go outside to familiarize yourself with your school grounds** (this could happen as a part of your planning session with an IslandWood educator)**:** Reference your school specific guide as you walk around the school grounds.
    - Can you locate the things pictured in the guide?
    - Are there any locations that weren't included that you could use?
    - If the school has bordering neighborhood streets with features of interest, make notes on them as well. Of special interest are nearby creeks or streams, which the storm drains may lead to as well as locations that frequently flood.
    - Where is a good location to test various surfaces with a small (5-15 degree) slope during the field investigation? (see next bullet point)
    - Where should students explore when adding to their maps?
- **Would you like the Investigation to be led by an IslandWood educator?** We are offering this support in 2022-23, and perhaps after that as well. Please be sure to reach out to celinas@islandwood.org.
- **Decide where to do your investigation:** The investigation in this lesson was designed to be done outside (as described in Part III below). Doing it outside greatly reduces your prep and instructional time and gives the students an experience in the real environment where rain actually falls. You could decide (because of outside conditions or a preference for a more controlled experiment) to do the investigation with the stormwater models in your classroom. If you do the investigation inside, you will still need to go outside to add to the map worksheet. You will also need to set up the stormwater models and dig up grass or other plant materials for some of them. Please check the lesson webpage for a detailed description of that option.
- **Plan how you will manage students outside:** You may want to refer to the "Strategies for Outdoor Learning" found in the Teacher Background section of the manual. Decide on where you will do the Initial Engagement outside as well as the Field Investigation and Mapping. This is also a good

time to plan for student boundaries for those activities and whether you will be bringing them to see specific features.

- **Determine Student Groups:** Plan for “investigation teams” of 4-5 students. Consider which groupings will be able to work together effectively outside while not overly distracting each other.
- **Chaperone(s):** Secure at least one other adult to act as support for the time outside during this lesson. Two to four adults per class is really helpful.

Part I: Initial Encounter with Water in the Schoolyard (15 minutes + transitions)

1. **Before heading outside (whole class)**
   Organize students into pairs.

   Partners will be given water bottles, milk jugs, or "rain jars" and the opportunity to pour them in various locations outside.

   When pouring the water, they should take note of what happens to it and what happens to the surface it is being poured on. Later they will be planning an investigation to explore this more closely.

   Emphasize that this time is not for recess or playing on the playground and the water should only be poured on the ground. Students should keep a science mindset and make thoughtful observations. Some students might be concerned about "wasting water" – if this is the case, you could set limits on amount of water used or frame the activity as not "wasting" if they are learning from the activity.

> **Timing Of This Activity**
>
> This outside activity is meant as a quick engagement with the students that could be used in a transition to outside recess or the end of the school day.
>
> If outside science norms have previously been established with your students, you could, alternatively, do the introduction outside as you pick them up from recess.
>
> On a **Rainy Day** this activity could also include observing what happens to the rain.

2. **Circling up outside (whole class):**

   Gather students in a circle outside to remind them of the intent of this activity, establish boundaries for the exploration, sort them into partners and hand out water bottles/rain jars.

   Let them know they'll have **10 minutes** to observe as they pour their water in various places before coming back together (outside or in classroom) to share what they observed.

   Demonstrate the pouring of the water to the whole class and have them help offer appropriate observations of what happens.

3. **Pairing Up**

   Have your assigned pairs turn and talk to decide where in the boundaries they want to pour first (and remind them to share observations when they pour).

   Then send them forth!

Back-Pocket Questions

Observations & Analysis

4. **Outside Exploration (partners)**

   Circulate amidst partners to redirect, refocus and/or ask “back pocket” questions as appropriate.

   When finished you could circle up outside for a quick sharing of what people noticed or head inside to share.

Back Pocket Questions

“Back Pocket Questions” are offered throughout this curriculum as ideas for prompting questions you could ask students while they are during an activity.

- Where is the water you poured going?
- I’m not seeing the water you poured, what happened to it?
- Are you seeing any signs of erosion? What would erosion look like?
- Why do you think the water is doing that?
- Where else could you pour the water to have it do something different?
- Is anything getting carried in the water if it flows downhill?

Part II: In Classroom (45 minutes)

Present Visual

Mapping your Schoolyard Worksheet (in your school specific manual)

1. **Review Experience and introduce map (whole class)**

   Remind students of the water pouring they did outside.

   Show your school’s **Mapping your Schoolyard worksheet** with your document camera.

   Discuss what students see, orient the map with them (rotating it to match up with the direction they are facing) and show them where they were on the map during the pouring.

   Have students share out loud the locations they poured water and show where some of them are on the map.

Present Visual

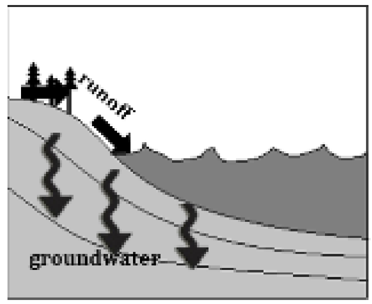
Just-in-Time Instruction – Runoff and Groundwater (at end of lesson)

2. **Provide terms to leverage (whole class)**

   These are terms that scientists use to refer where the water goes.

   Project the “**Just-In-Time Instruction – Runoff and Groundwater**” reading for students to see. (large version at end of lesson)

Just-in-Time Instruction – Runoff and Groundwater



When rain falls to earth, gravity pulls it down hillsides and into soil.

Scientists use the term **runoff** to refer to water that flows over the top of the land. **Erosion** occurs when fast moving runoff picks up soil and moves it.

Groundwater is water that soaks into soil and seeps gradually downward, in the spaces between soil particles.

Runoff, erosion, and groundwater are terms we can use to describe how water interacts with soil. You've been using the term **runoff** already when referring to "stormwater runoff," but the idea of fast runoff causing **erosion** may be a new one for many students. In addition, some water moves down into the soil between the soil particles as **groundwater**. These are all terms they can use to help describe what they observed.

- When the students poured their water outside, what did it look like when runoff was happening? [water flowing across the ground].
- Did the water flow faster in some areas than in others?
- Note that runoff happens down hills. We call the angle of a hillside the "slope." When the slope is steeper the water will flow faster and more erosion will occur. Even very small slopes might have runoff.
- If the ground is flat what happens to the water? [If it doesn't soak into the groundwater it will puddle]
- What did it look like when water was soaking into the groundwater? [the water that was poured "disappears" or absorbs, instead of puddling or becoming runoff]
- Did the students see any erosion when they were pouring their water? When the students poured water, if they saw dirt or rocks being moved, they were seeing erosion happen. Sometimes a sign of erosion is a place where soil is missing and sometimes it is the place where the soil has piled up/collected.

Add **erosion** and **groundwater** to your **Word Wall Cards**.

Turn-and-Talk

3. Understanding What Happens to Rainfall

What would the students predict happens to rain in different locations around the school? Where would it become runoff, cause erosion, and/or move into the groundwater?

Where could rain run off the ground, cause erosion, or soak into the groundwater?

Have students turn and talk with a partner to discuss this. Remind the students of your list of locations on the whiteboard as a help to prompt their thinking.

Those locations have different kinds of surfaces that interact with rainwater in different ways. Understanding what is happening with rainwater on difference surfaces will help students explain why flooding happens when it rains a lot. This could also be an important part of explaining the puddle in our explanatory model.

4. Planning an Investigation

We are going to conduct an investigation in our schoolyard to see if we can make claims about certain surfaces interacting with rainwater in certain ways. Our Investigation Question is: "**What happens when rain falls on different sloped surfaces in our schoolyard?"**

Math Standards

Slopes & Angles:
CCSS.MATH.CONTENT.4.G.A.2
Classify two-dimensional figures based on the presence or absence of parallel or perpendicular lines, or the presence or absence of angles of a specified size. Recognize right triangles as a category, and identify right triangles.

Slope and Angles
If your students have been doing geometry in math class you could connect a conversation about slope to angles (right, acute, and obtuse). Slope itself may not appear in standards until 6th grade.

The question asks what happens on **sloped** surfaces, as we need a slope for runoff and erosion to happen (show **the Just-In-Time graphic** again if needed to point out the text referencing hillside and fast-moving water).

Scientists make sure that investigations are clearly described and "fair tests" so that other scientists can repeat the same investigations. When we conduct an observational field investigation it's a little different from one in a lab as there are a lot more variables that can make it hard to make it a fair test.

To help us be able to compare the data we get from different groups, we will have investigation teams following a scientific procedure and recording information on a data table.

Questions for discussion with class:

Surfaces
Make sure the list of ideas include surfaces that will let students see where water runs off, soaks in, and where it causes erosion.

- What sort of surfaces do we want to test our water on? [*Concrete, grass, woodchips, bare soil…]* This is called the "**changed variable**" in our investigation.
- What should we be looking for that will help us think about whether runoff, erosion and/or soaking into groundwater is happening? [*What happens to the water and if any soil is moved by the water.]* Observations of the changes are the "**measured variable.**"
- What "**controlled variables**" would we want to make sure are the same for all locations and groups? An important one is that the amount of slope is roughly the same for all students. When we go outside, we'll want to agree as a class about the amount of approximate amount of slope we want to be present for all the

surfaces we test. [*How water is poured on the ground, the amount of water used, etc.]*

- Add terms to Word Wall.

DECISION POINT

Do you want the students to develop the procedure steps as a class or use the example provided on worksheet?

5. **Investigation Procedure**
This is printed on the students' **Surface Investigation Data Sheet** along with the group roles. (Group Roles are suggested in box on next page).

1. Write down the date, weather, and if the ground feels wet or dry.
2. Find a surface in our schoolyard that matches one of the rows on the table and the amount of slope we have agreed on. Confirm your location with an adult.
3. Write the number for that surface on your **schoolyard map** to show where it is located.
4. In the "Description of surface BEFORE pouring water" column, write a description of the surface.
5. In the "What plants are present?" column, note what kinds of plants are present (like grass, trees, bushes, etc), and if there are a lot or a little.
6. Shake a rainwater jar from <u>waist height in the same location</u> until 1000 mL has been released.
7. In the "observations of surface" column, make observations of what happened to the water and surface it fell on. Check the boxes in that column if you observe those things.
8. Find a different surface from a different row and repeat steps until all rows are filled in.

Example Data Table ROW:

Weather: *Cloudy and Cold* **Ground wet or dry?** *Dry*

Map #	Surface	Description of surface before pouring water	What plants are present?	Observations of surface after water is poured on it:
1	*Concrete*	*Hard and lumpy. Gray and dirty.*	*None*	*Water makes a puddle* ☑ *Water moves as runoff* ☑ *Water soaks into the ground* ☐ *Signs of erosion (dirt moved by water)* ☐ *If yes, what do you see?*

Yield signs show places you could split the lesson if time is limited.

If you are running out of time, stopping here could allow you (or an IslandWood educator if one is leading Part III) to demonstrate the procedure (below) as a review before going outside for the investigation.

Present Visuals

Example data table row
&
Mapping your Schoolyard Worksheet (in your school specific manual)

6. **Demonstrate Procedure**

   Fill out an example row (see above) under the document camera as you demonstrate the procedure.

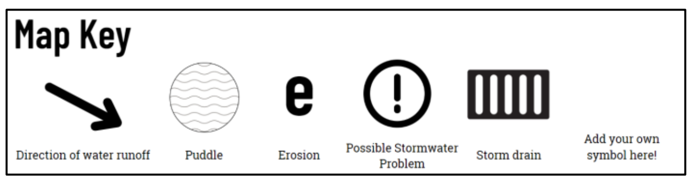
   - Use an empty tub (no dirt) with a slope created by some books for your demonstration surface.
   - Have the students help describe what you see and its slope.
   - Project the schoolyard map and mark the location of your classroom.
   - Use the rainwater jar to “rain” on the tub and ask for help describing what happens to the water and filling in the row.

7. **Additional Map Tasks**

   Groups will also be marking locations on their map where they find drains that rain might go into (storm drains for example) and any locations where runoff, erosion or puddles happen in the schoolyard during big storms.

   They will be able to work on this task after they have completed the investigation procedure for all locations.

   Show map key elements and demonstrate adding a feature on the projected map.



Small Group

Investigation Teams

8. **Investigation Teams**

   Divide class up into teams and provide each team a clipboard, Schoolyard Mapping Worksheet, Data Sheet, rain jar and digital camera (if using).

   Discuss team roles and have them decide on who will do each.

GROUP ROLES

Could be traded off if desired.

1. **Recorder:** Fills in the row for the location on the group’s data table
2. **Mapper:** Records the number of the location on the group’s schoolyard map.
3. **Photographer or Drawer:** Take before and after pictures of the location
4. **Water Shaker:** Shakes out the water.
5. **Water Filler:** Refills the rainwater jar to 1000 ml between uses.

ALL: Help the mapper find the location on the map and describe the location and what happens for the recorder to write down.

9. **Review expectations for having class outdoors (whole class)**

   Outside expectations

   - Students will be doing science during this time (not recess)
   - Class will stay together and within any boundaries that are set.
   - Classroom and school rules still apply.
   - Come together when asked and stay within boundaries.

Part III: Investigation Outside (45 minutes)

If an IslandWood educator is leading the outside investigation, they may want to start with #6 in Part II above so they can review the procedure and expectations before heading outside for Part III. Alternatively, if meeting the class outside, they may be able to do that review when you first gather up.

1. **Circle up and review (OUTSIDE BUILDING, whole class)**

   When you get outside, review the plan: Set the physical boundaries, remind them of behavior expectations, and orient them to the schoolyard map.

   Show the location of your bucket of water for refilling rain jars. Another adult could be helpful to manage the water.

   Remind students of the procedure (you could demonstrate it again if needed).

> **Weather Adaptations**
>
> The field investigation can still be done on a rainy day but will need to be postponed (or done with the stormwater models inside) if the ground is frozen or totally saturated with water.

2. **Investigate Surfaces (small groups)**

   Have all groups test the same surface for their first test. Make this location an easy and nearby one and give them a countdown to stand by the location as a team. Remind them to describe the location and mark it on their map before they pour the water.

   After teams finish their first surface, have them come back to a central location to refill their rain jars and wait. When all teams are done, send them to their second location.

   Continue to prompt for each new location as you go.

> **Self Direction?**
>
> Having the groups do each new location simultaneously can help keep the groups focused and on task. If you prefer, you could instead have them proceed through all locations (after the first) on their own and check in with you when done (before doing the additional mapping work).

3. **Investigation Check In (whole group)**

   Once all teams are finished, gather them up and ask how it went. What did they notice? What variables do they think were controlled well across groups?

   YIELD *If needed, you could stop here and return outside another day to do the mapping.*

Back-Pocket Questions

Observations & Inferences

4. Adding features to maps

Hand out a map to students that don't have one (those whose role was not to mark surface locations on the map) and give them time to copy the locations from their team map onto their map.

Students will be marking locations on their own map where they find drains that rain might go into (storm drains) and any locations where runoff, erosion, puddles and potential stormwater problems happen in the schoolyard during big storms.

Find a storm drain as a whole class and have each group's recorder mark it on their map. Then have the students partner up to work within the boundaries to see what they can add to their maps.

If a location with visible erosion exists in your schoolyard, make sure the class has a chance to see it and lead a discussion of what happened.

As time permits, gather the class at any locations you want to make sure they notice (either from your own observations or as recommended in the school guide).

Weather Adaptations

To avoid wet maps on rainy days, you could have students keep the maps under covered areas and write on them after exploring. Alternatively, a large Ziploc could be used to cover the map while writing.

Back Pocket Questions

Observations

- Which features at the school might slow down the water?
- Which features might increase the speed of the water?
- Which places at the school allow water to absorb into the ground?
- Do you notice any pollution concerns?
- Where are places that you have seen puddles form?

Inferences

- Where would the water go from here?
- Where did the water causing this problem (puddle or erosion) come from?
- Where does all the water flowing off this surface end up?

Your school's Guide may have other location-specific questions.

Lesson 2b will have students analyze the data they collected.

PLANNING NEXT STEPS

Fill in the Teacher Reflection Worksheet (below) to consider how well the tasks, talk, and tools worked for your students in this lesson and any equity issues that came up.

In 2b, the students will be sharing and analyzing the data they recorded in this lesson. Review student data sheets to consider whether students will have something to share for each row and whether the data will help them think about pervious and impervious surfaces and erosion.

Sometimes, students need extra practice in conducting investigations outside and might benefit from repeating the investigation and/or conducting parts of it in a more controlled environment in the classroom. If the latter, see the prep section for lesson 2a for an inside alternative to the outside investigation.

Surface Investigation Data Sheet

Investigation Team: ________________________________ Date: ____________

Weather: ______________________________ Ground wet or dry? ___________

Map #	Surface	Description of surface before pouring water	What plants are present?	Observations after water is poured on surface
Record the # on map	Find a location that matches this for your test	Use descriptive words. What do you see on the ground? What does it feel like?	What kinds and how many? *Grass? Trees? Weeds?* *A lot? A few?*	Check boxes below if "yes":
1	Concrete			❑ *Water in a puddle* ❑ *Water moving as runoff* ❑ *Water soaking into the groundwater* ❑ *Dirt moved by water or other forms of erosion* *What else do you see?*
2	Soil with Plants			❑ *Water in a puddle* ❑ *Water moving as runoff* ❑ *Water soaking into the groundwater* ❑ *Dirt moved by water or other forms of erosion* *What else do you see?*
3	Bare Soil			❑ *Water in a puddle* ❑ *Water moving as runoff* ❑ *Water soaking into the groundwater* ❑ *Dirt moved by water or other forms of erosion* *What else do you see?*

Lesson 2b: Analyzing and Interpreting Our Data

OBJECTIVES & OVERVIEW

Students have many experiences with rain without necessarily thinking about what is happening to cause the mud, puddles, and water flow that they see. This lesson (consisting of three parts) gives them the opportunity to explore what happens when rain falls on land in their schoolyard and build understanding of where it goes and what it does.

After completing the investigation in 2a, students will analyze their data and consider how some additional information about surfaces and plants helps them understand what they saw.

Focus Question: What happens when rain falls in our schoolyard?

Learning Target: I can analyze data from an investigation and read texts to understand what happens when rain falls on various surfaces.

New Terms: (same as 2a)

***Ambitious Science Teaching Framework:* SUPPORTING ONGOING CHANGES IN STUDENT THINKING**

This practice supports ongoing changes in student thinking by (1) introducing ideas to reason with, (2) engaging with data or observations, and (3) using knowledge to revise models or explanations. For more visit http://AmbitiousScienceTeaching.org

NEXT GENERATION SCIENCE STANDARDS

PE 4-ESS2-1. Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation. [Clarification Statement: Examples of variables to test could include **angle of slope in the downhill movement of water, amount of vegetation…**]

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
Analyzing and Interpreting Data- Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in	***ESS2.A: Earth Materials and Systems.*** Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. (4-ESS2-1)	***Cause and Effect* -** Cause and effect relationships are routinely identified, tested, and used to explain changes. ***Patterns:*** Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results.		

Common Core Connections:

ELA/Literacy: RI 4.9 Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably.

MATERIALS

- To project or print: Just-In Time readings found at end of lesson
- For classroom: Word Wall cards & Class Summary Table (see preparation section below)
  - **Mapping the Schoolyard Worksheet** completed in Lesson 2a
  - **Surface Investigation Data Sheet** completed in Lesson 2a

PREPARATION – 10 Minutes

DECISION

POINT

Could you incorporate the provided readings as ELA informational texts?

- **Consider the Readings:** There are three potential readings for this lesson provided in **Appendix 3: Student Readings** (also on communitwaters.org). They are intended to support building additional understandings about erosion, groundwater and human impacts on land. You could also use similar short readings on those topics from library books or other sources. Could you incorporate them as informational texts that you use as a part of your ELA time? Provided readings include:
  - **"Groundwater"** with an explanation about how water moves through the soil.
  - **"Earth Science for Kids: Erosion"** which explains water erosion and introduces the idea that there are other kinds of erosion.
  - **"Erosion: Human Impacts on the Land"**
- **Class Data Table:** Create a table to compile data from the different groups either on your whiteboard or on butcher paper (for a more permanent public record). Write in the surface the class chose for each row.

Map #	Surface	Observations	Similar Observations	Reasons
1				
2				
3				

- **Class Summary Table:** Create the first row in the class summary table* (on butcher paper or use digital template):

Public Record

Class Summary Table

Analyzing Data and Making a Claim (30 minutes)

1. **Returning to the Data from the Investigation**

   Students should sit with their investigation teams for this activity.

   Remind students of the investigation they did outside and their investigation question. **“What happens when rain falls on different surfaces?”**

   After collecting data, scientists need to ***analyze and interpret*** it to see what they learned and if they can answer their investigation question.

   The students’ observations from their investigation are one form of data that we can analyze to see if we can make any claims about what happens to water on different surfaces. If we see the same observations occurring across all tests of similar surfaces we can identify a ***pattern*** that we can use to make a claim. If we find differences in what happened on a surface we can think about if there were differences between tests that could explain what happened.

2. **Compiling the Data**

   On sticky notes, each team will write their observations of what happened to the water on each of the surfaces they investigated. Then the whole class will look at those observations together to see what patterns they can find.

   Provide each team a set of 5 pre-numbered notes and have each team take one to fill them in with the observation information from that row on their data sheet. As they finish filling in their post its, they can come add them to the observations column on the **class data table** (created earlier above or by you as they fill out their observations).

   Student Post-Its?

   If you don’t want to take the time to have students fill in sticky notes during class, you could do the writing as team members share or go through the team’s data sheets and compile the observations ahead of time.

3. Analyzing the Data

Analyzing Data

Looking for patterns

Consider one surface at a time: Read the observations out loud to the class while students listen for patterns in the observations. How are the observations similar and different at each location?

Get student input to decide which observations should be moved together into the "similar observations" column.

Is there enough of a pattern in the data to say that some surfaces usually result in runoff while others result in water going into groundwater?

DECISION POINT

Introduce "pervious" and "impervious" terms now or later?

This may be the right time to introduce some terms that will help students think about the reasons why they see patterns in which surfaces have runoff. You could, alternatively, skip to #6 and #7 below before returning later to think about the "whys" with students.

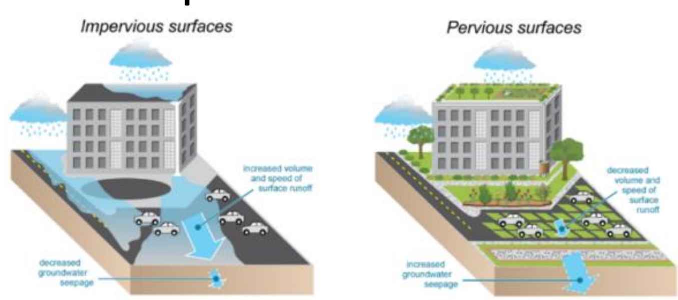
4. Just In time Information

Present Visuals

Impervious & Pervious Surfaces Graphic (end of this lesson)

Project the Impervious & Pervious Surfaces graphic (full size at end of lesson)

Impervious & Pervious Surfaces



Discuss the differences between impervious and pervious surfaces. Help students to understand that pervious surfaces are places where there are spaces between particles that allow the water to soak into the ground while impervious surfaces do not allow water to absorb into the ground.

You could note that some surfaces are less pervious when dried out (as there are no spaces for the water to penetrate) and other pervious surfaces may have limited capacity to absorb water (with excess water becoming runoff).

Add “Pervious” and “Impervious” to your Word Wall.

5. **Which Surfaces Are Pervious? Which Are Impervious?**

Return to the table with observations of different surfaces. How would these terms help us understand what has happened to the water when it fell on that surface? [e.g. We would see more runoff on an impervious surface and more water soaking into the groundwater on a pervious one].

Decide as a class whether each surface/location is “pervious” or “impervious” and add it to the reasons column for each. Does that help explain the reason for what they observed?

This is a spot where you could easily pause the lesson and return to it later. Just make sure you are saving the class data table so you can return to it when you reconvene.

6. **Analyzing data about erosion**

Remind the students that erosion can occur when fast moving runoff picks up soil and moves it. Show the **Just-in Time Runoff and Groundwater** graphic and/or the erosion word wall card again if you need to review the term.

Have the class consider which teams observed erosion happening and on which surfaces they observed it. Did all teams see runoff on those surfaces?

If some found evidence at certain location and others did not:

- Have those who did not see erosion share what soil and plants were like at their location.
- If the plants or soil were different between the two groups, could that difference help understand why some found erosion? *[more erosion is likely to be found on surfaces that less plants and looser soil]*

7. **More Information About Erosion**

VIDEO

Play the “Erosion and Soil” Video

Play the “Erosion and Soil” video for the class. Stop at various points to get students’ predictions about what is going to happen.

Link can be found at communitywaters.org or https://www.youtube.com/watch?v=im4HVXMGI68

Which surface in the video had the most erosion occur? Which had the least?

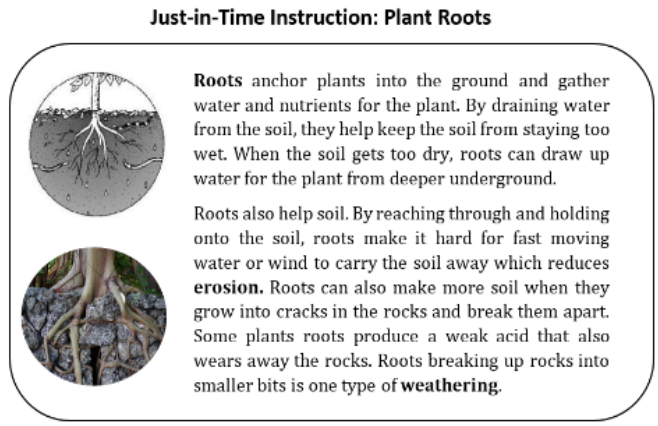
Present visual

Just-in-Time Instruction: Plant Roots (at end of lesson)

8. **Reading to support key understandings from the video**

Project the information (at end of lesson) about plant roots to reinforce what was in the video.

How does understanding how plant roots help hold soil in place relate to the data from our investigation?



Just-in-Time Instruction: Plant Roots

Roots anchor plants into the ground and gather water and nutrients for the plant. By draining water from the soil, they help keep the soil from staying too wet. When the soil gets too dry, roots can draw up water for the plant from deeper underground.

Roots also help soil. By reaching through and holding onto the soil, roots make it hard for fast moving water or wind to carry the soil away which reduces **erosion.** Roots can also make more soil when they grow into cracks in the rocks and break them apart. Some plants roots produce a weak acid that also wears away the rocks. Roots breaking up rocks into smaller bits is one type of **weathering**.

9. **Applying Learning to Observations on Schoolyard Maps**

Remind students of the schoolyard maps they did and have students look at their maps with a partner.

Turn-and-Talk

Why is the feature on your map in that location?

Project the schoolyard map used earlier during the investigation demonstration and have students share things you should add to it. [You could skip this if short on time.]

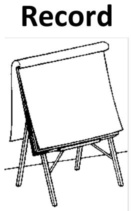
Have students choose a feature they added to their map and see if they can agree with their partner why it was found in that location. How do impervious and pervious surfaces and slopes and plants relate to the feature being discussed? (for example, why might they have found erosion next to an impervious surface?)

Example Explanations

- Storm drain in that location because the slope carries water there across the impervious concrete.
- Puddle there because the concrete is impervious.
- Erosion visible because fast water is carrying away the dirt.

Provide an opportunity for students to share their explanation with another pair of students (or the whole class).

Public Record



10. **Connections to the Phenomenon (whole class)**

Observations: Attach the schoolyard map with observations shared by students and the sticky notes from the field investigation in this section. Is there anything else students think should be in it?

Learning: Help students craft generalizable statements about what they learned from the investigation. They could also put questions or wonderings here.

Class Summary Table

Explaining Stormwater Runoff: How could what we learned about plants help us understand what happens to stormwater in the city? What surfaces could be adding to the stormwater runoff problems in our city? Which surfaces reduce the amount of stormwater runoff?

Example of what the Summary Table might look like:

Activity	**What did we observe?**	**What did we learn?**	**How does it help us explain and/or solve stormwater in the city?**
2: Investigating Effects of Stormwater "What happens when rain falls in our schoolyard" <Schoolyard Map taped here>	- Water soaked in some places better than others. - Water flowed across impervious surfaces - Water flows into storm drains - We have some places puddles form in our schoolyard	- Water soaks into pervious surfaces - Water flows across impervious surfaces - Stormwater runoff floods our <specific problem identified by students> - Plants and their roots help with stormwater	- Our city has lots of impervious surfaces which create more stormwater runoff. - Storm drains carry stormwater runoff away. - More plants would reduce runoff.

PLANNING NEXT STEPS

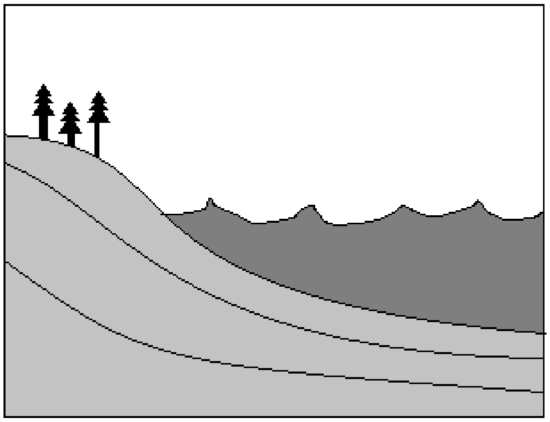
Fill in the Teacher Reflection Worksheet (below) to consider how well the tasks, talk, and tools worked for your students in this lesson and any equity issues that came up.

The upcoming lessons in this curriculum expand beyond the more immediate effects of stormwater to look at what happens to it in the broader community, and what problems could be solved at the school. If your students have more ideas to explore about how it moves or what it does where it falls, you might want to do that first.

One type of urban weathering that could come up during your investigations are the cracks in concrete created by frost wedging and the potholes created when you add in cars. There is more information on these processes in the teacher background section of this manual as well as a reading about it in the Appendix.

- You could have students read about it (in Appendix) and/or watch a short video with your students like this one from West Virginia Department of Transportation: https://www.youtraye.com/watch?v=rg5Hwety4RU (5:00)
- Alternatively, it could be interesting to develop an experiment to explore the phenomenon further.

Just-in-Time Instruction: Runoff and Groundwater

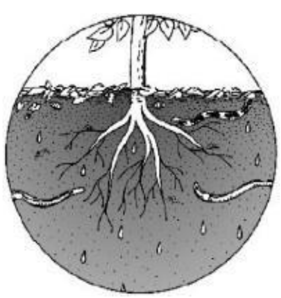


When rain falls to earth, gravity pulls it down hillsides and into soil.

The term **runoff** means water that flows over the top of the land. **Erosion** occurs when fast moving runoff picks up soil and moves it.

Ground water is water that soaks into soil and seeps gradually downward, in the spaces between soil particles.

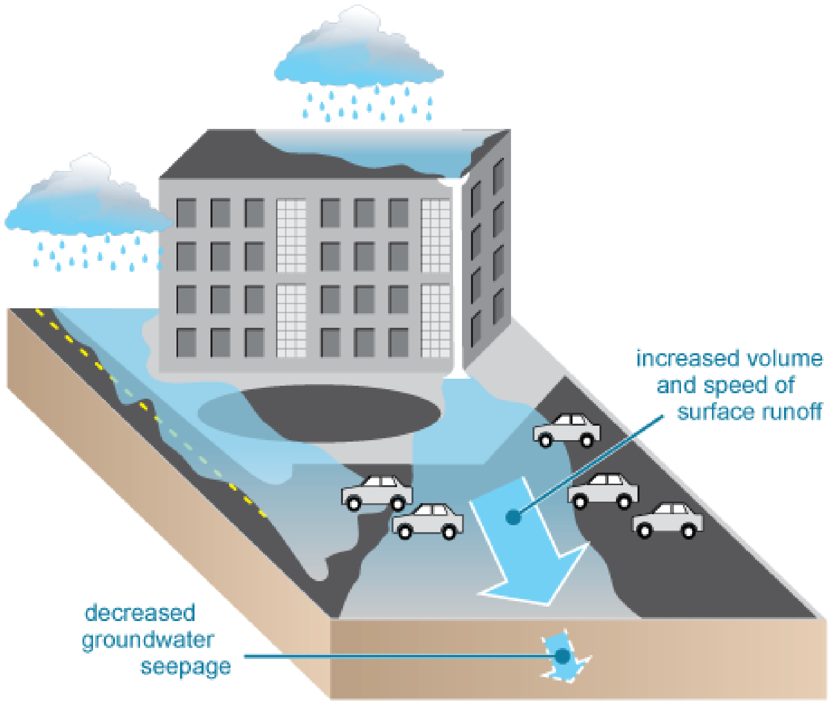
Just-in-Time Instruction: Plant Roots



Roots anchor plants into the ground and gather water and nutrients for the plant. By draining water from the soil, they help keep the soil from staying too wet. When the soil gets too dry, roots can draw up water for the plant from deeper underground.

Roots also help soil. By reaching through and holding onto the soil they reduce **erosion.** Roots can also make more soil when they grow into cracks in the rocks and break them apart. Some roots also produce a weak acid that wears away the rocks. Roots breaking up rocks into smaller bits is one type of **weathering**.

Impervious surfaces



Impervious 'hard' surfaces (roofs, roads, large areas of pavement, and asphalt parking lots) increase the volume and speed of stormwater runoff. This swift surge of water erodes streambeds, reduces groundwater infiltration, and delivers many pollutants and sediment to downstream waters.

Pervious surfaces

Pervious 'soft' surfaces (green roofs, rain gardens, grass paver parking lots, and infiltration trenches) decrease volume and speed of stormwater runoff. The slowed water seeps into the ground, recharges the water table, and filters out many pollutants and sediment before they arrive in downstream waters.

Conceptual diagram illustrating impervious and pervious surfaces. Impervious surfaces are hard and increase stormwater runoff, causing pollutant and sediment delivery in downstream waters. Pervious surfaces are soft and decrease stromwater runoff, which filters out pollutants and sediments before they arrive in downstream waters.

Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Chesapeake and Atlantic Coastal Bays Trust Fund, 2013. Stormwater Management: Reducing Water Quantity and Improving Water Quality. IAN press, newsletter publication.

Lesson 3: Local Stormwater Systems

OBJECTIVES & OVERVIEW

Students learn about the impact the stormwater runoff has after it leaves the site through a storm drain or ditch. Depending on your location, the stormwater runoff impacts local creeks, lakes and the Puget Sound with flooding, and pollutants carried by the stormwater. This is important towards understanding why adding more storm drains does not solve our region's stormwater runoff problems. It will be used when students are considering criteria for their stormwater solutions later in the unit.

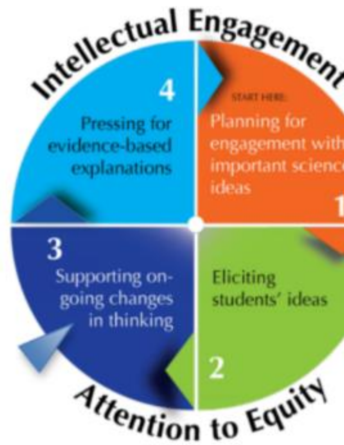
- Students analyze maps to identify where water goes after it lands on the ground in their neighborhood.
- Students use videos and/or graphics to identify the effects the stormwater from their neighborhood has elsewhere.

Focus Question: Where does our stormwater runoff go and what problems does it cause?

Learning Target: I can use maps to help me figure out what happens to the stormwater runoff from my neighborhood.

New Terms: Problem

Ambitious Science Teaching Framework:
SUPPORTING ON-GOING CHANGES IN STUDENT THINKING



This practice supports on-going changes in student thinking by (1) introducing ideas to reason with, (2) engaging with data or observations, and (3) using knowledge to revise models or explanations. For more visit http://AmbitiousScienceTeaching.org

NEXT GENERATION SCIENCE STANDARDS

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

PE 3-5-ETS1-1. **Define a simple design problem reflecting a need or a want** that includes specified criteria for success and constraints on materials, time, or cost.

Science & Engineering Practices	Disciplinary Core Ideas (DCI)	Cross-Cutting Concepts (CCC)
Obtaining, Evaluating, and Communicating Information. • Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem.	**ESS3.B Natural Hazards.** • A variety of hazards result from natural processes. Humans cannot eliminate the hazards, but can take steps to reduce their impacts. (4-ESS3-2) **ESS2.A Earth Materials and Systems.** • Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils and sediments into smaller particles and move them around. (4-ESS2-1)	**Systems and System Models.** • A system can be described in terms of its components and their interactions. • A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot.

MATERIALS

- School Guide Powerpoint
- Lesson 3/ Local Stormwater Systems: Tacoma Powerpoint

PREPARATION – 30 minutes

Website

The School Guide for your school as well as all worksheets, links and graphics can be found on communitywaters.org

DECISION POINT

Take students outside to check out storm drains or other places you see stormwater?

Use online maps?

- **Video:** Review the "When it Rains it Pours" video (from communitywaters.org or at https://vimeo.com/238134756
- In your School Guide: Review the information to learn where the stormwater from your school's neighborhood goes and which additional video(s) are suggested for watching with your students:
    - OPTION A = "Effects of Urbanization on Stream Ecosystems." https://www.youtube.com/watch?v=BYwZiiORYG8
    - OPTION B = "Drained: Urban Stormwater Pollution." https://vimeo.com/51603152
- **Make the maps less abstract?** Maps of underground pipes can end up being too abstract for some 4th graders. Depending on your local area and time available, consider whether you want to take students outside with the maps in hand to point out how they match up with the storm drains and land around the school. This could be especially useful if you have visible hills, ditches, ponds, or other terrain around the school that interacts with the pipes. You could also do this as part of the Walking Field Trip during your next lesson.
- **Digital Maps:** Try using Google Earth to "fly over" the area around your school, instead of using the "Local Stormwater Systems" PPT.
- Will you project the maps for the whole class or have students view maps on their own devices?
- Review the Powerpoints:
    - **Lesson 3/Local Stormwater Systems: Tacoma** includes several images, maps and graphics that may help students understand what happens to stormwater once it goes into the ground or a drain. There are also watershed graphics if some background or refresher is needed about the water cycle. You may not need or want to show students all of these.
    - **School Guide:** this includes a narrative explanation for teachers about where your school's water ends up and how it gets there, as well as the maps of where the water goes.

PROCEDURE

Engage and Encounter

1. Activate prior knowledge and experiences

Students have investigated as a class what happens to water that falls in their schoolyard.

They know from the investigations they have done that runoff can pick up and move materials like dirt and sand, causing erosion.

Ask students to think about what they've noticed around their own neighborhoods. *What kinds of things are on streets and sidewalks that stormwater runoff might pick up as it builds up speed? Where do they think that water would end up? Would it cause problems there?*

Have students create a chart in their on a blank page in their Student Packet, or create a class chart. On one side, list where stormwater would go in a city, and on the other any problems stormwater runoff might cause as it travels and wherever it ends up.

Example Chart:

Where might stormwater go?	*What problems might stormwater cause?*
Into the ground	*Flooding*
Into storm drains	*Erosion*
Into Puget Sound	*Pollution*

Explore and Investigate

2. Introduce and watch the video (whole class)

Video Clip

"When it Rains, It Pours"
Length: 2:47
communitywaters.org

Direct link: https://vimeo.com/238134756

This video is about what happens with stormwater runoff in the city. It helps answer the question of where stormwater might go and the problems it could cause.

After watching it, provide students the opportunity to add to their charts.

Then watch it again as a class with students adding additional things to their lists as they watch.

Review of terms?
The first part of the "When it Rains, It Pours" video reviews terms including: stormwater, pervious and impervious. This is a great opportunity to revisit and reinforce as needed.

3. Introduce the activity (whole class)

The video talks about cities in general but does not address what is going on in YOUR neighborhood.

From the Lesson or **"Local Stormwater Systems" PPT**, show the satellite view (Google Earth) images of western Washington, Puget Sound, and Tacoma. Help students identify where the school is (plus

Present visuals

School Guide: Local Pipes Maps
&
Local Stormwaters Systems PPT

other important landmarks) on the map. Help students orient to the features show on the map.

From the **School Guide PPT**, project the map that shows the pipes around your school.

The map shows where stormwater goes in your neighborhood – the green lines have arrows that show the direction the water flows in pipes underground.

Zoom in on your school on the map (or in Google Earth or Maps). Where is the playground or other recognizable features?

Small Groups

Where does the water in the schoolyard end up?

Back-Pocket Questions

Observations

4. Interpreting the Maps

There are many ways to do this! The goal is for students to begin to understand where, specifically, the stormwater ends up that starts at or near their school. You may invite individual students to come up to the screen to show where they think the water goes, trace the patch with your cursor, or have small group discuss what they see and then "reveal" the path of the water. If students can use their own devices, have them investigate the maps as individuals, pairs or small groups.

BACK-POCKET QUESTIONS

- What are different ways stormwater leaves the area?
- Did we find storm drains when we were exploring around the school? Where do those storm drains lead?
- What happens to the water when it leaves the edge of their map?

YIELD

This could be a place to pause if you are out of time.

5. Provide ideas to leverage (whole class)

By using the map, students identify where the stormwater runoff in your school's neighborhood goes. Does the water go directly into a stream or the Puget Sound? Does it enter a detention pond or other holding place?

Video Clip

Use option A or B depending on your school's location. Links can be found on communitywaters.org

Depending on where the water ends up, use the appropriate video (see your School Guide for suggestions):

OPTION A (stream, creek, or river):

View "**Effects of Urbanization on Stream Ecosystems.**"
Watch from 0:00 to 2:11.
Also available at https://www.youtube.com/watch?v=BYwZiiORYG8

This video focuses on the ecosystem impacts of urban pollution. It uses some big words and is pretty dense, so we recommend rewatching 1:21 to 2:11 several times with pauses to identify the problems the video is identifying.

OPTION B (Puget Sound):

View "**Drained: Urban Stormwater Pollution.**"
Watch from 0:00 to 2:57.
Also available at
https://vimeo.com/51603152

The "Drained" video is specifically about stormwater outfalls into Puget Sound; you will need to provide some additional thoughts if your school's stormwater goes into a stream or other water body before going to Puget Sound.

Later in the unit when considering Solutions: If students are having trouble connecting the solutions to the bigger problem of pollution in Puget Sound, you could watch the rest of the "Drained: Urban Stormwater Pollution" video.

Reflect and Explain

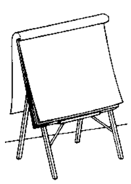
Turn-and-Talk

What problems does OUR stormwater cause?

6. Discuss observations from the maps and video (whole class)
Have students turn to a partner to look back at the chart they created earlier. Which of the possible things that they wrote on their chart actually happen with THEIR water?

Each student should add any missing items and underline on their lists the items that are relevant.

Public Record



Class Summary Table
Complete the Row

7. Connections to the phenomenon (whole class)

Return to the Class Summary Table to fill in a row for this lesson. Observations would be things they noticed on their maps. Learning could be general but also should include the things students underlined on their T-charts.

Example of what your finished summary table row might include:

Activity	What did we observe?	What did we learn?	How does it help us explain and/or solve stormwater in the city?
3: Local Stormwater Systems *"Where does our stormwater runoff go and what problems does it cause?"* Pipes map	– *There are a lot of stormwater <pipes and/or ditches>* in our area.* – *Water in our neighborhood goes into <stormwater pipes or combined pipes or stormwater ditches>** – *Our water ends up in <a creek, or the lake, or the Puget Sound>** ** Will vary depending on neighborhood.*	– *There are hidden pipes that help move stormwater.* – *Our water ends up in <a creek, or the lake, or the Puget Sound>. ** – *Our water causes problems when <too much floods the creek or it causes a combined sewer overflow or it carries pollution into the lake or sound>. ** – ** Will vary depending on neighborhood.*	– *Stormwater runoff in the city goes into pipes and ditches.* – *Putting stormwater into stormwater pipes causes problems elsewhere.*

TEACHER DECISION POINT

Assessment opportunity: will students draw, write, or discuss with others? See "Examining Student Work below".

8. Make the Connection (individual)

Challenge students to sketch a picture showing an effect the stormwater from their community could have **after** it flows into a storm drain. They should include labels.

OR

Have students write a story about a place and the people and/or animals (like salmon!) that would be affected by too much stormwater runoff (could be flooding or pollution).

OR

In pairs or small groups: Discuss why stormwater runoff matters to people and places. Who or what might be affected? How?

EXAMINING STUDENT WORK

Examine what students have drawn on their maps with the markers. Were they able to mark a path to the edge of the map?

From your observations after the video of the discussion and public record, are students understanding what happens to the stormwater runoff from their neighborhood? Do they care?

From your observations when students are examining and discussing the maps, are they able to relate them to the real world?

The pictures students draw, stories they write, or discussions they have offer an opportunity to see whether they are making the connection between the water going into their local storm drains and the problems it can cause further away. Do the pictures, stories or discussions reveal whether they care about the effects of the stormwater runoff? Are there ways to increase the personal or community connections students see with stormwater?

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below) to consider how well the tasks, talk, and tools worked for your students in this lesson and any equity issues that came up. Are there changes in approach you want to make going forward to address any concerns?

If the maps were too abstract for the students, consider bringing the local ones with you on a walk with your students. You could then have students find the storm drains on the map and walk the route taken by the underground pipes.

If students are not making the connection to the effects downstream or are not caring about it, consider whether that has an impact on your Decision Points in the next lesson. Is the stormwater outflow a place you could visit during the next lesson, might you have a guest speaker who is impacted by it or working on the problem, or could you otherwise investigate the impact it has?

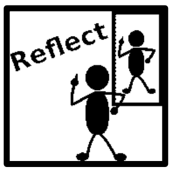
Check your School Guide to see if any local examples of problems created by stormwater are included. Here are some example relevancy connections to consider:

- A nearby stream that floods could end up as a walking field trip to examine the erosion caused by the flooding or you could have a local person in to share how the flooding has affected them.
- If you are raising salmon in your school, you (or a staff person more involved with the salmon) could talk further about how stream flooding or pollution might impact the salmon.
- If the students swim or otherwise recreate in or on a nearby body of water, it's likely stormwater has an impact on that water and if it's safe to swim in.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools & Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

Tools. How did the tools used (e.g. neighborhood maps and class summary table) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question).

Optional Take-Home: Stormwater in our Community

OBJECTIVES & OVERVIEW

IMPORTANT NOTE: This lesson has been designed as an at-home connection activity. This could be assigned any time between Lesson 2 and 5.

This lesson provides students an opportunity to see and think about what is happening to stormwater in their neighborhood and connect to where they live and is an opportunity to involve families or caregivers. They will look for where water goes, what effects it has, and if there are ways people are trying to deal with stormwater.

- Students explore their neighborhood to gather data about where water goes.

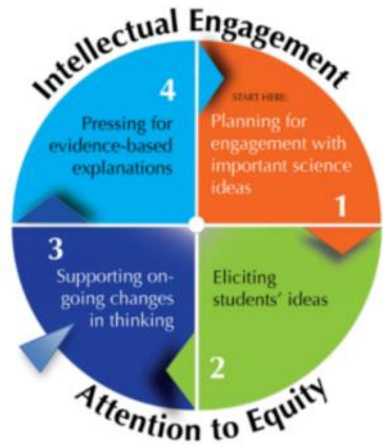
Focus Question: What happens to stormwater in our neighborhood?

Learning Target: I can make observations to understand what happens to stormwater in my neighborhood.

New Terms: None

Ambitious Science Teaching Framework:

SUPPORTING ONGOING CHANGES IN STUDENT THINKING



This practice supports ongoing changes in student thinking by (1) introducing ideas to reason with, (2) engaging with data or observations, and (3) using knowledge to revise models or explanations. For more visit http://AmbitiousScienceTeaching.org

NEXT GENERATION SCIENCE STANDARDS

PE 3-5-ETS1-1. Define a simple **design problem reflecting a need or a want** that includes specified criteria for success and constraints on materials, time, or cost.

PE 4-ESS2-1. Make observations and/or measurements to provide evidence **of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.**

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

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
Asking Questions and Defining Problems. • Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1) **Planning and Carrying Out Investigations.**	**ESS3.B Natural Hazards.** • A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts. (4-ESS3-2) **ESS2.A Earth Materials and Systems.** • Rainfall helps to shape the land and affects the types of living things found in a region.	**Cause and Effect.** Cause and effect relationships are routinely identified, tested, and used to explain change. (4-ESS3-2)

• Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.	Water, ice, wind, living organisms, and gravity break rocks, soils and sediments into smaller particles and move them around. **ESS2.E Biogeology.** • Living things affect the physical characteristics of their regions.	

MATERIALS

- **Printed Stormwater Scavenger Hunt** worksheet (one per student)*
- **Optional** (found on communitywaters.org)**: Neighborhood Stormwater Cards:** to project for introduction
- **Optional** (found on communitywaters.org)**: Stormwater Features Guide**: to send home for adults

For optional discussion as a class: 1 for every 4 students:

- Print **"Discussion Diamond Group Worksheet"** on 11x17 paper.

*There are versions of the worksheet on communitywaters.org that have been translated into Amharic, Arabic, Chinese, Somali, Spanish, Tagalog, Tigrinya and Vietnamese.

PREPARATION

DECISION POINT

When and how to assign this activity?

Website

Worksheets in different languages can be accessed on the website.

Individual students do a "Stormwater Scavenger Hunt" on a walk with an adult around their neighborhood to gather information about what happens to stormwater in their home neighborhoods. Students should think from the perspective of the water: "If I were a raindrop, where would I travel to? What would get carried along with me as I go? What would slow me down?" They will also look for an area that may help or have problems with too much stormwater.

We have videos that can support students and families in doing a walking field trip on their own:

"Neighborhood Scavenger Hunt" video with Jessica - https://vimeo.com/569607628/4b60efef2a

Preparation for Take Home Assignment:

- Send a note home to let families know about the assignment and invite their participation.
- Print Scavenger Hunt worksheet for students

PROCEDURE

Small Groups

1. **Activate prior knowledge and experiences**

What happens in your neighborhood when it rains a lot?

Thinking back to the previous lessons, where does our stormwater end up? Review the maps from Lesson 3.

Have small groups discuss what they have seen in their neighborhood when it rains a lot: Where does the water go? Are there puddles that cause problems? Flooding? Areas that get washed away? Other problems?

2. Introduce Activity (<u>IN CLASSROOM</u>, whole class):

Each student will be doing a scavenger hunt to figure out what happens to stormwater in their OWN neighborhood. They can talk with their adult at home to decide whether they do it on a walk together, do it themselves in an area they are allowed to go, or fill in what they can see from where they live.

Focus Question: What happens to stormwater in our neighborhood?

Present visual

Stormwater Scavenger Hunt Sheet

Project the worksheet, Neighborhood Stormwater Cards and/or Stormwater Features Guide (from printed or online copy) to show students what they should be watching for. Go over at the pace that best meets needs of students. Example of a card *(front and back):*

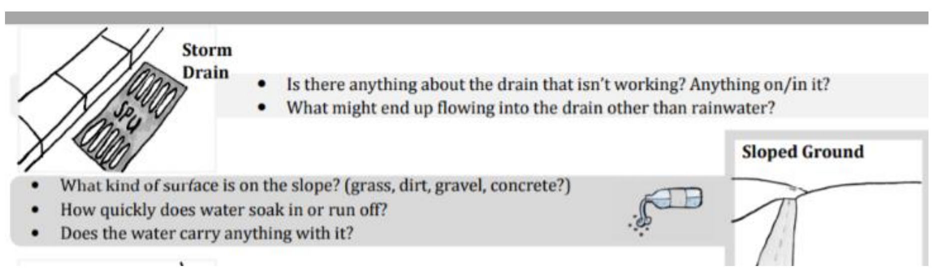
Storm Drain

Storm Drains move water into underground pipes to take it somewhere else. Anything that gets carried into the drain may end up in a local stream, lake, or Puget Sound.

- Why do you think the drain was built in this location?
- Is there anything about the drain that isn't working?

Investigation: Do you see anything IN the drain? Anything on top of it? What might end up flowing into the drain other than rainwater?

Stormwater Features Guide example:



Review with students the instructions printed on the **Stormwater Scavenger Hunt**.

Challenge students to find and draw an example of each of the scavenger hunt items in their neighborhood. You may want to use the Neighborhood Stormwater Cards to show students visuals of what they might find or look for. Make sure they know that they may not be able to find every item in their neighborhood.

They will be drawing a location that could have stormwater runoff problems – or be helping with stormwater runoff - in the box under #9. They will label

Turn-and-Talk

Practice explaining the assignment.

things that might slow down or speed up stormwater and include arrows showing the direction of water flow.

Have students turn-and-talk to practice explaining the assignment to an adult at home.

Provide a due date to have completed the assignment).

Reflect and Explain

Small Groups

Discussion Diamond to record and share observations

1. **IF MOST or ALL students do the activity, use a Discussion Diamond to have students process and share their observations in small groups.**

   Divide students into groups of 3-4.

   Have student worksheets on their desks for review.

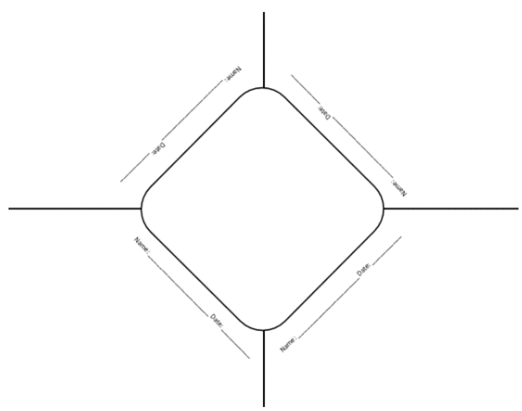
   Project the questions and procedure (at end of lesson):

   - *What did you notice or wonder about stormwater during your walk?*
   - *What did you find that would increase or decrease stormwater runoff in your neighborhood?*
   - *What problems did you find, if any?*

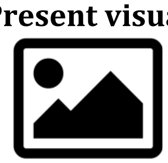
   Hand out **Discussion Diamond sheets** to each group of 3-4 students and explain how the sheet will be used.

Discussion Diamond

This AST strategy uses a writing scaffold to capture individual thinking as well as the group's consensus or summary of what was discussed.



Present visual



Discussion Diamond Questions and Procedure

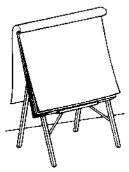
- Students will have about 3 minutes for silent thinking and writing time. Each student writes or draws in their corner of the paper.
- Then individuals will share what they wrote or drew in their small groups for a total of around 4 minutes. After each person shares, they should take some time for other students to ask questions, add on, or connect to what they wrote.

As students write, circulate and press deeper for students who claim they're done or help others get started who seem stuck.

- After all students have shared their corners, remind them of the question prompts, and then one member records a summary of things multiple members of the group observed or agreed on. Teams work together to help the recorder do this in 1-2 minutes.
- Designate or ask for one person to present their common idea to the class.

2. Apply understanding (whole class)

Public Record



Class Summary Table – fill in row

Have one student from each group share their group's observations while you write them in the observations section on the class summary table. Problems students found could be put in the learning column and things that decrease stormwater could go in the last column.

Prompt students to provide additional things they learned and ways what they learned or observed inform their model.

See below for some examples:

Activity	What did we observe?	What did we learn?	How does it help us explain and/or solve stormwater in the city?
Neighborhood Stormwater *""What happens to stormwater in our neighborhood?"* Tape map or blank scavenger hunt sheet	– *Our neighborhood has a lot of impervious surfaces.* – *There are steep hills* in our neighborhood.* – *We saw <*> storm drains.* – *Gravel moved on to the road by stormwater runoff. ** – *There is a stormwater ditch* near our school* – .... * *Observations could vary widely depending on the neighborhood.*	– *What we have been studying actually exists around our neighborhood(s).* – *We can identify what is going on with stormwater no matter where we are.* – *Stormwater runoff causes <Specific problem identified by student(s)> in our neighborhood.* – ** Will vary depending on neighborhood.*	– *We need to also be thinking about what is happening with stormwater outside the schoolyard.* – *We should add storm drains to our explanatory model.* – *There are things that help with stormwater already existing in our neighborhood. ** – ** Will vary depending on neighborhood.*

EXAMINING STUDENT WORK

Review the discussion diamonds for each group to see what each student contributed and what stands out. The student worksheets are another opportunity to see student thinking around stormwater. Is each student's work reflecting understanding of stormwater runoff? Are they able to identify what kinds of things are making it worse or better?

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make going forward to address any concerns?

The next lessons shift into applying student's understanding of stormwater to develop an explanatory model of a stormwater runoff problem at a local site.

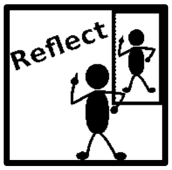
If students' understanding of "too much stormwater" is incomplete, what additional work needs to be done? Some ideas for further work are:

- Students could draw a model of the stormwater system as they understand it, from school or home to the stormwater "end" point.
- You could review student's original explanatory models to have students explain what they would add to the model to help it more accurately reflect what happens to stormwater.
- You could show more videos of stormwater, flooding, or storm events.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools & Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

Tools. How did the tools used (e.g. neighborhood maps and class summary table) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Stormwater Scavenger Hunt - *What's in my neighborhood?*

Name: ______________________________ **Date:**________________________________

We have been studying water runoff around our school. The purpose of this assignment is to gather information about the places and things that affect the amount and rate stormwater runoff in your community.

Directions: Take a walk with an adult around your neighborhood and search for the items listed in each of the boxes on this page and the next - how many can you find?

When you find an item, draw an example in the box and label your drawing. Keep an eye out during your search for an **area you predict or see could help or cause problems with stormwater runoff**. When you find one, draw a picture of it in box 9 on the back of this sheet.

Stormwater Scavenger Hunt Items:

1) Storm drain	2) Stream/creek, pond, or lake Do you know its name?
3) Garden or rain garden	4) Drain from a roof
5) Steep slope with plants	6) Steep slope with pavement
7) Something that might get carried into a storm drain	8) Something that collects stormwater runoff from a roof or pavement

Stormwater Scavenger Hunt - *What's in my neighborhood?*

9) Draw a picture of an area that is helping or causing problems with stormwater runoff:

Label the things that might **speed up** the water:

- ✓ Slopes or hills
- ✓ Rooftops
- ✓ Concrete or asphalt

Label the things that might **slow down** the water:

- ✓ Trees
- ✓ Other plants
- ✓ Ponds or other places for the water to sit

Use arrows to show the direction water is or would be flowing.

How well does this area handle stormwater runoff? Use evidence to support your answer.

____

____

____

____

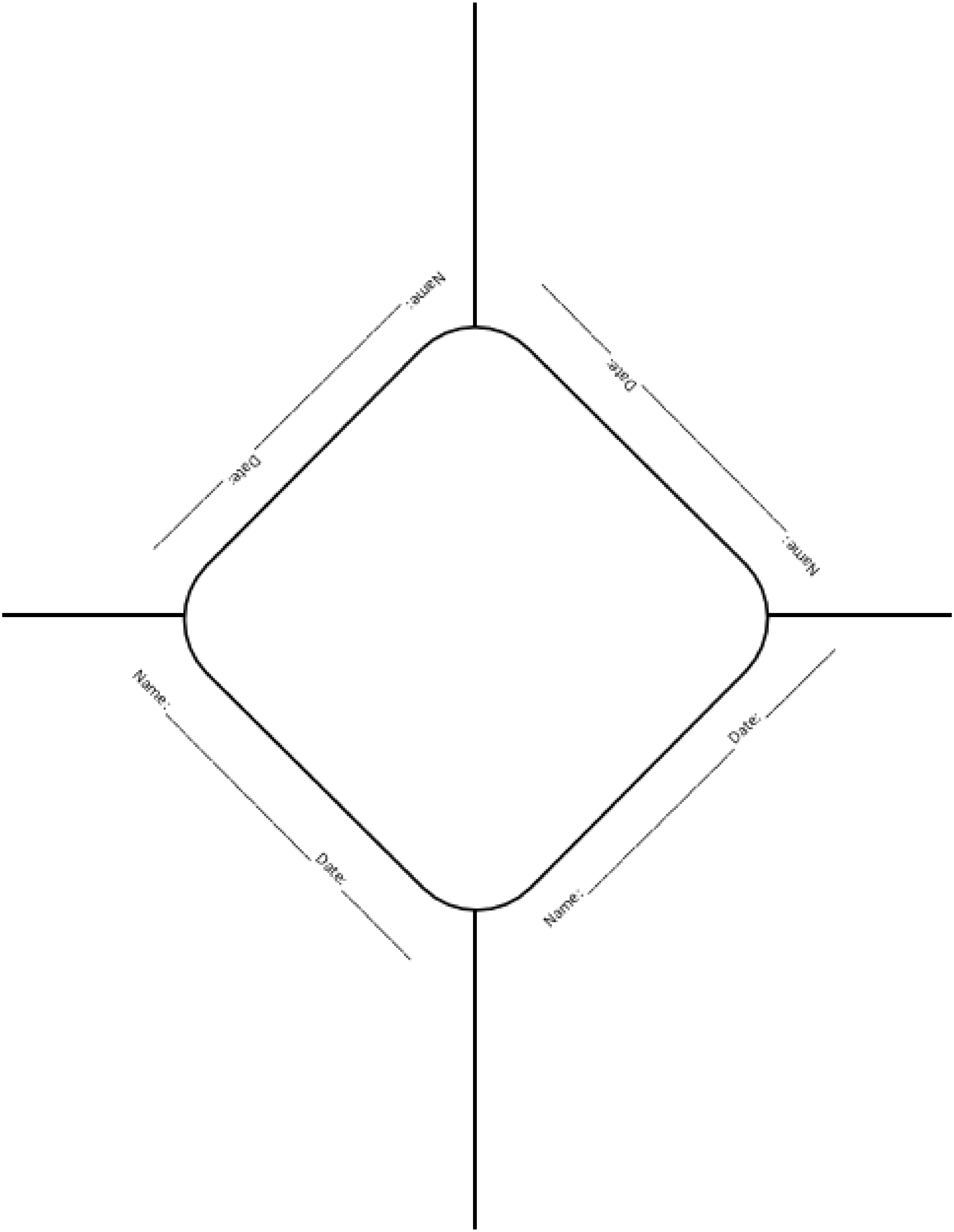
Discussion Diamond

Questions to Answer:

- What did you notice or wonder about stormwater during your walk?
- What did you find that would increase or decrease stormwater runoff in your neighborhood?
- What problems did you find, if any?

Using the Diamond:

1. Write your name and the date on your corner of the diamond then take 3 minutes to write or draw your answers in your corner.
2. Each group member shares their answers and answers other's questions.
3. Record a summary of discussion in center Diamond.
4. Share your group's summary with class.


Name:
Date:
Name:
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Name:
Date:

Assessment of Understanding

OVERVIEW

A new copy of the Explanatory Model from Lesson 1 is used at this stage to assess student understanding of urban stormwater runoff.

NEXT GENERATION SCIENCE STANDARDS

Students are provided the opportunity in this assessment to demonstrate their understanding of the following Dimensions:

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
Developing & Using Models: Develop a model to describe phenomena. **Constructing Explanations and Designing Solutions.** • Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem. • Identify the evidence that supports particular points in an explanation.	***ESS2.A: Earth Materials and Systems* -** Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. (4-ESS2-1) ***ESS2.E: Biogeology* -** Living things affect the physical characteristics of their regions. (4-ESS2-1) ***ESS3.B: Natural Hazards* -** A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts. (4-ESS3-2)	**Cause and Effect -** Cause and effect relationships are routinely identified, tested, and used to explain change. (4-ESS2-1)

MATERIALS

For the class:

- Butcher/chart paper or PPT slide for Explanation Checklist
- Markers

Per student:

- Copy of the **Explanatory Model Worksheet**. Printing these on 11x17" paper will provide more space for student explanations and later additions. This may have been printed on the back of the one used for lesson 1.

PREPARATION

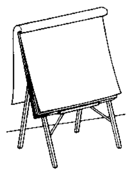
None

PROCEDURE

Explanatory Model

A new copy (or back side) of the model they have been using

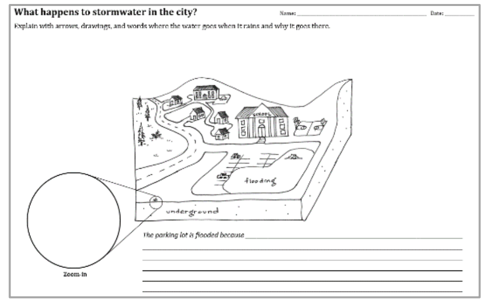
Public Record



Class Summary Table

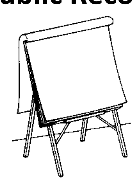
10. Share the Plan

Project (optional) a blank "**What Happens to Stormwater in the City"** explanatory model and explain that students will be creating a new version of the model they have been working on. This one will be an opportunity represent all the understandings they have built over the course of the unit.



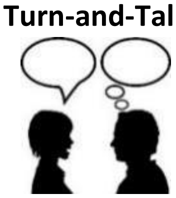
They will be using the knowledge they built up during this unit to create a complete explanation of what would happen to stormwater in the location pictured. In doing so, they can use their previous model and reference the **Class Summary Table**. They won't be allowed though to copy from other student's explanatory models and can't use the **Class Consensus Model** (if you have been creating one with the class). In addition, the class can create a shared checklist with everything we think should be included in the model.

Public Record



Explanation Checklist

Turn-and-Talk



What ideas do we need to include in our explanation of what happens to stormwater at our site?

11. Generate Explanation Checklist (whole class)

The checklist will be something students can reference while filling out the model to make sure they are providing a complete explanation that shows all of their understanding. It doesn't include the information to be shared, just the areas that need to be included.

The **Class Summary Table** and students' original explanatory models, are resources to help our thinking about what should be included in our checklist.

Use the first column from the class summary table to offer an example of what should go on the checklist (e.g. "Locations where stormwater moves on the surface and any spots where erosion occurs.")

Give private think time and then have students turn-and-talk to discuss what ideas will be important to include in our explanations.

Example Explanation Checklist

We should show or explain…

- ❑ Where runoff goes and where water moves into groundwater or leaves the map.
- ❑ Where the water ends up off map.
- ❑ The effect of plants on runoff.
- ❑ What could be causing too much runoff.
- ❑ Where pervious and impervious surfaces are how they work.
- ❑ Places where erosion might have occurred.

Share some ideas and generate an explanation checklist on chart paper with markers.

Explanatory Model

Showing what they understand.

12. Creating Explanatory Models (Individual) – 20 mins

Students should try to fully represent their understanding of stormwater runoff on their models. They can use the empty space around it for additional words and diagrams. The model should be something they could use to explain what they know to others.

After students begin working, circulate asking them about what they are including to help represent what happens to stormwater in that area. How could they sketch it or represent it with words?

Redirect students as needed to the explanation checklist, the summary table, or their notebooks to help them make progress on their models.

Differentiation

Consider the following for students with…

- **Limited English:** Could write explanations in their first language if desired (leaving it to you to find a translator) or dictate to another student who speaks both languages or explain in a video recording.
- **Limited Writing Skills:** Could initially focus on drawing and symbols and then dictate their words to you or another student or explain in a video.
- **Advanced Learners:** Challenge them to add more details and show greater understandings. Could provide them a version with less scaffolding (available on website).

Back-Pocket Questions

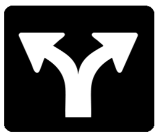
Modeling

BACK-POCKET QUESTIONS
Observations & Modeling

- What have you included on your model so far?
- Where do you think stormwater travels through the site? How are you going to represent that?
- What isn't on the map that should be represented?
- How have you included ______ from the explanation checklist?

This is a great place to stop and collect models. You could then look through them between classes (see Assessing Student Work section below) to decide whether you want to follow up with an opportunity for collaborative revising of the models.

DECISION POINT



PART II?
Do you have time?
Is it needed?

Collaboration?
The remainder of this lesson is a great opportunity for further collaborative revision of ideas but could be skipped if your time is short.

*NGSS Note: In Appendix F: Science and Engineering Practices, one performance of developing and using models for grades 3-5 students is to **collaboratively develop and/or revise a model** based on evidence that shows the relationships among variables for frequent and regular occurring events.*

PROCEDURE — PART II: OPTIONAL COLLABORATION

Turn-and-Talk

What have you shown in your model?

13. Collaboratively revising models (pairs)

Have students turn-and-talk to share their models and see what they agree or disagree on. Do their explanations agree? How might they adjust their models based on what their partners did?

Whole-class discussion

Collaboratively revising a model based on evidence

14. OPTIONAL: Public Comparison of Models (whole group)

Physically orient students towards each other: Have students bring their model sheets to the gathering area and sit so students can see and hear each other and the screen easily.

Set the purpose of today's discussion: Say something like: *We are coming together to see ways to represent ideas in models and how we use evidence to support our ideas. Give each other feedback by agreeing or disagreeing and saying why you think the evidence they picked supports their idea or if you think another piece of evidence from our summary table would be stronger. After the discussion, you will have time to add more evidence or clarify your ideas on your models.*

Allow students to use talk norms and lead and manage the talk*:* Remind students of talk norms and encourage them to call on each other and not look to the teacher.

Choose one pair to start the conversation and have them share something they agreed on with their evidence or reasoning. Encourage students to agree or disagree, in either case, saying what evidence they used or would use and how it supports their idea. Students should be sharing work under the document cameras as they have a discussion. Peers could suggest changes to either their ideas or the evidence they selected.

15. Make Adaptations to Models (pairs/individuals) – 10 mins

Have students go back to working individually and make changes to their models to clarify their ideas, add new ideas they heard during the discussion they agreed with, and to add or change the evidence they selected to support some of their claims.

By the end of the lesson students should have drawn and written about their ideas to explain the phenomenon and have at least two sticky notes with evidence to support two of their claims.

16. How Has My Thinking Changed? – 10 mins

Quick Write

How has my thinking changed?

Have students compare the models they created at the start of the unit with their new models. Have students write how their thinking has changed in this unit. Possible prompts

> **Sharing with Parents?**
> Consider having students share this reflection with an adult in their family. This could be especially useful if you have an upcoming parent-teacher conference that includes the students.

- *At first, I thought…. Now, I think…*
- *I used to think…. Now, I know…*
- *Before I didn't know how… But now, I learned that…*

Be sure to keep the students' Explanatory Models for reference in the remainder of the unit!

EXAMINING STUDENT WORK

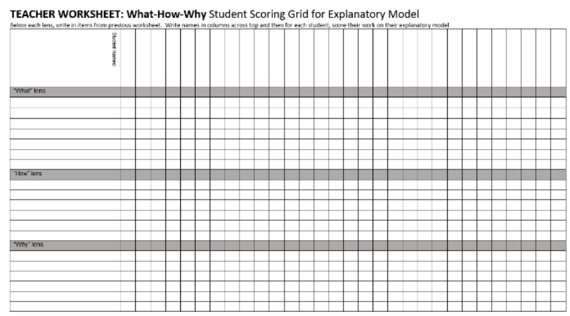
What understandings have the students represented in their models? Did they accurately represent what was on the explanatory checklist? We have provided several tools to support your understanding of this:

Explanatory Model Rubric

There is a rubric (at the end of this lesson) to help you score the student's models and assess their understanding. This could be used as a summative assessment for the first half of this unit if desired.

What How Why Assessment Tool

If you used it at the end of Lesson 1, you could return to the **What-How-Why Assessment Tool** in this section of that lesson to examine how each student's depth of understanding and capacity to represent it has changed. Go through your student's new explanatory models and add any new items to rows in the same sorting sheet you used before.


TEACHER WORKSHEET: What-How-Why Student Scoring Grid for Explanatory Model

When done, revisit your new items to see if you are still happy with the row you put them in. Move them as needed.

Then either add any new key points to the spreadsheet you used before or print a new copy of the **What-How-Why Scoring Grid** (2nd page of teacher worksheet) and fill it in for this new round with items and student's names. Revisit each student's explanatory model to check the boxes for what each student has represented in their model. There may be student representations you will want to follow up on with students to see what they were thinking when they wrote or drew them.

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make going forward to address any concerns?

Looking Forwards: In the remainder of this unit students identify a problem and then use the Engineering Design Process towards solving the problem at the site they have identified.

Key Ideas for student teams to understand as they start trying to solve their stormwater runoff problem, include:

- Stormwater runoff causes problems.
- Water moves across the surface when it can't soak in (impervious surfaces).
- Water soaks into the ground where there are pervious surfaces.
- Plants help with stormwater runoff.
- Water that leaves the site by pipes or ditches is going to cause a problem where it ends up.

If understandings are missing or alternative conceptions haven't been revised, you can return to the tables in this section of Lesson 1 to identify the lessons meant to address them. You could then remind students of those lessons to help them think further about their understanding.

For example, if you have students who didn't identify where the water went after it went into the storm drains, that table points out that "lesson 5: Stormwater Systems" addressed this and you could then pull the maps back out for students to consider.

Further lessons: If the lack of understanding is widespread and/or you have capacity to work with some smaller groups on understandings, you could consider the following:

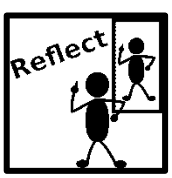
- **Need for more understanding of stormwater?** Is the lack of understanding something you could revisit with additional information or investigations? Consider, conducting an investigation in which you are pouring water outside as a way to make the learning more real.
- **Understanding of the larger problem?** Not getting that the stormwater causes problem elsewhere can lead students to conclude that their best solution is more storm drains to get the water off the site. Consider watching the video again from Lesson 3 that talks about where your school's stormwater ends up. You could also get school specific maps back out to review where the stormwater goes.

Engineering Teams: Think about your student's understandings when you divide them up into engineering teams later in the unit. The teams will need to be working together on researching and testing solutions but could ALSO provide great opportunities to share their understandings with each other.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools & Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Community Waters: Explanatory Model Rubric

Criterion	Not Yet (1 point)	Approaches Expectations (2 points)	Meets Expectations (3 points)	Surpasses Expectations (4 points)	Score or Notes
Uses a key to describe the symbols used by student.	No key is provided	The student's explanation does not need a key OR the key is included but it is missing some symbols	Key included with all the things represented on map	Additional explanation of what is represented in key provided.	
Rain and Runoff are included as a part of the model.	Does not include rain OR runoff	Rain OR runoff are included but are represented as only in ONE area	Rain AND/OR runoff are shown as occurring in multiple areas on the map.	Both rain AND runoff are shown in multiple areas.	
Shows* **movement of stormwater runoff** through the area. [With arrows, symbols or text.]	Stormwater runoff movement not represented or obviously mis-represented	Movement of stormwater runoff shown.	Stormwater runoff shown moving downhill across impervious OR soaking into pervious surfaces	Stormwater runoff moving downhill shown and explanation of how water interacts with both pervious AND impervious surfaces	
Pervious and Impervious surfaces represented*. [Accurately.]	Water is not shown as moving across or soaking into surfaces	Idea of water soaking in OR running off is represented	Both water soaking in AND water running off are represented	Pervious AND Impervious surfaces are shown AND labeled as pervious and impervious	
Shows* the **built systems** that are designed to move stormwater to another location.	Neither Storm drains OR ditches are added to model	Storm drains OR drainage ditches are added	Where the water goes after it leaves the area shown is included	Explains the impact the stormwater has after it leaves site	
Makes a claim and uses the model as evidence when explain why the parking lot is flooded. [Does not have to be correct.]	No explanation provided OR explanation an opinion only.	Explanation clear but does not reference model.	Explanation uses the model as evidence (e.g. slopes in drawing or features added by student)	Explanation uses model as evidence AND provides broader scientific reasoning for why the puddle happened	
Impervious surfaces and movement of stormwater runoff across surface are included in the explanation for the puddle. [Accurately.]	Explanation does not involve stormwater	Explanation includes either water not soaking in OR movement of stormwater runoff to the location.	Water not soaking in AND movement of stormwater runoff to the location are a part of explanation.	Accurate reasoning behind explanation provided OR explanation includes another possible factor.	

*Arrows, drawings and text are all valid ways for students to show what they know. If any one of these is sufficient, they do not have to use the others.

Lesson 4: Choosing a Problem Site

OBJECTIVES & OVERVIEW

This lesson shifts from building initial scientific understanding to applying it during engineering design. Students (or the teacher) choose a specific site with a stormwater runoff problem and apply the understandings they have built to explain what is happening with stormwater there.

- Students contribute their ideas to a class model of stormwater on a map of their site.

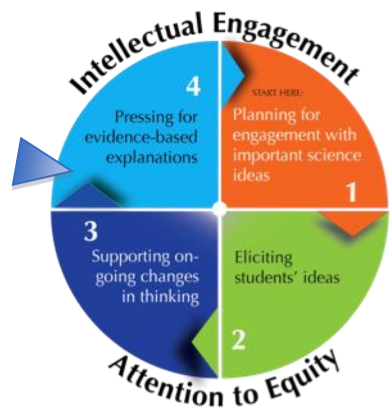
Focus Question: Where do we want to solve a stormwater runoff problem?

Learning Target: I can use what I know about stormwater to model what is happening at a specific site.

New Terms: Engineer, solution

Ambitious Science Teaching Framework:

PRESSING FOR EVIDENCE-BASED EXPLANATIONS



This practice happens as a summation, but parts can be introduced at other times when students talk about evidence. This requires that several tools be available to students: 1) their current models, 2) an explanation checklist, 3) the summary table, and 4) a scaffolded guide to help students create, in writing and drawing, their final model. For more visit http://AmbitiousScienceTeaching.org

NEXT GENERATION SCIENCE STANDARDS

Students begin this performance expectation in this lesson, but fill in more details in the next one:

PE 3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
Analyzing and Interpreting Data - Analyze and interpret data to make sense of phenomena using logical reasoning. (4-ESS2-2) **Developing & Using Models**: Develop a model to describe phenomena. **Asking Questions and Defining Problems.** Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, and/or cost. (3-5-ETS1-1)	***ESS2.A: Earth Materials and Systems*** **-** Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. (4-ESS2-1) ***ESS2.E: Biogeology*** **-** Living things affect the physical characteristics of their regions. (4-ESS2-1) ***ESS3.B: Natural Hazards*** **-** A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts. (4-ESS3-2)	**Patterns** - Patterns can be used as evidence to support an explanation. (4-ESS2-2) **Cause and Effect -** Cause and effect relationships are routinely identified, tested, and used to explain change. (4-ESS2-1)

MATERIALS

For the class:

- Butcher/chart paper or digital template
    - Problem-Constraint-Criteria Table and
    - Problem Site Explanatory Model
- Sticky Notes
- Markers
- Word Wall cards

PREPARATION – 30 minutes

DECISION POINT

Who chooses site?

Website

All worksheets are on communitywaters.org

- **Choosing a problem site:** Consider possible sites in your schoolyard that the class might focus on for the remainder of the unit (see criteria in lesson). Do you want to choose the site, or do you want the class to decide (within parameters)? Ideas to consider:
    1. Are there locations around your schoolyard or neighborhood that form puddles that cause problems for people? If not, is there another related problem you could focus students on (e.g. location where erosion is occurring because of stormwater runoff or an area with visible oil leaks, Astroturf rubber or other pollutants that go into a storm drain)
    2. Are there options the students would be especially engaged in solving? Is something obvious enough that they could propose it during the lesson? Having the students feel ownership of the site choice is a big help for the rest of the unit.

  Some schools do not have obvious locations to focus on as a problem site. If that is true for you, IslandWood staff would love to help. Please email us at communitywaters@islandwood.org.

- On butcher paper or using excel doc on the website, create a **Problem-Criteria-Constraints Table** as follows:

OUR SITE: ____

Problems to Solve	Criteria for Success	Constraints on Possible Solutions

- On butcher paper create a "**Problem Site Explanatory Model". (You can find examples on the Lesson webpage.)** Write "Explanatory Model for <school name> as a title (later you could fill that in with whatever you call the site the class will be working on). Below that write "What happens to stormwater here?”. Below this, draw a rectangle that roughly matches to the ratio in your classroom models. Leave some blank space around the outside of the rectangle similar to the explanatory model the students used. Don’t fill in the details yet!

PROCEDURE — PART 1: What Site to Use?

Engage and Encounter

Turn-and-Talk

What kinds of stormwater runoff problems have you seen that could be solved by an engineer?

17. Activate prior knowledge (whole class)

Now the students are going to shift focus towards doing something about the problems caused by stormwater runoff. They will be identifying a local location that has problems with stormwater and **designing a solution** for it.

Engineers solve problems and stormwater engineers all over the region are working right now to solve stormwater runoff problems. The students will be acting as engineers to come up with a solution for a local problem

Have students turn-and-talk: What kinds of stormwater runoff problems have the students seen so far that could be solved with some engineering?

Explore and Investigate

18. Decide on an area of focus (whole class or teacher)

DECISION POINT

Depending on your students, either tell them the site they will be focusing on, or work with them to choose a site.

Stormwater runoff is a BIGGER issue for our city and our region than we are going to solve with a single engineering solution.

Depending on the location, and the specifics of the problem, the best possible solution can be very different. To engineer a solution, we need to choose the location we want to focus on.

Write the criteria on the board and review it with the students.

The site we pick should:

- Include impervious surfaces that produce stormwater runoff.
- Include a couple possible areas where a solution could be constructed.
- Be nearby so we can walk to it.
- Be a site we care about.

- Have a local problem (like puddles during rainstorms or erosion from stormwater runoff).

Have students review the maps of their schoolyard (that they filled in during Lesson 2) as they think about possibilities.

Brainstorm site locations as a class to create a list of ideas.

Revisit what the site should include and then choose a location to work on as a class.

> *Example:*
>
> **Possible Ideas for our Site:**
>
> - *Portables and adjacent big play toy that floods when it rains*
> - *Front of school including roof, sidewalks, and bus drop off*
> - *Building exit to playground and surrounding area (floods)*
> - *The road and eroded stream bank across from the school*

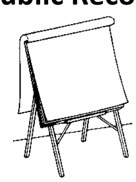
19. Develop a shared understanding of the site (whole class)

Once the site has been decided, refer the students back to previous explorations of the site.

Work with the class to agree on roughly rectangular boundaries (this will help when they create a model of it later).

> **Visit the Site?**
>
> If location, timing, and student behavior permits, you could walk to the site with the class to look at what is there and decide on the area to include.

Public Record



Problem Site Explanatory Model

Put up the blank "**Problem Site Explanatory Model**" you created earlier (you could also do this first on a projected sheet of paper if desired).

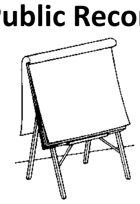
Explain that students will be creating a new version of the model they created at the start of the unit. This one will be specific to their site.

They will be using the knowledge they built up during this unit to explain what is happening to stormwater at the site when it rains. Where does it go, why does it go there, and why does it cause the problems the class just added to the table?

Solicit student input as you sketch a rough map of the buildings and areas in the box on the sheet.

Also refer to previous explorations of the site and possibly the schoolyard map that students created as needed.

Public Record



Problem-Criteria-Constraints Table

20. Name the Problem(s) they will try to Solve (whole class)

Start by introducing the big picture problem of there being too much stormwater runoff in the city as a whole. [Use your town or city instead of Seattle).

Then include any specific stormwater runoff problems they have identified at the chosen site.

Add both the general community-wide problem and any site-specific problems that students come up with to the **Problem-Criteria-Constraints Table**.

Example Problem-Criteria-Constraints Table:

OUR SITE: ***School play area and surrounding space***

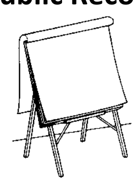
Problems to Solve	Criteria for Success
City wide: • *Too much stormwater runoff in Seattle.* *Site specific:* • *Puddles in play area.*	

Later the class will be filling in the additional columns and then picking one of the additional things they have come up with in each column to use when comparing possible solutions.

This would be a good place to stop if needed. If you are running out of time before this point, you could also wait on filling in the Problem Criteria-Constraints Table.

Visit the Site?
Between lessons could an opportunity to visit the site to look at what kinds of surfaces are present and where water goes. Maybe immediately after recess?

Public Record

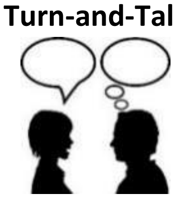


Problem Site Explanatory Model

21. Explaining the Site

Remind the students that they are going to be working as engineers to design a solution for the problem site they identified. Engineers design solutions to all kinds of problems, but to do so they need to understand what is causing the problem. The class is going to work together to show an explanation for what is happening to stormwater at our site using the **Problem Site Explanatory Model** we put buildings on earlier.

Turn-and-Talk



What should we put on our classroom model?

Have students look at their explanatory models from the mid-unit assessment to think about what should be included on the Problem Site Explanatory Model to explain what is happening there. After thinking individually, they will then talk about their ideas with a partner.

Student pairs will be figuring out together what they think should be shown on the model and putting each idea they come up with on a sticky note to be put on an appropriate part of the model.

Provide pairs some time to talk and create sticky notes.

Prompt students to bring their sticky notes up and

Back-Pocket Questions

Modeling

BACK-POCKET QUESTIONS
Modeling
- How is our site similar to the drawing on the explanatory model you created?
- What would help us understand the cause of the problem at our site?
- Are there any symbols you used on your explanatory model that we could use?
- Do you think your explanation of what cause the puddle in the parking lot on your explanatory model could be helpful in thinking about what causes the problem at our site? What should we use from it?

put them in an appropriate place on the Problem Site Explanatory Model.

Whole-class discussion

Collaboratively revising a model based on evidence

22. What should go on our class Problem Site Model?

Sort the sticky notes to find common ideas and discuss them as a class.

Create a common key with symbols the class can agree on.

Add any ideas the class agrees on to the model.

If needed, you could provide a second round for student pairs to consider what else needs to be added.

Explanation Checklist
(for teacher)

Make sure the class Problem Site Model includes:

- ❑ The problem area (and any other puddles on site)
- ❑ Previous and Impervious surfaces in the area
- ❑ Where the water in the problem area is coming from
- ❑ Things that are affecting the flow of water (e.g. gutters, storm drains, curbs….)
- ❑ Erosion (if there is any)
- ❑ Where the water leaves the site and problems it causes off-site

EXAMINING STUDENT WORK

Public Records: Consider the Problem Site Explanatory Model and Problem-Criteria-Constraints Table you created with the class:

- Does the model accurately portray what is happening with stormwater at the site? Does it include the items on the explanation checklist?
- Do the problems to solve on the table include a clear bigger picture AND a clear local effect problem?
- Do you feel like students have a good sense of the real-world site that they are going to be able to reference as they work with a physical model of it and start to think about solutions?

PLANNING NEXT STEPS

Looking Forward: In the next lesson students begin learning and using the Engineering Design Process towards solving the problem at the site they have identified.

- **Incomplete Model?** If the problem site explanatory model is missing things, consider how and when you want to add more to it.
    - Would it be helpful to revisit the Class Summary Table to consider something on it that should be added to the problem site explanatory model?
    - Are there specific understandings you need to revisit with students to help them translate to the site?
    - Do you want to wait to add things to the model until after the students have interacted with the physical models of the site or started to think about solutions?

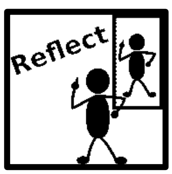
- Would a visit to the site to pour water and make observations help? What about a visit while it is raining?

- **Incomplete Understandings?** You could revisit the "Planning Next Steps" section in Assessment write-up just prior to this lesson for ideas.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools & Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson? Did it help students clarify and explain their thinking?

Tools. How did the tools used (e.g. explanatory model and your back-pocket questions) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Lesson 5: Defining our Problem

OBJECTIVES & OVERVIEW

In this lesson the students define the criteria for success and constraints that could limit the possible solutions for their stormwater problem site.

Students take the opinion of stakeholders into account as they define their specific criteria for success and constraints on any solutions.

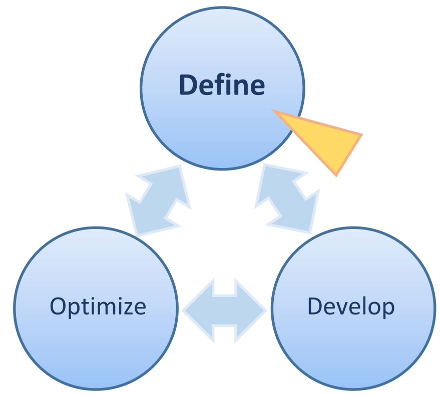
- Students represent a stakeholder perspective when discussing their site.
- Students decide on the criteria and constraints for a solution to too much stormwater runoff at their site.

Focus Question: What do we need to know before we research solutions for our site?

Learning Target: I can define a solvable local stormwater runoff problem.

New Terms: engineering design process, criteria for success, constraints, optimize, stakeholder

Engineering Design: DEFINE PROBLEM



***Define a problem**: specify criteria and constraints that a possible solution to a simple problem must meet.*

NEXT GENERATION SCIENCE STANDARDS

PE 3-5-ETS1-1. <u>Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.</u>

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
Asking Questions and Defining Problems. • Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, and/or cost. (3-5-ETS1-1)	**ETS1.A Defining and Delimiting Engineering Problems.** • Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). (3.5-ETS1-1)	**Influence of Science, Influence of Engineering, Technology, and Science on Society and the Natural World.** • People's needs and wants change over time, as do their demands for new and improved technologies. (3-5-ETS1-1

MATERIALS

Per Student:

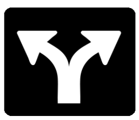
- **Stakeholder Interview Worksheet** (optional – see below)

For Class:

- **Problem, Criteria, Constraints Table** and **Problem Site Explanatory Model**
- Word Wall cards

PREPARATION – 30 minutes

DECISION POINT



Interview stakeholders?

- Prepare the **Engineering Design Process** image for projecting (either the example at end of lesson or image on communitywaters.org)
- Queue up and test **Engineering Solutions – Stormwater Runoff** video (on communitywaters.org) or at www.vimeo.com/238855219.
- **How will you incorporate stakeholder perspectives?** See options offered in lesson (below) and decide what will work best for your class.

PROCEDURE

Engage and Encounter

Turn-and-Talk

When have you had to solve a problem? What did you do, and how did you do it?

23. Activate prior knowledge (whole class)

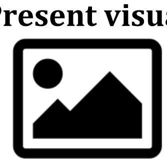
Reference the **Problem-Criteria-Constraints** table and the class's **Problem Site Explanatory Model** (created in previous lesson) as you revisit with students the problems they are trying to solve at their site.

Now they have a problem to solve….

Partners turn-and-talk to share an example of a problem they have had to solve and what they did to solve it. Have some students share their examples with the class.

24. Provide information to leverage (whole class)

Present visual



Engineering Design Process

Real-life engineers solve problems and use an "Engineering Design Process" to do so. The process has steps.

Project the **Engineering Design Process graphic** (on communitywaters.org and at end of lesson) as you introduce the Engineering Design Process to the class.

Define stakeholders, criteria for constraints, constraints, and optimize as you go through the information.

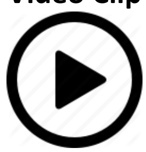
Point out that the arrows in the diagram point both ways as engineers often have to circle back as a part of the process. For example, an engineer might have progressed to the optimize stage but must return to developing other solution ideas if the chosen one doesn't work.

Just-in-Time Instruction

Engineers use a process to solve problems.

1) **Define the Problem:** Research the problem and interview stakeholders so we can define our criteria for success and the constraints that limit our solutions.
2) **Develop Solutions:** Imagine possibilities and research solutions. Evaluate our solutions based on criteria and constraints.
3) **Optimize the Solution:** Use test results to improve solutions.

Video Clip



"Engineering Solutions - Stormwater Runoff"
Length: 3:25
communitywaters.org

25. Introduce and watch the video (whole class)

This video shows an example of a student solving a stormwater runoff problem at their house. In the video the girl follows an engineering design process in just the same way as an actual stormwater engineer would.

Can students spot the steps in the process as they watch the video?

Also at https://vimeo.com/238855219

<Pause it when "Betsy the Engineer" comes on at 1:57>

Can any students point out when she followed the steps?

Watch it again from the beginning to the very end.

26. Make a plan (whole class)

Outline the remainder of the unit for students in the context of the Engineering Design Process:

Define the Problem:

- "You have already selected the problems you are trying to solve and built an understanding of what is causing the problems.
- We'll interview others who care about the site we have chosen to get their perspective on the problem.
- Then we will decide on the problems we want to address at the site, what their criteria will be for success, and any constraints on our possible solutions.
- After that we'll build models of the chosen site ."

Develop Solutions:

- "You will brainstorm possible ideas and do research to find solutions that could work at your site.
- Then you will compare the different solutions and choose which one your group wants to test."

Optimize Solutions:

- "We'll add our solutions to our models and run tests to see how they do.

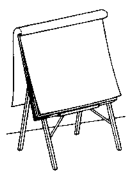
- Depending on the results, we'll redesign and come up with an optimized solution."

Develop Solutions:

- "We'll also use the data from tests as a part of comparing the various solutions our class has considered to see which ones we would recommend for our site."

"After we work through this Engineering Design Process, we will use what we learned to create a poster or some other way to share with others what we did. "Communicating Information" to others is part of science and engineering! Maybe we can even inspire others to take action to help their school or neighborhood."

Public Record



Problem-Criteria-Constraints Table

27. Get the Activity Started (whole class)

Revisit the **Problems-Criteria-Constraints table** you started filling in earlier. Remind students of the site chosen and the problems identified. To finish this stage in the Engineering Design Process ("Defining the Problem"), they will need to determine the criteria for success and constraints on any solution.

BEFORE they can do so, it is important to take into account the people who care about the site you are considering.

28. Who are the Stakeholders (whole class)?

Turn-and-Talk

Who are the stakeholders who might own, care about, or use the site?

When engineers are thinking about problems, they need to figure out who might be affected and how. We call the people who care about the solution "stakeholders." Stakeholders are important resources in thinking about the possible solutions for their community's stormwater problems. We need to know what they think about it because they may have important criteria or constraints for us to consider. We also want to make sure they are not unhappy with the solution we come up with.

Stakeholder examples:

- *Students*
- *Teachers*
- *Principal*
- *District Staff*
- *Custodian*
- *Grounds crew*
- *Neighbors*
- *Local Businesses*

Who are the stakeholders that use, own, care about, or interact with the site?

Students brainstorm a list with a partner.

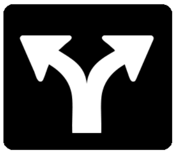
Then create a list as a whole class.

Who Else?

This is a great time to encourage students to be inclusive in their thinking: *Are there other stakeholders outside of our school who we aren't thinking of as stakeholders? What about other children or community members who might use the site? Who may have historical or current connections to this land?* Depending on your site, and your students' thinking you might also include birds and other animals as "stakeholders" (or as things human stakeholders might care about).

29. Optional: Interview the Stakeholders (individuals, pairs, or whole class)

DECISION POINT



Students interview stakeholders?

The best way to understand what a stakeholder wants is to ask them. This can be done in an interview. They can explain what stormwater is and use their models of the problem to describe the site. Then they should ask the following questions:

- Why do you care about this site?
- How do you use the site?
- Do you have any concerns about stormwater runoff or too much water in the area?
- Is there a project to help with these problems that you would recommend?
- Are there any concerns you have about changes to this site?

> **Stakeholder Interviews?**
>
> Options for stakeholder interviews include personal one-on-one interviews, recess time surveys, inviting somebody in to be interviewed by the class, and interviewing each other.
>
> You could alternatively skip doing actual interviews and have students speak on their behalf instead.
>
> If students **will** be doing stakeholder interviews, you will need to continue this lesson after they have sufficient time to complete the assignment (or after you interview somebody as a class).

Hand out the **Stakeholder Interview worksheet** and walk through with students how they would use it when doing interviews.

You could pause the lesson before incorporating stakeholder input. If you are running out of time but still want to do stakeholders interviews, that whole section (above) could be its own mini lesson (or fill a full session if you are bringing somebody into your classroom).

30. Incorporate Stakeholder Input (pairs)

Turn-and-Talk or **Discussion Diamond**

What does the stakeholder you represent want to have happen at the site?

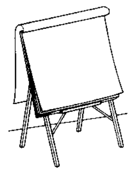
Challenge the students to represent the stakeholders they interviewed about the site and/or imagine themselves as one of the stakeholders. Have them pair off (or use a discussion diamond process like the one in Lesson 6) to consider: *What do the stakeholders want included in any solution? What are they going to want to make sure stays the same?*

Either ask the partners to represent their stakeholders as you continue or compile the key stakeholder inputs onto a large sheet and then decide as a class which ones are especially important to keep in mind (underlined).

> **Stakeholder Input:**
>
> *Students:*
> - *<u>Hate the puddles in the play area</u>*
> - *Want another 4-square court*
>
> *Principal:*
> - *More plants would be nice*
> - *<u>District will have to approve changes</u>*

31. Consider Criteria for Success (larger group)

Public Record



Problem-Criteria-Constraints Table

When engineers are defining a problem that they can come up with a solution for, they ask themselves what success will look like. These "criteria for success" are then something they can use to consider solutions, test their solutions, and ultimately decide if they succeeded. They are asking the question: How will we know when we're successful?

Ultimately for our community-wide problem, **less water leaving the site is a success**. (Write that down as a #1 criteria). Are there other things that should be considered? Any other problems at the site that need to be addressed or desires of stakeholders that would be important to consider?

Add to the table additional criteria students come up with.

32. Consider Constraints on possible solutions (larger group)

Turn-and-Talk

What limits would you and/or the stakeholders you interviewed want to put on possible solutions?

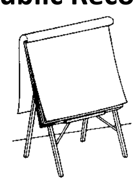
Students need to figure out the boundaries in which their solutions must fit. What limitations are there when it comes to materials, costs, or amount of space? Are there any other things about their site, or that they learned from stakeholders that limit which solutions they can choose?

Provide the students with two constraints that are a given (and write them on the chart):

1) **Work within the space available at the site:** Students need to find solutions that can work within the limits of the space available in the site.

2) Keep costs low: The solutions should be as inexpensive to build and maintain as possible given the criteria for success.

Public Record



Problem-Criteria-Constraints Table

Considering the location and stakeholders involved, what other constraints should be considered? Have students turn to a partner and talk about whether the stakeholder they interviewed would want to set any limits on possible solutions. Would they have any concerns if any parts of the site were no longer able to be used in the same way?

Discuss ideas with the class as a whole and add those agreed upon to the table.

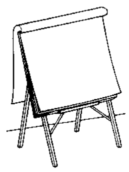
Example Problem-Criteria-Constraints Table:

OUR SITE: ***School play area and surrounding space***

Problems to Solve	Criteria for Success	Constraints on Possible Solutions
Citywide: • *Too much stormwater runoff in our region.* *Site specific:* • *Puddles in play area.*	*Citywide:* • *The amount of stormwater runoff leaving the site is reduced.* *Site specific:* • *No puddles in the play area when it rains.*	*General:* • *Work within the space available at the site.* • *Keep costs low.* *Site specific:* • *Students don't want to lose any play space.*

	• *Water available for school garden.* • *Add more play space.*	• *District will have to approve any changes to the site.*

Public Record



Problem Site Explanatory Model

Reflect and Explain

33. OPTIONAL: Add to model

Is there anything that should be added to the Problem Site Explanatory Model that came up when discussing stakeholder's input, criteria, and/or constraints?

EXAMINING STUDENT WORK

The stakeholder interviews (if you did them) are for students' reference more than yours. To assess their success, take note whether students can represent stakeholders during their discussion. Have they included any stakeholder-focused criteria or constraints on the table? If the students are not doing this on their own, you can remind them of the importance of community voices in decision making and prompt them for more thoughts.

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make going forward to address any concerns?

Also consider the following:

- Are the problems, criteria, and constraints the class agreed upon clear?
- Are there any that are not actually solvable?
- Are any going to preclude making a physical model of the site and solution in a stream table (happening in the next lesson)?

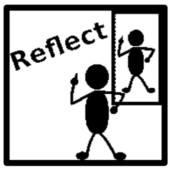
If any of the problems, criteria, or constraints end up being insurmountable, you can revisit them as a class later. Remind students that the Engineering Design Process is not linear, and even professional engineers sometimes need to go back to the Define Stage of the process to rethink what they have come up with.

If you feel like students are not getting the idea of stakeholders, you could invite a stakeholder to come into your classroom and look over with the class what you have come up with so far. Your principal or janitor or a student from another grade that uses the area might provide some interesting perspectives on the problem and possible solutions that the students wouldn't otherwise consider.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools & Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

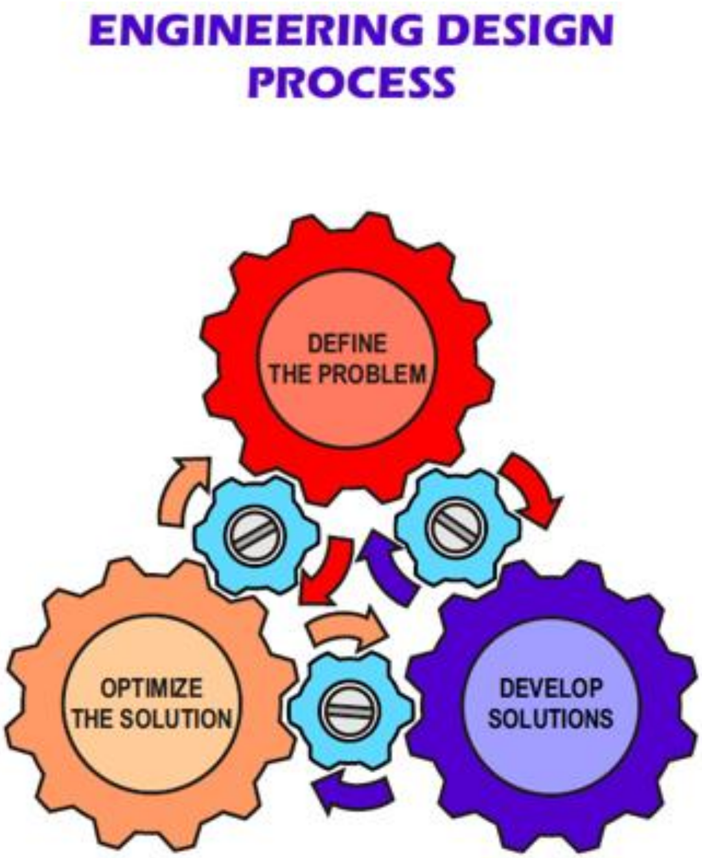
Talk. What was the nature of talk in this lesson?

Tools. How did the tools used support students?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Just-in-Time Instruction



Engineers use a process to solve problems.

1) **Define the Problem:** Research the problem and interview stakeholders so we can define our criteria for success and the constraints that limit our solutions.
2) **Develop Solutions:** Imagine possibilities and research solutions. Evaluate our solutions based on criteria and constraints.
3) **Optimize the Solution:** Use test results to improve solutions.

Stakeholder Interview

Your name: ___________________________ Date: __________________________

Name of person interviewed: ____

What is their role or job? (student, parent, school staff, something else?) ________________

Explain what you've been learning about (stormwater runoff in the city) and show the person you're interviewing your map of the site. Explain that it's showing a place that your class decided to focus on when thinking about solutions.

Questions for the stakeholder:

How do you use the site?

Why do you care about this site?

Do you have any concerns about stormwater runoff or too much water in this area?

Is there a project to help with these problems that you would recommend?

Are there any concerns you have about changes to this site?

Don't forget to thank the person you've been talking to for their time!

Lesson 6: Modeling the Site

TIMING NOTE: *This lesson could be done any time between Lessons 4 & 8.*

OBJECTIVES & OVERVIEW

In this lesson, the teacher provides (or creates with class input) an example of a physical model of the problem site in one of the stormwater models with soil. Pairs of students each then create a duplicate of the model. The teacher's model then has water added and its runoff measured to form a baseline against which student groups can compare their proposed solution.

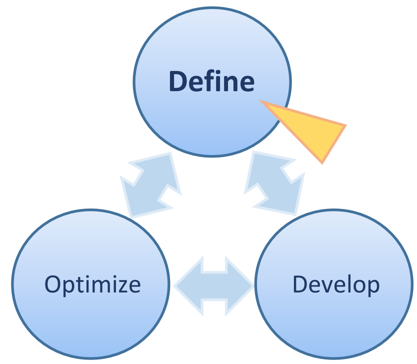
- Models are built to represent what happens to stormwater at a specific location.
- An investigation is run with one of the models.

Focus Question: How do we best model our stormwater runoff problem at our site?

Learning Target: We will use our understanding of surfaces to build a working model of our site.

New Terms: fair test, changed, measured, and controlled variables

Engineering Design: DEFINE PROBLEM



Define a problem: *specify criteria and constraints that a possible solution to a simple problem must meet.*

NEXT GENERATION SCIENCE STANDARDS

The students will address this standard over several lessons. In this lesson, they plan and carry out a fair test to form a baseline. In Lesson 16 the procedure is repeated with their prototypes to identify aspects that can be improved.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
Developing and Using Models • Identify limitations of models. • Develop and/or use models to describe a phenomenon. • Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events. **Planning and Carrying Out Investigations** • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. • Evaluate appropriate methods and/or tools for collecting data.	**ETS1.B: Developing Possible Solutions** • Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3)	**Cause and Effect.** • Events that occur together with regularity might or might not be a cause and effect relationship. • Cause and effect relationships are routinely identified, tested, and used to explain change.

MATERIALS

For each engineering team:

- stormwater model – tray with soil and rubber stopper (set up directions are in the Materials and Set-up section of this manual)
- spoon
- "Rain Jar" (container with holes in lid)
- gray catch basin
- spoon
- 2 absorbent pads – one for desk, one for floor
- Cleanup supplies (paper towels and/or rags)

For testing teacher's model:

- Stormwater model from with site model pre-built
- Gray catch basin
- Absorbent pads
- Trowel and spoon
- Rain jar

- **Measuring Stormwater Runoff Procedure and Data Sheet**

Materials to lay out in distribution area (for possible use when modeling the site):

- Extra Gravel, Sand, and Humus if available, or soil mix
- Toothpicks
- Tinfoil (represents impervious surfaces)
- Sponge pieces (represents trees/plants)
- 1-ounce and 9-ounce cups (represent rain barrels, cisterns, and ponds)
- Grass from yard/schoolgrounds/etc.

Additional materials that could help represent the site or solution materials might include:

- Rocks (boulders)
- Lunchroom milk cartons (small buildings)
- Wooden blocks (different size buildings)
- Large milk cartons or wooden blocks (large buildings)
- Small plastic items, boxes, lids, etc.
- Popsicle sticks

PREPARATION – 45-60 minutes

DECISION POINTS

Do you have time for students to do all of the lesson during class?

Engineering Teams: You will need the class to be in 7 groups with one model per group. Students will need to come to agreements and share tasks. Evenly distribute those with greater and lesser understanding of stormwater runoff among the teams.

Watch the Teacher Training Video for this lesson: It shows the creation of an example model and talks about considerations you will want to consider when creating an example model for your class. https://communitywaters.org/teacher-support/teacher-videos/

Short on Class Time? We have students build the site models in this lesson but you (and/or students and/or parent volunteers) COULD do so outside of class time and then skip to #6 "Discuss Procedure Variables" in the lesson. If time is very tight, you could also have your volunteers do the investigation procedure with each model (recording the data for students to compare with later).

How involved will students be in designing model?

How much do you want to involve students in creating the models? Pick an option:

- Build the example model ahead of time yourself (this is how the lesson is written).
- Involve the class in the design process by doing the first three steps in the lesson and having the class make suggestions as you build an example for them to duplicate. If you are going to build it during class, we recommend thinking through the dimensions and likely materials needed to represent the site ahead of time, so you can be ready to go.

Provide Investigation Procedure? There is a provided example Investigation Procedure. You could provide it to students or have the students create their own (see notes about this in lesson).

Materials Set Up:

- **Distribution Area:** Prepare a distribution area with materials to be used for models (see list above), ensuring there are enough items for all student groups. Look over the additional materials list above and think about whether there are any other materials (like lunchroom milk cartons) that would be helpful to use in site models for your site.
- **Plants:** Consider digging up some grass and/or other plant bits (moss off the sidewalk works!). It is helpful to have both small plants with roots and bigger sections of turf.
- **Build Example/Teacher Model** (or at least think through what it might look like if you want to design it with your students). There are a variety of things to keep in mind when building the model:

  Model Set Up:

  - <u>**Keep the drain hole clear:**</u> The drain hole in the model will represent the water that leaves the site.
  - The model should be left flat on the tables with any hills in the site represented by sloping the materials (otherwise water moves to quickly through the dirt and out the drain hole). This means impervious surfaces that normally drain into a storm drain should be sloped towards the drain hole.

  Modeling Surfaces

  - **Impervious Surface:** Use the tin foil. It can be cut and shaped as needed. Gravel on the edges of the tinfoil will help hold it down.
  - **Packed gravel** and hard-packed soil can be represented by tinfoil with a thin layer of sand or gravel on top of it.
  - **Grass surfaces:** Grass is only partially pervious so don't model it with the plants you have grown. Instead put down a layer of tin foil and then some moss or thin grass over the top.
  - **Gardens and other highly pervious planted areas** could be represented by plants grown in models, grass from outside, or sponges.
  - **Pervious surfaces** could also be represented with gravel.
- **Muddy areas** could be represented with humus or potting soil on top of tin foil. Don't add a lot of humus to a model as it will make it messy and hard to dry out between tests.

– If you have some existing things on the site that are helping with stormwater, you could check out the ideas for representing them in the preparation section of lesson 8 (e.g. trees can be represented by one of the narrow sponge pieces "planted" in the ground with a toothpick in it to hold it up).

Modeling Buildings

– Wood or plastic blocks could be useful to represent buildings. Lunchroom milk cartons could also work for buildings (with peak facing up or buried depending on the roof).
– Tinfoil on top of blocks or milk cartons can be shaped to create gutters.

- **Test Example Model**. If you are creating the model ahead of time, use 100 ml of water in a rain jar to test that water is flowing through it appropriately. Adjust the model as needed (often by lifting up tin foil and changing the shape of the land underneath) after testing it.

PROCEDURE

Engage and Encounter

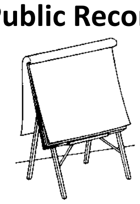
1. **Set the Purpose (whole class)**

   Students will be constructing a physical model to represent what is currently happening to stormwater at their site. Later, **after** engineering teams have researched and chosen a possible solution, they will be adding their chosen solution to the model and testing how well it works.

   When creating a model of our site, we need to keep in mind that **a model does not (and cannot) represent the real world perfectly.** The model only needs to represent the surfaces and where water goes in a general way. These models are not going to be precise and that's okay. We do not need to exactly represent each object and do not need perfection; a rough approximation is enough.

   Divide class up into 7 engineering teams.

Public Record



Problem Site Explanatory Model

2. **Activate Prior Knowledge (individual)**

   Have students look at the **Problem Site Explanatory Model** the class created, and think individually about what they would want to be represented in a physical model of their site.

3. **What to Represent in Models (whole class)**

   Work with the class to compile a list of what needs to be represented by the physical model. Some key points:

   - Water will need to runoff and soak in at the appropriate locations. This makes representing **pervious and impervious surfaces** important.

- The **citywide criteria for success** is less stormwater runoff leaving our site, so will want to measure how much water is leaving the models. To do so, we will measure the amount of water that leaves the model through the drain hole in the bottom. The students will be representing how stormwater moves through the site.
- The **site-specific problem** will need to be included in some way as well as how runoff flow is contributing to the problem.

Present visual

Example Site Model

4. Sharing Teacher Model (whole class)

Share the model you created with students and talk through with them what each part represents. Make sure to note:

- The rain jars used earlier in the unit will continue to represent rain.
- The drain hole in the model will represent the water that leaves the site.
- What surfaces each material is representing (e.g. tinfoil is the impervious concrete playground at their site).
- This model is NOT a physical representation of everything in the site. Instead, it is focused on the amounts of various surfaces in the site. Where are pervious or impervious surfaces in the site? How much of each is there?
- Nobody will be adding solutions yet. That comes later!

Designing With Students?

If you are having students design the example model with you, you will also want to go through the possible materials that could be used (as listed in the preparation section above). You will also need to shake 100 ml of water on the model to make sure the water is moving through the model the way it does at the actual site.

Challenge the students to duplicate the model as closely as possible. If all the models function the same, it will be possible to compare the data from the solutions students will be adding to them later.

Explore and Investigate

Engineering Teams

Create models of the site

5. Duplicate the model

Distribute a tray with soil and a plug to each engineering and have them set it on top of an absorbent pad.

Have students shape the soil in their tray to match the example model and circulate to make sure the slope and any indentations needed for puddle or water flow match up.

If it is helpful you could walk the students through each step of setting up the model. Otherwise, give time for student groups to craft the rest of the model using materials available.

Back-Pocket Questions

Modeling

As groups work, circulate and ask them appropriate questions to challenge their thinking:

BACK-POCKET QUESTIONS

Modeling

- What does this part of the model represent?
- What specifically is the drain in the model representing at the site?
- Is there anything about your model that is different than the example model?
- Do you think your site model will have the same results as the example model?
- Is there anything not represented in the model that should be there?

YIELD

You could pause the lesson here (or after the next task) if needed.

6. **Test Water Flow in models (engineering teams)**

Give each team 100 ml of water to shake onto their model with a rain jar. They should keep the holes in their models plugged and -if there is runoff -drain it at the end into a bucket.

While shaking they should note where the water is flowing. **Is it flowing in the right directions? Are things like roof gutters working correctly?**

Back-Pocket Questions

Observation & Modeling

BACK-POCKET QUESTIONS

Observations

- Where did you observe water runoff in your model?
- Where did puddles form in your model?

Modeling

- Does the water flow in the model match what happens at our site when it rains? Why or why not?
- Do you think the site model would have the same results as the example model?
- Is there anything you need to change to help the water flow be more accurate?

If a team's has water pooling or flowing where it shouldn't, they will need to adjust the model (often by lifting up tin foil and changing the shape of the land underneath).

DECISION POINT

You could do the remaining parts of this lesson now or wait to do it until the students are testing their solutions in Lesson 13.

7. Creating an Investigation Procedure

Engineers use repeatable **fair test** procedures to test, compare and optimize various solutions. By making their investigations a fair test they can get data that helps them determine if their solutions are successful.

Having a class procedure to test the original site model and using the same procedure on the solutions modeled by each engineering team will make it possible to compare the data between different solutions. Our investigation question we will be trying to answer is: "***How much does the amount of runoff change after we add our solution to the model?***"

> **Fair Test?**
>
> The intent in having students create these site models and then add their solutions (in Lesson 8) is for them to be able to go through the process of thinking about how the solution works and how it could be improved (optimized) (Lesson 9).
>
> In reality, the models the students create are unlikely to be precise enough to truly compare the data they get from their investigations.
>
> They also won't be able to run three tests of each solution (unless you decide doing so is a priority and have the class test just two solutions).
>
> Treat this as an opportunity to talk about the challenges of a fair test with the students while keeping them focused on how well their solution is working and how they would redesign it to help it work better.

8. Discuss Procedure Variables

When testing solutions in the real world, there are always variables (like weather) that can't be controlled. Engineers do the best they can and take note of things they couldn't control.

Similarly, the materials we are using for these models are limited representations and will not permit total control over all the variables that could affect our results but we still want to pay attention to where we can and cannot make it a fair test so we know how we can use the data we get.

Turn-and-Talk

What variables do we need to control?

We want to set up an investigation that will let us compare the **amount of water that drains out in the original site model to the amount of water that drains after we add and optimize our solutions**.

The **measured variable** in this investigation is the amount of water that drains out of the hole.

The **changed variable** will be the changes we make to the model to represent a solution (this comes later).

Students turn and talk to discuss what **variables they need to control, or keep the same.**

Discuss the need for multiple trials and the importance of resetting the wet models between trials.

Have students walk around and look at the various models groups have created. Do they look similar enough that we will be able to compare the data between groups? If not, do they have any suggestions for how the models could be more similar?

Controlled variables:

- *Amount of water poured over the site.*
- *Parts of the model that are not changed for the solution.*
- *Amount of time the water coming out of the hole is collected.*

9. **Discuss procedure (whole class)**

DECISION POINT

Either discuss the provided procedure or create one together.

Creating Procedure as a Class?
Depending on your students, you could create the procedure together as a class. If you do so, you could have smaller groups start off generating ideas with brainstorming or a discussion diamond like the one used in Lesson 6.

If Developing the Procedure:

- Don't forget to include setting up the pads and buckets.
- The provided example procedure has the students *add the stoppers immediately after the rain jars are empty*. This is because the water in the models drains out of the sand and gravel in the models over time. By putting the stoppers in right away we don't measure as much of the water that soaked into the soil.

Present visual

Procedure sheet and/or Example of Data Table

If you are using the provided procedure, project it for the class and have them help identify where variables are measured and controlled during the procedure.

Have students find the data table in their Student Packet. Project example if desired.

The procedure provided is built around roles for each person. They include:

1. **Materials Manager**
2. **Measurer**
3. **Rain Maker**
4. **Bucket Holder**
5. **Observer - Recorder**

See procedure for details on each.

10. Run investigation on teacher model and record results (whole class)

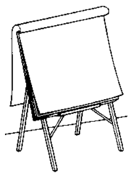
The investigation will ONLY be run on the teacher's model at this time.

Later, students will be doing the same investigation procedure with their team's model. This test will provide a baseline for them to compare to what happens once they add a solution.

Assign student roles for the test of the teacher model and run the investigation. When finished, provide time for the observer to share with the class what they noticed.

Project a copy of the **Measuring Runoff Data Table** from Lesson 9 and record the results and observations on it. Explain that you will be saving this for students to reference later after they have created and tested their solutions.

Public Record



Measuring Runoff Data Table from Lesson 9.

Why only test the teacher model?
Once 500 ml is added to a model the soil becomes saturated and takes a long time to dry out. If 500 ml is added to student models it is likely they will still be saturated when they test their solutions later and that would skew their results.

11. Model and Procedure Discussion (whole class)

Consider the following with the class:

- Is the procedure something they feel they can repeat as a "fair test" later with their own models?
- Models can never fully represent the real world and don't need to but: Does this model represent stormwater and runoff well enough for us to be able to add solutions and test their effect on stormwater?
- Is there anything that should be changed in it to improve the model's representation?

EXAMINING STUDENT WORK & PLANNING NEXT STEPS

Look over the models each group created and consider whether they are similar enough to provide roughly equivalent results. If not, make changes to them as needed (or follow up with the students to make the changes).

Measuring Stormwater Runoff Investigation Procedure

Purpose of investigation: To test how effective our solution is in solving the problem of too much stormwater runoff.

Investigation Question: How much does the amount of runoff change after we add our solution to the model?

Criteria tested: Reduction of stormwater runoff.

Materials: models of the site, gray basin, 2 absorbent pads, spoon, and rain jar (with holes in lid).

Set Up:

- Materials Manager brings over materials.
- Measurer fills rain jar to 500 ml (milliliter) mark & screws on lid.
- Place one pad on the table.
- Put the site model on the pad with the drain hole over the edge of the table.
- Place the other pad on the floor and put the basin on the pad under the drain hole so that it will catch any water that comes out of the drain hole.

Get Ready:

1. Materials Manager removes the drain plug from the model and holds it ready to replace in hole.
2. Rain Maker checks that the rain jar lid is screwed on **tightly!**
3. Bucket Holder holds bucket under drain hole.

During:

1. Rain Maker holds the rain jar upside down over the model and shakes the bottle to make it "rain" on the model. <u>Do not squeeze the bottle</u>. Move the rain jar around to all parts of the model so that rainfall is evenly distributed.
2. Materials Manager: Unplugs the drain hole in the model if it gets plugged.
3. Rain Maker continues shaking the rain jar over the model until only the lid has water in it.
4. Materials Manager: As soon as the Rain Maker is done, return the plug into the hole (preventing remaining water from continuing to drain into the bucket).

GROUP ROLES

1. **Materials Manager**
   Brings materials, clears drain blocks, and plugs drain hole when rain maker done.
2. **Measurer**
   Fills rain jar to 500 ml and measures runoff afterwards.
3. **Rain Maker**
   Shakes rain jar evenly around model.
4. **Bucket Holder**
   Holds bucket under drain hole to collect runoff. Rinses after amount measured.
5. **Observer - Recorder**
   Notes what happens during procedure and records group data on data sheet.

After:

- Measurer empties any water left in the rain jar and uses the jar to measure the amount of water in the bucket. Then rinses out rain jar.
- Observer records any important observations of what happened to the water in the model and the amount of water that ended up in the bucket.
- Bucket Holder drains any remaining water into the bucket, then empties the bucket and places it back under the drain hole.
- Restore any parts of the model or solution that were changed by the water.

Lesson 7: Researching & Evaluating Solutions

OBJECTIVES & OVERVIEW

Engineers research possible solutions before they propose a solution. Students will gain an understanding of different types of solutions that are used to help with stormwater runoff problems and evaluate the solutions based on how well they address the site's constraints and criteria for success.

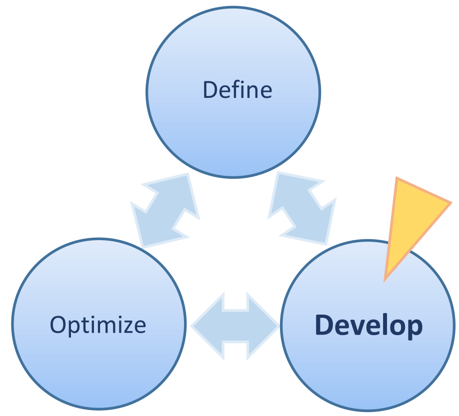
- Students research potential stormwater solutions
- Students evaluate potential solutions by considering how they meet the constraints and criteria for success.
- Students write a proposal for their solution using the analysis of their research.

Focus Question: Which solution will best meet our criteria and constraints?

Learning Target: I can research and evaluate solutions to identify which solution we should build in our model.

New Terms: bioretention (currently not in Word Wall cards; "Green Stormwater Infrastructure" is a new term used in the video, but is not a term students need to remember and is not included in the Word Wall cards.

Engineering Design: DEVELOP SOLUTIONS



***Develop solutions**: research and evaluate multiple possible solutions.*

NEXT GENERATION SCIENCE STANDARDS

3-5-ETS1-2. <u>Generate</u> and compare **<u>multiple possible solutions to a problem</u> based on how well each is likely to meet the criteria and constraints of the problem.**

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

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
Obtaining, Evaluating, and Communicating Information. • Compare and/or combine across reliable media to support the engagement of engineering practices.	**ETS1.A: Defining and Delimiting Engineering Problems** • Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or	**Influence of Engineering, Technology, and Science on Society and the Natural World.** • Engineers improve existing technologies or develop new ones to increase their benefits,

• Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem. • Communicate scientific and/or technical information orally and/or in written formats, including various forms of media and may include tables, diagrams, and charts. **Constructing Explanations and Designing Solutions.** • Apply scientific ideas to solve design problems. • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. (4-ESS3-2) (3-5-ETS1-2)	how well each takes the constraints into account. (3-5-ETS1-1) **ETS1.B: Developing Possible Solutions** • Research on a problem should be carried out before beginning to design a solution. **ESS3.B Natural Hazards.** • A variety of hazards result from natural processes. Humans cannot eliminate the hazards, but can take steps to reduce their impacts. (4-ESS3-2)	to decrease known risks, and to meet societal demands. (3-5-ETS1-2, 4-ESS3-2).

Common Core Connections:

CCSS.ELA-LITERACY.CCRA.R.1 - Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.
CCSS.ELA-LITERACY.RI.4.1 - Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.
CCSS.ELA-LITERACY.RI.4.3 - Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.
CCSS.ELA-LITERACY.RI.4.7 - Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, timelines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears.
CCSS.ELA-LITERACY.RI.4.9 - Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably.
From <http://www.corestandards.org/ELA-Literacy/RI/4/#CCSS.ELA-Literacy.RI.4.4>

MATERIALS

- **Problem-Criteria-Constraints** Table for class
- **Stormwater Solutions Research** PPT (can be printed if desired – see preparation section below)
- From Student Packet:
    - **Evaluating Solutions** worksheet

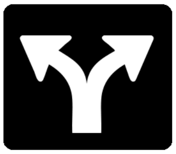
PREPARATION – 15 minutes

Website

All worksheets, links, and graphics are on communitywaters.org

DECISION POINTS

- Queue up and review video: "**Green Solutions to Stormwater Runoff.**" (direct link: https://youtu.be/bsNjk0gpir4)
- Review the **Stormwater Solutions Research PPT** to see if they are at the right level for your students. Do you want to use all ideas (solutions) provided or narrow them based on your own judgement? If you would like other research options, you can find them with the other links for this lesson on communitywaters.org.
- Look over the **Evaluating Solutions worksheet** and consider if you prefer a different note-taking approach.



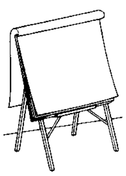
What resources to use and how to do the research? Use ELA time?

- Decide how you want to divide up the student research. Will students view the resources on their own devices, or will you need to print* anything, or will you project and work as a class? Some possible approaches:
  1. Have individuals each research some of the possible solutions and then share them with their team (this provides an opportunity for differentiation in which research options you provide each student).
  2. Divide up the solutions among the members of each engineering team for individuals to research and then share with their team.
  3. Divide solutions so each group gets one solution to research and present to the rest of the class (listeners take notes).
  4. Review all the solutions being considered as a whole class by reading through one at a time.

  *A black and white printable version of the Solutions Research pages is on the website with this lesson.
- Consider whether the reading and the note taking could fit into your ELA time.

PROCEDURE

Public Records



Problem-Criteria-Constraints Table & Class Summary Table

34. Activate Prior Knowledge (whole class and pairs)

Review the **Problem-Criteria-Constraints Table**, the definition of criteria and constraints and the perspectives of the stakeholders represented by the site-specific items the class added.

Remind students of the citywide and site-specific items in the table. In this lesson, they will focus on the site-specific problem if there is one, and the citywide problem if there is no visible problem at the school.

Work with the class to **choose two criteria and two constraints** to focus on as they compare the possible solutions they research. Underline them in each column when agreed upon. (They will later fill in the worksheet with these).

Problem-Criteria-Constraints Table example (with citywide, general, and one site specific item underlined in each column)**:**

OUR SITE: ***School play area and surrounding space***

Problems to Solve	Criteria for Success	Constraints on Possible Solutions
Citywide: • *Too much stormwater runoff in our region.* *Site specific:* • *Puddles in play area.*	*Citywide:* • *The amount of stormwater runoff leaving the site is reduced.* *Site specific:* • *No puddles in the play area when it rains.* • *Water available for school garden.* • *Add more play space.*	*General:* • *Work within the space available at the site.* • *Keep costs low.* *Site specific:* • *Students don't want to lose any play space.* • *District will have to approve any changes to the site.*

35. Brainstorming Ideas (whole class or engineering teams)

DECISION POINTS

Brainstorming before or after video?

When developing solutions for a problem, engineers apply their scientific understanding towards both reading what others have done and brainstorming their own ideas.

This brainstorming session begins applying our understandings toward thinking about solutions, but does not replace the value of researching solutions others have already used. These ideas are not final!

Brainstorming after Video?

The video below provides students a review of what the problem is and some ideas for possible solutions.

If you feel the students need a bit more guidance in thinking about what might help with runoff, show the video below first, THEN do the brainstorming.

Turn-and-Talk

What might a solution look like for this location and problem?

Return to **Class Summary Table**, to look at the "How does it help us explain and/or solve stormwater in the city?" column. What have they learned so far that would help them think about possible solutions for their site's problems? If students observed something at school or in their neighborhood or in a video (for example, a rain garden or other stormwater feature), have students think back to what they saw and what was doing the work to reduce or slow down stormwater runoff.

Students can create their own list of ideas in their student notebooks and then turn-and-talk to see what a partner has come up with.

Ask students to share ideas with the whole class. Students can add ideas they like to their list as they are shared.

36. Overview of solutions (whole class)

Video Clip

"**Green Solutions to Stormwater Runoff**"
Play to 1:09
communitywaters.org

Video: Green Solutions to Stormwater Runoff -
https://youtu.be/bsNjk0gpir4

This video provides a quick review of the causes of stormwater problems and some of the solutions engineers are using to address stormwater runoff problems. This video is focused on a type of solution called "Green Stormwater Infrastructure" (GSI). GSI refers to solutions that use nature and natural processes. For example, instead of cleaning water with chemicals and filters, it would use plants and soil to do so.

Stop video at 1:09 and notice with students the many different possible solutions pictured.

YIELD

You could pause here if out of time. You could also split the student research time up over several days as desired.

37. Preparing for the activity (whole class)

Show Visuals

Stormwater Solutions Research PPT & Evaluating Solutions worksheet

Students will work in their engineering teams to conduct research on possible stormwater solutions and select a solution that they want to test. They will use the Stormwater Solutions Research PPT as their reference. Students will be reading about possible solutions and taking notes in the **Evaluating Solutions Worksheet** about how each fits the site's criteria and constraints. (see Decision Points in Preparation above).

On their worksheet, **have student fill in the problem and two criteria and two constraints** they'll focus on at the top.

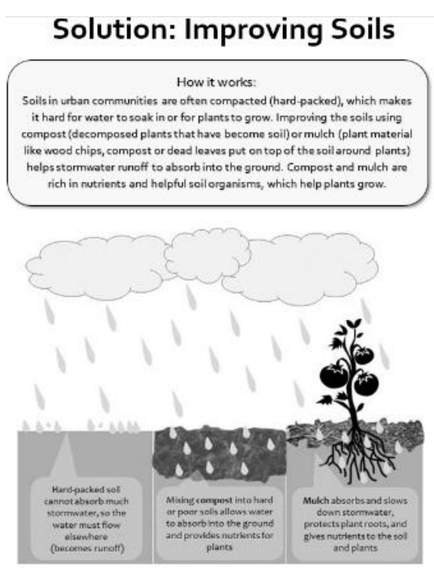
The **Stormwater Solutions Research** PPT provides information about common stormwater runoff solutions. It includes information about what the solution is and how it works, a local and non-local example, and some of the benefits and challenges of the specific solution.

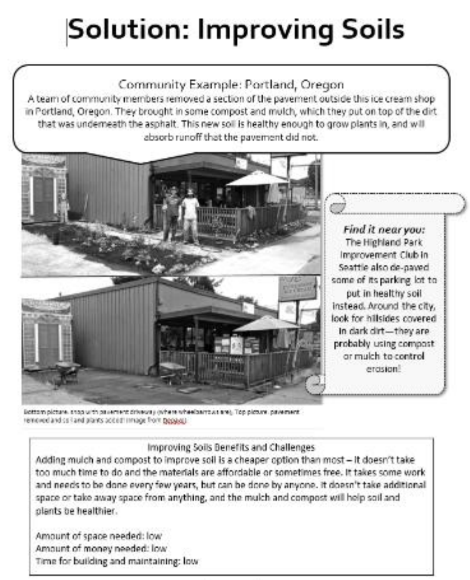
Solutions Research PPT includes the following solutions:

- Rainwater collecting
- Bioretention
- Planting trees
- Rain gardens
- Pervious surfaces
- Improving soils

> **Additional Research Options**
> There are links to videos about some of the solutions and other research options on communitywaters.org.
>
> Web-savvy students could also do a search for "green stormwater infrastructure" or "stormwater solutions."

Example Research page (2 pages/slides per Solution):





38. Introducing the Research Plan (Whole Class):

Students will take notes about how the solution helps meet the criteria for success and fits within the constraints. Students should attempt to summarize these in their own words.

DECISION POINTS

Use ELA Time?

How best to divide up the research among students?

On the Solutions Research pages, the primary location to find information about advantages and disadvantages is in the box about "Benefits and Challenges." It also includes a rating of the amount of space, money, and time a solution might need. For example, in *Improving Soils*:

Amount of space needed: low
Amount of money needed: low
Time for building and maintaining: low

This information can be used when comparing solutions to each other.

Project one of the Solutions from the Powerpoint to review what they're looking at, and do one example with the class (with them making notes in their own worksheets).

Example:	Criteria 1: amount of stormwater leaving our playground is reduced	Criteria 2: keep play area	Constraint 1: keep costs low	Constraint 2: can't take up a lot of space
Trees - Evergreen trees are best for helping with stormwater	*Trees will slow down and soak up some stormwater*	*Trees don't take up very much space.*	*Trees are pretty affordable or free*	*Trees are different sizes but we can get small ones.*

NOTE: This is also a time to include a solution's advantages or disadvantages that were identified by stakeholders or discovered through videos, readings, or personal experience!

39. Conduct research (individual, engineering teams, or whole class)

ELA Connection

Read and interpret informational text and graphics

Give students time to read and take notes about the different solutions presented in the Stormwater Solutions Research.

See "Decision Point" suggestions above in Preparation section.

There are a total of 6 different solutions to learn about, but you may decide to only research a limited number of them if working as a whole group.

Circulate to check for understanding and help interpret graphics as needed.

Checking for Understanding
Students need to be able to determine the advantages and disadvantages (labeled "benefits and challenges") to be able to figure out which solutions will fit the criteria and constraints of their site. If students are struggling with the research, you could revisit it as a whole class or work with them individually.

Small Groups

Engineering Teams: "Which solution might work well for our site?"

40. Choosing a solution (engineering teams)

Each engineering team will need to come to a consensus on **<u>one</u>** solution to test in their models, **but <u>different teams will need to test different ideas</u>.**

Lay out your guidelines for how they can share ideas and come to a consensus based on any norms you have established for your class. Consider emphasizing that it is not critical that they pick the "best" choice right now, but for them to come up with a choice they would like to test as a group.

Once a team has decided on their solution, they work together to write out their **solution proposal** on the back side of the worksheet (see example below). Their proposal must include how it will meet the criteria for success and include evidence to support their decision.

> **Choosing Different Solutions to Test**
> In order to "compare multiple solutions" at the end, not all the engineering teams will be testing the same solution. You could choose to have the class test just two top solutions if you feel making the testing a fair test (with multiple trials of each solution) is a priority.
>
> If all groups end up testing the same solution, students won't have data to compare their solution's results with. **If all groups have chosen the same solution, consider asking for a group to volunteer to test another solution.**

Solution Proposal example:

"After evaluating the solutions based on our research, our idea for a solution would be <u>a small rain garden</u>.

This solution would meet the criteria for success because <u>it will fit the space and we can plant native plants that we can study. The plants and soil will help absorb rainwater, so it doesn't end up in the storm drains.</u>

Evidence from the summary table that supports my thinking is that <u>plants help to slow down runoff.</u>

Our group's favorite thing about this solution is <u>that there are lots of plants and we could plant flowers in the rain garden.</u> "

EXAMINING STUDENT WORK

Look at the students' Evaluating Solutions worksheets:

- Are they successfully pulling out the most important ways each solution meets criteria and constraints? Can students summarize those differences?
- If you ask, can they tell you why the solution they want to test would be good or bad at the site?
- Can they tell you what problem(s) they are trying to solve?
- Are they using the table to compare possible solutions?
- Has every student or group filled out information for at least two possible solutions?

Review the solution proposals each group writes to see if they were able to explain why their proposal would meet the criteria for success. When reviewing their drawings, how different are each student's images of what the solution might look like? This may be useful to help guide what scaffolding is needed when they model the solution.

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** for this lesson: Are there changes in approach you want to make going forward to address any concerns?

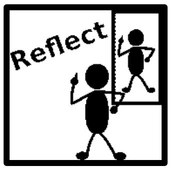
Comparing solutions based on criteria and constraints is key to this stage of the engineering design process (and the 3-5 ETS1-2 standard). If students are not grasping this, consider providing more examples, and walking them through a comparison.

Be sure to hold on to student work for the next lessons.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools & Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

Tools. How did the tools used (e.g. class summary table) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Evaluating Solutions Worksheet

The stormwater problem that we care about is ____.

Read about a solution and write down its name and one interesting thing you found out. ↓	*How does the solution help meet the criteria for success?*		*How does the solution fit within the constraint?*	
	Criteria #1:	Criteria #2:	Constraint #1:	Constraint #2:
Solution:				
Solution:				
Solution:				
Solution:				
Solution:				
Solution:				

Solution Proposal Evaluating Solutions Worksheet Page 2

After evaluating the solutions based on our research, we would like to test out this solution:

____

This solution would meet the **criteria for success** because:

____

____

____

Evidence from the summary table that supports my thinking is:

____

____

____

Our group's favorite thing about this solution is:

____

____

____

Lesson 8: Modeling Solutions

OBJECTIVES & OVERVIEW

In this lesson the engineering teams plan how they are going to model the solution they have chosen and then add it to the site model they created earlier.

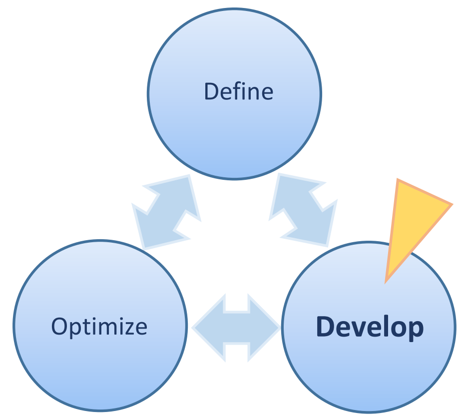
- Student engineering teams design a model of the solution they want to test and add it to their site model.

Focus Question: How do we model our solution?

Learning Target: I can design and create a model of a solution that represents how it would function in the real world.

New Terms: failure point

Engineering Design: DEVELOP SOLUTIONS



***Develop solutions**: research and evaluate multiple possible solutions.*

NEXT GENERATION SCIENCE STANDARDS

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a **model** or prototype that can be improved.

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
Developing and Using Models • Identify limitations of models. • Develop a model using an analogy, example, or abstract representation to design a solution.	***ESS2.A: Earth Materials and Systems*** - Rainfall helps to shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around. (4-ESS2-1) ***ESS2.E: Biogeology*** - Living things affect the physical characteristics of their regions. (4-ESS2-1) ***ESS3.B: Natural Hazards*** - A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts. (4-ESS3-2)	**Cause and Effect** • Cause and effect relationships are routinely identified, tested, and used to explain change.

MATERIALS

For Class: Word Wall cards

Materials to lay out in distribution area (for groups to use when designing solutions):

- Gravel, Sand, and Humus (or soil mix)
- Toothpicks and popsicle sticks
- Tinfoil
- Sponge pieces (you may need to cut larger sponges into ½ x ½ inch pieces & 2x2 inch pieces)
- 1-ounce and 9-ounce cups
- Grass saved from earlier (grown previously and/or brought in)
- Other small plants (optional but useful if available to bring in)

Per group:

- Site model created in Lesson 6
- Catch basin
- Graduated cylinder
- Absorbent pads
- Spoons
- Rain Jar (with holes in lid)
- **Measuring Stormwater Runoff Investigation Procedure** from Lesson 6
- Solutions resources as reference material
- **Discussion Diamond** worksheet (optional)

PREPARATION – 20 minutes

Website

Pictures of example solutions (and graphics) can be found on communitywaters.org

Watch the 3-minute "Solution Explanations" video if you would like a better idea of what solutions might look like modeled, and how exemplary students might describe what they have done. (found communitywaters.org under "Teacher Supports"). Also, **"Designing a Stormwater Solution Model"** video can be useful to gain ideas. (found on this lesson's webpage).

Print Discussion Diamonds for each team, ideally larger than 8.5x11" paper.

Queue up the **Engineering Design Process graphic** and the **Materials Set Up Directions** to be projected.

Distribution Area: Lay out materials that students could use to model their solutions (see above).

Review list of **Solution Suggestions.** It can be challenging for students to effectively model their desired solutions in this lesson. To prepare yourself to help guide them, review the solution suggestions below and/or on website (with pictures) and think about questions you could ask to help guide students as they are designing their solutions.

Ideas for Modeling of Solutions:

- **Bioswale/bioretention** = dig a deep trench and stand popsicle sticks on edge to slow down water flow through trench. Add sand to represent the engineered bottom of a bioswale. Add additional popsicle sticks on top of the initial ones. Top off with small clumps of grass.
- **Improve Soils** = If the soils being improved were impervious, they should be represented with tinfoil (possibly with sand on top of it) before the solution is implemented. The tinfoil could be removed, some humus mixed in, and a layer of wood chips added to the top. Be aware that if a lot of humus is added it will be messy and hard to dry out.
- **Pervious Concrete** = use toothpicks to poke holes in tinfoil.
- **Pervious Pavers** = lay popsicle sticks side by side.
- **Planting Trees** = Poke a toothpick through the center of a long sponge piece (easier to do when wet). Dig a deep hole and "plant" the bottom of the sponge in the soil with the rest sticking straight up. Popsicle sticks can also be used to support the sponges if they are drooping over.
- **Rain Garden** = dig a hole and put humus in the bottom of it. Place plants with roots on top and around sides. Alternatively, dig a hole and put sponge pieces in it.
- **Rainwater Harvesting** (rain barrel or cistern) = Use small or large cups from kit. Cover building with tinfoil and shape its edges to create a "gutter" that directs rain to where the cup is. Make a hole in the tinfoil over the cup and angle everything so roof water drains to the hole. [getting drainage to work can be challenging for students.]

PROCEDURE

Engage and Encounter

1. Activate Prior Knowledge (whole class)

Each engineering team will add the solution they decided to test to their site model that the class created earlier in the unit.

Engineering teams review their notes from the previous lesson so everybody in the team understands which solution their team decided to test and why they think it is a good option.

When everybody is ready, call on a member of each team to share which solution they will be testing and why it is a good choice.

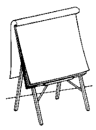
Too Abstract? Make it Real!
You could take your students outside to look again at the problem site and think about where their chosen solution could be built. You could give them chalk, flags, and or cones to mark out where they want to put their solution.

2. Set the Purpose (whole class)

Project the **Engineering Design Process graphic** (from earlier lesson). Testing <u>different</u> solutions is an important part of developing and optimizing solutions. While developing a solution, our tests can help us figure out which parts of the solution could be improved. By carefully observing the tests, the students may be able to find **"failure points"** in their designs; if so, they can make changes to improve them.

They will also be recording data from their procedure to assist in figuring out which of the many possible solutions would be best for their site. Then we can use that data during the "optimizing" stage to decide which solution will best solve our site's stormwater runoff problem.

Public Record



Important constraints from Problem-Criteria-Constraints Table

Models students create will clearly not be perfect representations of their solution; the students' task will be to represent their specific solution to the best of their ability.

Share the options for materials the students will be able to use (see distribution area materials above). There may also be other items in the room that could be used (only with teacher's permission).

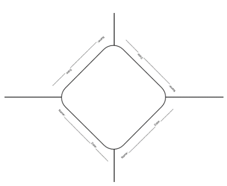
Remind students of constraints from the class that could impact their solution's location or size within the model (like maintaining an area to play).

Explore and Investigate

3. Discussion Diamond for solution design (engineering teams) (15 minutes)

Small Groups

Engineering Team: Discussion Diamond to find consensus.



Each group will fill in a discussion diamond. This time, they will be thinking about how they might model the solution with the materials they have available. By the end of this activity, groups need to have an agreed upon plan on how they want to represent their model.

> **Discussion Diamond?**
> Feel free to use a different strategy for small group consensus if desired.

Hand out Discussion Diamond sheets to each group.
If a group has more than 4 members, you could provide additional members with a large post it to record their ideas on.

- Students will have about 3 minutes for silent thinking and writing time. Each student writes or draws ideas for how to model their solution in their corner of the paper.
- Then individuals share what they wrote or drew in their small groups for a total of around 4 minutes. After each person shares, they should take some time for other students to ask questions, add on, or connect to what they wrote.
- After all students have shared their corners, the team should discuss which ideas they want to incorporate into their model. The point of this is not to include every idea in the model. What is important is that the model accurately represents how their proposed solution would actually interact with stormwater. This will likely take time.
- When they are ready, they should raise their hands for the teacher to come to their table and hear their plan.

Back-Pocket Questions

Maintaining Focus on the Problem & Modeling

Back-Pocket Questions

Maintaining Focus on the Problem

- What is the problem you are trying to solve?
- What are the criteria for success we are focused on?
- How are the criteria being measured when we test this model?

Modeling

- What solution are you modeling?
- How does that solution help with stormwater?
- How are you going to represent your solution?
- What materials are you going to use?
- How will those materials help with the problem?

YIELD

This is a good place to pause the lesson. Adding the solutions to model (below) can take a lot of class time depending on your students.

Small Groups

Engineering Teams: Building solution models

4. Add solution to model (engineering teams) (20 minutes)

Project the **materials set up directions** (available at end of lesson or on communitywaters.org).

Once they have an agreed upon a plan and have shared it with the teacher, engineering teams can set up their models and start building their solutions.

While groups are working on their models you can circulate and continue to check in on their thinking (see Back Pocket Questions above).

5. Run an initial test (engineering teams) (15 minutes)

Students can get their rain jar with 100 ml when their solution design is ready.

This initial testing does not need to be precise <u>or recorded</u> in their data table. Encourage students to observe where the water is flowing. Is it flowing into the solution they modeled?

If students have extra time while others are building their solutions, they could adjust their models.

Model Saturation

To avoid over soaking the models and control variables, we suggest limiting all groups to 100 ml.

If 100 ml is not enough to see movement of water you could add another 100 ml.

Be careful to not keep adding water, as it's important to NOT oversaturate the soil.

Reflect and Explain

Turn-and-Talk

What should we change about our model to make it better?

6. **Discuss results (pairs or engineering teams)**

   What happened to their solutions as the water was added? Did any **"failure points"** come up in their initial tests? How could they adjust their design to do a better job of capturing stormwater runoff?

   Next time, students will have an opportunity to adjust their models before using the investigative procedure the class used earlier on the teacher's model to collect data so they can compare how well their solution worked to other student's solutions and the unchanged teacher model.

EXAMINING STUDENT WORK

Look over the student models and consider whether their solution design is likely to interact with stormwater in the way intended. Will it soak up water or help it soak in?

Examples of designs that won't function as intended include trees represented by toothpicks and rain barrels that aren't going to get runoff from a roof.

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Did any issues come up for groups trying to work together? Was everybody heard? Are there changes in approach you want to make going forward to address any concerns?

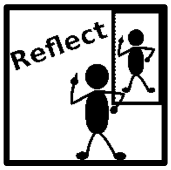
If there are models that are clear misses, consider whether you want to press further about their design before or after students can see the results for themselves. If you do it after the next lesson, will students have sufficient time to redesign the model to better reflect what they are attempting?

If you would predict there will be significant student stress around their models "failing" and you didn't read it yet, consider reading Rosie Revere, Engineer by Andrea Beaty. The main character in this book is an inventive girl who gets frustrated at failure but then learns how engineers design, test, redesign, and retest over and over again. See https://teachscience4all.org/ngss-resources/ for a teacher guide.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools & Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

Tools. How did the tools used (e.g. diamond discussion and group work) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Materials Set Up

Do all the following before working on modeling your solution:

1. Materials Manager brings materials to work area.
2. Place one absorbent pad on the table.
3. Put the site model on the pad with the drain hole over the edge of the table.
4. Place the other pad on the floor and put the basin on the pad under the drain hole so that it will catch any water that comes out of the drain hole.
5. Make sure the drain plug is in the hole.

Leave the rain jar in materials area.

Once your model is set up, let an adult know what additional materials you will need from the class supply.

Lesson 9: Testing Solutions

OBJECTIVES & OVERVIEW

Student groups adjust the solution models they built in the previous lesson. Then they run the same procedure as was used for the teacher's model earlier to record data about the runoff that occurs with the solution in place.

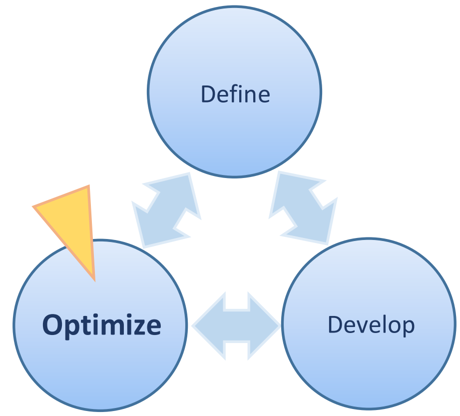
- Students use an investigation procedure and record data.

Focus Question: How can we improve our solution?

Learning Target: I can run an investigation to improve my solution.

New Terms: none

Engineering Design: OPTIMIZE



Optimize the solution*: improve a solution based on results of simple tests, including failure points.*

NEXT GENERATION SCIENCE STANDARDS

3-5-ETS1-3. Plan and **carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved**.

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
Developing and Using Models • Identify limitations of models. **Planning and Carrying Out Investigations** • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered. (3-5-ETS1-3).	**ETS1.B: Developing Possible Solutions** • Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3) **ETS1.C: Optimizing the Design Solution** • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3)	**Cause and Effect** • Cause and effect relationships are routinely identified, tested, and used to explain change.

MATERIALS

YOU WILL NEED THE SAME MATERIALS AS PREVIOUS LESSON
Plus **Measuring Stormwater Investigation Procedure** and the **Data Table** found in the Student Packet

OPTIONAL per group
- Print **Team Observation Sheet** (see below)
- Colored pen

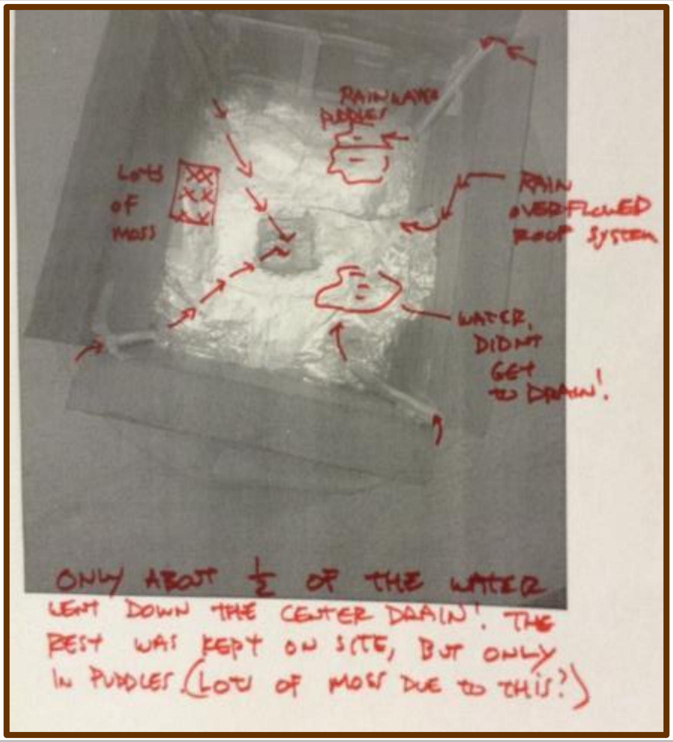
PREPARATION

DECISION POINT

Print photos for recording observations?

OPTIONAL: Create Team Observation Sheets
You could take a digital picture of the solution built by each engineering team and print it for the team to record observations. If you do this, make one also of the teacher's example model to use as a demo.

Example ➔



PROCEDURE

Engage and Encounter

Present visual

Procedure Sheet

1. **Set up for the activity (whole class, engineering teams)**

   Students will have the opportunity today to made additional adjustments to their models and then test how they perform with the same investigation procedure that was used previously on the teacher's model.

   For Engineers, this kind of testing is a critical step in the Engineering Design Process to "**Optimize"** the solution. Engineers are testing specifically to find out where failure points occur and to compare possible solutions so they can choose the best one for the problem.

   Ask why it matters for them to follow the procedure exactly. *[To make it a fair test so they can use the data to figure out the best possible solution.]*

   Project the **Measuring Stormwater Investigation Procedure** and have groups decide on group roles:

   1. **Materials Manager**
   2. **Measurer**
   3. **Rain Maker**
   4. **Bucket Holder**
   5. **Observer – Recorder**

Small Groups

Engineering Teams assign roles and set up materials

Class Designed Procedure?
If you developed a different investigation procedure with the class, use that again this time (and adjust group roles as needed).

Depending on the group size, the measurer could also be the bucket holder and the materials manager could be the observer.

Don't hand out the rain jars yet, but otherwise, follow the **set-up portion** of the procedure.

Back-Pocket Questions

Maintaining Focus

2. **Refine Solutions (engineering teams)**

Groups look over the solution they modeled in the previous lesson and see if there are any small adjustments they want to make before running the test.

Back-Pocket Questions

Maintaining Focus on the Problem

- What is the problem you are trying to solve?
- What are the criteria for success we are focused on?
- How are the criteria being measured when we test our solutions in the model?

Explore and Investigate

DECISION POINT

Using Team Observation Sheets?

3. **Review procedure (whole class)**

If it would help to review the procedure, you could run the teacher "control" model through the procedure again with student assistance.

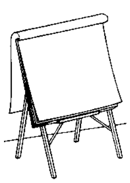
Note that the teacher model will still be saturated from the previous test. This means student models should be compared to that test rather than this one. Project the data table you recorded on previously and have students copy it into the first column of their data tables.

Optional: Team Observation Sheets

If you created the optional **team observation sheets** (printed photographs as described in the preparation section above), have an observer add to the teacher model version as an example.

Provide each team's observer the sheet and a brightly colored pen to record observations. Other team members can add to the observations after the procedure is complete.

Public Record



Measuring Runoff Data Table with teacher data from previous lesson.

Emphasize with students the importance of carefully observing what happens in their model as water is added. If they are watching closely, they may be able to identify "failure points" in which some part of their solution isn't working properly, or problems occur.

Small Groups

Engineering Teams run procedure

4. **Run test and record results (engineering teams)**

Provide time for students to follow the procedure (or lead them through each step if desired).

Groups should record results in the second column of their data table (if using the optional team observation sheets, they can use them for observations instead).

Example data table:

Trial	Amount Runoff Collected	Observations
Teacher Site Model without solution	_430_ ml	*Water collected in puddles on the tinfoil*
Our Site Model with solution Our solution is: *Rain Garden*	_400_ ml	*Some water didn't flow into rain garden. Water soaked in there. There were still some puddles*

This could be a good place to pause the lesson if needed. If you do so, you could proceed directly from the next section into the lesson that follows.

Reflect and Explain

Small Groups

Engineering Teams analyze their results and discuss learnings

5. Analyze your data (engineering teams)

Engineering teams will now consider how the test went and what lessons they can learn. When considering learning, it is important to remember that the designs and models engineers create often "fail." This **optimizing** stage of the engineering design process is about looking at how the tests went and considering what failures can tell you about what needs to be improved or redesigned. Nobody will be graded based on how well their models did; what is important is what you can learn from them.

Each team member should write the answer to the first question below the data table (**the difference in the amount of runoff collected**).

Questions for each group to consider:

- *How did your results compare to the results from the teacher model?*
- *Did you reduce the amount of mL? If so, by how much?*
- *What did you observe during the procedure?*
- *Does anything you observed help explain the results of the trial?*
- *Does anything you learned earlier in the unit help explain your results?*
- *Are there changes you could make that would help your solution work better?*

Back-Pocket Questions

Observations & Optimizing

Back-Pocket Questions for data analysis

Observations

- Where did you observe runoff occurring?
- Was there a certain point that the solution stopped working?
- Was your solution able to handle the amount of water added to the model?
- What happened when there was more water added than your solution could handle?

Optimizing

- Does your model seem to be working?
- What worked well?
- Were there failure points you would want to fix?
- Did the solution cause any new problems?
- What would you want to do to improve your design?

6. **Personal Reflection (individual)**

   Each person should write down at least one change to the model they would do to optimize their solution (question #2 below the data table). Sentence prompt: "If we were to make changes to our model, I would..."

   Next, respond to question #3: "A lesson from our investigation to share with the class is:"

   Have students share their lessons with others through a pair-share, a poster with sticky notes, group share-out, etc.

EXAMINING STUDENT WORK

Consider the test results and learnings and whether they will be able to support choosing a "best" solution in the next lesson. Have students been able to identify what they learned? Will their data support making a decision? Do you need to revisit the test, data, or learnings before proceeding?

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make going forward to address any concerns?

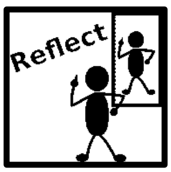
If there was a lot of student stress around their models "failing" and you didn't read it yet, consider reading Rosie Revere, Engineer by Andrea Beaty. The main character in this book is an inventive girl who gets frustrated at failure but then learns how engineers design, test, redesign, and retest over and over again. See https://teachscience4all.org/ngss-resources/ for a teacher guide.

If investigation procedures didn't go well, you could lead a group discussion about why fair test procedures are important in science and engineering. What happens if the data isn't an accurate representation?

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools & Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

Tools. How did the tools used support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Measuring Stormwater Runoff Investigation - Data Table **Date: ______**

Team Member Names: ____

Trial	Amount Runoff Collected	Observations
Teacher Site Model without solution	_____ ml	
Our Site Model with solution Our solution is:	____ ml	

1) The difference in amount collected between the teacher model and our team model: _______________

2) If we were to make changes to our model, I would:

____

____

____

3) A lesson from our investigation to share with the class is: _________________

____

____

Lesson 10: Comparing Solutions

OBJECTIVES & OVERVIEW

In the first part of this lesson, students share their learnings with the class. Then students analyze their own and others' data to make a claim about the effectiveness of the solution they modeled.

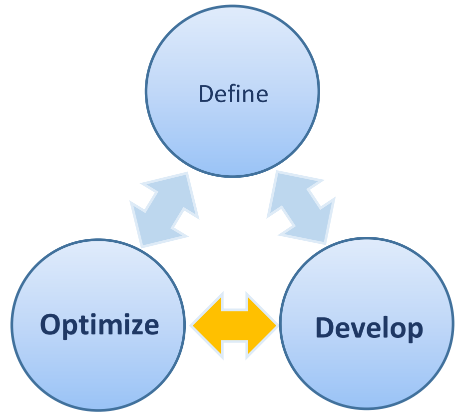
- Students engage in arguing from evidence and write a claim about their solution.

Focus Question: How effective is the solution my group modeled?

Learning Target: I can make a claim about my solution and support it with evidence and reasoning.

New Terms: none

Engineering Design: DEVELOP & OPTIMIZE



Develop and/or Optimize a Solution: *Tests can help improve a solution when they identify failure points. They can also be used to determine which proposed solution will best solve a problem.*

NEXT GENERATION SCIENCE STANDARDS

3-5-ETS1-2. Generate and **compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.**

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

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to **identify aspects of a model or prototype that can be improved**.

Science & Engineering Practices	Disciplinary Core Ideas	Cross-Cutting Concepts
Analyzing and Interpreting Data • Use data to evaluate and refine design solutions. • Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings. **Engaging in Argument from Evidence.** • Respectfully provide critiques about a proposed explanation by citing relevant evidence and posing specific questions. • Construct an argument with evidence, data, and/or a model. (4-LS1-1)	**ETS1.B: Developing Possible Solutions** • Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3) **ETS1.C: Optimizing the Design Solution** • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3) **ETS1-B Developing Possible Solutions**	**Cause and Effect** • Cause and effect relationships are routinely identified, tested, and used to explain change.

• Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem. **Constructing Explanations and Designing Solutions.** • Apply scientific ideas to solve design problems. • Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. (4-ESS3-2) (3-5-ETS1-2)	• At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. **ESS3.B Natural Hazards.** A variety of hazards result from natural processes. Humans cannot eliminate the hazards, but can take steps to reduce their impacts. (4-ESS3-2)	

Common Core Connections:

Writing

CCSS.ELA-LITERACY.W.4.1 - Write opinion pieces on topics or texts, supporting a point of view with reasons and information.

CCSS.ELA-LITERACY.W.4.1.A
Introduce a topic or text clearly, state an opinion, and create an organizational structure in which related ideas are grouped to support the writer's purpose.

CCSS.ELA-LITERACY.W.4.1.B
Provide reasons that are supported by facts and details.

CCSS.ELA-LITERACY.W.4.1.C
Link opinion and reasons using words and phrases (e.g. *for instance*, *in order to*, *in addition*).

CCSS.ELA-LITERACY.W.4.1.D
Provide a concluding statement or section related to the opinion presented.

CCSS.ELA-LITERACY.W.4.4 - Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1-3 above.)

CCSS.ELA-LITERACY.W.4.5 - With guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, and editing.

MATERIALS

Per group:

- **Measuring Stormwater Runoff Investigation - Data Table** from previous lesson
- Solutions resources from Lesson 7 as reference material
- Stormwater models with solutions

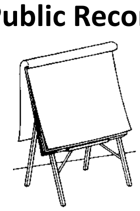
Per student:

- **Stormwater Solution Conclusion (CER)** worksheet (in Student Packet)

PREPARATION – 20 minutes

Create a Class Data Table - For easy reference as student's consider each other's results. Write the runoff amount from the teacher model in the first column.

Public Record



Class Data Table

Team	Solution Tested	Runoff Amount	Key Learnings
Teacher	Control		
1			
2			

…			

DECISION POINT

Differentiation Needed?

Differentiation Needed for CERs?

Writing out a full Claim-Evidence-Reasoning can be challenging, and some students may need additional scaffolding or alternative options:

- Would they be helped by more scaffolding with sentences mostly written out for them?
- Could they instead explain it to you or an assistant who could write it out?
- Could they better represent their thinking with diagrams or pictures?

Any of these alternatives could still be evaluated with the rubric (at end of lesson) used for written CERs. We also have several whole class CER alternatives linked under this lesson on communitywaters.org.

If you are going to use the CER, queue up the CER conclusion template to be projected.

PROCEDURE

1. **Sharing your learnings**
   An important part of Developing and Optimizing solutions is learning from other engineer's efforts to solve a problem. This sharing is so that everybody can consider the best possible solution together.

Thinking like an Engineering Firm
You could frame the share out as the class being an engineering company that is trying to meet their criteria for success and constraints of a specific site. Within the company, smaller teams have been modeling and investigating different possible solutions. Now they are coming together to look at how the different solutions compare. This is **NOT** a competition to see which group did "better," it is a opportunity to see what we can all learn about what would be the best possible solution for our site.

Small Group

What is a key learning we want to share with other teams?

Back-Pocket Questions

Maintaining focus on solving the problem

In teams, each member will share what they wrote down at the end of the previous less as a change they would make.

The team should then discuss what key learning they want to share with the other teams. *Do they feel their solution successfully reduced the amount of runoff? What would it be helpful for other teams to know?*

When it is time for sharing, the teacher will then call on one member of each team (randomly?) to share their data and a learning.

Back-Pocket Questions

Maintaining Focus on the Problem

- Does the solution you tested solve the problem?
- How well does your solution meet the criteria for success?
- What have you learned that others need to know about this solution at our site?

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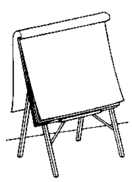


Record each group's results on a class data table.

2. **Engineering Teams Share Out**
   Call on a member of each team to share their data and a key learning.

   As the groups share the data, record their numbers on a class data sheet. If you do this before putting it up on the wall, it might help reduce the feeling of competition between groups.

   Tape up (or project) the class data table once all groups are finished for analyzing in the next section.

3. **Analyze the data from teams (whole class)**

   Discuss whether it is fair to compare the data from the different teams:

   - *Were the original models similar enough to each other?*
   - *Did everybody control the same variables?*
   - *Were there enough trials of each solution?*

Whole-class Discussion

How do the different results compare?

If the answer to any of those questions is no, we can still look at the differences in data to see what we notice, we just can't use the differences as evidence in claiming one is better than the others.

Discuss the different results as a group.

Provide individuals a chance to consider the results on the Class Data Table. What do they notice? What are the implications of the data?

What would they want to do to analyze the data?

Analyzing Data

Using Math to find patterns & cause and effect

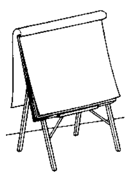
Ideas (if prompts are needed):

- *Would it help to put it into a bar graph or other graphical representation?*
- *Would they want to sort it from most to least amount of runoff?*
- *Should similar solutions be put together? Averaged?*
- *What would they consider a significant different between results?*
- *What is the range of results between the highest to the lowest change?*

> **Math Time?**
> Consider whether you want to do a deeper analysis of the data during math time. Could it help you reinforce any Measurement & Data standards?
>
> CCSS.MATH.CONTENT.4.MD.B.4
> CCSS.MATH.CONTENT.4.MD.A.1
> CCSS.MATH.CONTENT.4.MD.A.1

4. Considering the Problem

Public Record



Problem-Criteria-Constraints Table

Return to **the Problem-Criteria-Constraints table** and challenge the students to think beyond the data from the tests of the models.

How effective are the solutions in meeting all the underlined criteria for success and constraints?

Provide an opportunity for students to present a claim to the class about whether their solution is a good one. Their argument should include evidence that supports it. Other students then are given an opportunity to ask questions or present evidence that the original claimant may not have considered.

> **Arguing from Evidence**
>
> Sentence starters can help students who are unfamiliar or uncomfortable with disagreeing with others publicly. There is a good example on: http://uwcoeast.wpengine.com/tools-scaffolding/

5. Make a claim from evidence (individual)

ELA Connection

Write a conclusion as a research-based argument essay

Each individual student will now be writing a conclusion about what they have learned about the solution their group modeled. They will be making a claim about the question: **“How effective is the solution my team modeled?”**

> **Differentiation?**
> See preparation section for discussion of differentiation approaches. If you are providing more scaffolding or other alternatives, share those during this time.

Students’ claims should include the data they gathered as **one part** of how effective the solution would be at meeting each of the Criteria for Success and Constraints that the class is focusing on. In addition to the data, students should provide other evidence from what they have read or experienced that supports their claim about the solution.

Conclusions should take the form of a “Claim-Evidence-Reasoning.”

For a scaffold, use the **Stormwater Solution Conclusion** template:

a. **Claim:** A general statement about the effectiveness of the solution.

b. **Evidence:** Possibilities to include:
   - Data from their tests of the solution.
   - Reference to where the solution has worked elsewhere.
   - Site specific criteria and constraints that it meets, partially meets, or does not meet.

c. **Reasoning:** The reasons why the evidence meets (or does not meet) the criteria for success and the constraints (how the evidence supports the claim). Reasons may also include scientific understandings that help explain the evidence.

CER Exemplars:

CER Example #1

Claim: "Building a bioswale through the line of six storm drains on the playground would work as a solution for stormwater runoff at our site."

Evidence: "Bioswales are being used by many cities around the United States and have been effective in reducing the amount of storm water runoff entering our waterways. When we tested a bioswale in our models, the water from the model with the solution was 200 milliliters less than when we tested the model without a solution. In addition, bioswales include plants and can be narrow to avoid taking up too much space."

Reasoning: "This shows that a bioswale would meet the criteria and constraints for our site. Stormwater will be absorbed by the ground and plants in the bioswale instead of entering the storm drain, people will like the plants, and there will still be space for children to play during recess."

CER Example #2

Claim: "Building a rain garden is an option for our site, but it wouldn't be very effective."

Evidence: "Rain gardens are used in many yards and some schoolyards around our city. When we tested a model rain garden it reduced the amount of stormwater runoff by only 20 milliliters. Our research shows, it would have pretty plants but would require a lot of maintenance."

Reasoning: "Therefore, a rain garden would not do a great job of meeting the criteria and constraints for our site. Rain gardens help water be absorbed by the ground and the plants in them, but would have to be much bigger than our model to make a difference. If the rain garden was bigger, there wouldn't be enough space for children to play during recess and it would be hard for the school to maintain."

EXAMINING STUDENT WORK

Review and score each student's Claim-Evidence-Reasoning, using the following rubric:

	0	1	2	3
CLAIM *A statement that answers the original question.*	Does not make a claim or makes a claim that does not answer the question.	Makes a claim that addresses the question, but it is incomplete or vague.	Makes a complete claim that addresses the question.	X
EVIDENCE *Scientific data that supports the claim.* *Data needs to be <u>appropriate</u> and <u>sufficient</u> to support the claim.*	Does not provide evidence, or only provides inappropriate evidence (evidence that does not support claim).	Provides appropriate but insufficient evidence to support claim. May include some inappropriate evidence.	Provides appropriate and sufficient evidence to support claim.	Provides appropriate and sufficient evidence to support claim including evidence beyond what they gathered.
REASONING *Explain why your evidence supports your claim. This must include scientific principles/knowledge that you have about the topic to show why the data counts as evidence.*	Does not provide reasoning or provides reasoning that does not link evidence to claim.	Provides reasoning that links claim to evidence but does not include scientific principles.	Provides reasoning that links the claim to evidence using scientific principles, but not sufficient.	Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles.

Students succeeding at making a complete claim and supporting it with appropriate and sufficient evidence accomplishes what is expected for 3-5 graders in the NGSS "Engaging in Argument from Evidence" Science and Engineering Practice. Including scientific principles in their reasoning (row three) isn't expected as a part of the practice until the Middle School band (6-8).

PLANNING NEXT STEPS

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make going forward to address any concerns?

If students are not using evidence to support their claims or are not actually answering whether the solution they modeled is effective, you may need to revisit the CERs as a class. Consider whether clarifying the question, modeling more examples, or other re-teaching could help.
Also consider the CERs individuals completed together with other members of their engineering team:

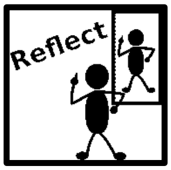
- If students on the same team are coming to different conclusions in their CERs, you may need to provide more time at the beginning of the next lesson for the team to develop a consensus on the conclusion they are going to present.
- If students on the same team are showing widely different grasp of the evidence or reasoning, consider whether it might help to assign group roles during the next activity to support their strengths or provide opportunities for peer teaching.

Be sure to hold on to student work for the next lesson when students are asked to communicate their results.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools & Equity

Task. What was the nature of the task in this lesson? Overall, what was the cognitive load?

Talk. What was the nature of talk in this lesson?

Tools. How did the tools used (e.g. class summary table) support students in communicating and capturing their ideas/thinking?

How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this lesson. Consider change(s) to the next lesson to help address this issue. (Lesson 1 has more prompts for this question)

Stormwater Solution Conclusion

Claim-Evidence-Reasoning (C-E-R)

Student Graphic Organizer

Name: ______________________________ Date: ____________

☆**Question:** How effective is the solution your group modeled?

C **(Claim)** • Write a statement that says what solution your group modeled and how effective it would be for our site.	
E **(Evidence)** • Provide scientific data from investigations and research to support your claim. • Your evidence should be appropriate (relevant) and sufficient (enough to convince someone that your claim is correct).	
R **(Reasoning)** • Begin your reasoning with "Therefore," or "Hence," or "This shows." • Explain how your data proves your claim. • Use **scientific principles and knowledge that you have about the topic** to explain why your evidence (data) supports your claim.	

Lesson 11: Communicating Our Results

OBJECTIVES & OVERVIEW

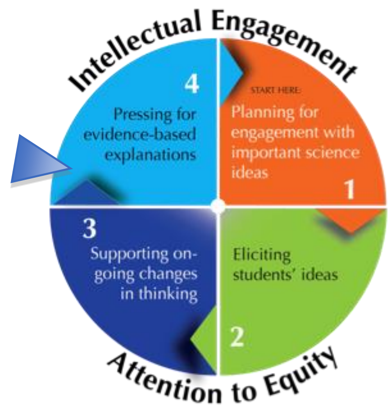
Evaluating and communicating solutions is an important part of the engineering process. Engineers share their design solutions with each other and stakeholders to evaluate the solutions based on how well they meet specific criteria or consider constraints. This lesson will provide an opportunity for students to share their proposed solutions for their site and discuss them with their classmates.

- Students communicate about their solutions to peers and/or stakeholders.

Focus Question: What should we know about the stormwater solution your team tested?

Learning Target: I can share with others about my groups' stormwater solution and why it might or might not work.

Ambitious Science Teaching Framework:
PRESSING FOR EVIDENCE-BASED EXPLANATIONS



This practice happens as a summation, but parts can be introduced at other times when students talk about evidence. For more visit http://AmbitiousScienceTeaching.org

NEXT GENERATION SCIENCE STANDARDS

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

Science & Engineering Practices	Disciplinary Core Ideas (DCI)	Cross-Cutting Concepts
Engaging in Argument from Evidence. • Respectfully provide critiques about a proposed explanation by citing relevant evidence and posing specific questions. • Construct an argument with evidence, data, and/or a model. (4-LS1-1) • Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem. **Obtaining, Evaluating, and Communicating Information.** • Communicate scientific information orally and/or in written formats, and may include tables, diagrams, and charts.	**ETS1.A Defining and Delimiting Engineering Problems.** • Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5 ETS1-1) **ETS1-B Developing Possible Solutions.** • At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. **ESS3.B Natural Hazards.** • A variety of hazards result from natural processes. Humans cannot eliminate the hazards, but can take steps to reduce their impacts. (4-ESS3-2)	**Influence of Engineering, Technology, and Science on Society and the Natural World.** • People's needs and wants change over time, as do their demands for new and improved technologies. • Engineers improve existing technologies or develop new ones to increase their benefits, to decrease known risks, and to meet societal demands. (3-5-ETS1-2)

Common Core Connections:

Speaking and Listening

CCSS.ELA-LITERACY.SL.4.1 - Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on *grade 4 topics and texts*, building on others' ideas and expressing their own clearly.

CCSS.ELA-LITERACY.SL.4.2 - Paraphrase portions of a text read aloud, or information presented in diverse media and formats, including visually, quantitatively, and orally.

CCSS.ELA-LITERACY.SL.4.3 - Identify the reasons and evidence a speaker provides to support particular points.

CCSS.ELA-LITERACY.SL.4.4 - Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

MATERIALS

- **Problem Site Explanatory Model** (site explanatory model on paper)
- **Stormwater Solution Conclusion (**CER from Lesson 10)
- **Materials for product** – may include large paper, markers,

PREPARATION – 45 minutes

DECISION POINT

Product?

Audience?

Room arrangement?

Presentation format?

Decisions to be made:

- **How much time to spend?** Determining the product (the thing students create to share) and how you wish them to share it will determine how much time this will take. If short on time, creating a poster per group and sharing within the class may take the least amount of time.
- **Who will be in the audience?** Are there stakeholders you could invite to watch the student presentations? This could include people interviewed previously, or (if the site is on school grounds) someone from the district, facilities crew, or PTA. OR, will the audience be just your class, a younger class or other?
- **What will be presented?** Will students share a poster they create, or a poster and their models? This lesson focuses on a poster, but many other ways to communicate and share might be used, including creating a PowerPoint presentation as a "poster". See below for additional ideas.
- **How will the room be arranged**? Where will students present from, and how will they show their models and/or posters to the rest of the class?
- **How will presentations be shared?** What is the best way to have students share their work? You may want student groups to present one at a time to their audience, or you may choose a "gallery walk" format where the audience rotates to each group. Each is described below. Consider sharing, also, during your school's science or engineering fair!

Additional Ideas instead of poster

Letter writing: Write a letter to a local or state elected official, letting them know about the work you've done and the importance of taking care of stormwater runoff in your community. This can really influence how money is spent in our region and help get more funding for stormwater solutions! The letters could share what students learned about stormwater, why they care, and what solutions they suggest to these policy makers and stormwater managers.

> Who to write to?
>
> Tacoma Public Schools Facilities department
>
> Tacoma Environmental Services
>
> Port of Tacoma
>
> Pierce County

Video product – similar to the letter writing option, these videos could include student teams showing their models and telling others what they did and learned, and what solutions they think should be implemented to prevent stormwater pollution from entering Puget Sound (for example).

Multi-media presentation using FlipGrid – students can share video or images of their models, drawings and video of them presenting their findings.

Poster Campaign in local community – expand on the poster sharing idea by having students create posters to be put up in windows in businesses, the school, homes, etc. to share their learning with the broader community.

Write a grant request to take action – if students want to plant trees, build a rain garden or other action, they may be able to help raise money to do that!

PROCEDURE

Engage and Encounter

1. **Get the Activity Started (whole class)**

   After designing a solution, engineers present it to stakeholders who can then decide whether to implement it.

   Each team will put together an explanation of the solution they developed to share with the class and/or others (depending on who will be attending). Their job is not to convince others that the solution they tested is the right or wrong solution for the site; it IS to give people all the information they need to be able to consider the **advantages and disadvantages** of the solution in comparison to other possible solutions.

Explore and Investigate

2. Develop presentations (engineering teams)

Create a checklist on the whiteboard (or elsewhere) of all the things to include in their posters and/or share the rubric with students.

If Creating a Poster: Draw the problem area and the imagined solution, or incorporate pictures or other images cut and paste onto a poster. If pictures were taken, those could be printed, or students can draw or make copies of earlier drawings.

A checklist for the poster could include:

- **Diagram or image** of current Problem area (somewhat like a “before” picture). This could be adapted from the class’s **Problem Site Explanatory Model**. It should show:
    - Surfaces in the area that contribute to the problem
    - Arrows showing how water moves through the site during a storm.
- Diagram or image of Solution (like an “after” picture), showing the proposed solution and its features.
- Key (if using symbols in drawings)
- Claim about effectiveness of solution with at least two pieces of evidence.

Additional things to include could be:

- The criteria for success and constraints that were considered.
- A description of the solution they tested and how it would work to help slow or absorb stormwater.
- How the solution would address (or not address) each of the criteria and constraints.
- Why they chose the solution to test in the first place (using evidence from multiple sources).
- Stakeholder needs for the site.

This time could be split up into multiple days if needed.

ELA Connection

Students expand on written conclusion and communicate results with peers.

Small Groups

Groups will create their poster and plan their presentation

ELA Connection

Use this as an opportunity for persuasive writing and speaking!

3. **Create and Practice the Presentation**

During the presentation, student groups could share:

- And Introduction to the Problem – what's the issue, and why does it matter?
- How they researched solutions and stakeholders (for example, through testing solutions using models, researching using texts, interviews, etc.)
- Description of criteria for success and constraints
- Description of the solution
- Results of testing the solution or the CER

Student Jobs

You could provide students assigned jobs for the poster and presentation.

Poster Creation Jobs (examples):

- ❑ Title and decorating of poster
- ❑ Site with current problem (drawing or photograph)
- ❑ Solution with key (2 students?)
- ❑ CER written so that people can easily read and see it
- ❑ Perspective of stakeholders with the Criteria and Constraints being focused on and how the solution would (or would not) address each written out.
- ❑ Preparing model (if using)

Presentation Roles:

Could be presenting the section they prepared on the poster.

If needed, this would be a great place to pause the lesson.

Reflect and Explain

DECISION POINT

Will you have stakeholder guests for the students to share with and how do you want to set up the sharing?

Could you record the presentations and put them on FlipGrid for feedback?

4. **Deliver Presentations (whole class)**

If you have guest stakeholders in attendance introduce them and the importance of bringing them on board to consider the feasibility of actual implementation. You could invite the stakeholders also to contribute questions as the presentations proceed.

Have each group stand by their posters or models. One group at a time presents about their proposed solution for approximately 5 minutes. The groups should plan out who will share which parts of their presentation.

Student listeners (audience) will write down the group name, the problem, and the proposed solution. They will write down something they notice about the solution and something they wonder. If they have any ideas that will help **optimize** (improve) the solution, they will take note of those.

After the group is finished presenting, the audience may ask questions, offer up things they appreciated, or suggestions for improvements.

Bring the whole class together again to reflect and explain interesting solutions and ideas for improvements.

OR

Gallery walk: posters/models placed around the classroom; half of the groups will stay with their poster, and half will be the audience; after the audience groups rotate to the presenters, the groups will switch so the audience groups are now the presenting groups. Audience groups will rotate to all presentations and ask questions and/or use sticky notes for comments and questions. A whole group debrief discussion might be useful to wrap up the gallery walk, when students have a chance to share appreciations (what they liked) about other groups presentations.

If student groups create a PowerPoint presentation, these can be remotely or digitally shared!

Examples of student products from this lesson can be found on

www.communitywaters.org, including posters, letters and other work.

EXAMINING STUDENT WORK

The presentations of the students are the culmination of learning about what is going on with stormwater at the school, local and city level, and how people are designing and building solutions to stormwater runoff problems using an engineering design process.

EXAMPLE RUBRIC for Poster

Community Waters: Poster Rubric

Criterion	Not Yet (1 point)	Approaches Expectations (2 points)	Meets Expectations (3 points)	Surpasses Expectations (4 points)	Score or Notes
Solution is Described	No solution shown	Solution is incompletely or inaccurately represented	The solution is clear and includes how it would help with stormwater.	Solution is clear and provides a detailed explanation that fully explain why its components help with stormwater.	
Solution is Drawn	Poster is all text	A drawing of the solution and/or site is included	Solution drawing accurately represents the site and the solution tested	Solution drawing is precise and effectively shows the site and solution tested.	
Includes Problem, Criteria and Constraints	Not shown	Describes some but not all three.	All three are described accurately.	Describes the problem both locally and regionally and connects one or more criteria or constraints to stakeholders.	
A claim is made about the solution and is supported with evidence.	Does not say whether the solution is recommended.	Claim is clear and evidence is provided to support it	A clear claim is supported by at least two relevant pieces of evidence.	A clear claim is supported with evidence that includes why it is the best option give the location's criteria and constraints.	
Poster is clear and free of errors.	Title is missing	Poster is titled	Poster is titled, and everything is accurately labelled	Poster is titled, accurately labeled, neat, and colorful	

PLANNING NEXT STEPS

Based on the presentation rubric and your observations: Are there any understandings you want to revisit or misconceptions you want to request before students share their knowledge at home and/or do the summative assessment?

End-Of-Unit Assessment

OBJECTIVES & OVERVIEW

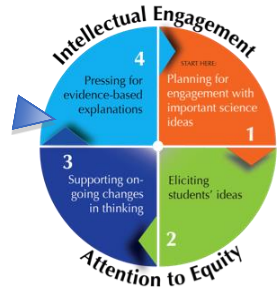
This final section provides opportunities for students to show what they have learned, beyond their "communication" products from Lesson 15.

- A Take Home Interview provides an opportunity for students to pass along what they learned to those they live with.
- A 3-Dimensional Summative Assessment provides the teacher with a way to determine what their students have learned during the unit based on the NGSS's three dimensions. This is ideally put in context with students' final presentation and other demonstrations of understanding the students have provided over the course of the unit).

Focus Question: What have we learned?

Learning Target: I can show what I have learned.

Ambitious Science Teaching Framework: PRESSING FOR EVIDENCE-BASED EXPLANATIONS



For more visit http://AmbitiousScienceTeaching.org

NEXT GENERATION SCIENCE STANDARDS

This 3 Summative Assessment in this section is focused on:

PE 3--5-ETS1- 2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem and

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

Students are provided the opportunity to demonstrate their understanding of the following dimensions (with an emphasis on the Engineering Design Process and a focus for simplicity in this assessment on criteria over constraints):

Science & Engineering Practices	Disciplinary Core Ideas (DCI)	Cross-Cutting Concepts
Asking Questions and Defining Problems • Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon. (4-ESS2-1) • Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost. (3-5-ETS1-1) **Constructing Explanations and Designing Solutions**	**ETS1.A Defining and Delimiting Engineering Problems.** • Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (3-5 ETS1-1) **ESS3.B Natural Hazards.**	**Cause and Effect** - Cause and effect relationships are routinely identified, tested, and used to explain change. (4-ESS2-1)

• Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design problem. (3-5-ETS1-2) • Apply scientific ideas to solve design problems. (4-ESS3-4)	• A variety of hazards result from natural processes. Humans cannot eliminate the hazards, but can take steps to reduce their impacts. (4-ESS3-2)	

MATERIALS

Print for each student:

- **After-Unit Take Home Interview** – one per student (Amharic, Arabic, Chinese, Somali, Spanish, Tagalog, Tigrinya and Vietnamese versions of this document available on communitywaters.org).
- **"Show Your Understanding" Assessment** (3-Dimensional Summative Assessment available on communitywaters.org) – one per student on legal size (8.5x14) paper.

PREPARATION – 45 minutes

DECISION POINT

How do you want to prep students?

Decisions to be made:

- **Are there any understandings or misconceptions you want to address?** Was anything revealed during the presentations that you want to revisit with students?
- **Take Home Interview Prep?** What do your students need to be successful with the Take Home Interviews?
- **3-Dimensional Summative Assessment?** Review the assessment questions and decide whether they will be helpful to you. Do you want a more formal assessment of what students learned? Do you want to take class time for it?

PROCEDURE

Reflect and Explain

1. Reflect on the unit (individual)

Have students reflect on the Community Waters unit as a whole, having them do a quick write or turn and talk, etc.

Questions you may want to use as prompts:

- What did they learn during this unit?
- What was the most fun part of the engineering process? The most challenging?
- Why should we care about stormwater?
- Did you prefer the science learning or the engineering and why?

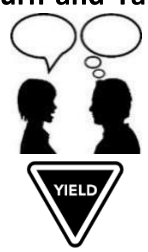
- What other environmental or community problems can you think of that could use engineering solutions?
- What was their favorite part about their solution?

Apply and Extend

Present visual

Take Home Interview

Turn-and-Talk



2. Take Home Interview

This homework assignment is a follow up to the Take Home Interview students did at the start of the unit. Unlike that one, this interview is focused on the student sharing with their adult about what they learned and then thinking together about what their family might do to help with urban stormwater problems in their neighborhood.

Optional Preparation for Take Home:

- Students practice answering the questions in the “Adult Asks Student” section with a partner.

You could easily do the next session on a different day if desired.

Present visual

Photo From Assessment

3. 3D Summative Assessment

This end of unit assessment provides an additional opportunity for students to show their understanding of stormwater runoff problems and solutions.

- Project the image and explain the problem scenario (at end of lesson):

"After building a new parking lot at a light rail station in the city, it is flooding when it rains and people are getting their feet wet when they park. The city wants to fix the parking lot so people won't get their feet wet. The city is also concerned about reducing pollution that might end up in Puget Sound."

- Make sure they see the puddle in the picture (often difficult in black and white).
- Give students an appropriate amount of time to fill in their answers and use the rubric provided in "Examining Student Work" below.

EXAMINING STUDENT WORK

The Summative Assessment provided focuses on **PE 3--5-ETS1- 2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem** and **PE 4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.** It is intended to assess all three NGSS dimensions (Practices, Disciplinary Core Ideas and Cross-Cutting Concepts) with a focus on the Engineering Design Process taught in the second half of the unit.

You can use this Rubric to score each student's responses to the assessment. For each item, use the text provided in the scoring column as a guide but ideas could be expressed that are still valid answers and get the points. The sample responses (in italics) are not all inclusive. There are 10 possible points for this assessment.

Community Waters Take Home Interview   Date: ___________

Student's Name: ___________________ Adult's Name: _____________________

Ask an adult in your household to do this assignment with you. In the first section are some questions for them to ask you. Don't forget to share this back with your teacher!

Adult Asks Student:

Interview your student by asking the questions below to find out what they have learned in science class.

1. Why are there stormwater problems in cities? What kinds of things increase the amount of stormwater runoff?

2. What stormwater problem did you design a solution for? What was the solution you designed?

3. What could you and I do that would help with stormwater problems?

Community Waters Summative Assessment Rubric

Item	Scoring	Possible Points
1. Based on the description above, what are the two criteria that will help the city decide if a solution has been successful?	One point for each of the following: • Feet won't get wet • Reduces pollution	**(2 points)**
2. What would you suggest as a solution for the parking lot, instead of storm drains? [Provides scaffolding for 4)	One point if there is enough information for the reader to see that the student has chosen a viable solution that relates to the problem. Students can draw or describe in words any solution they like. Don't assess the details of their solution here.	**(1 point)**
3. Which solution will better reduce flooding in the parking lot and reduce pollution in Puget Sound? (CIRCLE ONE) [Provides scaffolding for 4 and 5]	Students who understand the criteria and constraints related to the design scenario will <u>choose their own solution</u>, provided it is a legitimate design strategy for meeting the city's goals.	**(1 point)**
4.b. My claim that **______________________** **Is a good one because:** [Provides scaffolding for 5]	One point for naming at least one of the science ideas in 4a and a second point for using it accurately in the response. Sample responses: *The bioswale **filters** polluted water from the parking lot so it does not go into the Puget Sound, it would also not let litter through, and is not ugly.* *My solution will be **pervious** so more water can be absorbed. This means less **runoff** and pollution will go into Puget Sound.*	**(2 point)**
4.c. The other solution will not be as successful because: [Provides scaffolding for 5]	One point for naming at least one of the science ideas in 4a and a second point for using it accurately in the response. Sample responses: *Storm drains will stop flooding for a while, but will eventually clog. They also let pollution in the **runoff** dump into the ocean which is bad for the environment.* *The city's idea is not as good because building more storm drains will not **filter** the pollution in the water going to Puget Sound.*	**(2 point)**
5. What is one kind of data that you could collect that would support your claims? **5a. Data I would collect:**	One point for naming data that would support at least one part of their answer in question 4. Sample responses: For different solutions, collect and compare data about: • How much water there is (e.g., gets collected, is runoff, puddles:	**(1 point)**

	how many, depth, where) ● How clean the water is when it is collected or goes to Puget Sound (e.g., turbidity). ● Data that describes impacts of different solutions on the health of Puget Sound (e.g., pollution levels, fishing outputs) ● Observations or Ideas from people about how well a solution is working (e.g., dry feet, complaints, people getting splashed by cars driving through puddles) ● Other ideas that don't meet the criteria: people's opinions about aesthetics, etc.	
5b. How would this data help you understand how well the solution is working:	One point for connecting their data to their answer in question 4. Sample response: *This data would tell us how effective each solution is at meeting the criteria. Solutions that collect more water or clean water better before it goes to Puget Sound would be more successful at meeting the criteria.*	**(1 point)**

PLANNING NEXT STEPS

Congratulations! You've completed the Community Waters Science unit!

Fill in the **Teacher Reflection Worksheet** (below): Are there changes in approach you want to make in the future to address any concerns?

DECISION POINT

Do you want to extend this unit into an action project? Having done all this work to think about solutions to a local problem, why not channel students' energy to bringing actual change?

Possible Extensions:

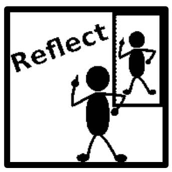
Sharing at school: Put up posters and models in the library or other common space at the school so that other students can learn about stormwater and engineering. Share during a Science Night.

Building solutions: Implementing the student's solutions is beyond the current scope of this unit. However, we are developing next step options for interested teachers. This is a work-in-progress, with ideas at: https://communitywaters.org/implementing-a-project-at-your-school/.

TEACHER REFLECTION WORKSHEET

See the more detailed prompts (if needed) in the Lesson 1 Teacher Worksheet.

Teacher Reflection



Task, Talk, Tools & Equity

Task. What was the nature of the task in this unit? Overall, what was the cognitive load?

Talk. What was the nature of talk in this unit?

Tools. How did the tools used support students in communicating and capturing their ideas/thinking?

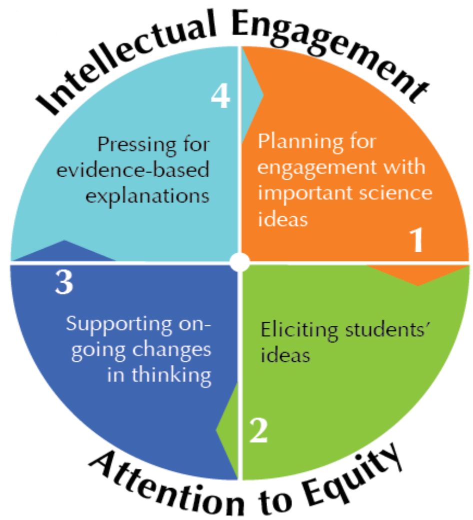
How well did the combination of task, tools, and talk work for your students?

EQUITY. Name and describe one issue around equity that arose during this unit.

Community Waters "Show your understanding"

After building a new parking lot at a light rail station in the city, it is flooding when it rains and people are getting their feet wet when they park. The city wants to fix the parking lot so people won't get their feet wet. The city is also concerned about reducing pollution that might end up in Puget Sound.

Appendix 1: The Ambitious Science Teaching Framework



Ambitious Science Teaching (AST) was developed at the University of Washington based on classroom research about how best to help students develop scientific understandings. See http://ambitiousscienceteaching.org/ for in-depth information. The following is provided by AST:

Ambitious Science Teaching is teaching that is effective, rigorous, and equitable. But more than that, it is a framework of research-based teaching and a wide range of tools that can transform how students learn in your classroom. The vision, practice, and tools will furnish a common language about teaching for a group of science educators committed to the improvement of teaching. You will be able to identify "what we will get better at" and how to get started.

Ambitious teaching aims to support students of all racial, ethnic, and social class backgrounds in deeply understanding science ideas, participating in the talk of the discipline, and solving authentic problems. This teaching comes to life through four sets of teaching practices that are used together during units of instruction. These practices are powerful for several reasons. They have consistently been shown through research to support student engagement and learning. They can each be used regularly with any kind of science topic. And finally, because there are only four sets of practices, we can develop tools that help both teachers and students participate in them, anyone familiar with the practices can provide feedback to other educators working with the same basic repertoire, teachers can create productive variations of the practices, and everyone in the science education community can share a common language about the continual improvement of teaching.

VIDEOS of teachers in practice (7-10 minutes per video) can be found here: https://ambitiousscienceteaching.org/foothold-practices/

"Foothold Practices" include

- Scaffolds to make students' initial ideas public
- Responsive talk: How students use vocabulary
- Using back-pocket questions to make sense of activities
- Using a gallery walk to critique student models and explanations
- Everyday language and science language
- Comparing students' science ideas: scaffolding debate
- Creating a "Gotta Have" checklist
- Using models to develop a scientific explanation: A sound unit overview

The Four AST Practices	What does it LOOK like?
1. Planning for engagement with important science ideas	Planning a unit that connects a topic to a phenomenon that it explains Teaching a topic within a real-world context
2. Eliciting students' ideas	Asking students to explain HOW and WHY they think a phenomenon happens (How did the bike change? Why did it change? What is happening at the unobservable level?)
3. Supporting ongoing changes in thinking	• Using ALL activities/lessons to explain the phenomena. • Giving students opportunities to revise their thinking based on what they're learning
4. Pressing for evidence-based explanations	• Allowing students to create a final model or explanation about the phenomena • Pressing students to connect evidence to their explanation

What Ambitious Science Teaching Looks Like in the Classroom

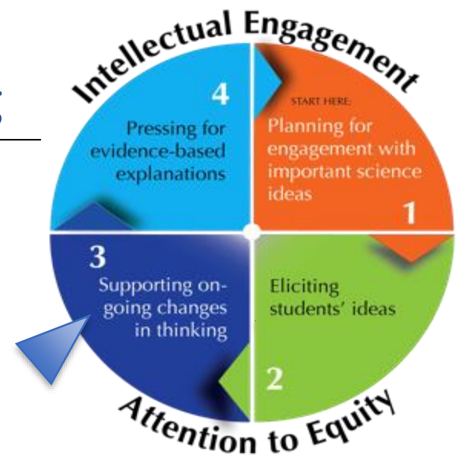
Many teachers want to know what their classrooms should look like and sound like—they want to understand how to interact with their students about science ideas and students' ideas. This is especially true now that the *Next Generation Science Standards* are being used in many states.

As a result of the last 30 years of classroom research, we know enough about effective instruction to describe in clear terms what kinds of teaching practices have been associated with student engagement and learning. This research tells us that there are many ways that teachers can design and implement effective instruction, but that there are common underlying characteristics to all these examples of teaching that can be analyzed, described, and learned by professionals. These practices embody a new form of "adaptive expertise" that EVERY science educator can work towards. Expert teaching can become the norm, not reserved for a select few. Ambitious teaching is framed in terms of practices that any teacher can learn and get better at over time. What would we see if we entered the classroom of a science educator using ambitious teaching? To give you a sense of what ambitious teaching looks like, we have described below some features common to all science classrooms where ambitious teaching is being implemented (listed on right). These features address everyday problems with learning and engagement that teachers face (listed on left).

Common problems in supporting student engagement and learning	What you'd see in a science classroom where ambitious teaching is the aim
The problem: *Students don't see how science ideas fit together.* Each day is perceived by students to be the exploration of ideas that are unconnected with previous concepts and experiences.	At the beginning of the unit, students are focused on developing an evidence-based explanation for a complex event, or process. Students know that throughout the unit, most of the activities, readings, and conversations will contribute to this explanation.
The problem: *An oversimplified view of what it means "to know."* Science ideas perceived to be straightforward and learnable within a lesson—either you get it, or you don't.	An idea is never taught once and for all, but revisited multiple times. Students' science explanations are treated as partial understandings that have to be revisited over time to become more refined and coherent.
The problem: *Lack of student engagement.* Students' experiences and interests not elicited or seen as relevant. Student ideas treated as "correct" or "incorrect."	Students' ideas and everyday experiences are elicited and treated as resources for reasoning; students' partial understandings are honored as a place to start. They are made public and built upon.
The problem: *Students reluctant to participate in science conversations.* Teachers dominate the talk, ask primarily for right answers, get brief responses from students.	Teachers use a varied repertoire of discourse moves to facilitate student talk. Guides and scaffolds for talk help students feel comfortable interacting with peers.
The problem: *Some students have little support for accomplishing tasks that would otherwise be within their grasp.* Little or no guidance for students' intellectual work. Giving "clear directions" is seen as enough to ensure participation in activities.	There is scaffolding that allows students to participate in science-specific forms of talk, in group work, and in science practices.
The problem: *Invisibility of student ideas and reasoning.* Teacher does not know what students think—their heads are a black box. Cannot then work on students' ideas. Students cannot take advantage of the ideas or ways of reasoning by their peers.	Students' thinking made visible through various public representations (tentative science models, lists of hypotheses, question they have, etc.). The teacher can see how students think and how that thinking could change over time. Students benefit from seeing and hearing the reasoning of others.
The problem: *Illusion of rigor.* Students reproduce textbook explanations, lean on vocabulary as a substitute for understanding. Talk of evidence and claims are rare.	The teacher presses for complete, gapless explanations for unique real-life events or processes, and press for the use of evidence to support claims.

Ambitious teaching is not a "method," and the teaching practices are not scripts. It is a set of principled practices that must be adapted to your classroom needs. Coaches and other teachers can work with you to do this ambitious work.

Appendix 2: Tools for Supporting Ongoing Changes in Student Thinking



Purpose of these tools

1. To ensure students understand *why the activity makes sense to do* at this point in the unit.
2. To help students *bridge the activity with a larger scientific idea.*
3. To *support the development of students' academic language*, using the activity as a context.

When providing students with an idea to use as leverage during the activity. Select some key idea from your target explanatory model. Provide a 10-15-minute presentation of content on this idea.

You need to plan to: • Link verbally what was done by student previously to a "need to know" a new idea. • Be explicit about new vocabulary being introduced. • Use multiple representations of the idea, ask students to look across these and compare how the idea shows up. • Plan for check-in questions to gauge understanding as you go.

***Getting the activity started: Helping students uncover observation and patterns* (use back-pocket questions).**

Start activity, when students break into small groups, circulate among them and consider these questions.

You ask:	*What you need to listen for, plan to respond to:*
• "What are you seeing here?" (or similar broad observational question) • "What might these patterns tell you?" • "You may want to focus on…"	What if students *can* cite relevant features of the activity? What if students are focused on extraneous features of activity? What if students mention patterns, but do not explain the significance?

***Helping students connect activity to the anchoring event* (use back-pocket questions).**

Your second round of interactions in the small groups tests whether kids understand **why** they are doing this activity in the first place. It's easier for them to discuss this after you've asked them what they are observing, inferring.

You ask:	*What you need to listen for, plan to respond to:*
• "Can you explain what you are doing or what is happening in terms of [the anchoring event]?"	What if students hesitate or seem to rely on vocabulary? What if students *can* make connections between activity and some aspect of big ideas?

Whole class coordination of students' ideas & their questions

You return to whole class conversation. This is where you can help kids see broad trends or patterns of data for different groups in the classroom. You then need to help students "map" these onto a real-world situation. Students' new questions should be addressed, not put on the shelf.

You ask:	*What you need to listen for, plan to respond to:*
• "What did you find?" • "I heard these three hypotheses, which ones do you agree with? Based on what evidence?"	What if students hesitate? How will you handle a conversation about evidence?

Creating or revising a public record of student thinking (see notes on the summary table on next page)

Option 1: Add to, revise, consolidate an explanation checklist	Option 2: Use post-it notes to revise your small group models (you need to do this once or twice in the middle of a unit, not after every activity).	Option 3: You could cite one or two possible explanations for your anchoring event and ask the whole class, "Which of these do we think is now more likely? Why?"

After instruction, use the Rapid Survey of Student Thinking Tool (below) to analyze student responses and make instructional decisions

There is also a section at the end of each lesson in this unit with reflective questions to help you think about where the students are and what you want to do next.

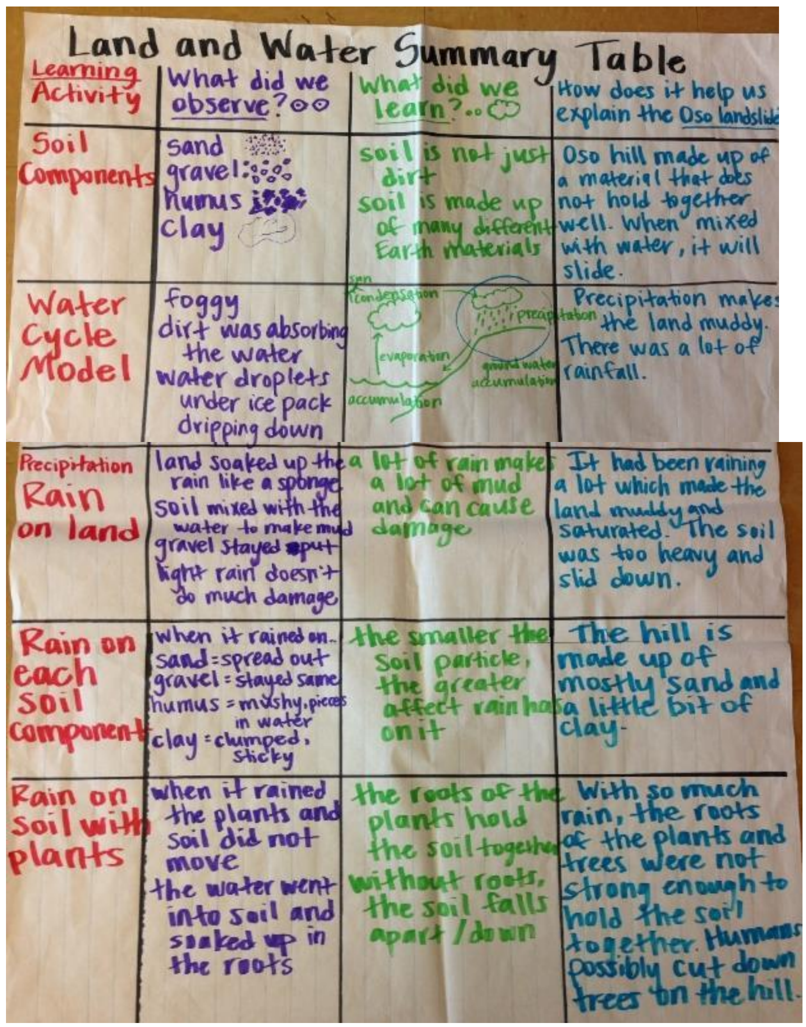
Summary Table: a "Public Record of Student Thinking"

WHAT: A summary table is a large chart that captures the learning progression of a unit. It has four columns: title of lesson, what did we observe, what did we learn, and how does it help us explain our phenomenon. It is posted at the front of the classroom. *(Note: the below example is for a similar unit to Community Waters).*

HOW: Each column builds on one another and each row is one lesson in a unit. At the start of each lesson, we take one moment to review the summary table to "prep our brains" for the new learning about to occur. At the end of a lesson, the students think-pair-share their ideas for each column. The teacher then records their ideas in their own wording on the chart.

WHY:

- It is a great way to wrap up a lesson to solidify students' learning.
- It is a visual record of their learning progress throughout a unit. This allows students to reference past learning experiences, and then build upon those when gaining new learning experiences.
- It features key vocabulary words and definitions, as well as drawings, which support their learning. This component is especially helpful for English Language Learners.
- It pushes their thinking beyond what they see in front of them in their investigations. They synthesize information and apply their learning to explain a phenomenon.
- Students use their summary table to help them construct their final explanations of the unit's phenomenon. They use the learning experiences as evidence to support their claims.



Rapid Survey of Student Thinking (RSST)

Directions: Complete the RSST either during class or right after a class.

Categories	Trends in student understandings, language, experiences [sample sentence starters included below]	Instructional decisions based on the trends of student understanding
Partial understandings What facets/ fragments of understanding do students already have?	List partial understandings: What approximate % of your students have these partial understandings?	★Star the ideas on the list that need action. Instructional options: • Do further eliciting of initial hypotheses to clarify your understanding of students' partial understandings • Do 10-minute whole class whole class conversation of 2-3 key points elicited • Write multiple hypotheses on board and/or develop an initial consensus model •
Alternative understandings What ideas do students have that are inconsistent with the scientific explanation?	List alternative understandings: What, if any, experiences or knowledge bases are they using to justify these explanations?	★Star the ideas on the list that you *really* need to pay attention to based on the following criteria… 1. Which alt. conceptions seem deeply rooted (kids seem sure about)? 2. What % of kids think this? 3. Which are directly related to final explanation (not just a "side-story") Instructional options: • Do further eliciting about what experiences/frames of reference students are drawing on • Pose "what if" scenario to create conceptual conflict about validity of alt. ideas • Challenge students to think further/give them a piece of evidence to reason with • Target a round of "Discourse 2" to address this alt. conception
Everyday language What terms did you hear students use that you can connect to academic language in upcoming lessons?	Cite examples: What approximate % of your students use these terms and phrases?	★Star the ideas on the list that you can leverage in non-trivial ways. Instructional options: • Use language to reframe essential question in students' terms • Use as label in initial models that you make public. Work in academic versions of these words into public models and discussions later. •
Experiences students have had that you can leverage What familiar experiences did students describe during the elicitation activity?	What was the most common everyday or familiar experience that kids related to the essential question or task? What were the less common experiences students cited?	★Star the ideas on the list that you can leverage in non-trivial ways. Instructional options: • Re-write the essential question to be about this experience • Make their prior experiences a central part of the next set of classroom activities • If kids cannot connect science idea to familiar experiences they've had, then provide a shared experience all kids can relate to (through lab, video, etc.)

Making Responsive Instructional Decisions

This tool can be used when reflecting on any science lesson. It can help you organize what you noticed from students so that you can make instructional decisions that respond to and build on where they are.

What resources did you notice?

Specific productive ideas or ways of reasoning from students? Positive group work dynamics? What did you see from students that you think was useful or could be useful moving forward?

What concerns came up for you?

Were there aspects of the lesson that didn't go as well as you hoped? Unanticipated difficulties?

How can these inform your instruction?

Can you capitalize on particular resources from students? Are there ways of drawing on items in the resources column to address concerns?

If you were to teach this same lesson again:

Moving forward instructionally:

Appendix 3: Student Readings

Suggested Lesson	Title of Reading
2	Groundwater
2	Earth Science for Kids: Erosion
2	Erosion: Human Impacts on Land
Optional Background	The Water Cycle
Optional	Urban Weathering

Groundwater

Groundwater is water that is moving or sitting in the soil. Most plants and soil organisms need the groundwater to live. As the water flows through ground it moves into streams, bubbles forth as springs, or is drawn up by wells for people and animals to drink. Groundwater is an important source of water for plants, animals, streams, and people!

Water flows between soil particles:

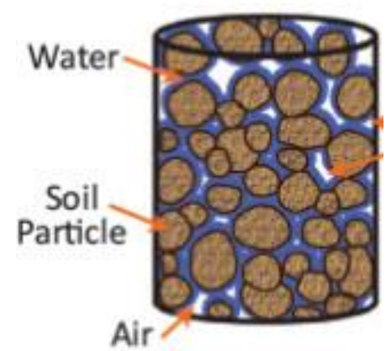


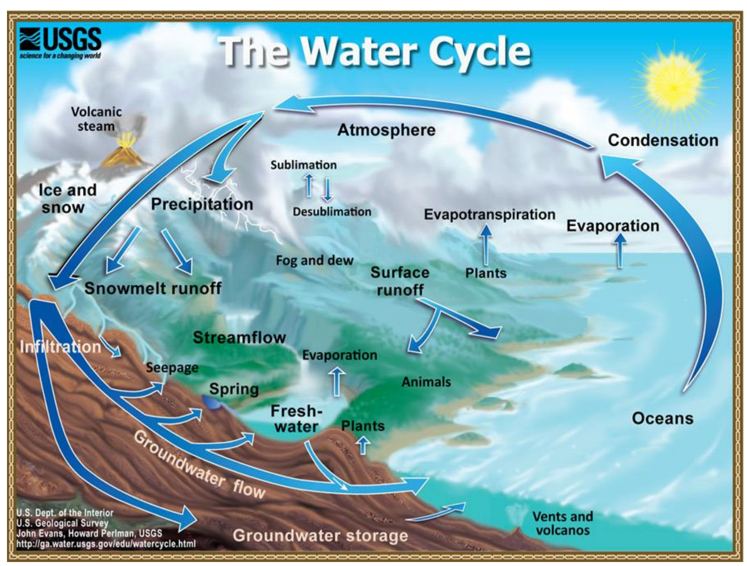
Image credit: Dupont from https://www.pioneer.com/home/site/us/agronomy/library/soil-water-mgmt/

Soil is made up of materials like rocks, sand, clay, and humus. Groundwater clings to these materials and moves through the spaces between them.

How fast groundwater moves through the soil or rock depends on the material. Some materials, like gravel, have interconnected cracks or spaces that are large enough to allow water to move freely. Materials with few spaces between them, like clay or solid rock, force the water to move very slowly or not at all. Groundwater may move several yards each day in gravel, but only a few inches in a hundred years through clay!

The source of most groundwater is rain and snow that falls on the surface of the ground. If there is a surface like concrete that the water can't soak through, then less water moves into the ground, and less water is stored there for later use by plants, animals, streams, and people.

Can you find the groundwater, in this picture of the water cycle?



Earth Science for Kids: Erosion

Text Source: http://www.ducksters.com/science/earth_science/erosion.php
Image sources: http://www.drawingtutorials101.com/drawing-tutorials
Edited and formatted by: C. Colley & B. Street

Word Study:
The word erosion comes from the Latin word "erosionem" which means "a gnawing away."

erosion - noun
erode - verb
erosive - adjective

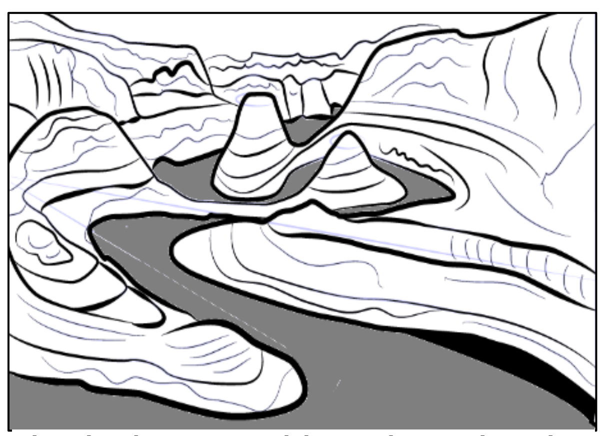
Erosion is the carrying away of land by forces such as water, wind, and ice. Erosion has formed many interesting features of the Earth's surface including mountain peaks, valleys, and coastlines. There are different forces that cause erosion. Depending on the type of force, erosion happens quickly or takes thousands of years. The major forces that cause erosion are water, wind, ice, and vegetation.

Water Erosion

Water is the main cause of erosion. Water is one of the most powerful forces on the planet. Some ways that water causes erosion include rainfall, rivers, waves, and flooding.

Rainfall can cause erosion two ways. First, when the rain hits the ground and the drops move little bits of soil. This is called splash erosion. Second, raindrops land, roll together, and then flow as runoff across the surface in small streams that can carry pieces of soil.

Rivers also erode soil over time. They break up particles along the river bottom and carry them downstream. One example of river erosion is the Grand Canyon which was formed by the Colorado River. The size of earth materials that are carried away by rivers depends on how fast the water is moving. A fast-flowing river can carry



The Colorado River created the Grand Canyon by washing away bits and pieces of rock over thousands of years.

large pebbles and rocks. A slow-moving stream might only be able to move very small bits like clay, silt, and sand.

Ocean waves can cause the coastline to erode. The energy and force of waves cause pieces of rock and coastline to break off and be carried away, changing the coastline over time.

Large floods cause erosion to happen very quickly, washing away loose soil and moving it to new places.

Other Types of Erosion

Other forces that cause erosion include wind, animals, vegetation, and gravity. Wind causes erosion, especially in dry areas. Wind can pick up and carry loose particles and dust from one place to another. Small animals, insects, and worms can help erosion by breaking up the soil so it is easier for the wind and water to move pieces around. Plant roots hold onto soil which prevents erosion. In areas where trees are cut down the soil is no longer held together and can more easily be carried away by water and wind. The force of gravity can cause erosion by pulling rocks and other particles down the side of a mountain or cliff. Gravity can cause landslides which can significantly erode an area.

Additionally, humans have increased erosion in some areas. This happens through farming, ranching, cutting down forests, and the building of roads and cities. Humans cause about one million acres of topsoil to erode each year. Planting trees around farmland and replacing trees that are cut down are two ways to limit the amount of erosion caused by human activity.

Erosion: Human Impacts on the Land

Text Source: http://www.ducksters.com/science/earth_science/erosion.php
Image sources: http://www.drawingtutorials101.com/drawing-tutorials
Edited and formatted by: C. Colley & B. Street

Erosion can cause problems that affect humans. Erosion is the process of natural forces moving rocks and soil. The natural forces that cause erosion are water, wind, ice, and gravity. Soil erosion, for example, can create problems for farmers. Soil erosion can remove nutrient-rich topsoil, leaving rocky soil behind. Erosion can also cause problems for humans by removing or weakening soil that supports buildings.

Water erosion happens when water moves the pieces of rock or soil downhill. Waves carry away small pieces of material. A wave can wash up onto the surface of rock or soil and carry away pieces of material as it flows back into the ocean or lake.

Homes built on a cliff near Pacifica, California collapse as ocean waves erode the cliff.

Ocean waves slowly erode cliffs near the beach. Many people like to live near the beach; however, this can be dangerous if they build their houses too close to the edge of the cliff. Over decades, ocean waves eat away at the soil, undercutting the cliff. Erosion destabilizes the cliff and can cause homes to fall down the cliff.

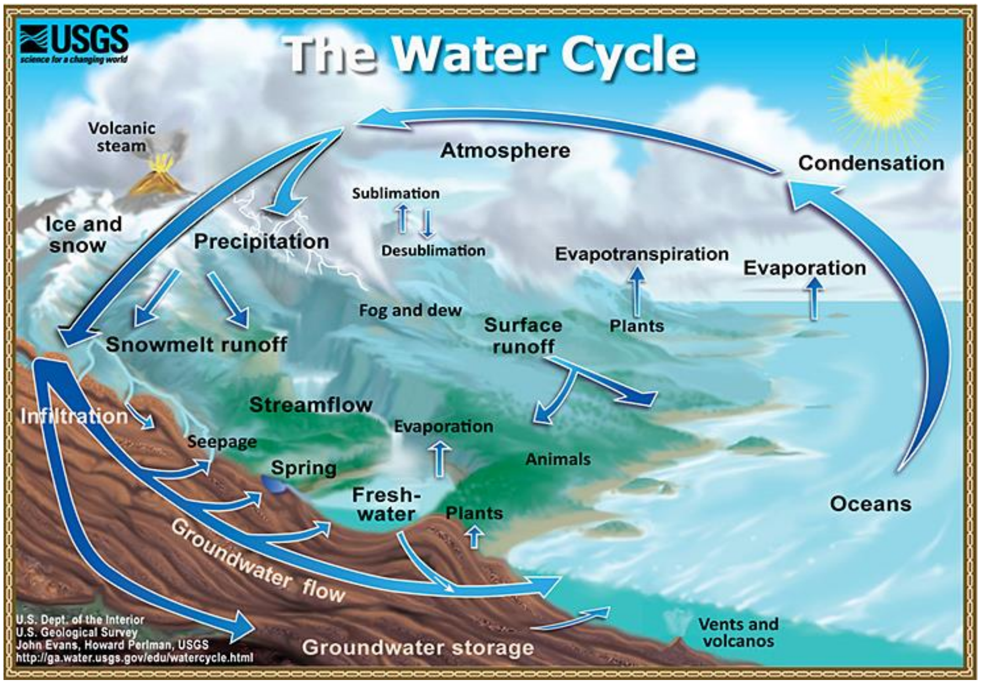
This landslide in El Salvador destroyed many homes in the valley below the hill. It happened after recent logging on the hill.

Human actions can increase the effects of water erosion. Clear-cutting trees to create farmland or to sell as timber can cause erosion problems. With no tree roots to hold soil, the topsoil easily washes away in heavy rains. Erosion caused by deforestation can lead to increased flooding because there is not as much topsoil there to absorb rain water. In hilly regions, deforestation can lead to increased chance of landslides.

The Water Cycle

Adapted from: http://www.k12reader.com/worksheet/water-cycle/

The water cycle is the continuous movement of water as it changes from one state to another throughout the Earth. Water on Earth can be found in three forms: ice, water, and water vapor.



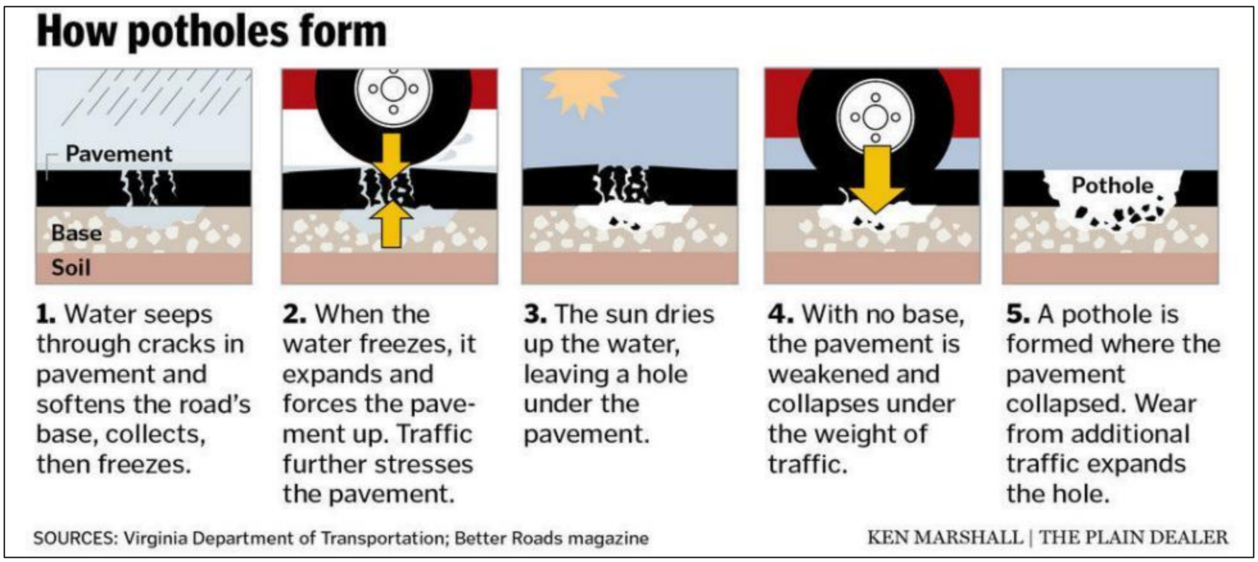
When the heat of the sun shines on water, the water evaporates, rising into the air as water vapor. As it moves higher into the sky, it cools. The cooled water vapor begins to form water drops, which gather together as clouds. This process is called condensation. The drops of water join together in the cloud. Finally, the cloud becomes so heavy that the drops start to fall. Any form of water that falls from the sky is called precipitation. Precipitation will take on different forms such as rain, snow, sleet, or hail.

No matter what form the precipitation takes, much of it will become runoff and find its way back to the sea. Most of the water will join surface water in lakes and streams or soak into the ground and become groundwater. Some groundwater is absorbed by plant roots and ends up as water vapor from the leaves of plants. Some water will spend some time atop mountains as ice and snow. Over time, all water keeps moving and returns to the water cycle at different stages and in different states. The water cycle never ends.

Urban Weathering

Weathering is the breaking down of rocks and minerals on Earth's surface. Water, ice, acids, salt, plants, animals, and changes in temperature can all contribute to weathering. Weathering occurs over various periods of time and can affect surfaces either physically or chemically.

In cities, weathering can be observed in potholes and cracks in pavement. Water contributes to creating potholes and other cracks in roads and sidewalks by seeping into the surfaces and then freezing and expanding. The space where the water expands when it is frozen leaves behind a hole under the pavement. This hole eventually collapses under the weight of traffic.



Plants can also contribute to weathering as their roots grow up through the surface of the ground. Roots eventually push up on the surface with enough force that the surface weakens, causing cracks that can lead to breakage.

Many other chemical elements and physical structures affect weathering over long periods of time. This causes change to occur in both natural and human made structures.

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