12

Modeling Cliff Erosion

MODELING

1–2 CLASS SESSIONS

ACTIVITY OVERVIEW

NGSS CONNECTIONS

Students apply what they have learned about the phenomena of erosion and deposition to a model of cliff erosion. They use the model to construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. Then they design an erosion-mitigation structure for the cliff using relevant scientific principles that might limit solutions. They use design criteria to develop a solution that is evaluated by others using a systematic process to determine how well they meet the criteria and constraints of the problem. Again, they use the crosscutting concept of scale, proportion, and quantity to observe phenomena using models to study systems that are too large. Students are formally assessed on Performance Expectation MS-ETS1-1.

NGSS CORRELATIONS

Performance Expectations

MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

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

Working towards MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

Disciplinary Core Ideas

MS-ESS2.C The Roles of Water in Earth's Surface Processes: Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.

MS-ETS1.A Defining and Delimiting Engineering Problems: 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.

MS-ETS1.B Developing Possible Solutions: There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

Science and Engineering Practices

Constructing Explanations and Designing Solutions:

Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe nature operate today as they did in the past and will continue to do so in the future.

Apply scientific ideas or principles to design an object, tool, process or system.

Asking Questions and Defining Problems: Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

Developing and Using Models: Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.

Engaging in Argument from Evidence: Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Crosscutting Concepts

Influence of Science, Engineering, and Technology on Society and the Natural World:

The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus, technology use varies from region to region and over time.

All human activity draws on natural resources and has both short- and long-term consequences, positive as well as negative, for the health of people and the natural environment.

Scale, Proportion and Quantity: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

Energy and Matter: The transfer of energy can be tracked as energy flows through a designed or natural system.

Stability and Change: Stability might be disturbed either by sudden events or gradual changes that accumulate over time.

Common Core State Standards—ELA/Literacy

RST.6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

WHAT STUDENTS DO

Students model the effect of ocean waves on a cliff. They then design, test, and redesign structures to prevent cliff erosion. They use their observations and understanding of erosion to compare the likely rate of erosion on a hillside and a shoreline cliff.

MATERIALS AND ADVANCE PREPARATION

- *For the teacher*

1 Scoring Guide: ENGINEERING DESIGN SOLUTIONS (ENG) (optional)
*1-2 large containers or tubs
* 1+ large syringes or turkey basters

- *For each group of four students*

Parts A and B

1 plastic box with line
1 plastic cliffmaker
1 wavemaker holder (with slot)
1 wavemaker paddle
1 river model catch basin
1 graduated cup (30-mL)
1 spoon
1 plastic cup (9-ounce; to hold sand)
* supply of moist sand (about 175 mL)
* supply of water in a plastic container (e.g., a 1-L bottle)
* newspaper (optional)

Additional Materials for Part B

2 mesh sleeves of small rocks
9 building bricks

- *For each student*

1 Student Sheet 12.1, "Evaluating Designs: Cliff Erosion"

**not included in kit*

Make sure that each group of four students has access to a work surface that won't be damaged by spilled water or sand. Gather a large container or tub for sand setup and cleanup. Provide them in a common area where students can collect and return the sand. Even if your classroom has sinks, you should have an additional container available into which students can dump their dirty (sandy) water so it doesn't clog the drain. Another useful disposal method is to use a large syringe or turkey baster to remove the water from the basin before disposing of it in a tub or sink.

For this activity, each group of four students will need a 9-ounce cup filled with moist sand. Prepare the sand by adding just enough water to make a consistency similar to dough, as in the previous activity. If the sand becomes too wet during the day, drain it as well as possible and add a little more dry sand to create the right consistency.

Each group will also need two mesh sleeves of retaining rocks. The first time you use the kit, either you or your students will need to insert the small rocks into the mesh sleeves.

TEACHING SUMMARY

GET STARTED

1. Introduce the idea that the coastline is another location where land and water interact.
   a. Review student understanding of where erosion occurs.
   b. Discuss the introduction and Guiding Question.

DO THE ACTIVITY

2. Facilitate the investigation of the erosive power of waves.
   a. Assist students as they set up and use the cliff model.
   b. Briefly review student observations from Part A.
3. Prepare students for Part B of the Procedure.
   a. Discuss the engineering challenge, criteria, constraints, and testing procedure.
   b. (ENG QUICK CHECK) Remind students of the ENG Scoring Guide.
4. Facilitate the design and testing of erosion-control structures.
   a. Guide students as they decide on their initial design.
   b. Help students use their prototype results to optimize their designs.

5. Facilitate the presentation and critique of student designs.
   a. Make clear your expectations for the presenters and the audience.
   b. Have students engage in the engineering practice of evaluating designs.

BUILD UNDERSTANDING

6. Discuss cliff erosion, erosion control, and the possible effects of both on Boomtown.
   a. Review the role of energy in the processes of erosion and deposition.
   b. Evaluate use of erosion-control structures.
   c. Consider factors that influence the rate of erosion.
   d. Assess Performance Expectation MS-ETS1-1 in Analysis item 7.

TEACHING STEPS

GET STARTED

1. Introduce the idea that the coastline is another location where land and water interact.
   a. Review student understanding of where erosion occurs.

      Remind students that previously they modeled erosion made by water flowing down a slope. Ask, "Can you think of any other places where land and water interact?" They are likely to suggest the shores of lakes and oceans. A few may even suggest glaciers (frozen ice and snow) scraping at the land. Ask them to describe their ideas about erosion at the shore of a large body of water, such as a lake or ocean. Collect their ideas, and try to address them during the activity.
   b. Discuss the introduction and Guiding Question.

      Have students read the introduction and Guiding Question, and then ask students for, and briefly discuss, any questions or comments. If needed, review the meaning of the terms *criteria*, *constraints*, and *mitigate*.

DO THE ACTIVITY

2. Facilitate the investigation of the erosive power of waves.
   a. Assist students as they set up and use the cliff model.

      Distribute the needed materials to each group. Consider having students cover their work areas with newspaper before setting up their models. Point out that although it is almost impossible to avoid small spills, it is really important to be as careful as possible to avoid any major spills.

Students may need a little help setting up the sand in the boxes and gently adding water so the sand doesn't immediately wash away. Monitor their progress to be sure they have prepared their workspaces correctly. Before letting them begin, warn them to avoid splashing the sand and water out of the boxes when they produce the waves in the box. Encourage them to begin Part A of the Procedure and to observe the effects closely, measure and draw changes to the shoreline, and write down any additional observations in their science notebooks.

b. Briefly review student observations from Part A.

Have several students share their responses to Procedure Step 9.

PROCEDURE STEP 9 SAMPLE STUDENT RESPONSE

- What happened to the cliff?

  The cliff was eroded by the water. The first few waves undercut the lower half of the cliff face. The next few waves made the cliff face above the undercut area collapse.

- What happened at the bottom of the model?

  The sand at the bottom was quickly flattened by the water and made a small "beach." Some of it was suspended by the waves and moved in and out with them.

- What earth processes did you observe in action?

  Erosion and deposition were the processes, but these processes moved more material more quickly than in the river model.

3. Prepare students for Part B of the Procedure.

a. Discuss the engineering challenge, criteria, constraints, and testing procedure.

Read aloud, or have students read, Part B of the Procedure. Distribute the additional Part B materials, and make sure students are clear about the criteria and constraints for the challenge. If you would like to add a monetary constraint, provide relative prices for the structure items, making each 2-button brick the most expensive, and each rock and/or mesh sleeve less expensive.

b. (ENG QUICK CHECK) Remind students of the ENG Scoring Guide.

Part B of the Procedure is an engineering opportunity that correlates with the SEPUP eng Scoring Guide. The task in this activity does not prompt a Level-4 response on the ENG Scoring Guide, but you may want to use it with students to achieve a Level-3. Optionally project or distribute the Scoring Guide, and review the levels as needed. For more information, see Teacher Resources III, "Assessment."

4. Facilitate the design and testing of erosion-control structures.

   a. Guide students as they decide on their initial design.

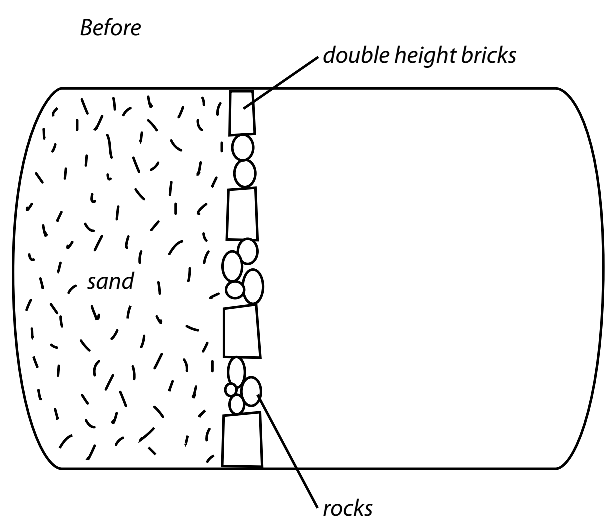
      Encourage students to review the results of Part A and pinpoint the location(s) where the most erosion occurred. If students are not sure how to choose an initial design, ask them to brainstorm a list of potential designs and the reasoning behind each one. As a group, they can go through the list, eliminate the weakest ideas, and select the strongest.

   b. Help students use their prototype results to optimize their designs.

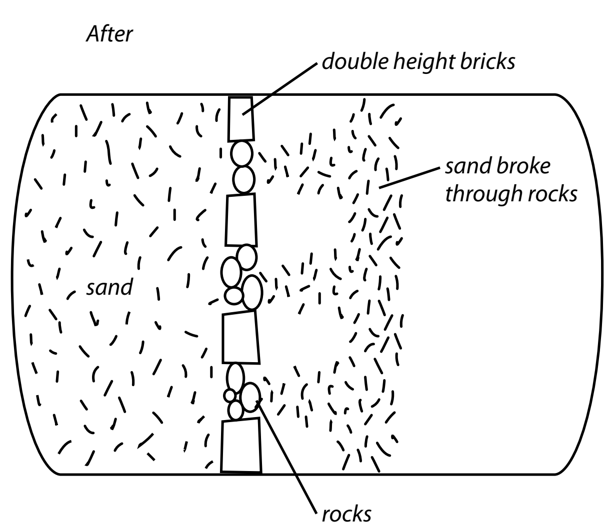
      If students are struggling with how to optimize their designs, ask them to brainstorm a list of potential design improvements and the reasoning behind each improvement. If needed, suggest placing the barrier(s) at an angle or stacking them. As a group, they can go through the list, eliminate the weakest ideas, and select the strongest.

PROCEDURE STEPS 15–20 SAMPLE STUDENT RESPONSE

15.



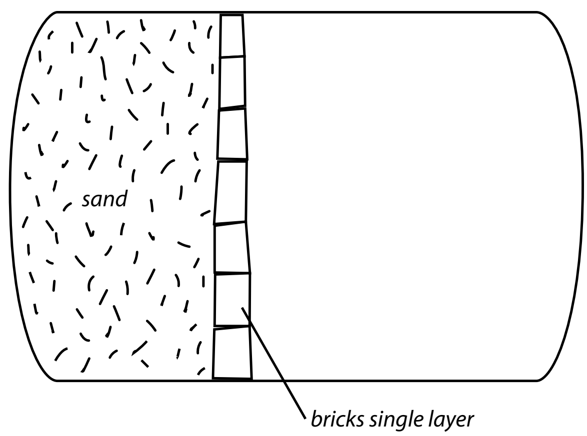
16.



17. *Our structure used building bricks placed at the base of the cliff. This structure reduced erosion but didn't prevent it. The worst erosion was at the edges of the structure. We found that the building bricks seemed to work better than the rocks and that the position of the building bricks and rocks wasn't the best.*

18. *We need to control sand breaking through rocks. We could try adding rocks to those sections or replacing the rocks with building bricks.*

19.



20. *For our final design, we changed the position of some of the building bricks and rocks so that they were at an angle. We were happy to see that this resulted in less erosion than the original. Based on our observations, we think we would need to put building bricks along the whole cliff for the best possible results.*

5. Facilitate the presentation and critique of student designs.

   a. Make clear your expectations for the presenters and the audience.

   For the final step in the Procedure, each student group should make a brief presentation to the class of their design and its effectiveness. This sharing of results helps students prepare to present a school design in the last activity.

   b. Have students engage in the engineering practice of evaluating designs.

   While attending the open session for the design presentations, students should complete Student Sheet 12.1, "Evaluating Designs: Cliff Erosion." This sheet serves as the assessment for Performance Expectation MS-ETS1-2. Evaluating competing designs is a critical step for engineers to take so they can see how well other designs meet the criteria and constraints. Use a numerical evaluation system, such as 1–3, or a qualitative one, such as "not yet meets criteria," "meets criteria," and "exceeds criteria." Avoid letter grades. It may be helpful to remind students that after a design is made, engineers and architects continue to make improvements on that design. See Sample Student Response to Student Sheet 12.1 at the end of this activity.

BUILD UNDERSTANDING

6. Discuss cliff erosion, erosion control, and the possible effects of both on Boomtown.

   a. Review the role of energy in the processes of erosion and deposition.

      Begin by reviewing students' answers to Analysis item 1, which should include observations of the erosion of the cliff and the deposition of the resulting sand on the sea floor. Discuss the process of erosion below the wave surface and the collapse of the cliff above the undercut area. This process of erosion below the water surface is called *undercutting*. You may want to introduce this term, although it is not key vocabulary.

      Emphasize that erosion and deposition are a result of the transfer of energy, which is part of the crosscutting concept of energy and matter. The energy in the movement of the waves erodes the sediments when it is transferred to the cliff face. As the water returns to join the calmer "ocean," its energy decreases. It can no longer carry the sediments, and deposition occurs. Erosion-control structures help absorb and reflect the energy of moving water and keep it from being transferred to earth materials.

   b. Evaluate use of erosion-control structures.

      When discussing Analysis items 2 and 3, focus student attention on the potential negative impacts of placing structures, particularly large ones, in a natural environment. Use this opportunity to discuss the crosscutting concept of influence of science, engineering, and technology on society and the natural world and how the uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus, technology use varies from region to region and over time.

   c. Consider factors that influence the rate of erosion.

      Analysis items 4 and 5 provide opportunities for students to think about erosion rates at different locations. Although students may not have a strong understanding of factors that influence erosion rates, these questions are designed to make them think about how rock type, the power of the erosive force, and built objects are important factors. This will be an important aspect of evaluating the stability of the possible building sites in Boomtown.

The students learned in this activity that the cliff is subject to the strong erosional force of the ocean's waves in addition to rainfall. Remind students that the topographic maps of Boomtown show that the cliff has changed more than the hill (except on the portion of the hill where construction has taken place).

d. Assess Performance Expectation MS-ETS1-1 in Analysis item 7.

Analysis item 7 assesses students' abilities to sufficiently define the criteria and constraints of a design problem. In addition to being the assessment for Performance Expectation MS-ETS1-1, it prepares students for the design challenge in the next activity where they will complete a school design, including monitoring and mitigation plans, for the selected site. Review the science practice of asking questions and defining problems by reviewing the concepts of criteria and constraints, as well as the previously discussed crosscutting concept of the influence of science, engineering, and technology on society and the natural world, to prepare students for the assessment.

SAMPLE RESPONSES TO ANALYSIS

1. In Part A, what did the waves do to the cliff model? Explain in terms of energy, erosion, and deposition.

   The waves made the sand cliff erode, or wash away. The process began with erosion in the lower portion followed by a collapse of the upper portion. The sand that was washed away from the cliff was then deposited as a beach or underwater shelf (or sandbar) on the bottom of the model.

2. Think about the different designs for reducing cliff erosion.

   a. Explain how they reduce erosion.

      All the erosion-control structures placed a more resistant material (rock or plastic) between the sand cliff and the water so that the waves hit the structures rather than the cliff. The structures reduced erosion by absorbing and reflecting the energy carried by the waves. This prevented the sand grains from getting knocked apart and carried away by the wave energy.

   b. Are there any drawbacks to building structures to protect cliffs? Explain your reasoning.

      Adding structures, especially large ones, lessens the natural beauty of the coastlines. The cost of building the structures is another drawback, especially if the cliffs are big. Also, structures only reduce erosion temporarily. In the long term, the forces of nature cannot be stopped.

3. Do you think you could improve your cliff-erosion structure if you had
   a. more of the materials provided? Explain using evidence from your investigations.

      Yes. The area to either side of the barrier still had significant erosion, so if we had more material, we could have built a bigger structure to protect the whole cliff.

   b. different materials than those provided? Explain using evidence from your investigations.

      Yes. Some water got through the rocks, and if the waves were strong enough, maybe could have broken the building bricks apart or washed the rocks away. So, if we had a material that didn't have cracks or spaces, such as solid plastic or metal, that would probably keep even more water away from the cliff.

4. Imagine two identical cliffs, one next to an ocean and one far away from any water. Compare the erosion at these two locations if both locations receive the same amount of rainfall and
   a. both cliffs are made from the same type of rock. Explain your reasoning.

      It is likely that the coastline cliff will erode more rapidly than the inland cliff. The cliff not next to water will erode mainly due to forces from wind, rain, and flowing runoff water, whereas the coastal cliff will erode from these forces and the force of water waves. Not only are there more forces acting on the coastline cliff, but the waves are likely to be more constant and more powerful than the other erosive forces.

   b. the rocks on the inland cliffs are made of a softer type of rock than the coastal cliff. Explain your reasoning.

      It is still possible that the coastline cliff will erode more rapidly than the inland cliff because it erodes from runoff and waves. However, since the inland cliff is made from softer rocks, which likely more easily erode, the erosion there may be the same or more than at the sea cliff.

5. Imagine two identical cliffs, one with stores and a parking lot built close to its edge and the other undeveloped. Compare the erosion at these two locations if both receive the same amount of rainfall. Explain your reasoning.

   It is likely that the developed cliff will erode more rapidly than the undeveloped cliff. The buildings and parking lot will prevent rainwater from soaking into the ground, so more will end up as flowing runoff water. More water flowing over the cliff edge will cause more erosion.

6. What other design criteria or constraints do you think there should be for the building of the new school and fields on the cliff?

   I think the criteria should include a plan to reduce erosion, maybe by requiring a lot of vegetation or no parking lot or require that it uses porous brick. Also, I think a constraint should be that buildings should not be built too far out on the cliff.

7. Consider a real city that wants to build a new school. The city is located in a hot, urban climate in an area prone to hurricanes.

   Student responses may vary. One sample response that fulfills the assessment for Performance Expectation MS-ETS1-1 is shown here:

   a. What additional criteria and constraints might the city have in building their new school?

      One of the criteria might be that the building stays cool, either with air conditioning or by engineering design. Additional criteria might be that it has hurricane-resistant windows. Since it is in an urban area, the biggest constraint on a similar school is likely to be the size of it. There might be constraints on the square footage or height of the school. It is likely they do not have room for a sports field. Another constraint that applies to this school and any other is how much it costs. Energy efficiency could be another important criteria. Some schools might have different criteria, such as a performing arts center instead of fields.

   b. How could the additional criteria and constraints you described help ensure a successful building design?

      The more criteria, the more likely the design will work. For example, if there wasn't a cost limit, the building could be designed to be more than the city can afford. Or if a lot of vegetation was part of the criteria, it is more likely the design will create less erosion.

   c. What determines which technology is used in the design?

      The technology is determined by cost and need. For example, the school may want to install solar panels if it is located in a sunny place. Another school might want to use that same money to buy hurricane-resistant windows, more energy-efficient air conditioning, or lights for the field.

   d. What are the consequences for the people and the environment in using natural resources for the building?

      The consequences would be positive for the people in the city who get to use the school. The only negative consequence for the people is that they have pay to build the school. The consequences for the environment are negative because *resources are used for building it. It may not be all negative, however, because it is in an urban environment. If the old school is all concrete, perhaps the new school could be built with some vegetation that absorbs water, use porous bricks, or have a roof garden. It could also be more energy efficient which, over time, could offset the resource use to build it.*

REVISIT THE GUIDING QUESTION

How can we reduce the effects of ocean waves on coastal areas?

Erecting barriers that block waves from hitting the rocks along the coastline can reduce coastal erosion. The placement of barriers must be thoughtful, however, because poorly-thought-out barriers just defer and/or concentrate the erosion in a different location.

ACTIVITY RESOURCES

KEY VOCABULARY

causal relationship

constraint

correlation

criterion, criteria

deposition

erosion

mitigation

model

BACKGROUND INFORMATION

CLIFF EROSION

Cliff erosion caused by waves begins with undercutting of the cliff below the waterline. This eventually leads to collapse of the material above the undercut and the receding of the clifftop. Depending on coastal topography and the composition of the rock, coastal erosion can also lead to the formation of caves, arches, and sea stacks.

In some cases, erosion of cliffs takes place at a surprisingly rapid rate due to the power of the ocean's waves. In areas where cliffs are made of compacted sand or soft rock, cliffs can erode a meter or more each year. In other cases, the erosion is more gradual but may still be significant over a period of several years.

MITIGATING CLIFF EROSION

The most common structures used to reduce the rate of cliff erosion caused by waves are (1) seawalls made of concrete or (2) piles of large boulders or other material to create what is called *riprap*. These structures frequently delay erosion but cannot completely stop it and, in some cases, may accelerate it on either side of the structures.

Cliff erosion can also be caused by runoff at the upper edge of the cliff. Although not dealt with in this activity, these effects can be mitigated by situating buildings back from the cliff edge, engineering an appropriate drainage system, and planting appropriate vegetation. (*Note*: Some vegetation can create cracks that may make the area more vulnerable to weathering.) These measures can reduce the runoff of water over the cliff face and thereby slow the rate of erosion.

Name____ Date___________

STUDENT SHEET 12.1

EVALUATING DESIGNS: CLIFF EROSION

Group	Meets criteria to reduce erosion	Meets criteria for 5 waves (1 wave/3 s)	Design strengths	Design weaknesses	Evaluation
1					
2					
3					
4					
5					
6					
7					
8					

Name *Sample student response* Date

STUDENT SHEET 12.1

EVALUATING DESIGNS: CLIFF EROSION

Group	Meets criteria to reduce erosion	Meets criteria for 5 waves (1 wave/3 s)	Design strengths	Design weaknesses	Evaluation
1	*Yes*	*No*	*Water stays in channel*	*Uses additional materials*	*Does not yet meet criteria*
2	*Yes*	*Yes*	*Very little erosion*	*None*	*Exceeds criteria*
3	*Yes*	*Yes*	*Uses only the rocks (less expensive)*	*Some water gets through rocks*	*Meets criteria*
4	*Yes*	*Yes*	*Withstood more than 5 waves*	*Small amount of erosion*	*Meets criteria*
5	*No*	*Yes*	*Only built on top half of model*	*Bottom half had visible erosion*	*Does not yet meet criteria*
6	*Yes*	*Yes*	*Wall was low but water did not go over it*	*Materials sometimes moved*	*Meets criteria*
7	*Yes*	*Yes*	*Did not use all materials*	*Difficult to build*	*Exceeds criteria*
8	*Yes*	*Yes*	*Very little erosion*	*Needed*	*Meets criteria*

ENGINEERING DESIGN SOLUTIONS (ENG)

When to use this scoring guide:

This scoring guide is used when students design, evaluate, and refine solutions.

What to look for:

- Response includes a complete design relevant to the problem to be solved
- Response includes evidence of how well the design meets criteria within the defined constraints
- Response indicates how scientific ideas and concepts relate to the successful design

Level	Description
Level 4 Complete and correct	The student's design: • meets all of the criteria within the defined constraints, AND • has further improved on the design, AND • uses relevant scientific concepts to explain why any revisions were made to optimize the design.
Level 3 Almost there	The student's design: • meets all of the criteria within the defined constraints, AND • explains the relevant scientific concepts.
Level 2 On the way	The student's design: • meets all of the criteria but exceeds the defined constraints OR • meets some of the criteria within the defined constraints.
Level 1 Getting started	The student's design does not meet any of the criteria.
Level 0	The student proposes no design or an irrelevant design.
x	The student had no opportunity to respond.

NGSS UNIT OVERVIEW

LAND, WATER, AND HUMAN INTERACTIONS

Performance Expectation MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

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

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

Performance Expectation MS-ETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

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

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
1. **Investigation: Where Should We Build?** Students are introduced to the human impact on land and water use with a scenario that engages them in the issues in the context of a community's building project. When considering the impact of development, they apply the crosscutting concept of the influence of science, engineering, and technology on the natural world.	MS-ESS3.C	Asking Questions and Defining Problems	Cause and Effect Influence of Science, Engineering, and Technology on Society and the Natural World	
2. **Laboratory: Does It Dissolve?** Students carry out a laboratory experiment that helps them develop a conceptual model for the phenomenon of dissolving salts in water. They apply what they have learned in the investigation to explain how the natural world is affected by the physical properties of water. The movement of dissolved substances into water is related to the crosscutting concept of energy and matter.	MS-ESS2.C MS-PS1.A	Constructing Explanations and Designing Solutions Planning and Carrying out Investigations	Energy and Matter	ELA/Literacy: RST.6-8.3
3. **Investigation: Water Quality** Students conduct a data analysis of water-quality indicators that monitor the human impact on waterways. They compare graphical displays of data that show changes to Earth's surface water at varying times in relation to increases in population. The crosscutting concept of cause and effect is explored through the introduction of a correlation and a causal relationship.	MS-ESS3.C	Connection to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence Analyzing and Interpreting Data	Cause and Effect Patterns Influence of Science, Engineering, and Technology on Society and the Natural World	Mathematics: 6.SP.B.5 MP.4

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
4. **Investigation: Living Indicators** Students identify patterns in data from simulated catches of aquatic invertebrates and construct arguments for possible cause-and-effect relationships to human activities. The crosscutting concept of cause and effect is applied to the phenomenon seen in the effect that human activity has on the types and number of aquatic invertebrates found over time.	MS-ESS2.A MS-ESS3.C MS-LS2.A MS-LS2.C	Analyzing and Interpreting Data Engaging in Argument from Evidence Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Patterns Cause and Effect Scale, Proportion, and Quantity Influence of Science, Engineering, and Technology on Society and the Natural World	Mathematics: 6.SP.B.5 6.RP.A.1 ELA/Literacy: RST.6-8.3
5. **Laboratory: Nutrients as Contaminants** Students use a model to gather evidence about the interaction of soil, water, and fertilizers in a laboratory investigation to understand how human activities have altered the environment. They apply the crosscutting concept of cause and effect to human activity and environmental impacts.	MS-ESS3.C MS-ESS2.C	Developing and Using Models Constructing Explanations and Designing Solutions Planning and Carrying Out Investigations	Cause and Effect Influence of Science, Engineering, and Technology on Society and the Natural World	ELA/Literacy: RST.6-8.3
6. **Reading: Gulf of Mexico Dead Zone** Students read about the phenomena of dead zones—their formation, causes, and effects on the environment. They apply the crosscutting concept of scale, proportion, and quantity when they draw a model diagram to explain how human impact on natural resources in one place can have large-scale impacts in another, distant part of the ecosystem.	MS-ESS3.C MS-ESS2.A	Developing and Using Models Obtaining, Evaluating, and Communicating Information Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Cause and Effect Scale, Proportion, and Quantity Influence of Science, Engineering, and Technology on Society and the Natural World	ELA/Literacy: RST.6-8.1
7. **Modeling: Cutting Canyons and Building Deltas** Students model the phenomenon of sediment movement in a river to provide evidence for how geoscience processes change Earth's surface. They demonstrate how water's movements under the force of gravity contribute to the formation of landforms. Students then apply the scientific and engineering practice of asking questions and defining problems as they use criteria and constraints to design a system to hold sediments in place in the stream.	MS-ESS2.A MS-ESS2.C MS-ETS1.A	Asking Questions and Defining Problems Constructing Explanations and Designing Solutions Developing and Using Models	Scale, Proportion, and Quantity Energy and Matter Influence of Science, Engineering, and Technology on Society and the Natural World Stability and Change	ELA/Literacy: RST.6-8.3

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
8. **Investigation: Traveling with the Water Cycle** Students model the phenomenon of global water movement as driven by the sun and gravity. Students construct an explanation on the water cycle and the cycling of matter. They consider how the planet's systems interact over various time and spatial scales. They use the crosscutting concept of scale, proportion, and quantity to discuss how water movement can be studied using a model of a system too large to observe all at once.	MS-ESS2.A MS-ESS2.C	Developing and Using Models Constructing Explanations and Designing Solutions	Scale, Proportion and Quantity Energy and Matter	ELA/Literacy: WHST.6-8.2
9. **Reading: Human Impacts on Earth's Water** Students read about human impacts on Earth's water. Scientific principles are applied to discuss methods for monitoring and minimizing human impacts on Earth's water. The crosscutting concept of the influence of science, engineering, and technology on society and the natural world is developed as students consider the health of people and the natural environment. Students are formally assessed on Performance Expectation MS-ESS2-4.	MS-ESS2.C MS-ESS3.C	Constructing Explanations and Designing Solutions Obtaining, Evaluating, and Communicating Information Developing and Using Models	Energy and Matter Influence of Science, Engineering, and Technology on Society and the Natural World Stability and Change	ELA/Literacy: RST.6-8.1 RST.6-8.9
10. **Investigation: Making Topographic Maps** Students conduct a hands-on investigation to model Earth's landforms using topographic maps. They create a map of a landform and then apply their understanding to interpret other maps. The consider how the maps reflect evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.	MS-ESS2.A	Developing and Using Models Planning and Carrying Out Investigations Analyzing and Interpreting Data	Patterns Scale, Proportion, and Quantity	Mathematics: MP.2 MP.4 ELA/Literacy: RST.6-8.3
11. **Problem Solving: Boomtown's Topography** Students analyze data from topographic maps that display temporal and spatial information about a particular area. They construct explanations based on this evidence for how geoscience processes have changed Earth's surface over time. They consider how water's movements on the land and underground have changed the land's form. The crosscutting concept of stability and change is applied to the scenario as students use evidence from the past to make predictions of what future changes are likely in Boomtown.	MS-ESS2.A MS-ESS2.C	Constructing Explanations and Designing Solutions Analyzing and Interpreting Data Connections to Nature of Science: Scientific Knowledge Is Based on Empirical Evidence	Cause and Effect Scale Proportion and Quantity Stability and Change	Mathematics: MP.2 MP.4

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
12. **Modeling: Modeling Cliff Erosion** Students apply what they have learned about the phenomena of erosion and deposition to a model of cliff erosion. They use the model to design an erosion-mitigation structure for the cliff using relevant scientific principles that might limit solutions. They use design criteria to develop a solution that is evaluated by others using a systematic process to determine how well they meet the criteria and constraints of the problem. Students are formally assessed on Performance Expectation MS-ETS1-1.	MS-ESS2.C MS-ETS1.A MS-ETS1.B	Constructing Explanation and Designing Solutions Asking Questions and Defining Problems Developing a Model Engaging in Argument from Evidence	Influence of Science, Engineering, and Technology on Society and the Natural World Scale, Proportion, and Quantity Energy and Matter Stability and Change	ELA/Literacy: RST.6-8.3
13. **Reading: Weathering, Erosion, and Deposition** Students read about the phenomena of geologic processes and how they work on Earth's surface over varying time and spatial scales. They investigate how changes in the soil and water change the landscape either by sudden events or gradual changes that accumulate over time. Students construct an explanation about changes they observe due to erosion and deposition based on information in this and previous hands-on activities. The crosscutting concept of energy and matter is used to examine how the transfer of energy drives the motion and/or cycling of matter in geologic processes.	MS-ESS2.A MS-ESS2.C	Constructing Explanations and Designing Solutions	Energy and Matter Stability and Change Scale, Proportion, and Quantity Influence of Science, Engineering, and Technology on Society and the Natural World	ELA/Literacy: RST.6-8.9 WHST.6-8.9
14. **Role Play: Building on the Mississippi** Students apply what they have learned about geologic phenomena and the monitoring and mitigation of human impact to the Mississippi River and Delta. They use the crosscutting concepts of cause and effect, and stability and change to investigate how New Orleans has coexisted with the river. The use of unprecedented engineering in this area was driven by the needs of the city and its people. Students are formally assessed on Performance Expectation MS-ESS2-2.	MS-ESS2.A MS-ESS2.C MS-ESS3.C	Constructing Explanations and Designing Solutions Obtaining, Evaluating, and Communicating Information	Scale, Proportion, and Quantity Energy and Matter Influence of Science, Engineering, and Technology on Society and the Natural World Stability and Change	ELA/Literacy: RST.6-8.1

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Disciplinary Core Ideas	Science and Engineering Practices	Crosscutting Concepts	Common Core State Standards
15. **Investigation: Building in Boomtown** Students use criteria and constraints for building and the information provided in the unit to choose a building site. They identify the consequences of their choices on the health of the people and environment. Then they compare and critique others' choices and determine whether they emphasize similar or different interpretations of evidence.	MS-ESS2.A MS-ESS2.C MS-ESS3.C	Constructing Explanation and Designing Solutions	Influence of Science, Engineering, and Technology Connections to the Nature of Science: Science Is a Way of Knowing Cause and Effect	ELA/Literacy: WHST.6-8.9 WHST.6-8.2
16. **Investigation: Building Site Plan** In this final activity, students apply scientific principles and knowledge of geologic phenomena to design the school and fields at one of the sites. Students then evaluate the solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. Students are formally assessed on Performance Expectations MS-ESS3-3 and MS-ETS1-2.	MS-ESS3.C MS-ESS2.C MS-ETS1.B	Constructing Explanations and Designing Solutions Engaging in Argument from Evidence Analyzing and Interpreting Data	Cause and Effect Influence of Science, Engineering, and Technology on Society and the Natural World	ELA/Literacy: WHST.6-8.2 SL.8.4

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

LAND, WATER, AND HUMAN INTERACTIONS

This is a work in progress. Please check the Tools and Resources opening page in the online Teacher Portal for future updates.

This unit explores the anchoring phenomenon: The landscape is constantly changing due to natural processes and human activity. Examples include formation and destruction of beaches and impacts of homes on cliff erosion. Students generate and answer questions such as: How do earth processes, like wind and flowing water, change Earth's surface? How do human activities change Earth's surface?

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
Land development by humans has an impact on the environment.	How can people mitigate the negative impact on the land and water when building new construction?	What is the human impact of building construction? (Activity 1) What location is best for a new school and fields? (Activity 15) How can you design the new school and fields to mitigate the human impact on the environment? (Activity 16)	1, 15, 16	MS-ESS3-3	Human population growth leads to the need for more use of land and water resources and more impact on these resources. Responsible development reduces this impact where possible.
Human activities disrupt water quality.	How do human activities on land negatively impact water quality?	Which liquid best dissolves salts? (Activity 2) What can water-quality indicators show? (Activity 3) How can organisms living in a stream indicate water quality? (Activity 4) Can using fertilizers have harmful effects on the environment? (Activity 5) How does nutrient runoff effect the environment? (Activity 6)	2, 3, 4. 5, 6	MS-ESS3-3	Substances dissolved in the earth's water affect water quality and animal habitats. Water movement is driven by gravity though and on top of soil. As it moves, it can pick up and dissolve contaminants such as excess nutrients from fertilizers. These contaminants reduce water quality.

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
As water moves through the water cycle, it can dissolve and carry substances from one location to another.	How does the water movement through the water cycle move energy and matter?	Which liquid best dissolves salts? (Activity 2)	2, 7, 8, 9	MS-ESS2-4	Water moving through the soil and on top the surface is part of a greater system of water movement. This global system is the water cycle and it moves water and contaminants around the planet.
		How does moving water affect the areas through which it flows? (Activity 7)			
		How does water move around the planet? (Activity 8)			
		How can we mitigate modern society's harmful effects on Earth's water? (Activity 9)			
Humans disrupt geologic processes.	How do human activities interact with the processes of erosion and deposition?	How does a topographic map show landforms? (Activity 10)	10, 11, 12, 13, 14	MS-ES2-2	Water running through the land can move sediments from one location to another. The geologic processes of erosion and deposition have been occurring for millions of years but humans have disrupted this natural movement of materials and have changed land formations. Building on the land accelerates the movement of sediments. The outcome of theses geologic processes are altered when wetlands are filled in, farms are created, vegetation is removed, and/or the hard surfaces of buildings are installed.
		How can topographic maps help you evaluate potential building sites? (Activity 11)			
		How can we reduce the effects of ocean waves on coastal areas? (Activity 12)			
		What happens when earth processes move soil and rocks from one place to another? (Activity 13)			
		What has been the human impact on geologic processes of the Mississippi River Delta? (Activity 14)			

PHENOMENA, DRIVING QUESTIONS AND STORYLINE

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Phenomenon	Driving Questions	Guiding Questions	Activities	PE	Storyline/Flow (How an activity leads to subsequent activities)
Engineering can help mitigate the problem of habitat destruction and land mismanagement.	How can we engineer structures to mitigate environmental impact?	How does moving water affect the areas it flows through? (Activity 7) How can we reduce the effects of waves on coastal areas? (Activity 12) What has been the human impact on geologic processes of the Mississippi River Delta? (Activity 14) How can you design the new school to mitigate the human impact on the environment? (Activity 16)	7, 12, 14, 16	MS-ETS1-1 MS-ETS1-2	Changes in the land and water can be monitored to help in the effort to mitigate impact. People can develop design solutions while building to reduce negative outcomes on the environment. Humans controlling water flow does not always reduce the impact, but thoughtful designs can be beneficial. Building designs can evaluated to determine how well they meet specific design criteria and constraints in an effort to reduce impact on the environment.

UNIT OVERVIEW

LAND, WATER, AND HUMAN INTERACTIONS

This unit explores the issue of how geoscience processes and human activities change Earth's surface. Listed below is a summary of the activities in this unit. Note that the total teaching time is listed as 19-34 periods of approximately 45 to 50 minutes (approximately 5-7 weeks).

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
1. **Investigation: Where Should We Build?** Students examine photographs of undeveloped and developed hillsides, wetlands, and clifftop areas. Students make observations about changes that have happened to the land and water in these areas.	evidence human impact trade-offs LITERACY	Prepare Student Sheet.		1
2. **Laboratory: Does It Dissolve?** Students compare the solubility of solids in three different liquids. They compare the ability of the liquids to dissolve salts and apply the results to the natural world.	dissolve evidence human impact LITERACY	Set up containers.	ODA Proc.	1–2
3. **Investigation: Water Quality** Students construct graphs of three common water quality indicators and compare them to a graph of Boomtown population. Students then consider whether the increase in population is a correlation or causal relationship between the population and the decline in water quality.	causal relationship correlation dissolve evidence human impact indicator water quality LITERACY MATHEMATICS	Prepare glasses of water; gather local water quality report.	AID Proc. Part B	1–2
4. **Investigation: Living Indicators** Students analyze and interpret data collected from simulated catches of aquatic invertebrates collected at three different points in time corresponding with different levels of human impact. They identify patterns in the data and construct arguments for possible cause-and-effect relationships.	causal relationship correlation human impact indicators macroinvertebrates model pattern water quality LITERACY MATHEMATICS	Prepare Student Sheet.	AID A1 ARG QC A2	1–2
5. **Laboratory: Nutrients as Contaminants** Students explore one of the major routes for contaminants to enter the water supply by investigating water that passes through soil. They first test unfertilized soil and fresh water for the presence of nitrates then add fertilizer to the soil and test both the fertilized soil and the runoff water for nitrates.	contaminants evidence groundwater indicator nutrients runoff trade-offs	Gather and prepare local soil.	OAD Proc. E&T QC A5	1–2

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
6. **Reading: Gulf of Mexico Dead Zone** Students read about the large-scale impact of human activity on aquatic systems. Students use an Anticipation Guide before, during, and after the reading to make predictions based on prior knowledge and then examine how their understanding has changed at the end of the activity. Students draw a model diagram to explain the chain of events leading to the formation of dead zones. They also discuss ways to minimize the size and impact of dead zones.	causal relationship contaminant correlation dead zone evidence indicator model nutrients runoff trade-offs LITERACY	Prepare Student Sheet.	MOD A4	1–2
7. **Modeling: Cutting Canyons and Building Deltas** Students use a river model to investigate how flowing water erodes and deposits sediments to create common landforms. They then design erosion-control structures and use the river model to test them. Based on the results of their initial testing, students redesign and retest their structures.	constraint criterion, criteria delta deposition erosion model sediments LITERACY	Gather large containers for sand and water; gather newspapers; confirm level work surfaces; prepare Student Sheet.	ENG QC Proc. Part B	2–3
8. **Investigation: Traveling with the Water Cycle** After reviewing the three most common phases of matter and the phase changes of water, students use a card-based simulation to follow water as it travels through the water cycle. Each pair of students writes a story that describes and demonstrates their understanding of the water cycle's major processes and reservoirs, and the types and sources of contaminants that can be picked up along the way.	condensing contaminant energy evaporation freezing gravity melting water cycle LITERACY	Set up stations around room (optional); prepare Student Sheets.	MOD A4 COM A5	1–2
9. **Reading: Human Impacts on Earth's Water** Students complete a Three-level Reading Guide as a means to increase their comprehension of a reading that describes some ways in which human activities affect Earth's water. The reading focuses on how humans impact water quality and the water cycle, and on how these effects can be mitigated.	condensation contaminants evaporation freezing human impact melting mitigate monitor water cycle water quality LITERACY	Prepare Student Sheet.	MOD A3 (Assessment of PE MS-ESS2-4) ARG A6	1–2

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
10. **Investigation: Making Topographic Maps** Students use a small-scale plastic model to construct a topographic map of a land formation. This experience provides students with a better understanding of topographic maps and how to interpret them. In the next activity, they apply this understanding to compare topographic maps of Boomtown made at different times.	contour line topographic map topography		MOD QC A5	1–2
11. **Problem Solving: Boomtown's Topography** Students compare the street maps and topographic maps of Boomtown in the present with topographic maps of Boomtown from 25 and 100 years ago. They identify changes that have taken place in the landforms at the building locations. They consider how evidence from the topographic maps might suggest potential problems for the three possible building locations.	contour interval contour line landform scale topographic map topography LITERACY	Prepare Student Sheets.		1–2
12. **Modeling: Modeling Cliff Erosion** Students model the effect of ocean waves on a cliff. They then design, test, and redesign structures to prevent cliff erosion. They use their observations and understanding of erosion to compare the likely rate of erosion on a hillside and a shoreline cliff.	causal relationship constraint correlation criterion, criteria deposition erosion mitigation model	Gather large containers for sand and water; prepare Student Sheet.	ENG A7 (Assessment of PE MS-ETS1-1)	1–2
13. **Reading: Weathering, Erosion, and Deposition** Students read about geoscience processes that include those they investigated in the last activity—erosion and deposition—and the related earth process of weathering. The impact of human activity on these earth processes is presented with information on how to monitor and mitigate changes caused by development.	deposition earth processes erosion human impact sediment weathering mitigation monitor LITERACY		MOD A2 EXP A6	1–2
14. **Role Play: Building on the Mississippi** Through a role-playing exercise, students explore the history of New Orleans' location on the Mississippi River and the interaction of the city and the river. Students focus on the impact of human activities that have prevented natural cycles of erosion and deposition in the Louisiana Delta region	dead zone deposition erosion evidence mitigation monitoring trade-offs LITERACY	Prepare Student Sheet.	EXP QC E&T A4 EXP A5 (Assessment of PE MS-ESS2-2)	1–2

LAND, WATER, AND HUMAN INTERACTIONS (continued)

Activity Description	Topics	Advance Preparation	Assessment	Teaching Periods
15. **Investigation: Building in Boomtown** Students use the information they have gathered throughout the unit to create a report about the geology at each of the building locations in Boomtown. Then they use their reports and information from the Boomtown City Council to make their decision.	causal relationship constraint criterion, criteria deposition erosion evidence nutrient runoff sediments topographic map trade-off LITERACY	Prepare Student Sheets.	COM Proc. E&T A1	2–3
16. **Investigation: Building Site Plan** Students play the role of a building team that generates a site plan for the school and fields. They also design a plan for monitoring and minimizing soil erosion, increase nutrient run off, or reduce the water quality of Boomtown River.	causal relationship constraint criterion, criteria deposition erosion evidence mitigation monitor nutrient runoff sediments trade-off water quality LITERACY	Prepare Student Sheets.	COM PROC. ENG QC Proc. (Assessment of PEs MS-ESS3-3 and MS-ETS1-2)	2–3