NATURE LAB Educator Resources

WHERE'S THE BEACH?
Investigating Coastline Erosion Protection

Subject Area: Science – Earth Science, Environmental Science

Grades: 6th – 8th

Time: This lesson can be completed in four 45-minute sessions (two for Session 1 and two for Session 2).

Volunteers in Alabama help to build oyster reefs in Mobile Bay. © Erika Nortemann/TNC

Essential Questions:

- How do waves cause coastline erosion?
- What engineering solutions protect coastlines?
- Which engineering solutions suit a particular type of coastline?
- How are oyster reefs beneficial to both people and the environment?

Overview:

In this lesson plan, students look at different ways to protect coastlines. Students first use an online tool to find historic tide data in a selected coastal location: The Gulf Coast of the United States. Then students use a hands-on model to explore the use of different materials in protecting coastlines. As they progress, students learn how and why oyster reefs are being used to protect the coastline of the Gulf of Mexico. In this STEM lesson, students will get the opportunity to practice and learn across a wide range of disciplines.

Themes:

Oyster reefs provide a valuable food source.

Oyster reefs serve as a natural barrier against wave action.

Introduction:

In this lesson plan, students study methods for protecting coastlines. Coastal erosion is a serious problem, since almost half the U.S. population lives near or along the coast. Hurricanes and other strong storms cause a lot of damage to a beach in a short time. In this lesson, students learn that continuous waves are a force that the ocean exerts over time and that they can change a landscape as much as a hurricane can. Coastal erosion devalues or destroys property, impacts fisheries, and necessitates expenditures for prevention and remediation. Engineers must first characterize a location in terms of risk. They need to know the wave history of a particular location. Students will use an online tool to select a specific location and then interpret charts to estimate maximum wave height. To evaluate the strength of different materials, students conduct a hands-on experiment using a wave table.

Coastal erosion facts and figures*:*

- The highest erosion rates in the U.S. are in coastal areas bordering the Gulf of Mexico.
- Over the next 60 years, erosion may claim one of every four houses within 500 feet of the U.S. shoreline.
- A major storm can erode the coast inland 100 feet or more in a single day.
- Coastal erosion is likely to increase during the next 50 to 100 years as polar ice caps melt and cause a rise in sea levels.
- The Cape Hatteras lighthouse was constructed in 1870. At that time, it was 1,500 feet from the shore. By 1987, the lighthouse was 160 feet from the sea due to coastal erosion.
- Coastal Louisiana wetlands make up the seventh largest delta on Earth, contain about 37 percent of the estuarine herbaceous marshes in the conterminous U.S., and support the largest commercial fishery in the lower 48 States. These wetlands are in peril because Louisiana currently undergoes about 90 percent of the total coastal wetland loss in the continental U.S.

*Sources:

- http://oceanservice.noaa.gov/education/classroom/lessons/09_coastmanag_erosion.pdf
- http://gallery.usgs.gov/videos/433

Objectives:

The student will…

- Model and compare ways in which coastlines can be protected.
- Calculate wave energy from wave size.
- Investigate geographic data to analyze site characteristics related to ocean conditions.
- Solve quantitative problems to illustrate differences between different coastal erosion protection solutions.
- Classify methods of coastal erosion protection as "hard" or "soft" engineering.
- Interpret tables and charts related to wave energy and size.
- Understand why coastal erosion is an important conservation issue with significant engineering challenges.
- Know that engineering solutions to coastal erosion include use of natural systems as well as artificial structures.
- Know that coastal erosion has negative effects on human property and wildlife habitat.

Standards:

[*Next Generation Science Standards*]

Disciplinary Core Ideas

- PS2.A Forces and Motion
- PS3.B: Conservation of Energy and Energy Transfer
- PS3.C: Relationship between Energy and Forces
- PS4.A Wave Properties
- LS1.B Growth and Development of Organisms
- LS2.C Ecosystem Dynamics, Functioning, and Resistance
- ES3.B Natural Hazards
- ES3.C Human Impacts on Earth Systems

Crosscutting Concepts

- Causation
- Patterns
- Energy and Matter
- Stability and Change
- Systems

Science and Engineering Practices

- Asking Questions/Defining Problems
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematical and Computational Thinking
- Constructing Explanations and Designing Solutions
- Arguing from Evidence
- Communicating information

Performance Expectations Middle School

- PS2-1: Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.
- PS2-2: Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
- PS3-2: Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
- PS3-5: Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
- PS4-1: Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.
- PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
- LS1-4 Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.
- LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
- LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
- LS2-5: Evaluate competing design solutions for maintaining biodiversity and ecosystem services.

- ES3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
- ES3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Common Core English and Language Arts Standards for Writing Grades 6-8

- CCSS.ELA-LITERACY.WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.

Vocabulary:

Coastal erosion: Result of wave action removing quantities of soil or sand or resulting in permanent incursion of salt water onto land.

Oyster reef: A shallow natural structure comprised of oysters, usually parallel to the shore line.

Materials:

Videos that support this lesson plan:

- Introductory video ***The Amazing Oyster Reef*** - https://vimeo.com/77811133
- Scientist interview videos
  - ***Coastal Protection #1: Oyster Reefs*** - "How does an oyster reef protect coastlines and therefore people?" http://vimeo.com/78921442
  - ***Coastal Protection #2: Additional Benefits*** - "What are additional benefits of oyster reefs besides protecting coastlines?" https://vimeo.com/78921443
  - ***Coastal Protection #3: Science*** - "How can science help decide between oyster reefs or construction materials to protect coastlines?" https://vimeo.com/78921441
  - ***Coastal Protection #4: Why Reefs?*** - "Why should we use oyster reefs to protect coastlines, instead of just building the biggest seawalls possible?" https://vimeo.com/78921444
- ***Meet the Scientist: Jonathan Hoekstra*** - http://vimeo.com/77229004

For teachers:

Photos of coastal erosion

- Before and After Hurricane Katrina - Gulf Coast, Louisiana (USGS) http://soundwaves.usgs.gov/2005/09/Katrina_chandel_pair1LG.jpg
- Hurricane Rita - Gulf Coast, Louisiana (USGS) http://coastal.er.usgs.gov/hurricanes/rita/photo-comparisons/loc2_holly_bch_la.jpg
- Hurricane Ike - Gulf Coast, Texas (USGS) http://soundwaves.usgs.gov/2008/10/Ike_XalBch_TX_Loc1LG.jpg
- Land area change in Coastal Louisiana (USGS) http://gallery.usgs.gov/videos/433#.VRNDCPnF98E
- Shoreline Change Atlas (University of Texas) https://coastal.beg.utexas.edu/shorelinechange2012/
- Tides and Currents Online Tool (NOAA) http://tidesandcurrents.noaa.gov/map/

For each individual or group of students:

Session 1

- Computer with Internet access
- Copies of the student handouts **Coastal Erosion Concept Map** and **Wave Energy Calculation Worksheet**
- Wave charts (Douglas Sea Scale) https://en.wikipedia.org/wiki/Douglas_sea_scale
- Calculator
- Graph paper

Session 2

- Copies of the student handouts **Wave Simulation Experiment** and **Data Table**
- Concrete paver or paving brick (1" thick)
- Pebbles
- Sand
- Lego® pieces or other blocks
- Large shallow container or tub with long sides (or stream table)
- Water
- Wooden board - same width as container (Part 2 only)
- Marker pen (Part 2 only)
- Ruler (Part 2 only)
- Timer (optional)
- Digital or video camera (optional)
- Gloves (optional)
- Waterproof apron (optional)

* Session 2 Materials Notes:
Use as lightweight a paver as possible, and ensure it is wide enough to reach as close as possible to the sides of the tub, without touching them. For example, if the tub is 12 inches high and 18 across, a suitable sized paver would be 10 inches long and 6 inches wide (preferably ½ inch thick).

If you use a paver, the student handling it should wear gloves to avoid accidental abrasion. If a paver is unavailable, cut a plank to the appropriate dimensions. Use duct tape to secure heavy washers to the plank. The idea is to weight the plank so it will sink immediately after being dropped into the water. Students should be advised to wear a waterproof apron to avoid being wet by inadvertent splashes. Use as big a tub as possible for best results. A large baking pan may suffice, but it will be more difficult to make suitable waves.

<u>Classroom Activities:</u>

Session 1

Part 1: Engage

1. Show before and after photos of coastal erosion as a result of hurricanes (web addresses listed in materials).

2. Explain that hurricanes cause extensive damage in a short time. Ask students what they believe causes the damage. Ask them to support their claims with evidence (personal observations of beaches, images of storm damage from news programs, etc.). Guide them to the conclusion that damage is caused by the <u>energy</u> in ocean waves. The impact can be devastating and gets the most media attention.

3. Since all waves have energy, ask students what they think might be the effect of smaller amounts of wave energy over time. Ask them to support their claims with evidence. Students who have visited a beach may have noticed the shifting beach over time. Note that students may believe that daily wave action does not affect beaches as much as large storms. Note their ideas and supporting evidence and come back to this during Explain in Session 2.

4. Divide students into pairs or small groups. Prep each group that they will be required to use the materials to make a list of the causes and consequences of coastal erosion.

   In preparation for having them make a list of causes (Step 7), have each group review the coastal erosion facts and figures. Show the coastal Louisiana USGS video: http://gallery.usgs.gov/videos/433#.VRNDCPnF98E

5. Ask each group of students to make a list of the causes and consequences of coastal erosion. Lead them to specific examples, such as coastal erosion being caused by:
   - Occasional weather events such as hurricanes and storms
   - Extreme tide conditions
   - Regular waves over time
   - Human activity that alters natural barriers such as oyster reefs and salt or sea marshes.

   The effects of coastal erosion include:
   - Devalues or destroys property
   - Impacts fisheries by removing nursery habitats in shallow, low-lying areas
   - Causes siltation of economically important waterways
   - Necessitates expenditures for prevention and remediation.

6. Have groups create a concept map of coastal erosion. You can have students create their own from scratch, or use the concept map template provided below. There are spaces on the concept map template, but students can add more bubbles as needed. If needed, guide them to include why coastal erosion has serious consequences. Encourage groups to show in their concept map reasons why we want to control erosion, but at the same time keep coastlines beautiful and useful. For example, erosion destroys property, but natural

coastlines provide benefits for humans such as fisheries and recreation. Have students brainstorm to include in their concept map how people can control coastal erosion while minimizing environmental impact.

7. Present students the key question: How do scientists get the data to help them decide what structures and materials to use to protect coastlines?

8. Explain that they will use an online tool to examine the kinds of wave data that scientists use.

Part 2: Explore

1. Demonstrate to students how to use the online tool.

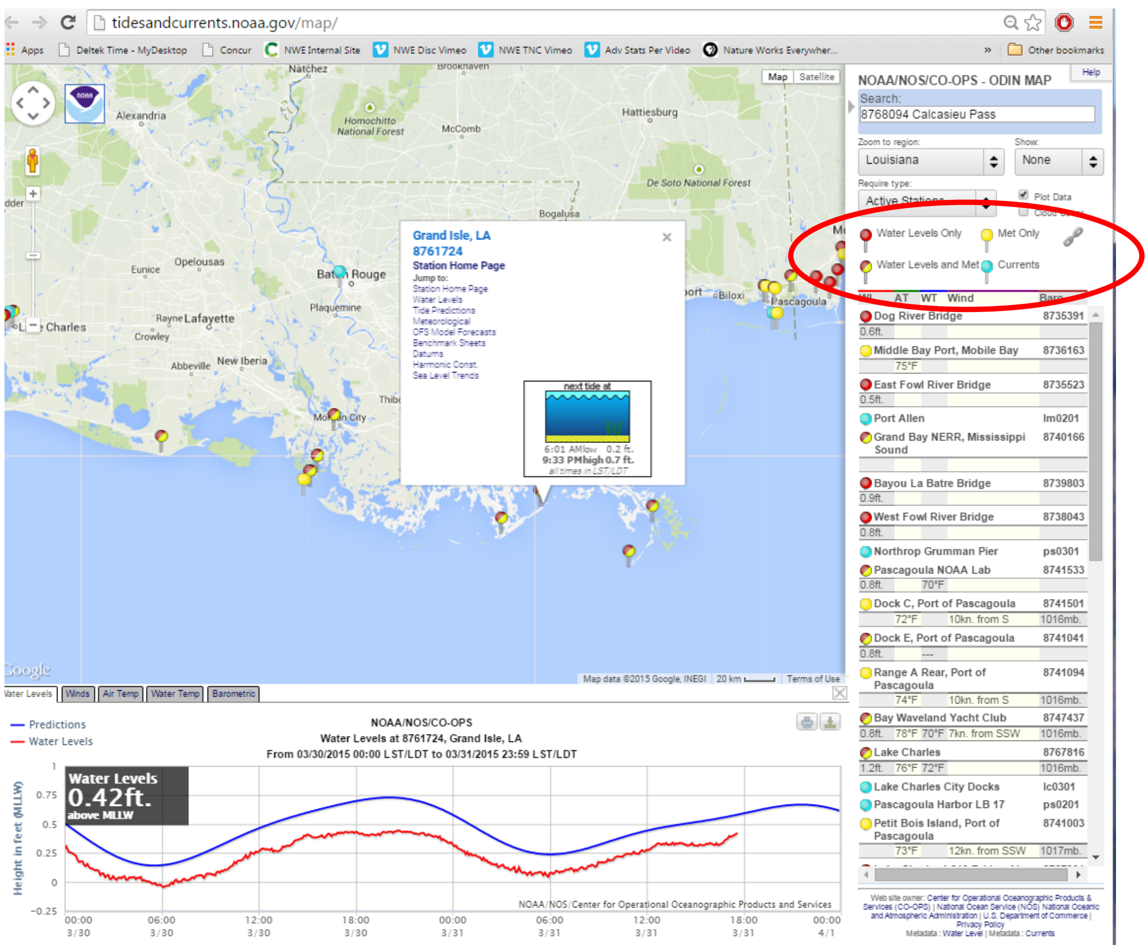
2. Go to the NOAA website online tool: http://tidesandcurrents.noaa.gov/map

3. On the dropdown menu under “zoom to region”, select the region of the U.S. that you wish to observe. The map will zoom in so that students can access data from data collection stations.

4. Each station has a marker that indicates which data points are measured at each station (e.g. water levels, “met” or meteorological data, and currents).

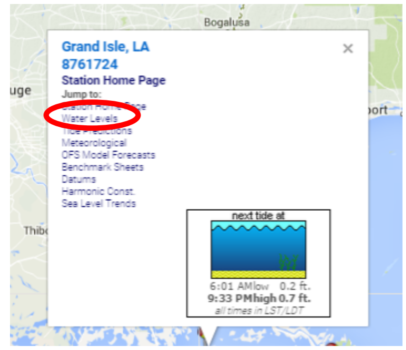
5. Click one of the markers that represent data collection stations (Hint: hover over the marker to see the name of the station; e.g., Grand Isle, LA). A pop-up window provides preliminary information if applicable.

6. Be sure to select stations where **water levels** (indicated by the red or red and yellow markers) are available; select another location by clicking on a different marker.



7. Have students find sea level data for their selected location (Steps 8 to 10).

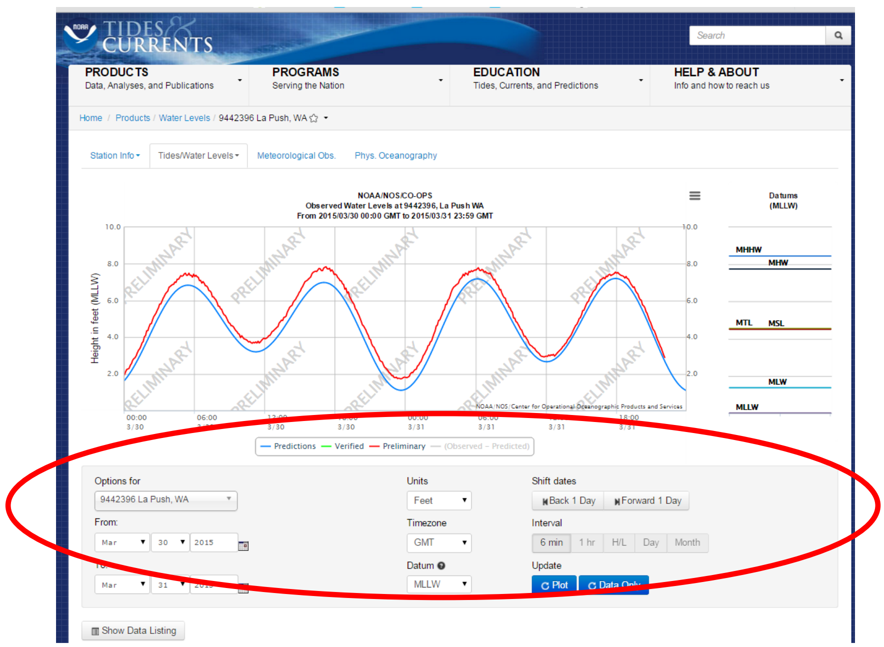
8. When they click on the marker for their selected station, tide information will show up in a pop-up window over the map and graphs for water levels, winds, air temperature, water temperature, and barometric pressure will appear below the map as seen in the screen shot below.



9. Click once on the marker for any station with water level measurements. On the pop-up for the station, under "jump to" click on "water levels".

10. After clicking on "water levels" a graph like the one below will appear. The students' goal is to find the **highest** recorded tide water level above mean sea level, as follows. In order to do this, they should follow the steps below:

    a. Towards the bottom-middle of the screen, change the units from "feet" to "meters" using the drop-down menu.

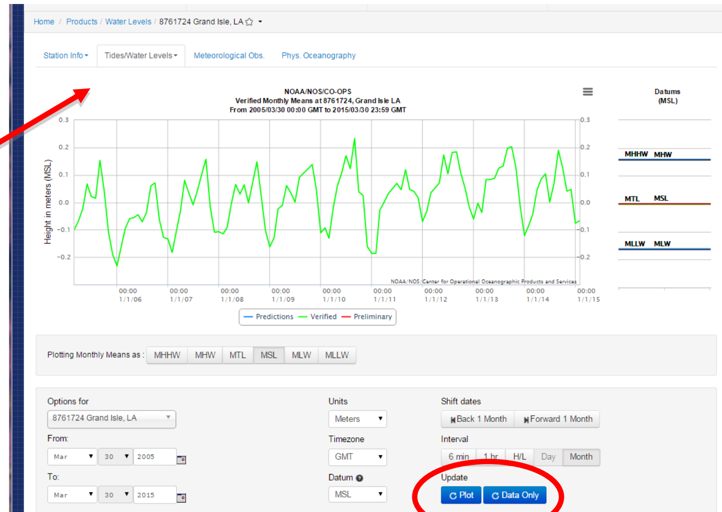


    b. On the left hand-bottom side of the data screen, set the "to" date to yesterday and the "from" date to 10 years prior. So, if yesterday was March 30, 2015, then set the "to" date to March 30, 2015 and the "from" date to March 30, 2005.

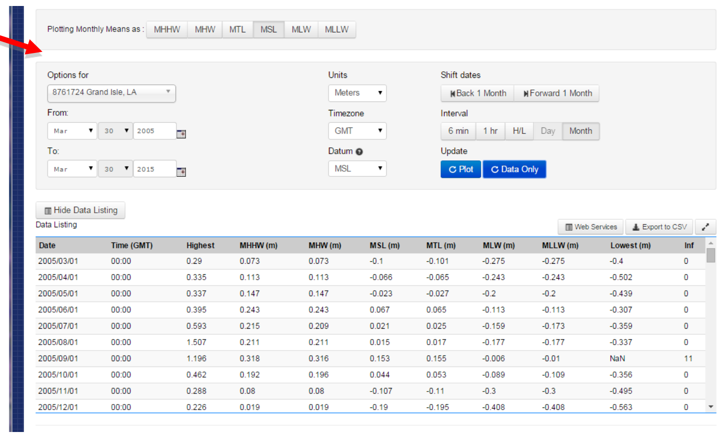
    c. On the right side under "interval," select "month." Note that you must set the date range before selecting the interval.

    d. Under the "datum" menu, select "MSL," this stands for mean sea level.

e. At the bottom-right under "update," click "plot." You will see the graph of mean sea level for the last ten years. As shown to the top right here.



f. Under the "datum" menu, now click "data only." You will now see the monthly data points for mean sea level for the last ten years. There is a slider bar on the right side of the table that allows you to scroll through the data. As shown to the bottom right here.



g. Under the column "highest," find the largest number. If your students are familiar with using Microsoft Excel, they can click the "export to CSV" button just above the table and then use Excel to sort the data from highest to lowest for the column with the title "highest." For example, during the period from March 30, 2005 to March 30, 2015, the highest recorded level above mean sea level (MSL) at the Grand Isle, LA station was in August of 2012 at 1.515 meters above mean sea level.

h. If time allows, have students research online to investigate the cause of the high water. For example, Hurricane Gustav made landfall in Louisiana in September 2008. Explain to students that storm surge increases normal tide levels.

11. Introduce the concept of wave energy (Wave energy is measured in units of joules. In this activity we will be using a simple correlate in place of joules.)

12. Divide students into four groups. One group represents a wave 1.25 meters high, another group represents a wave twice as high (2.5 meters) and two more groups represent waves twice as high again (5 meters and 10 meters). Have the first group use a creative way to demonstrate a height of 1.25 meters, and have the other groups do the same for their respective heights.

13. Explain that their waves have energy. Have students brainstorm what they know about energy. Have them give examples of energy.

14. Have students try to assign values to the energy of their waves. The exact amounts or units are not important. Just keep students on track in terms of thinking about the energy in a wave.

15. Have students go back to their wave's representation of 1.25, 2, 5 or 10 meters. Ask students to compare the energy in each size of wave. For example, how much energy is in the 2-meter wave compared with the 1.25-meter wave?

16. Show students the wave graphic:

17. Divide students into small groups. Form differentiated groups, so each group is formed of students of different math skills. Show students the following table (with two rows intentionally blank):

Wave height (m)	Wave energy
1	
2	4
3	
4	16

18. Have each group develop a hypothesis to explain how wave energy is related to wave height. Each group will then use their hypothesis to complete the table and explain their reasoning to the class. Again, the units of energy are not important, as long as each group has a relative quantity that relates the energy in one size wave to the energy in successively larger waves.

19. Ask students if they stick with their earlier conclusion about the amount of energy in each wave? (In most cases, students will first assume a wave that is twice as high as twice the energy). But the graphic makes them realize that the volume of the wave rather than just the height determines the energy. Because of the cube relationship between linear dimension and volume, the energy of the wave increases exponentially. You don't need to explain this to students. Just ensure they understand that the energy of the second wave is much more than twice that of the first.

20. Explain that wave energy depends on the overall size of the wave including its length and height. The wave energy that hits a coast depends on the size of the wave and other factors such as depth. Have the groups demonstrate how the wave energy of different sized waves causes erosion. For example, the groups can use a T chart to show how many small waves over time might have comparable effects as one big wave.

21. Have students quantify the energy for their waves. For this activity students will use only the height of the wave.

22. Distribute the Wave Energy Calculation Handout and have students calculate the energy of a variety of waves.

23. Emphasize that these calculations are simplified, and that engineers use additional data when calculating wave energy in real-world applications.

24. Have students draw a graph of the data from the wave energy worksheet. The graph shows that wave energy increases exponentially as the size of the wave increases. (For independent inquiry have students determine the appropriate axes.)

25. Share with students the Douglas Sea Scale Wave Chart (to the right and found online here https://en.wikipedia.org/wiki/Douglas_sea_scale) that describes different sized waves. This will help them to visualize what the sea looks like with different wave heights.

26. Have students brainstorm to imagine examples of the effect of increasing power of waves with height. For example, if a barrier stops waves 1 meter high, does it have to be twice as strong to stop a wave 2 meters high?

27. Have each group of students propose the best solution to stopping their waves (1.25, 2, 5 and 10 meters). Remind students that biggest isn't always best because the appearance of a barrier and its construction cost are important, as well as its strength. (This serves as a useful prequel to the next lab.)

Height (m)	**Description**
no wave	Calm (Glassy)
0 - 0.10	Calm (Rippled)
0.10 - 0.50	Smooth
0.50 - 1.25	Slight
1.25 - 2.50	Moderate
2.50 - 4.00	Rough
4.00 - 6.00	Very Rough
6.00 - 9.00	High
9.00 - 14.00	Very High
14.00+	Phenomenal

Part 3: Explain

1. Have students create a graphic or poster to illustrate the various tide water levels.

2. Students should be able to describe the difference between different water levels that characterize measurement of historic tide data.

3. Have students characterize the causes and features of waves compared with tides. Have students draw a simple diagram to explain that waves occur as a result of wind, while tides are caused by the gravitational pull of the sun and moon, but both affect water level at any given time. (If students become confused on the difference, they can refresh their knowledge from the Smithsonian page: http://ocean.si.edu/ocean-news/currents-waves-and-tides-ocean-motion.)

4. Ensure that students can explain the simplified procedure to calculate wave energy.

5. Have students devise a suitable metaphor for the relationship between wave height and energy. The basic concept for them to grasp is that energy increases non-linearly with height. That is, it is not a one-to-one relationship.

6. Have students create a simple graphic to show that erosion increases with wave energy. (This can be a graph showing a linear relationship between wave energy and erosion.)

7. Have the student groups write a brief report on why their solution to coastal erosion was better than other options.

Part 4: Extend

1. Have students research the general concept of energy in more detail. Wave energy, is measured in units of joules. Have students research this unit to characterize its definition and use. (They should learn that the joule is a measure of work done, which is the force exerted on something over a distance. If you move a toy car you exert a force over a distance. The work done, measured in joules, moves the car.)

2. Have students generate some examples to illustrate the joule. For example, it takes 0.005 joules to move a toy car weighing 10 grams at 1 meter per second. Or it would take about 100 joules to throw a football (about 410 grams) at 50 mph (22 meters per second), about the average speed of a throw for an NFL quarterback.

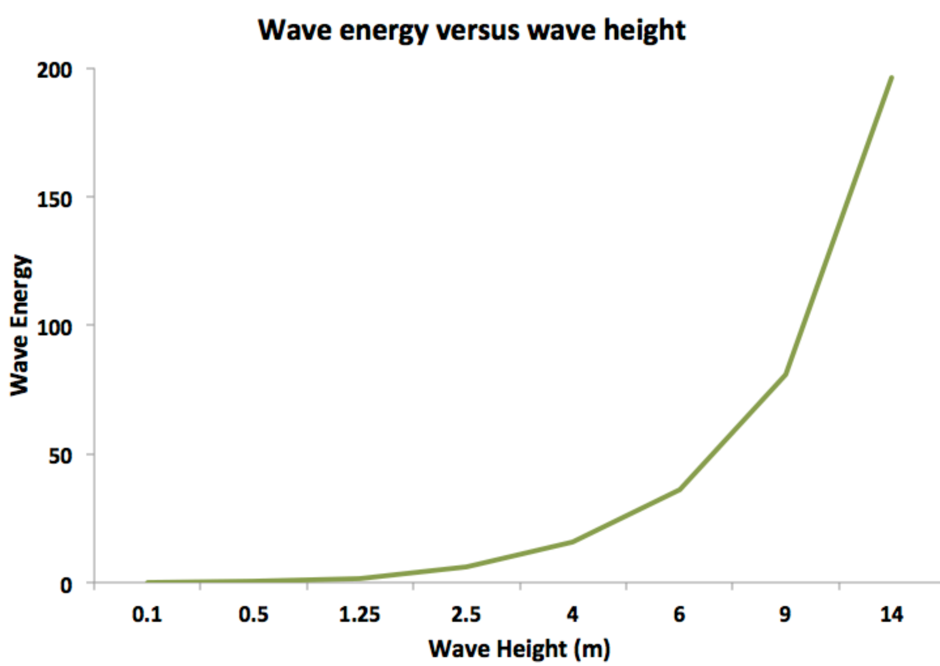
3. To help students prepare for the next lesson, have them brainstorm about how engineers use wave energy data to select different materials to protect a coastline.

Part 5: Evaluate

1. Have students self-evaluate how well they understood the tide and wave data and can state that the wave strength is exponential to the wave height. Students should be able to take values for wave height and show that corresponding values for wave energy increase as a square of height.

2. Ensure that students can relate the amount of energy in waves to the amount of erosion caused by waves of different height.

3. Evaluate students on whether or not their calculations of wave energy were correct, and whether the graph was correctly drawn. Example graph:



Specific questions:

1. Use the descriptions of different sized waves to describe the waves during Hurricane Ivan that reached 7.6 meters.

2. Describe the relationship between energy and wave height that you observed in your graph.

3. In a low energy wave environment, would a high strong barrier be better than a low shallow one? Use evidence to support your answer.

Scoring key for evaluation

1. Waves of 7.6 meters are "High."
2. Wave energy increases exponentially with wave height.
3. In a low energy environment, a high strong barrier would likely be unnecessary. It would be more expensive than a low shallow barrier and might be less attractive too. If the low

barrier provides enough protection to do the job, it would be better than the high strong barrier.

Additional Resources and Further Reading:

Websites

- Nature Works Everywhere video **Coastal Resilience** https://vimeo.com/154663129
- Douglas Scale (Euro Weather) http://www.eurometeo.com/english/read/doc_douglas
- Energy Ultra Calculator http://www.1728.org/energy.htm
- Creating a Concept Map Tutorial (Penn State University Libraries) http://www.libraries.psu.edu/psul/lls/students/research_resources/conceptmap.html
- Florida: Coastal Resilience (The Nature Conservancy) https://www.nature.org/en-us/about-us/where-we-work/united-states/florida/stories-in-florida/florida-keys-reef-resilience-program/

Journal Articles

Huang, J., P. J. Poor and M. Q. Zhao. 2007. Economic Valuation of Beach Erosion Control. Marine Resource Economics 22: 221–238.

Panchang V. G. and D. Li. 2006. Large Waves in the Gulf of Mexico Caused by Hurricane Ivan. Bulletin of the American Meterological Society 87: 481–489.

Piazza, Bryan P., Patrick D. Banks, Megan K. La Peyre. 2005. The Potential for Created Oyster Shell Reefs as a Sustainable Shoreline Protection Strategy in Louisiana. Restoration Ecology: 13: 499-506.

Session 2

Background for the Teacher
In this session, students learn how different materials provide different levels of protection. For example, concrete and steel provide more protection than oyster reefs. However, artificial structures are more expensive to build. In the Explore section of this session, students construct and use a stream table with sand and water to simulate wave action. The Extend section challenges students to develop a protocol for evaluating the cost-benefit of using different structures in locations with varying risk of wave damage. In situations where coastlines are subject to high energy waves, more robust (and expensive) barriers are needed. Where coastlines are subject to low energy waves, less robust (but cheaper) barriers will suffice. The kinds of barriers on the Gulf Coast are typically subject to lower energy waves, so natural barriers in the form of oyster reefs are a viable alternative to expensive artificial barriers.

Part 1: Engage

1. Show the ***Amazing Oyster Reef*** (http://vimeo.com/78921442) introductory video followed by the scientist interview video ***Coastal Protection #1: Oyster Reefs*** (http://vimeo.com/78921442) that answers the question, "How does an oyster reef protect coastlines and therefore people?"

2. Have students form pairs or small groups and discuss photos and video where sea defenses have failed. Encourage the groups to list the possible solutions for sea defenses, based on the photos and videos.

3. Have each group choose just one solution to protecting people and property along coastlines. Have each pair explain why they chose that particular solution, justifying their decision based on the photo and video evidence. If necessary, lead the class to conclude that no single solution will always protect human beings from the most extreme waves.

4. Explain that nature protects coastlines with structures such as oyster reefs. Pollution and coastal development can hinder growth of oyster reefs. But we can also create oyster reefs through devices and methods that encourage oyster growth.

5. Oyster reefs are an attractive option for coastal protection because they are relatively inexpensive and self-renewing, minimizing maintenance costs. Oyster reefs offer other benefits such as food and jobs.

6. Have the student groups list criteria for determining the relative cost of different methods of protecting coastline. Use the graphic to illustrate the basic options.

7. Have students again review the previous session and why some options are better for coastal protection than others: there is no one size fits all. Also explain that just looking at damage or high waves is not enough to make an engineering decision. Scientists must use data and models to help with decisions.

8. Show the scientist video ***Coastal Protection #2: Additional Benefits*** (https://vimeo.com/78921443) that answers the question, "What are additional benefits of oyster reefs besides protecting coastlines?"

Part 2: Explore

Wave Simulation Experiment

1. Show the scientist interview video ***Coastal Protection #3: Science*** (https://vimeo.com/78921441) that answers the question, "How can science help decide between oyster reefs or construction materials to protect coastlines?" Explain to students that they will conduct an investigation to determine which type of barriers best protect coastlines. Through discussion, they can further examine the cost and benefit of different approaches as presented in this video.

2. Distribute the student handouts, Wave Simulation Experiment and Wave Simulation Experiment Data Table

3. Review the handout with students and have the groups construct their wave devices based on the diagrams on the handout.

4. Remind students that they will conduct the experiment under three conditions to demonstrate the extent of erosion:
   (1) without a barrier,
   (2) with a narrow barrier (to simulate a small oyster reef) and
   (3) with a wide barrier (to simulate a more extensive oyster reef).

5. Have students record their results on page 1 of the Data Table handout

6. Assign each group to one of the following additional conditions:
   (1) Vary the **height** from which you drop the paver to vary the strength of the wave. Experiment to see how high to drop the paver to start moving the sand around and "eroding" the beach.
   (2) Vary the **total time** the block is moved to simulate the duration of a storm.
   (3) Vary the **depth of the water** in the tub to simulate different tide levels.

6. Have student groups vary each condition three times and record each condition at the top of the data table on page 2 of the handout. They should then record the results of each trial on the data table.

(Optional) Continuous Wave

1. In this investigation, students use a board to create continuous waves and observe the effect on the barrier. Review the Continuous Waves portion of the handout with students.

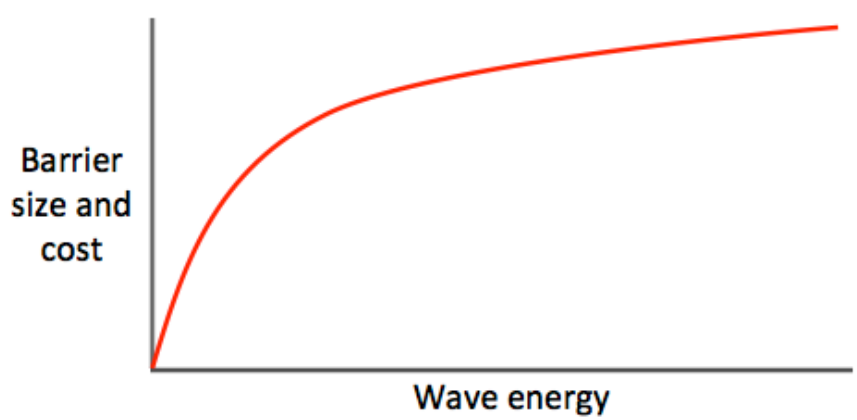
2. Remind students to record their results on a data table. No data table is provided for this extension so that students can gain experience in developing their own method to record data.

Wrap Up

Have students answer the questions on the handout.

If they need help, refer them back to the first lesson, which dealt with how energy causes erosion. (They should understand that barriers absorb energy, so there is less energy to transport sand or other materials away.)

Sample graph for handout question 4:



Part 3: Explain

1. Have student groups present their results and ideas to the class. This could be as presentations or in the form of a gallery walk or similar format.

2. Students should

    a. review their different experimental setups in terms of wave energy. They should be able to explain why a low barrier may still protect prevent erosion of the sand when waves are smaller.

    b. be able to explain that there are numerous different approaches to protecting coastlines and to describe the considerations that go into evaluating the total cost for a coastal protection program. (Groups should include criteria such as material cost and strength and amount of material needed to protect a given length of coast.)
    c. describe the trade-off between the expense and size of a barrier versus the wave energy it is designed to absorb. (The larger the wave, the larger and more expensive

the barrier.) However, in the long run, cost of maintenance may offset the benefit offered by higher protection.

3. After students discuss and reflect upon which barrier works best, ask them to ponder the benefit of using a natural barrier like an oyster reef. Have them list the pros and cons of using a natural barrier versus a human-made barrier. Then show the scientist interview video ***Coastal Protection #4: Why Reefs?*** (https://vimeo.com/78921444) that answers the question, "Why should we use oyster reefs to protect coastlines, instead of just building the biggest seawalls possible?" and see if they came up with some of the same rationale for using a natural barrier.

Part 4: Extend

1. Have students create a table with a list of benefits of oyster reefs in addition to protecting coastlines.

2. Unlike artificial barriers, oyster reefs may strengthen over time. Ask students to brainstorm why this might be the case. (The main difference is that oyster reefs are comprised of living organisms. Over time the shells of oysters fuse, in process called accretion. An old reef comprised of mostly accreted shells is stronger than a young reef of loosely connected shells. Accretion can result in oyster reefs with strength comparable to that of concrete.)

3. Have students form small groups. Give the groups an engineering challenge to propose the best barrier to use in (a) a high energy environment and (b) a low energy environment. Have the groups use the following data to help them with their proposal.

Material	Strength	Amount needed*	Cost per cubic meter
Natural Rock	30	330	$50
Masonry	40	250	$150
Wood	4	2500	$25
Steel	90	110	$225
Concrete	50	200	$180
Oyster reef**	40	250	$10

*Amount needed is the amount needed to protect a given amount of coastline in cubic meters of material.

4. Have the teams account for extreme events such as storm surge. For example, the cost of repairs after a storm may be higher with more expensive materials. For the challenge, assume that in the high energy environment a barrier with strength 50 or less is destroyed every 10 years and needs to be rebuilt. The team needs to find which materials are most cost-effective over 100 years. The point is for students to understand that there is a tradeoff between protection and cost, and that in reality such calculations depend on many variables.

5. Have students create a list of why coastal erosion is an important issue, even if they live far from the ocean. For example, coastal erosion
   - Impacts wildlife habitats, reducing habitat for coastal animals such as shore birds

- Reduces shallow areas that serve as nurseries for fisheries that people need for food, fewer fish increases the prices of fish in stores
- Can destroy property, reducing availability of accommodation for vacations and recreation
  a. Increases siltation, which may cause coral bleaching and increase the need of dredging of seaways
  b. Results in incursion of seawater into low-lying areas, increases salinity of freshwater and thereby increasing costs of purification for drinking water and agriculture, and impacting wildlife.

6. Have students explore ideas about material strength. Show students the following table:

Wood

Material Strength	Percent Storm Damage
10	100
20	50
30	33
40	25
50	20
60	17
70	14
80	13
90	11
100	10

   b. Divide students into groups. Have each group devise a way to demonstrate the data in the table, and to develop a conclusion about any patterns they observe. Explain that material strength is a complex property, measured and tested in various ways.

   c. Have each group brainstorm or research online ways that properties of materials can be tested to quantify strength of a material. The groups can develop ways to display this information graphically. (Groups should determine that properties of materials related to strength include compressibility, brittleness, hardness, weight, shear strength and so on. There are at least 5 main properties and 15 or more other more technical properties.)

   d. Have students list different types of material from their daily experience (wood, brick, concrete, steel, etc.) and indicate in their graphic which are relatively weak, and which are relatively strong.

Part 5: Evaluate
Have students self-evaluate on how well they completed the hands-on activity. Did they take a systematic approach to creating waves? Did they record the data adequately? Did they understand the concept of material strength to erosion control?

Specific questions:
1. What is the main purpose for using a barrier to control erosion?
2. List two advantages and one disadvantage of oyster reefs for controlling erosion.
3. When is a steel barrier a better solution for controlling erosion than an oyster reef?

4. Using the data in the table provided (Extend) section, draw a graph to show the relationship between material strength and percent storm damage. How would you characterize this graph? Show the relative strengths of wood versus steel on the graph.

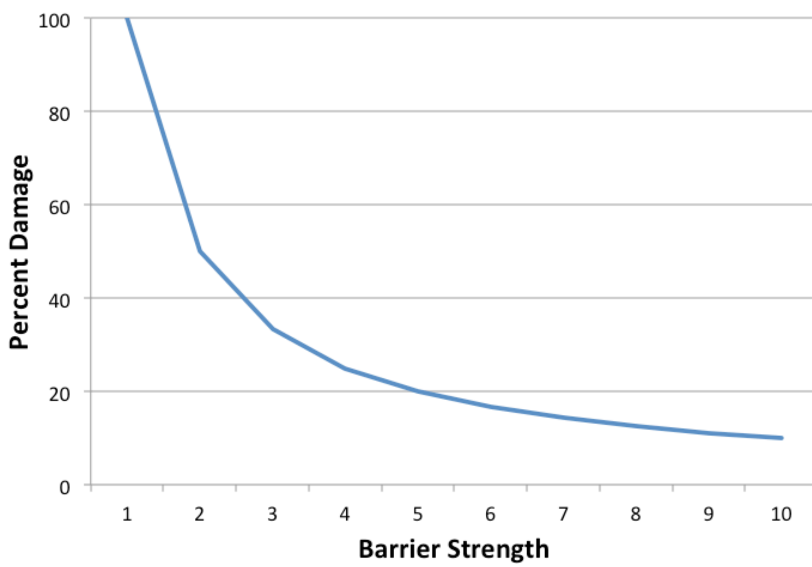
Scoring key for evaluation

1. The main reason to use a barrier to control erosion is to prevent waves removing material from shorelines. The barrier absorbs the energy of the waves, reducing the energy available to transport away coastal sand, soil and structures.

2. Two advantages of oyster reefs are that they are relatively inexpensive to construct and that over time, they actually increase in strength due to accretion. A disadvantage is that they are only appropriate in low-energy environments.

3. A steel barrier is a better solution to control erosion in a high energy environment.

4. Example graph:
   This relationship is an exponential decline. That is, damage declines exponentially with strength of the barrier material.



Additional Resources and Further Reading

Websites

- Oyster Reefs Are In Trouble: So Can We Still Eat Oysters? (The Nature Conservancy) https://blog.nature.org/conservancy/2011/03/08/oyster-reefs-are-in-trouble-so-can-we-still-eat-oysters/
- New study evaluates water quality benefits of Harris Creek oyster reef (The Nature Conservancy) https://www.nature.org/en-us/explore/newsroom/water-quality-benefits-harris-creek-oyster-reef/

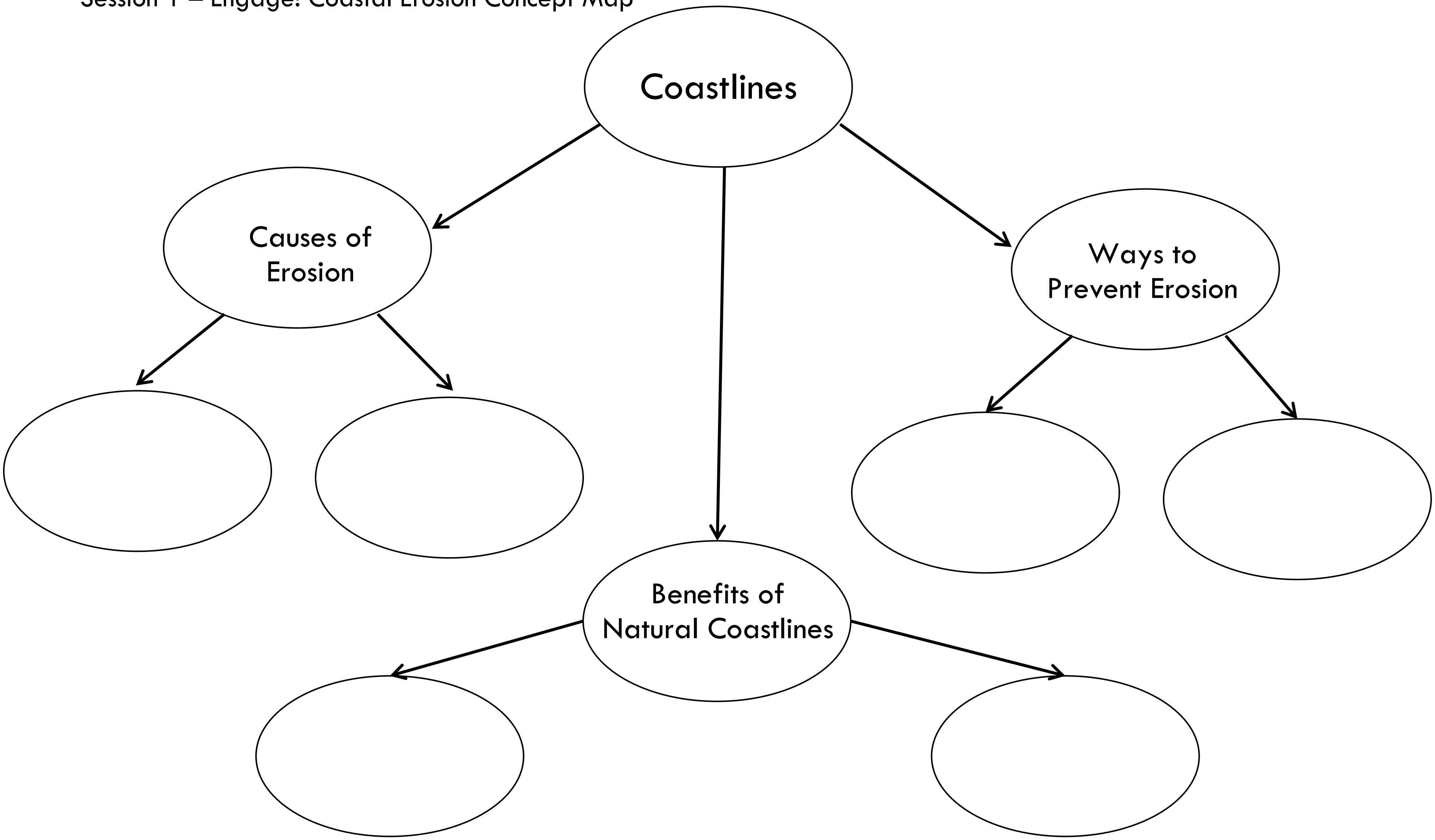
Journal Articles

Scyphers, S.B., S.P. Powers, K.L. Heck, Jr., and D. Byron (2011) Oyster reefs as natural breakwaters mitigate shoreline loss and facilitate fisheries. *PLoS ONE* 6(8):e22396. doi:10.1371/journal.pone.002239

Name:________________Date:________________________________Period:__________

WHERE'S THE BEACH?

Session 1 – Engage: Coastal Erosion Concept Map



Name: ____Date: ________________________Period: ______

WHERE'S THE BEACH?

Session 1, Explore: Wave Energy Calculation Worksheet

To determine the energy contained in a wave, use the following equation based on the height of a wave:

wave energy = *wave height squared* or *wave energy* = *wave height*^{2}

Example calculation for a wave that is 2 .5 meters high:
wave energy = (2.5×2.5) = 6.25

1. Use the following wave heights to calculate the wave energy:

Height (m)	**Wave energy (= Wave height^2)**
0	
0.1	
0.5	
1.25	
2.5	
4	
6	
9	
14	

2. Using graph paper, draw a graph showing the wave energy for the different sized waves in the table.

WHERE'S THE BEACH?

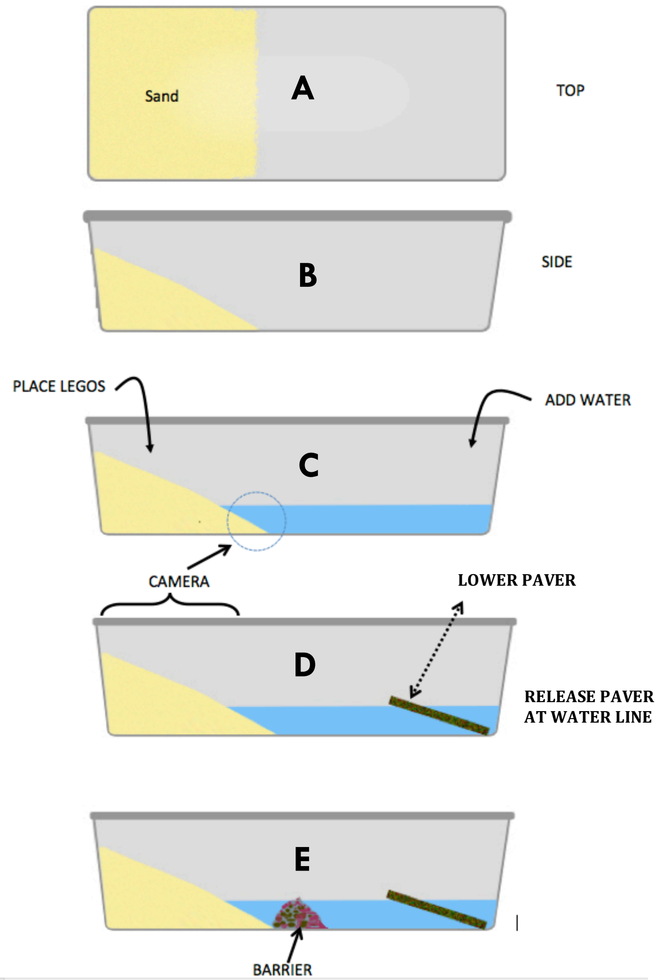
Session 2, Explore: Wave Simulation Experiment

Directions: Use the diagram here as a guide to build your device and follow the instructions below to simulate wave action in three different conditions.

Materials:

- Concrete paver or paving brick (1" thick)
- Pebbles
- Sand
- Lego® pieces or other blocks
- Large shallow container or tub with long sides (or stream table)
- Water
- Wooden board - same width as container (Part 2 only)
- Marker pen (Part 2 only)
- Ruler (Part 2 only)
- Timer (optional)
- Digital or video camera (optional)
- Gloves (optional)
- Waterproof apron (optional)

Construct a Wave Device



1. Be sure to thoroughly wet the sand provided before adding to your clear tub.

2. Add enough sand to one end of the tub to come about half way up the side of the tub and about half way along the length of the tub (image A).

3. Carefully add water to the tub. Try to disturb the sand as little as possible. Add enough water to cover about 1/3 of the width of your sand "beach" (image B).

4. Place the Lego® pieces on the sand at various distances from the "shore" (image C). These will represent the "built environment".

5. *(Optional)* If digital or video camera is available, photograph your set-up from the top so you have a birds-eye view of the tub. Place the video camera on the side of the box so that you can document wave action. Be sure to start the video camera before each investigation (images C and D).

6. Follow the instructions for creating a barrier on the next page (image E).

Part 1: Wave Simulation Experiment

You will conduct three investigations to demonstrate the extent of erosion without a barrier, with a narrow barrier (to simulate a small oyster reef), and with a wide barrier (to simulate a more extensive oyster reef).

Tub set-up for each experiment:

- Condition 1 (no barrier): Use the set-up as is, do not add a barrier.
- Condition 2 (narrow barrier): Use pebbles to simulate the reef. Place the "reef" in front of the sand for the second trial.
- Condition 3 (wide barrier): Add more pebbles to make the reef wider.

1. Use the following instructions to test each condition. Record your observations on page one of the data table.

2. To create a wave in the tub, place the paver on its edge and lower it toward the water. Just before it is immersed in the water drop the paver the last height (the depth of the water). This will create a wave. **Do not let go of the paver until it is at the waterline**. If you drop it far above the waterline, it will create a splash, and this is not the desired effect.

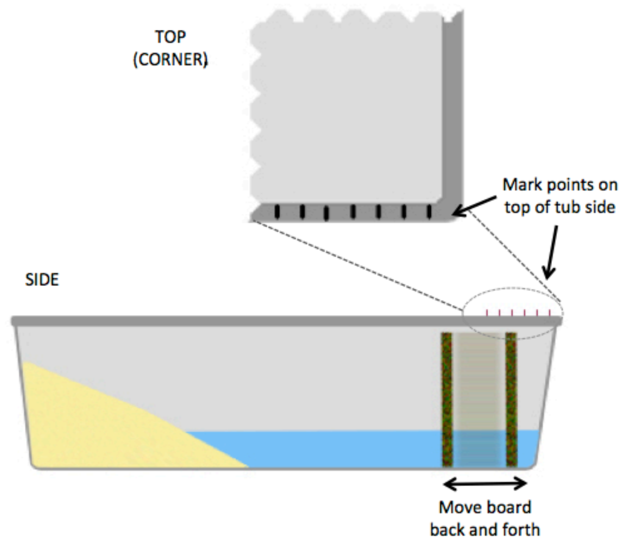
3. Observe the effect of the wave and record your observations. Was there erosion? Did the Lego® pieces move around? Do this for each of the three conditions, being sure to "reset" the beach after each trial if there was any erosion.

4. Your teacher will assign your group one of the following additional experiments for each of the conditions:

   a. Vary the **height** from which you drop the paver to vary the strength of the wave. Experiment to see how high to drop the paver to start moving the sand around and "eroding" the beach.
   b. Vary the **total time** the paver is moved to simulate the duration of a storm.
   c. Vary the **depth of the water** in the tub to simulate different tide levels.

5. You will vary the height, time, or depth **three times** during your investigation, be sure to record these numbers at the top of the data table on page two. Conduct your investigations and then record observations on the data table. As before, be sure to reset the beach before the next round.

Part 2: (Optional) Continuous Waves Experiment
Compare the wave effects created by the paver with the effects of continuous waves created by board movement.



1. You will need to create your own data table for this experiment. Read through the steps below and determine the data you will be collecting.

2. Mark points with a marker pen along the top edge of the tub. Use the ruler to ensure the points are equally spaced.

3. Use a board about the same width as the tub to create a continuous wave motion. Use the points along the top edge to ensure waves are uniform. You will not need to move the board far to get significant waves.

4. Repeat the above step moving the board a greater distance or for longer times.

5. Record the distance you moved the board each time and write the corresponding observations on your data table.

<u>Wrap-up Questions:</u>

1. Which barriers were most effective in preventing beach erosion?

2. Discuss why barriers prevent erosion and how that relates to the concept of energy. What is the relationship between barrier size and wave size?

3. Given the results of your experiments, hypothesize on the relationship between barrier cost and size, and the wave energy such a barrier will protect against. What might be the limiting factors to implementing the most successful barriers?

4. Create a graph that depicts the relationship between barrier cost and size (y-axis), and the wave energy such a barrier will protect against (x-axis). Don't worry about the exact numbers, just depict the general idea of the relationship between these characteristics.

Where's the Beach: Wave Simulation Experiment Data Table

Condition	Observations
1 – No Barrier	
2 – Narrow Barrier	
3 – Wide Barrier	

Wave Simulation Experiment Data Table (varied time, height, or depth)

	Observations		
Condition	**Time/Height/Depth #1:______________**	**Time/Height/Depth #2:______________**	**Time/Height/Depth #3:______________**
1 – No Barrier			
2 – Narrow Barrier			
3 – Wide Barrier			