MODULE 2: NATURAL SOLUTIONS

MODULE & LESSON TIMING: There are 3 lessons in Module 2. Each lesson should be able to be completed in one or two class periods, with student readings before or during.

WHAT TO EXPECT: Module 2 examines sea-level rise resilience through natural solutions.

2.1 Tides and Wetlands – wetlands (page #4)

2.2 Living with Living Shorelines – living shorelines (page #20)

2.3 Puddles to Gardens – rain gardens (page #37)

TEACHER BACKGROUND RESOURCES:

Educational Resources

- Informational booklet on plants found in coastal wetlands by MS Extension
  - "Coastal Wetland Restoration Plant Fact Sheets" http://extension.msstate.edu/sites/default/files/publications/publications/p3356.pdf
- Informational guide for plants found in coastal wetlands by USDA
  - Coastal & Shoreline: Gulf of Mexico" https://www.nrcs.usda.gov/wps/portal/nrcs/detail/plantmaterials/technical/publications/?cid=stelprdb1044274
- Infographic about the benefits of living shorelines by NOAA Ocean Service
  - "What is a living shoreline?" https://oceanservice.noaa.gov/facts/living-shoreline.html

Readings

- Website with resources on the benefits of living shorelines, and images of different types
  - "What is a living shoreline" http://floridalivingshorelines.com/what-is-a-livingshoreline/
- Database of existing living shorelines including maps of projects across the US
  - Living Shorelines Academy: https://www.livingshorelinesacademy.org/
- Informational guide for creating a rain garden
  - Rain Gardens: http://extension.msstate.edu/rain-gardens
- Informational guide for integrating water conservation in landscaping including the use of rain gardens

    - Water Conservation in Your Landscape: http://extension.msstate.edu/sites/default/files/publications/publications/p3146.pdf
- Article by Mississippi State University Extension about rain gardens
    - “Rain gardens are good water management tools” http://extension.msstate.edu/news/feature-story/2018/rain-gardens-are-good-water-management-tools
- Informational booklet about the home watershed including tips for reducing runoff, conserving water, and reducing pollution
    - “Managing Your Home Watershed” https://extension.msstate.edu/sites/default/files/topic-files/healthy-soils-and-water/managing_your_home_watershed.pdf
- Information from City of Durham about rain gardens
    - “Rain Gardens” https://durhamnc.gov/787/Rain-Gardens
- Information from Alabama Cooperative Extension System about rain gardens
    - “Rain Gardens” https://www.aces.edu/blog/topics/landscaping/rain-gardens/
- Step by step guide to building a rain garden by This Old House
    - “How to Build a Rain Garden to Filter Run-Off” https://www.thisoldhouse.com/gardening/21016338/how-to-build-a-rain-garden-to-filter-run-off
- NPR article about Mobile-Tensaw Delta habitats.
    - “On A Tour Of 'America's Amazon,' Flora, Fauna And Glimpses Of Alabama's Past” https://www.npr.org/2020/12/06/943088103/on-a-tour-of-americas-amazon-flora-fauna-and-glimpses-of-alabamas-past
- Informational website with introductory educational information on how to develop a coastal restoration project from concept to proposal.
    - “Coastal Restoration Toolkit” https://restoreyourcoast.org/coastal-flooding/

RECOMMENDED CURRICULUM CITATION:

Vedral, Sonia, Collini, Renee C., Miller-Way, Tina, Rellinger, Alison N., Sempier, Tracie T., Smallegan, Stephanie M., Sparks, Eric. (2021). Sea-Level Rise in the Classroom. MASGP-21-056

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2.1 Tides and Wetlands

AGE RANGE

9th—12th grade

TIME REQUIRED

90 minutes

ACTIVITY OVERVIEW

Engage: NERR Image

Explore: NOAA Tides

Explain: Discussion

Elaborate: Salt Marsh Profile

Evaluate: Discussion

MATERIALS

Computers
Graph Paper
Wetland Plant Cards
Tape

BASED ON:

"Water Going Up, Water Going Down" from NERR TOTE & Mock Marsh

LESSON TOPIC: Wetlands and wetland plants

ACTIVITY SUMMARY: Exploration of local tidal patterns and the distribution of northern Gulf of Mexico wetland plants.

OBJECTIVES:

Students will be able to explain that:

- Estuaries are dynamic ecosystems with variability in physical and biological components.
- Estuaries support an abundance of life and a diversity of habitat types.
- Salt marshes are dominated by a variety of plant species and influenced by tides.
- Plants that live in salt marshes tolerate different levels of flooding and this tolerance level determines where the plant lives in the marsh.
- Rising sea levels may change the plant species distribution and composition in salt marshes, impacting the entire marsh ecosystem.

LESSON BACKGROUND:

TIDES

Tides are caused by the gravitational attraction of the moon and sun on water in the ocean and in very large lakes. Tides originate in the ocean and move toward coastlines as very long-period waves, giving the appearance of regular rise and fall of the sea surface. High tide occurs when the highest part of the wave, the crest, reaches the coast, and low tide occurs when the lowest part, the trough, reaches the coast. The gravitational pull of the moon is greater than the sun, and the moon plays a larger role in producing tides.

The position of the moon and the sun in relation to Earth cause variations in the heights of tides. During new moon and full moon, the sun, moon, and Earth form a line and we experience the greatest tidal amplitude with highest high and lowest low tide. This is termed “spring tide.” When the position of the moon is at a right angle to the Earth and sun we experience “neap tide” with tides with the least amplitude. Spring tide and neap tides occur twice each month.

The physical geography of the coastline influences tidal patterns in different locations. There are three basic tidal patterns: semi-diurnal, mixed semi-diurnal, and diurnal. Semi-diurnal means that there are two high tides and two low tides each day. Mixed semi-diurnal means that the high and low tides differ in height. Diurnal means that there is only one high tide and one low tide each day. Along the Mississippi and Alabama coasts, we experience diurnal tides.

ESTUARIES

Estuaries are the transition zone between freshwater environments and marine environments. Estuaries are fed by one or more freshwater rivers or streams and are open to the ocean, and the water is a mixture of fresh and salt water - often termed “brackish.” Wetland habitats might be present in estuaries. A salt marsh is a type of wetland that is flooded and drained by salt water brought in by tides. Tides affect the height of water within estuaries and salt marshes since they are open to the ocean.

Plants that live in salt marshes are affected by abiotic factors including water level and salinity, as well as competition among plant species. Marshes generally have three vegetation zones: low marsh, high marsh, and upland edge. The plants that grow in each zone are determined by their ability to tolerate water level and salinity. The more flooding-tolerant plants are located in the lower marsh zones.

With sea-level rise, wetlands and marshes will erode. High water levels will flood farther inland and new wetlands can form. However, the rate of new wetland growth may be less than the rate of wetland loss as many developed areas with hard structures like bulkheads and roads prevent the marsh from moving inland.

Understanding coastal processes allows for the use of natural systems to reduce flooding and sea-level rise impacts in coastal to urban areas. Wetlands and coastal marshes along the northern Gulf of Mexico provide many natural solutions. Wetlands act as speed bumps for storms, slowing the storms as they come ashore, 15 ft of marsh can absorb 50% of incoming wave energy. One square mile of salt marsh stores the carbon equivalent of 76,000 gal of gas annually. Marshes trap sediments from tidal waters, allowing the marsh to grow in elevation as sea level rises.

VOCABULARY:

Abiotic	A nonliving condition or thing, as climate or habitat, that influences or affects an ecosystem and the organisms in it.
Biomass	Organic matter derived from living, or recently living organisms.
Biotic	Biotic components, or biotic factors, can be described as any living component that affects another organism or shapes the ecosystem.
Carbon Sink	Anything that absorbs more carbon that it releases.
Carbon Storage	Capture and storage of carbon dioxide before release to the atmosphere (also known as 'carbon sequestration') through natural and/or anthropogenic (i.e., human) processes in order to mitigate climate change.
Diurnal Tide Cycle	An area has a diurnal tidal cycle if it experiences one high and one low tide every lunar day. Many areas in the Gulf of Mexico experience these types of tides.
Dynamic	Characterized by continuous action or change.
Ecosystems	All the living things in a particular area as well as components of the physical, non-living environment with which they interact (e.g., air, soil, water, and sunlight).
Elevation	Height above or below a fixed reference point.
Estuary	Estuaries and their surrounding wetlands are bodies of water usually found where rivers meet the sea. A mixture of fresh water draining from the land and salty seawater.
Forestry	Science and practice of planting, managing, and caring for forests.
Inundation	To flood; cover or overspread with water.
Invasive Species	Introduced, non-native organism (e.g., disease, parasite, plant, or animal) that rapidly expands its range, displacing other species, and causes harm to the environment, the economy, or to human health.
Mixed Semidiurnal Tide Cycle	An area has a mixed semidiurnal tidal cycle if it experiences two high and two low tides of different size every lunar day. Many areas on the western coast of North America experience these tidal cycles.

Salt Marsh	A salt marsh or saltmarsh, also known as a coastal salt marsh or a tidal marsh, is a coastal ecosystem in the upper coastal intertidal zone between land and open saltwater or brackish water that is regularly flooded by the tides.
Seagrass	Seagrasses are flowering plants which grow in marine environments.
Sediment	Fragmented organic and inorganic material, typically occurring due to erosion or weathering, that is easily transported by water, wind, or ice.
Semidiurnal Tide Cycle	An area has a semidiurnal tidal cycle if it experiences two high and two low tides of approximately equal size every lunar day. Many areas on the eastern coast of North America experience these tidal cycles.
Sequestration	The net removal of CO2 from the atmosphere by plants and micro-organisms and its storage in vegetative biomass and in soils.
Subsidence	Sinking of the ground due to underground movement or soil compaction and/or degradation; most often caused by the removal of water, oil, natural gas, or mineral resources from the ground by draining, pumping, fracking, or mining activities.
Tide	Tides are the rise and fall of sea levels caused by the combined effects of the gravitational forces exerted by the moon and the sun, and the rotation of the Earth.
Transect	A transect is a line across a habitat or part of a habitat. It can be as simple as a string or rope placed in a line on the ground. The number of organisms of each species along a transect can be observed and recorded at regular intervals.
Wetland	Wetlands are areas where water covers the soil, or is present either at or near the surface of the soil all year or for varying periods of time during the year, including during the growing season.
Wetland Change	When coastal wetlands, especially estuarine and marine wetlands, are naturally or unnaturally altered by high energy events such as erosion and inundation from sea level rise and storms.

ENGAGE:

Watch with students the introductory video "What is an estuary?" (2 minutes) about estuaries and the National Estuarine Research Reserves (NERRs):
https://oceanservice.noaa.gov/facts/estuary.html

Display a map of the NERRs and show Weeks Bay NERR in Alabama and Grand Bay NERR in Mississippi. Ask students what estuaries might be stressed by given their location on the coast next to the Gulf of Mexico. Answers to highlight: storms, tides, sea-level rise.

Alternative: Show students the short video of rapid erosion at Grand Bay NERR:
https://www.youtube.com/watch?v=S6TGEmu9dcA (1 minute 25 seconds)

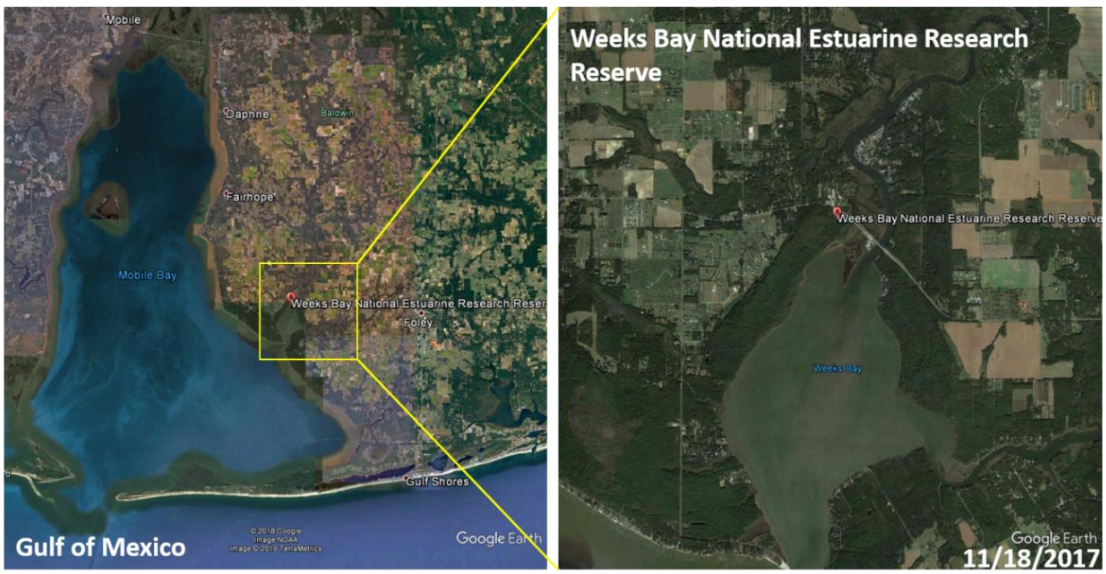


Image: Google Earth image of Weeks Bay NERR in Alabama.

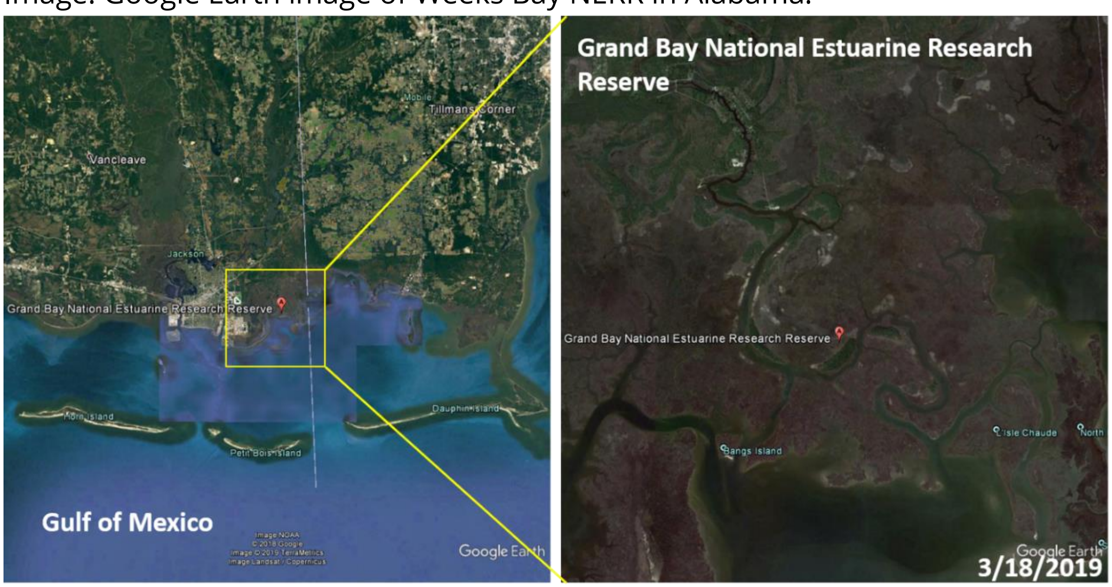


Image: Google Earth image of Grand Bay NERR in Mississippi.

EXPLORE:

Activity description: students will use NOAA’s Tides and Currents website to explore tidal data from tide stations in Alabama and Mississippi.

Materials: access to computers with internet access and graph paper.

Procedure:

1. Open NOAA's Tides and Currents website: http://tidesandcurrents.noaa.gov/. Click on a state to be directed to local tides and currents information.
2. In the Legend on the right side make sure only “Water Level and Met” and “Water Levels” pins are checked. Locations in Alabama and Mississippi are given below, but students may work on stations located on other United States coasts. Ensure that at least one student group has selected a location outside of the northern Gulf of Mexico to allow for comparisons at the end.

    Alabama:
    Weeks Bay, Mobile Bay, AL;
    Dauphin Island, AL;
    Dog River Bridge, AL;
    East Fowl River Bridge, AL;
    Coast Guard Sector Mobile, AL;
    Mobile State Docks, AL;
    Chickasaw Creek, AL;
    West Fowl River Bridge, AL;
    Bayou La Batre Bridge, AL.

    Mississippi:
    Grand Bay NERR, Mississippi Sound, MS;
    Pascagoula NOAA Lab, MS;
    Bay Waveland Yacht Club, MS

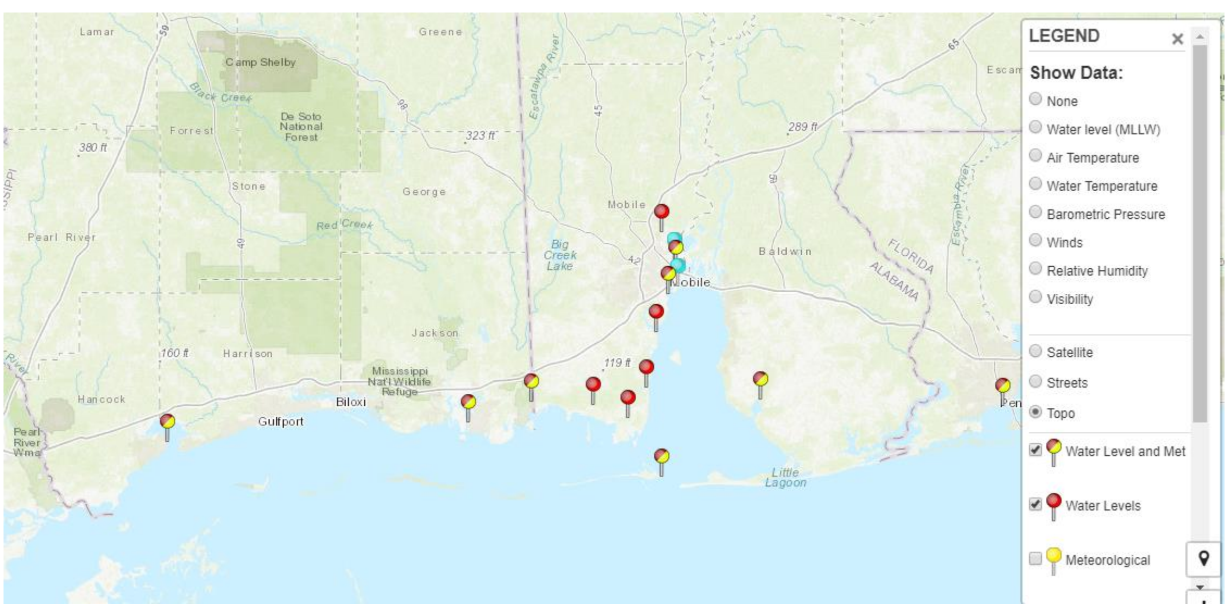


Image: Mississippi and Alabama display from NOAA Tides and Current website. Source: https://tidesandcurrents.noaa.gov/map/index.html

3. Students can access the tidal height data by clicking on the pin, then clicking on “More Data” in the dialog box that opens, and clicking on “Water Levels.”

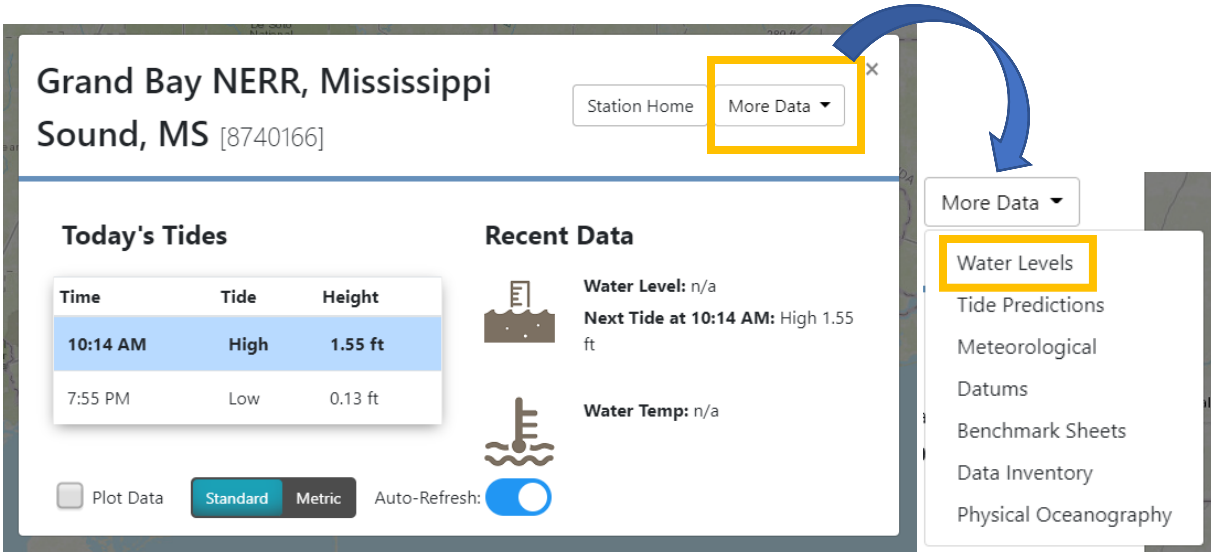
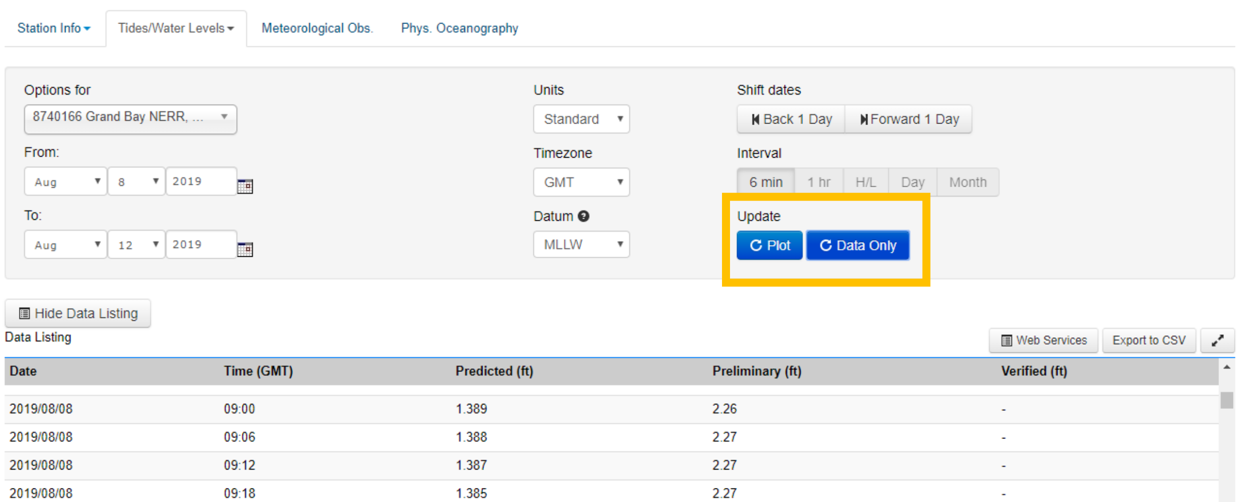


Image: The dialog box that opens when a tidal gauge pin is clicked. Source: https://tidesandcurrents.noaa.gov/map/index.html

4. Have students examine a range of time with tide data for their station. They select the range of time using the date selection and access the data by clicking the “Data Only” button.



5. Using the graph paper have students create a line graph of the tidal change at their location. Record the water height every two hours for at least a three-day length of time.
6. Have students calculate the tidal range - this is the difference in tide height from the low tide to the high tide.

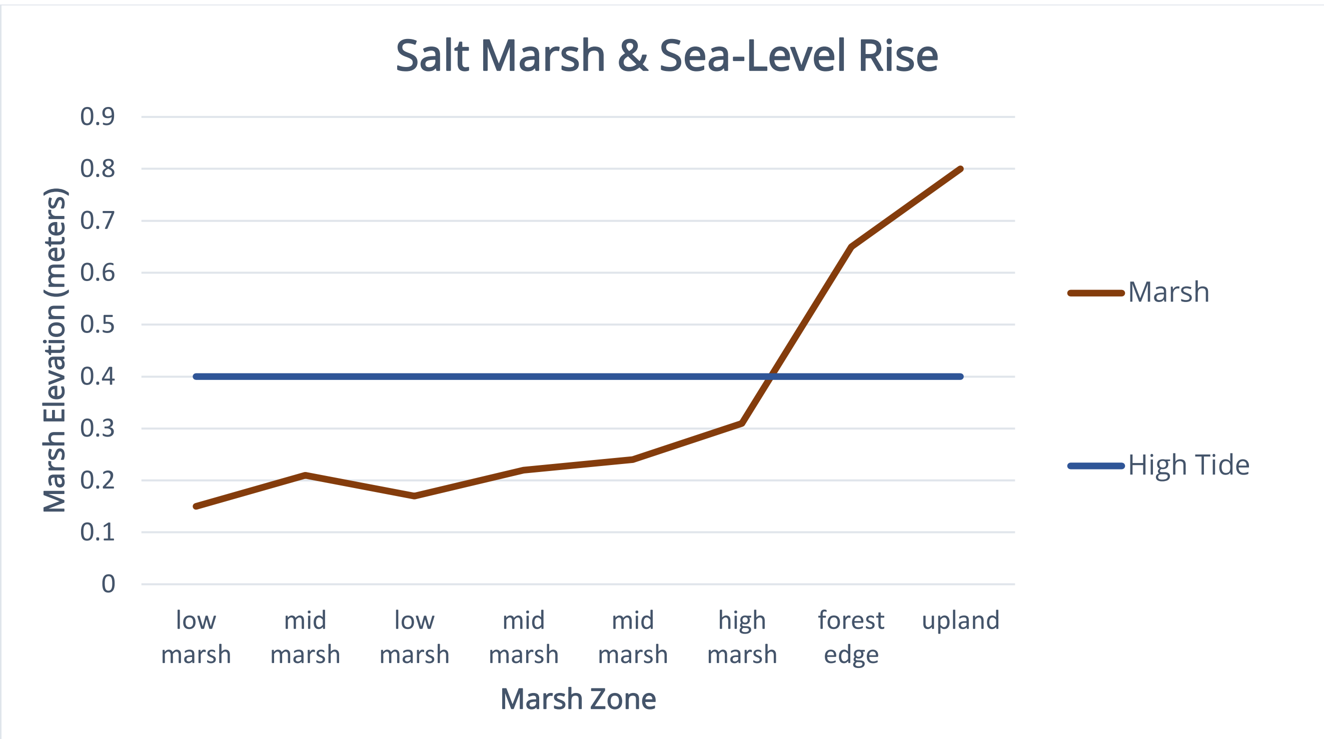
EXPLAIN:

Discuss the trends in tides that students found from graphing the tidal range. Compare graphs from locations with diurnal and semi-diurnal tides. In the Gulf of Mexico, we have a small tidal change, but the east coast has relatively large changes in their tides.

Guide students into thinking about how tidal changes might influence coastal wetland habitats.

Note: at this point the lesson can be paused for the day.

Across the board, or along one wall with string, create the graph below showing high tide, and marsh elevation. This could also be projected onto the wall.



This is a mock transect of a northern Gulf of Mexico marsh.

- The marsh elevation follows the brown line
- Current High Tide Elevation: 0.4 meters
- Current Sea-Level: 0

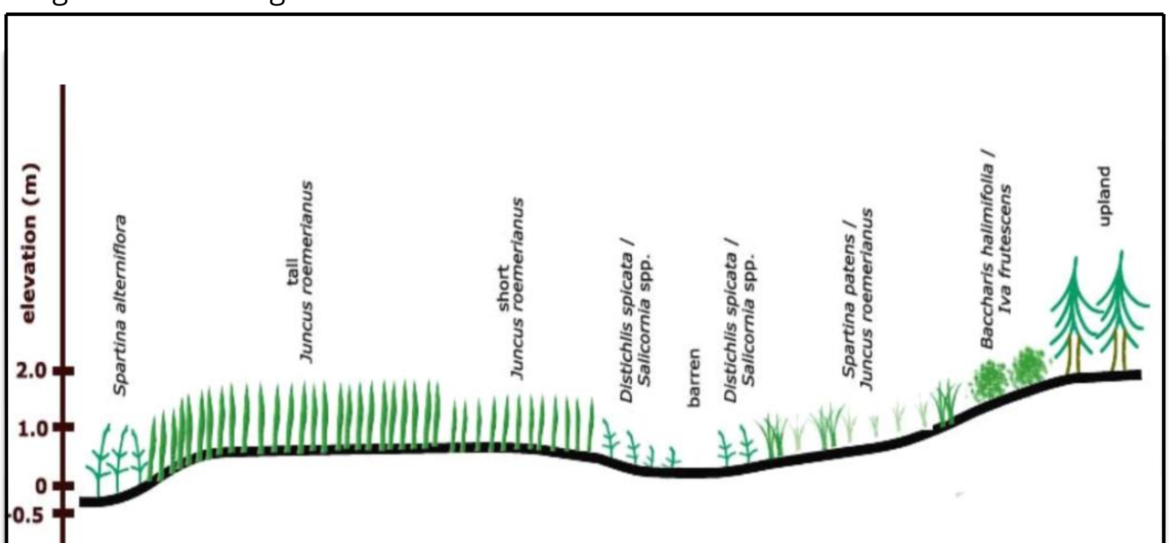
ELABORATE:

Materials: Enlarged version of the Salt Marsh Profile, Preserved specimens or cutout copies of the "Coastal Wetland Restoration Plant Fact Sheets"
http://extension.msstate.edu/sites/default/files/publications/publications/p3356.pdf

This activity will have students exploring the plants commonly found in salt marshes in Mississippi and Alabama and understanding the marsh zones.

Procedure:

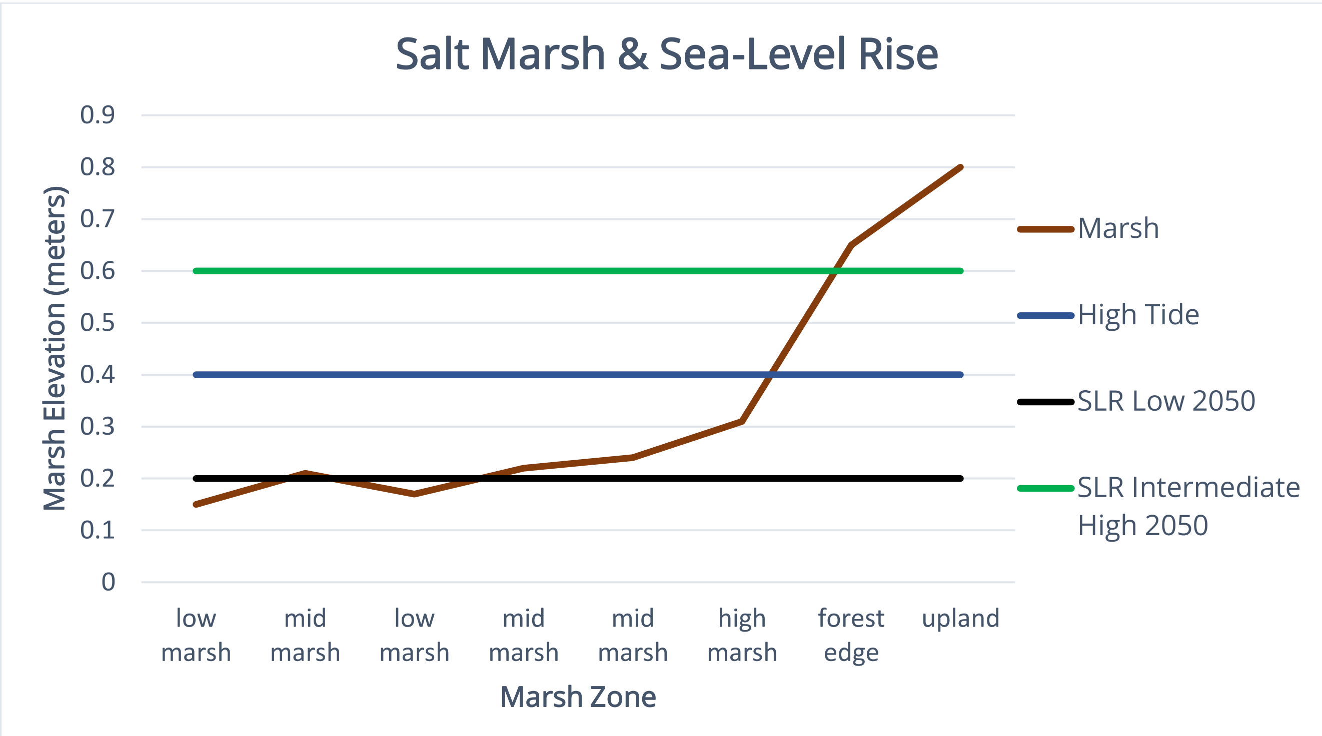
1. Discuss the different vegetation zones of the marsh and have students brainstorm what might impact where plants can grow in a marsh (low marsh = plants have to withstand more or constant flood inundation of salt water; high marsh and upland edge = plants will rarely be exposed to water inundation from incoming tides).
2. Ask students what kind of adaptations they think plants living in a salt marsh might have. This can include things like the ability to excrete, exclude or sequester the salt, rhizomes, or developed aerenchyma to channel to get air to the roots.
3. Using identification cards or preserved specimens, have students identify the common salt marsh plants. Common name in regular text, scientific name in italics.
    a. Low marsh: smooth cordgrass *Spartina alterniflora,* Black needlerush *Juncus roemerianus*
    b. High marsh: Black needlerush *Juncus roemerianus,* Saltmeadow cordgrass *Spartina patens,* Bulrush *Schoenoplectus americanus,* Salt grass *Distichlis spicata*
4. Discuss with students the adaptations that each plant has that allows it to survive in the marsh and determine the marsh zone the plant is located.
5. After discussing the salt marsh plants, place them in the marsh zone displayed on the graph, using the below image for marsh zone reference.



Credit: wetlandextension.ifas.ufl.edu

Image: Marsh profile showing elevation gradient graphic. Source: UF/IFAS Wetlands Extension.

7. Once all the plants have been placed, display the graph below with additional lines showing the projected sea-level rise by 2050 under the Low and Intermediate High scenarios. These sea-level rise projections show the change in low tide.
8. If needed, change the location of the plants based on the water levels from sea-level rise.
9. Students can use corresponding worksheet for notes.



- The marsh elevation follows the brown line
- Current High Tide Elevation: 0.4 meters
- Current Sea-Level: 0
- Sea-Level under the Low Scenario in 2050: 0.2 meters
- Sea-Level under the Intermediate High Scenario in 2050: 0.6 meters

Sea-level rise poses a challenge for marsh plants. Greater and more frequent inundation of the marshes leads to flooding stress and brings salt water into the higher marsh zones. In the northern Gulf of Mexico, we are experiencing sea-level rise at rates greater than the global average, so our marshes are being faced with this challenge now. The plants living in salt marshes have two options for keeping pace with sea-level rise: landward migration or vertical accretion. For landward migration, salt marsh plants move upslope into upland habitat. For vertical accretion, salt marsh plants trap sediment and vertically build up the land to stay above water with sea-level rise. Both of these pathways are relatively slow processes.

Landward migration is a process where the marsh zones shift upslope. However, landward migration is limited by steep slopes or barriers like human-built sea walls, parking lots, roads, or houses. This creates “coastal squeeze”, where the natural movement of the coastal habitat is prevented by physical barriers on the upslope side (see image below). Vertical accretion allows salt marshes to move up vertically as sea-level rises. This process occurs as salt marsh plants physically reduce the speed of water, which allows sediment particles to settle out and accumulate around the base of marsh plants. However, vertical accretion is limited by changes in marsh plant abundance and sediment supply; as plant biomass decreases there are less plants to slow the water velocity and accumulate sediment.

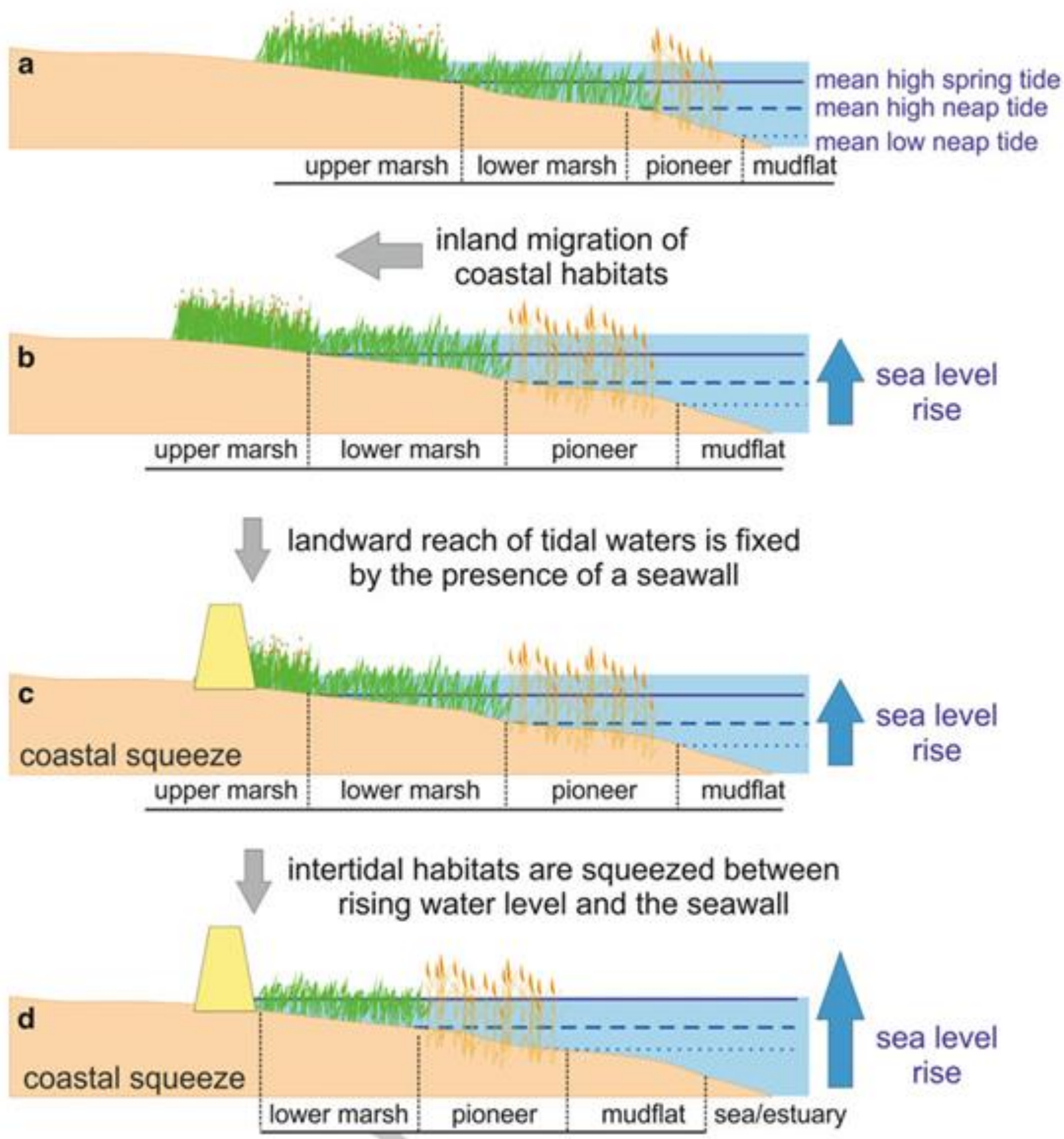


Image: The elevation in relation to the tidal range is one of the key factors determining the type of intertidal habitat that may develop in a particular location (a). Natural habitats tend to migrate inland as a response to rising sea levels (b). As a result of this migration the intertidal area may expand or reduce depending, for example, on the coastal topography. Hard engineering structures will invariably fix the landward limit of intertidal areas (c), which will be reduced in extent as sea levels rise and more land becomes permanently inundated (d). The loss of coastal habitats due to rising sea levels in front of artificially fixed shorelines is known as coastal squeeze. Image source: Esteves, L.S., 2015. Coastal squeeze. *In*: Kennish, M.J., ed. *Encyclopedia of Estuaries 2016 ed.* Dordrecht: Springer.

As marsh plants try to adapt to sea-level rise, many human-made stressors can reduce their ability to adapt. With wetland restoration and resilient sea-level rise actions, we can provide pathways for marshes and the animals that rely on them to keep pace with sea-level rise and continue to provide flood protection and other valuable services.

EVALUATE:

Ask: How does the tide influence salt marshes and the plants that grow there?

The incoming tide floods the marsh with brackish water, which is a mixture of salt and fresh water. Most plants cannot tolerate being regularly flooded or exposure to salt water, so salt marsh plants must have special adaptations that allow them to grow there. The frequency and duration of tidal inundation will determine where certain species of plants can grow.

Ask: How might sea level rise impact the marsh zones and subsequently the plants that grow there?

As marshes become more frequently flooded or hold more standing water, plants that are less salt or flood tolerant may die back and be replaced by the very few tolerant species that inhabit the low marsh.

Introduction to Estuaries and Wetlands

Along the Gulf of Mexico, we have many areas that provide habitat for animals. An estuary is the area where freshwater meet the saltwater ocean. The mixture of fresh and salt water is often called "brackish" water. Since estuaries are located along the coast, they are impacted by tides. As the water level of an estuary rises and falls, the water level and chemistry changes create a wide range of habitats. The marsh and seagrasses along the coast slow the moving water, allowing sediment and food particles to settle to the bottom. The maze of grasses provide many hiding places to small fish and crabs, giving estuaries the name "nursery of the sea."

Types of coastal estuaries include brackish or freshwater marshes, salt marshes, seagrass beds, and oyster reefs. Some coastlines may only have a soft shoreline of sand. Wetlands are what their name implies, areas of land that are wet enough to influence the plants and soils. Wetlands can be found inland or along the coast.

A salt marsh is a type of wetland that is flooded and drained by salt water brought in by tides. Tides affect the height of water within estuaries and salt marshes since they are open to the ocean. Plants that live in salt marshes are affected by abiotic factors including water level and salinity, as well as competition among species. Marshes generally have three vegetation zones: low marsh, high marsh, and upland edge. The plants that grow in each zone are determined by their ability to tolerate flooding (or inundation) and salt water. The more flood tolerant plants will be located in the lower marsh zones. The high marsh and upper marsh edge are generally only flooded by the tide during spring tides or during storms. Sometimes the high marsh area has a high salt concentration due to evaporation, which can lead to the formation of salt pannes.

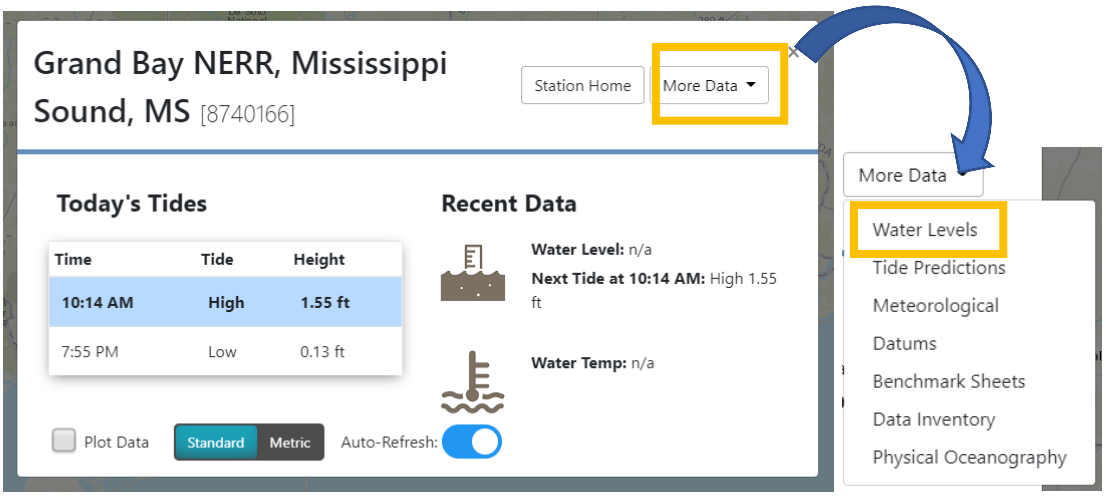
Most plants have one of three adaptations to deal with the salt from tidal influences: excrete the salt through specialized glands, exclude the salt at the roots, or sequester the salt in its leaves. Black needlerush (*Juncus roemerianus*) is the most common salt marsh plant in Mississippi and Alabama and has adaptations to handle anaerobic (i.e., no oxygen) conditions, as well as wide ranges of pH fluctuations. Saltmarsh cordgrass (*Spartina alterniflora*) thrives in the lower elevations of the marsh and alongside tidal creeks because of its tolerance to a high level of salinity. It excretes the excess salt onto the blades of the grass, which you can see as small crystals. Most salt marsh plants have an underground system of stems called rhizomes. These send out shoots, anchor the plant in unstable sediment, and help the plants survive in the harsh conditions of a salt marsh.

An essential component of a salt marsh is peat, the 'ground' of a marsh, providing the foundation for plants and animals living there. Often several feet thick, waterlogged, and composed of decomposing plant material, peat is low in oxygen, leading to a condition known as hypoxia. Certain bacteria thrive in hypoxic conditions, emitting the characteristic rotten egg smell associated with salt marshes. Examining a handful of peat shows the abundance of organic matter as well as its capacity to hold water. This ability of peat to act like a sponge means that marshes play a vital role in soaking up excess water during storm events, resulting in diminished flooding along the coast.

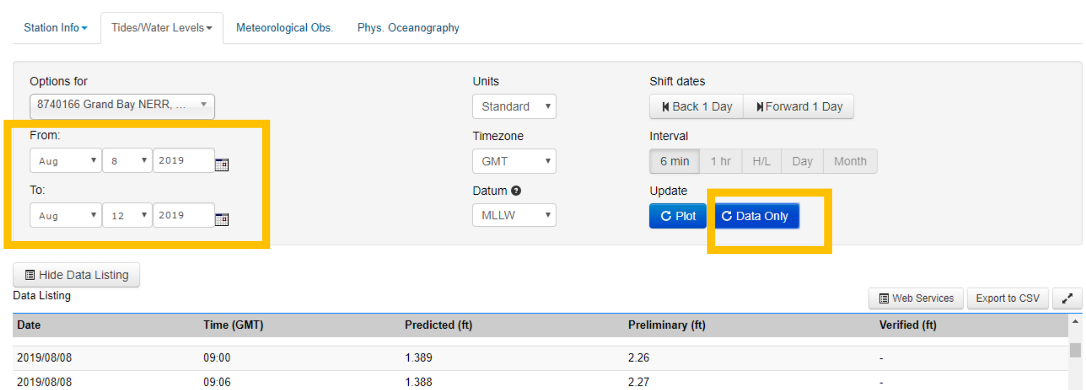
NOAA's Tides and Currents Investigation

What is your assigned tide station? ______________________________

1. Go to http://tidesandcurrents.noaa.gov/ and search for your tide station by checking the “Water Level Met” and “Water Levels” pins in the right-side Legend.
2. Access the tidal height data by clicking on the tide station pin.
3. Click on “More Data” in the dialog box that opens, then click “Water Levels.”



4. Select a range of time (at least 3 days) and click the “Data Only” button.



5. On graph paper record the water height every two hours for at least a three-day length of time. Create a line graph of the tidal change.
6. Calculate the tidal range:
   a. What is the height of the **high tide**? ________________________
   b. What is the height of the **low tide**? ________________________
   c. Tidal range = High tide minus low tide → ____________________

STUDENT PAGE | Tides and Wetlands

Answer the following questions based on the marsh plant and sea-level rise activity.

1. When you first placed your plants, what plant did you place nearest the water's edge? How did you decide where to place your plants in your mock marsh habitat?

2. What is the difference in elevation between the mean high tide line and sea level projection for 2050, and for the accelerated rate by 2050?

3. When you moved your marsh plants where did you decide to place them and why?

4. What happened to the marsh as a result of sea-level rise?

5. How might marshes be able to adapt to sea-level rise?

6. What management activities could we do to allow marshes to adapt to sea level rise?

STUDENT PAGE | Tides and Wetlands

DO NOW:

Draw a coastline.

EXIT TICKET:

How does sea-level rise impact coastal wetlands in undeveloped and developed areas?

2.2 Living with Living Shorelines

AGE RANGE

9th—12th grade

TIME REQUIRED

90 minutes

ACTIVITY OVERVIEW

Engage: Shoreline Images
Explore: Water Pan Demos
Explain: Discussion
Elaborate: Reading
Evaluate: Discussion

MATERIALS

Clear plastic containers (4 per group)
Sand (1 bag per ~8 containers)
Playdoh Dough (1 tub per group)
Water
Plastic aquarium grass
2 small vinyl siding samples
Small mesh bags
Small pebbles/rocks inside
Rubber bands
Small paint scrapers
Towels
Saran /Plastic Wrap
Rulers
Masking Tape
Wet/Dry Erase Markers

BASED ON:

"Shifting Shorelines" from North Carolina Coastal Federation

LESSON TOPIC: Living shorelines

ACTIVITY SUMMARY: Students compare erosion from waves and storms on four different beach types.

OBJECTIVES:

Students will be able to:

- Identify components of a living shoreline and built stabilization structures.
- Understand coastal erosion and erosion control methods.
- Describe benefits of living shorelines to animal habitat and economic benefit.

LESSON BACKGROUND: Shorelines are the first line of defense against storms in the Gulf of Mexico. A healthy coast helps to protect our communities. Coastal erosion results in loss of land and can be caused by wind, waves, storms, boat wakes, and rising water levels. Some techniques to protect the coast from erosion are human built structures like bulkheads and seawalls. These structures provide a barrier to water stressors, but they require expensive maintenance and during strong storms they can fail. Additionally, hardened structures can often lead to loss of natural intertidal habitat and all of the benefits they provide. Natural shoreline protection can come in the form of oyster reefs and wetlands. These act as speed bumps to storms, slowing them down and reducing erosion. Living shorelines is a broad term that covers a variety of shoreline construction & protection techniques that harnesses the ability of natural habitats to provide shoreline protection, through using natural elements like native marsh grasses and oyster shells to stabilize the shore. Another benefit of living shorelines is that they offer habitat for animals like fish, crabs, and oysters. Oysters are filter feeders and help clean the water they are in, so using oyster shells in living shorelines promotes oyster reef growth to clean the water while also preventing erosion. Marsh grasses provide habitat for fish to hide while they are young. Adult fish will venture into the Gulf of Mexico. The Gulf of Mexico is the second largest area of fish landings in the United States, second only to Alaska. Commercial fisheries in the Gulf of Mexico have an economic impact through job creation, including processors, dealers, retailers, restaurateurs that transport seafood from the ocean to our plate. Utilizing living shorelines helps to affordably and sustainably protect our coasts while also supporting fisheries and clean water.

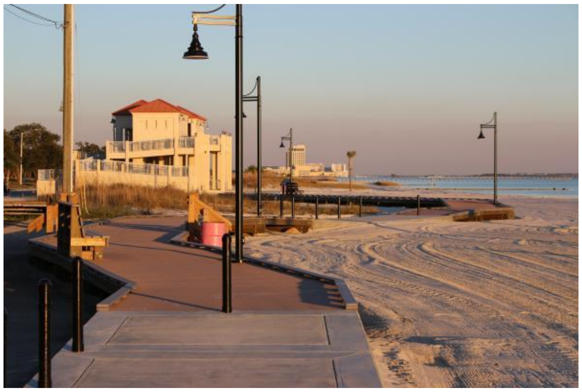
Mississippi State University Coastal Conservation and Restoration Program has developed larger scale living shoreline education tanks. At several locations along the MS and AL, coast there are living shoreline education tanks – also called SWASH tanks – Gulf Coast Research Laboratory Marine Education Center, Pascagoula River Audubon Center, Grand Bay National Estuarine Research Reserve, Mississippi Aquarium, and Dauphin Island Sea Lab Estuarium. Each tank is actually a set of three tanks that each have a different type of shoreline on one side. Those shoreline types are bulkhead, natural shoreline, and living shoreline (with breakwater). On the other end of the tank is a paddle connected to a lever. When the lever is pushed it creates an equal-sized wave in each tank that then crashes into the different shoreline types. You will notice that the wave dissipates quickest (i.e., the water gets calmer – faster) in the natural shoreline and living shoreline tanks than the one with the bulkhead. The bulkhead is essentially a flat wall that reflects waves instead of dissipating them, which can cause erosion on neighboring shorelines. The natural or living shoreline tanks have several characteristics that help dissipate wave energy and reduce potential erosion – those are a gentler slope, vegetation, and a breakwater. This demonstration shows that the more natural shorelines you have, the more waves will be dissipated.

VOCABULARY:

Coastal Processes	Physical, biological, and geological processes and affecting coastlines and coastal habitats.
Ecosystem Service Valuation	Quantifying the benefits that humans receive from natural systems; often utilizes economic value.
Erosion	Process wherein sediments are broken down and worn away by waves, currents, wind, and/or precipitation.
Habitat Management	Manipulating an ecosystem in order to suit a purpose, especially to balance environmental and human activities.
Living Shoreline	A living shoreline is a protected and stabilized shoreline that is made of natural materials such as plants, sand, or rock.
Restoration	Manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning previous function(s). Includes ecological, ecosystem, and habitat restoration.
Rhizome	A rhizome is a modified subterranean plant stem that sends out roots and shoots from its nodes.

ENGAGE:

Display the images of the sand beach, wetland salt marsh, living shoreline planted with marsh grass and oyster reef, hardened shoreline near city, and bulkhead. Have students discuss the benefits of each type of shoreline. Then ask students to rank the images according to how well they think the type of shoreline will protect upland habitat.



West Biloxi Beach Boardwalk. Source: GulfCoast.org

A natural shoreline at Guana Tolomato Matanzas National Estuarine Research Reserve. Source: Melody Ray-Culp, US Fish and Wildlife Service

A living shoreline in Panama City, Florida. Source: Florida Living Shorelines

Hardened shorelines in South Florida. Source: Florida Living Shorelines

Hardened bulkhead shoreline in Scarborough, ME. Source: Maritime Construction and Engineering, LLC

EXPLORE:

Activity Overview: water pan demos - Students will explore how various shoreline stabilization methods influence coastal erosion and the surrounding habitat. They will rotate through four stations: a bare sand shoreline, a hard structure protection method, a living shoreline with planted marsh grasses, and a living shoreline with both planted marsh grasses and a constructed oyster reef. While rotating through the stations in small groups, students will simulate wave energy and observe which method works best to protect estuarine shores.

Materials:

- Clear plastic containers (11 in X 16 in, 15 Qt.), enough for students to work in groups of 3
- Playdoh or Crayola Dough (1 tub per group)
- Saran /Plastic Wrap

- Sand (1 bag per ~8 containers)
- Plastic aquarium grass used in fish tanks
- 2 small vinyl siding samples from Lowes Hardware (for bulkhead/seawall)
- Small mesh bags with small pebbles/rocks inside (for oyster reef)
- Rubber bands
- Small paint scrapers or dust pans (as many as plastic containers)
- Water (enough to fill each contained ½ way)
- Rulers (one for each station)
- Wet/Dry Erase Markers or Masking Tape (one for each station)
- Towels

Procedure:

1. Divide students into groups of 2-3. Each group will build a shoreline. Depending on your class size there may be duplicate shorelines.
    - All: Make a one-inch layer of playdoh along the bottom of the plastic container from the edge to 1/3 of the way. Place a sheet of plastic wrap over the playdoh, to help with cleanup. Add sand on top of the playdoh and form a gentle slope to create a beachfront/shoreline. Add water to the opposite end of the container so it reaches roughly ¼ of the sandy shore. The only sand shoreline is complete, all other shorelines continue with the following directions.
    - Bulkhead/seawall: Add the small vinyl siding samples and place them side by side. Stick them down into the playdoh.
    - Living shoreline with plants: Add aquarium plants and bury down in the sand/playdoh a bit to represent plant roots. You may need to cut the aquarium plants so they fit in your container correctly.
    - Living shoreline with plants and oyster reef: Add plants and then place pebble bags slightly in front of plants. You may need to use rubber bands around the pebble bags to make the reef more streamline.

Image: From left to right, sand only, bulkhead, living shoreline with plants, living shoreline with plants and oyster reef. Image showing the complete shoreline setups.

2. Rotate student groups through the shoreline stations to observe wave action and erosion. At each station have students record the following:
    - Their prediction/hypothesis for amount of erosion they expect from the type of shoreline.
    - The number of millimeters of erosion they measure after making waves.
3. When a group arrives at a shoreline have them mark the end of the shoreline (the coast) with tape on the outside of the container.
   Alternative: students trace the edge of the shoreline with a dry or wet erase marker. If you want to prevent the students from writing directly on the bin, each group can tape a transparent paper (sheet protector or laminated page) to the bin to draw the "before" shoreline in one color permanent marker and the "after" shoreline in another color permanent marker. These transparent pages can be kept to compare all bins at the end of the lesson.
   One student per group will make 20 waves in the water using the paint scraper.
4. Using the ruler, the group will measure the distance from the coast to their piece of tape.
   Alternative: students measure the distance to their traced line. This will show the amount of erosion. Before the group rotates to the next station have them repair the shoreline back to the original condition and remove the tape/erase the line.
5. Groups continue rotating until each group has been to each type of shoreline at least once.

Image: Marker on the outside of the container showing original shoreline shape compared to new shoreline share.

Tips for resetting the activity between classes:

- Have extra sand on hand to replace
- Use fresh playdoh if it has dried out
- Have dump buckets for used water and sand

EXPLAIN:

With groups all together discuss with students what they saw and how it might translate to what we experience on the Gulf Coast.

- Which shoreline eroded the most during the wave experiment?
- Which shoreline offered the most protection from erosion?
- What happened to the sand? Where did it go? Why did this happen?
- What do you think would happen if a hurricane came to the shorelines? At this point the teacher or a student can simulate a hurricane on each shoreline with strong waves.
- What do you think the different shorelines would look like a year after the hurricane? (Plants and living shorelines are able to recover naturally).
- How do you think the plants and oyster reefs can help keep the surrounding water clean? (plants can help filter any pollutants coming from the mainland, and the oyster reefs will attract new oysters, which naturally help clean and filter water)
- What other benefits do they provide?

ELABORATE:

Students read “Living with Living Shorelines” and then look over living shoreline resources available to homeowners.

Protection your property and the environment: A homeowner’s guide to living shorelines in Alabama. Martin SE, Sparks EL, Temple NA, Firth DC. 2017. http://extension.msstate.edu/sites/default/files/publications/publications/P3063.pdf

Protection your property and the environment: A homeowner’s guide to living shorelines in Mississippi. Martin SE, Sparks EL, Temple NA, Firth DC. 2017. http://extension.msstate.edu/sites/default/files/publications/publications/P3062.pdf

Living shorelines can be implemented as a buffer in many areas: homes, bridges, roads, and more.

Discussion questions for students:

- How do we rely on wetlands?
  - They offer protection from erosion. They buffer the coastline during storms, thus protecting our structures. They are a nursery habitat for fish and crabs and help contribute to the large seafood industry in the Gulf of Mexico.
- What plant grows in a salt marsh?
  - Common salt marsh plants along the northern Gulf of Mexico inclide: smooth cordgrass *Spartina alterniflora*, Black needlerush *Juncus roemerianus,* Saltmeadow cordgrass *Spartina patens*, Bulrush *Schoenoplectus americanus*, and Salt grass *Distichlis spicata*
- Where are salt marshes located?
  - Salt marshes are wetlands located along the coast and influenced by tides.
- What organisms rely on salt marsh habitat?
  - Blue crab, shrimp, red drum, osprey, blue heron, periwinkle snails, and many more.
- What is a rhizome and what is the function?
  - A rhizome is a horizontal underground root. It spreads to produce new clones of the plant.
- Why are salt marshes threatened?
  - Salt marshes are threatened from upland sources like human development and runoff, and from sea-level rise.
- Why are sea walls not as good as natural shorelines?
  - Sea walls and hardened structures are not able to adapt and change over time. Also, due to their impermeability they redirect wave energy and can increase erosion in adjacent locations.

- Name 3 benefits of restoring natural shorelines on private properties.
    - Restoring natural shorelines on private property can help reduce erosion, support healthy coastal ecosystems, and boost local economies.
- Which was more efficient at protecting the shoreline, the 50 percent coverage area or the 100 percent coverage area?
    - The area planted at 50 percent coverage was the most efficient as it performed just as well as the area plated at 100 percent but cost less to install.
- Which would be cheaper and less labor intensive (less hard work)?
    - The 50 percent coverage.
- What is a breakwater?
    - A nearshore breakwater is a structure used to help reduce wave energy before it hits the marsh. Depending on the site, these breakwaters can be made of temporary materials, such as biodegradable coir logs or short, board fences, or longer-term materials, such as loose stone, concrete structures, or oyster shell cages.

Connect the outcomes of the water pan demonstration to coastal building ordinances in Module 3 (Lesson 3.3) and Module 4 (Lesson 4.1).

EVALUATE:

Return to the images from the start of the lesson. Ask students if their thoughts changed on the erosion protection.

Ask students: What causes erosion? What are examples of different shorelines? Which shoreline offered the most protection from erosion? Which shoreline offered the most habitat to animals?

STUDENT PAGE | Reading – Living with Living Shorelines

Salt marshes are coastal wetlands common throughout the globe and visible just about any time you drive over a bridge along the coast. Found in estuaries, where rivers meet the ocean, these wetlands stabilize the shoreline, act like kidneys to filter nutrient pollution, and offer food and shelter for birds and fish. Black needlerush is one of the dominant species of grass-like perennial foliage native to the Gulf and Atlantic coasts. It grows moderately fast, forming a deep, fibrous root system and dense above-ground canopy that provide habitat for waterfowl, muskrats, nongame birds, and organisms that are the base of the food chain for fish, shrimp, crabs and other commercially important seafood. The hardy root system essentially grabs and holds sediment in place, which, in turn, slows down shoreline erosion.

Salt marshes are rapidly disappearing as people build hard structures, such as seawalls and bulkheads, to help lessen erosion. Human development in these wetlands all over the world is causing large losses of marshland, but the most dramatic losses in the United States are happening in the northern Gulf of Mexico, which includes Mississippi, Texas, Louisiana, Alabama, and Florida. Natural shorelines are much better at providing a long-term solution for lessening coastal erosion. Sea walls and other hard structures deteriorate from exposure to saltwater, and many must be replaced every 10 to 30 years.

Restoring natural shorelines on private property can help reduce erosion, support healthy coastal ecosystems, and boost local economies. In fact, scientists have conservatively estimated that coastal marshes provide more than $20 billion worth of shoreline stabilization and storm protection services in the United States alone. The majority of our shoreline is small, privately owned tracts of property.

Resent research explored the most economical and effective method of salt marsh restoration for small-scale projects. Restoring natural shorelines on private property can help reduce erosion, support healthy coastal ecosystems, and boost local economies.

In the study, scientists from Mississippi State University, the University of South Alabama, Dauphin Island Sea Lab, the University of Connecticut, The Nature Conservancy, and the Grand Bay National Estuarine Research Reserve planted black needlerush in two different designs at the Grand Bay National Estuarine

Black needlerush lines many Mississippi and Alabama coastal areas and protects them from erosion. Extensive root systems protect bayou and bay shorelines from low to moderate wave energy. (Photo by MSU Extension Service/Eric Sparks)

Research Reserve in Moss Point, Mississippi. They harvested the marsh plants from a nearby marsh and used this donor area as a control site for comparison. Transplants were planted in one design area at 100 percent coverage. The second design area was planted at 50 percent coverage, which was less costly and labor-intensive. After two years, both design areas performed similarly. The area planted at 50 percent coverage was the most efficient as it performed just as well as the area planted at 100 percent but cost less to install.

The techniques used in living shorelines are extremely site specific, but an essential aspect of the construction is a nearshore breakwater to help reduce wave energy before it hits the marsh. Depending on the site, these breakwaters can be made of temporary materials, such as biodegradable coir logs or short, board fences, or longer-term materials, such as loose stone, concrete structures, or oyster shell cages. Temporary breakwaters are intended to persist long enough for plants to get established or rerooted. In higher wave energy environments, the more permanent breakwaters may be needed for sustained shoreline protection in conjunction with the shoreward salt marsh.

Reading adapted from publications by Dr. Eric Sparks: Salt marsh plants offer valuable shoreline service, Sparks EL. 2018. Research helps landowners reduce erosion and support ecosystems. Sparks EL, Cebrian J. 2016. Salt marsh plants offer valuable shoreline service, Sparks EL. 2018.

Shoreline #1: ___________________________________

Draw a picture of what the shoreline looks like before any wave action:

Write your hypothesis for what you think will happen when waves come up to this shoreline?

Place a piece of tape on the outside of the container where the sand stops.

One student per group will make 20 waves in the water using the paint scraper.

Marks where the sand stops with another piece of tape.

Use a ruler to measure how far the sand traveled from the first piece of tape to the last piece of tape. How many millimeters did the shoreline move back from the start of the experiment to the end? ___________________________________

Draw a picture of what the shoreline looks like after all 20 waves:

Before you rotate to the next station, repair the shoreline back to the original condition and remove the tape.

Was your hypothesis supported by the data? Explain.

Shoreline #2: ______________________________________

Draw a picture of what the shoreline looks like before any wave action:

Write your hypothesis for what you think will happen when waves come up to this shoreline?

Place a piece of tape on the outside of the container where the sand stops.

One student per group will make 20 waves in the water using the paint scraper.

Marks where the sand stops with another piece of tape.

Use a ruler to measure how far the sand traveled from the first piece of tape to the last piece of tape. How many millimeters did the shoreline move back from the start of the experiment to the end? ______________________________________

Draw a picture of what the shoreline looks like after all 20 waves:

Before you rotate to the next station, repair the shoreline back to the original condition and remove the tape.

Was your hypothesis supported by the data? Explain.

Shoreline #3: ___________________________________

Draw a picture of what the shoreline looks like before any wave action:

Write your hypothesis for what you think will happen when waves come up to this shoreline?

Place a piece of tape on the outside of the container where the sand stops.

One student per group will make 20 waves in the water using the paint scraper.

Marks where the sand stops with another piece of tape.

Use a ruler to measure how far the sand traveled from the first piece of tape to the last piece of tape. How many millimeters did the shoreline move back from the start of the experiment to the end? ___________________________________

Draw a picture of what the shoreline looks like after all 20 waves:

Before you rotate to the next station, repair the shoreline back to the original condition and remove the tape.

Was your hypothesis supported by the data? Explain.

Shoreline #4: ____

Draw a picture of what the shoreline looks like before any wave action:

Write your hypothesis for what you think will happen when waves come up to this shoreline?

Place a piece of tape on the outside of the container where the sand stops.

One student per group will make 20 waves in the water using the paint scraper.

Marks where the sand stops with another piece of tape.

Use a ruler to measure how far the sand traveled from the first piece of tape to the last piece of tape. How many millimeters did the shoreline move back from the start of the experiment to the end? ____

Draw a picture of what the shoreline looks like after all 20 waves:

Before you rotate to the next station, repair the shoreline back to the original condition and remove the tape.

Was your hypothesis supported by the data? Explain.

STUDENT PAGE | Living with Living Shorelines

DO NOW:

Describe the following terms:

Landward Migration

Vertical Accretion

EXIT TICKET:

What characteristics make a shoreline more resilient to wave action?

2.3 Puddles to Gardens

AGE RANGE
9th—12th grade

TIME REQUIRED
90 minutes

ACTIVITY OVERVIEW
Engage: Rain Garden Introduction
Explore: Tour of Potential Locations
Explain: Drainage Calculations
Elaborate: Rain Garden Planning
Evaluate: Presentations

MATERIALS
Student Worksheet
graph paper
pencil
tape measure
long handle shovel
ruler
hose or watering can

BASED ON:
"Rain Gardens" by Kids Gardening

LESSON TOPIC: Community implementation of rain gardens

ACTIVITY SUMMARY: Students explore the mathematics involve with planning a rain garden.

OBJECTIVES:

Students will be able to:

- Understand the impact of stormwater runoff and water pollution on the environment.
- Explore the ability of plants to absorb and filter water.
- Design a rain garden for their school.

LESSON BACKGROUND: In suburban and urban settings, much of the rain that falls hits impervious surfaces such as roofs, parking lots, and roads, where it cannot be absorbed. It becomes runoff, moving across the ground to areas where it can be absorbed or into local waterways, either directly or via storm sewers. In urban settings, as little as 15% of the water may be absorbed where it falls and up to 55% will run off. Not only does this result in lower groundwater reserves which endangers drinking water supplies and can ultimately cause land to sink (subsidence), it also creates a significant amount of water to deal with above ground.

Although rain is an important contributor for recharging local waterways, the problem with runoff from urban environments is what the runoff is carrying. As the water moves across surfaces such as streets, parking lots, and roofs, it picks up all sorts of pollutants, from nutrients like nitrogen and phosphorous that fuel algal blooms to pesticides, herbicides, oil, grease, heavy metals, and harmful bacteria. These pollutants can kill water life and interfere with the delicate balance of the aquatic ecosystem.

A rain garden is a garden planted in a low area to encourage water collection. This design enables rain gardens to trap stormwater before it becomes runoff and filter it before it's absorbed into the soil. The plants in a rain garden have high tolerance for excess moisture and the increased levels of nutrients often found in stormwater. Rain gardens are most useful if situated downhill from impervious surfaces, such as rooftops and roads, and are designed to collect runoff from those surfaces. They slow down the flow of stormwater by collecting it in the sunken garden area and allowing it to absorb into the soil rather than cause erosion and carry pollutants into our waterways.

Note: this lesson has the option to explore an area outside after a rain and to use tools to collect soil samples and plant. Consider safety measures you need to put in place.

VOCABULARY:

Conservation Planning	To maintain natural values and assets in a specific landscape or seascape with competing uses, values, and other threats and opportunities.
Stormwater Runoff	Rain that falls on streets, parking areas, sports fields, gravel lots, rooftops or other developed land and flows directly into nearby lakes, and rivers.

ENGAGE:

Introduce the students to this lesson by observing a rain event or by walking around the school following a rain event. If your class time overlaps with an active rainstorm have the student watch the rain. Ask students: What happens to the water once it hits the ground? If your class time occurs after a rainstorm has passed, take the students outside to observe areas of flowing or standing water. Ask students: How is the water from rain managed at our school? If no periods of rain coincide with your class, ask them to recall rain experiences at school or home.

Make the connection of rain gardens to wetland plants. Rain gardens bring the benefits of wetlands -water filtration, reducing runoff, limiting erosion, and providing animal habitat – to areas beyond the coast.

EXPLORE:

Materials:

- graph paper
- pencil
- tape measure
- long handle shovel
- ruler
- hose or watering can

Procedure:

1. Divide students into pairs or small groups.
2. Take the class on a tour of the school ground to identify a good location to build a rain garden, looking for an area lower in elevation and at least 10 ft away from buildings. The garden should not be placed over a septic system or under mature trees to protect the roots.
    a. This lesson will only be for the students to plan the garden, but if your supplies allow and your school is willing, you may be able to implement your garden. Make sure to call your local utilities hotline to have them mark any underground lines on the property before you dig your garden.
3. Once you identify a possible site, test the drainage of the soil. It is important for the garden to contain well-draining soil so that the collected water dissipates within two to four days. If water sits for too long, plant roots will suffocate, and insect breeding will become a problem. Ideal rain garden soil is comprised of 20-25% leaf mulch or compost, sandy soil, and topsoil.
    a. To test the drainage of the soil in each a potential rain garden location:
        i. Dig a hole 6 inches wide and 18 inches deep in each location
        ii. Fill each hole with water and measure depth with a ruler.
        iii. Check on water depth every hour and record results.
    b. If all the water drains within a few hours, the site has excellent drainage. If the water drains within 24 hours, then it is still an acceptable site for a rain garden. If the water has not drained in 48 to 72 hours, then you should choose a different location.

Rain Garden Examples:

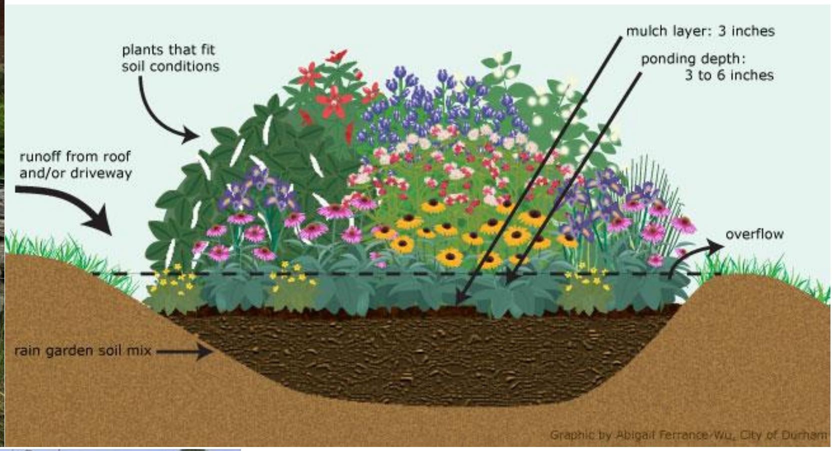


Image: Rain gardens, such as the one at the Mississippi State University Landscape Architecture Facility (left), are designed to channel and filter excess rainwater. Diagram on the right is from City of Durham, NC. Bottom shows rain garden picture overlaid with diagram of water flow, from Alabama Cooperative Extension System.

EXPLAIN:

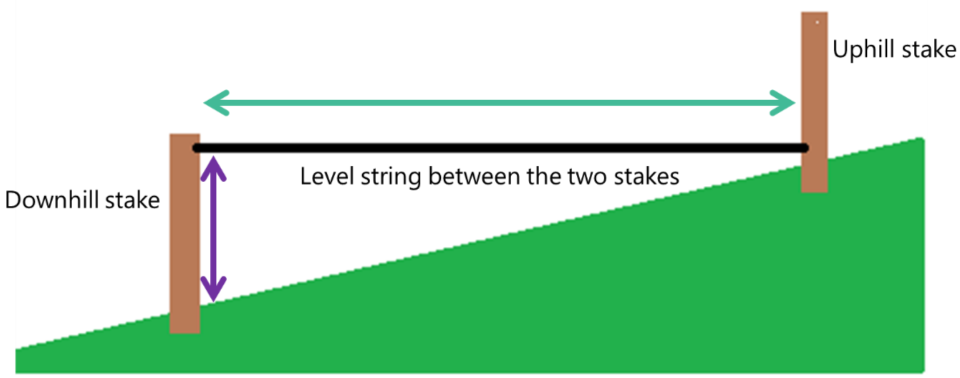
To design an effective rain garden, students will need to consider the drainage from the test earlier as well as the slope. Calculations can be conducted inside, and then include an outside exploration.

How to Calculate Drainage Area:

To determine the size of the area that will drain into the rain garden, measure the amount of impervious surfaces surrounding the location of your rain garden.

length (ft) x width (ft) = _____________ft ^{2} (drainage area)

How to Determine the Slope or Necessary Depth of the Rain Garden:



1. Place a stake at the uphill end for the rain garden and another at the downhill end.
2. Level the string between the two stakes.
3. Measure the total length of the string (teal arrow) and height of the string at the downhill stake (purple arrow) in inches.
4. Divide the height by the length of the string and multiply the result by 100. This is the slope as a percentage.

Slope = (height/length) x 100

The slope into the rain garden will help you figure out how deep the soil in your garden needs to be. Once you have calculated the slope, use the chart to identify the appropriate soil depth for your rain garden.

Slope	Depth
<4%	3-5 inches
5-7%	6-7 inches
8-12%	8+ inches

How to Determine the Soil Type in Your Rain Garden:

1. Grab a handful of moist soil and roll it into a ball in your hand.
2. Place the ball of soil between your thumb and the side of your forefinger and gently push the soil forward with your thumb, squeezing it upwards to form a ribbon about ¼" thick.
3. Try to keep the ribbon with a uniform thickness and width. Repeat the motion to lengthen the ribbon until it breaks under its own weight. Measure the ribbon and evaluate according to these specifications:
    a. Sand: soil does not form a ribbon at all
    b. Silt: soil forms a weak ribbon <1.5 inches before breaking
    c. Clay: soil forms a ribbon >1.5 inches long

EXTENSON: A more in-depth soil texture analysis can be conducted as part of this lesson by following "The Jar Test" procedure.

Materials:

- Straight edged, clear jar
- Permanent marker
- Ruler
- Timer
- 1 tablespoon of powdered dishwashing detergent
- Mesh sieve or old colander

Procedure:

1. Using a mesh sieve or old colander, sift the soil to remove any debris, rocks, and large organic matter (leaves, sticks, roots, etc.).

2. Fill the jar ⅓ full of the soil to be tested

Jar filled a ⅓ of the way full with soil.
Andrew Jeffers, ©2018, Clemson Extension

3. Fill the remainder of the jar with clean water and leave some space at the top.

4. Add 1 tablespoon of powdered dishwashing detergent.

5. Cap the jar and shake vigorously until the soil turns into a uniform slurry.

6. Set on a level surface and time for one minute.

7. Place a mark the outside of the jar, showing the coarse sand layer settled at the bottom of the jar.

Jar showing the coarse sand layer settled at the bottom of the jar.
Andrew “Drew” Jeffers, ©2018, Clemson Extension

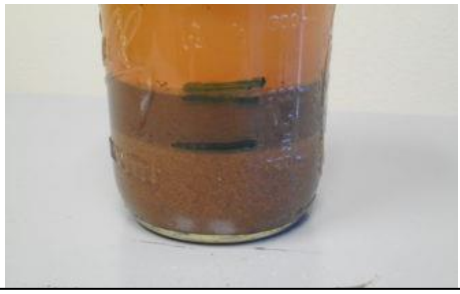
8. Leave the jar in a level spot for 2 hours.

9. Mark the top of the next settled layer with the permanent marker. This is the silt layer.

Jar showing the silt layer.
Andrew “Drew” Jeffers, ©2018, Clemson Extension

10. Leave the jar on a level spot for 48 hours.

11. Mark the top of the next settled layer with the permanent marker. This is the clay layer that has settled on top of the silt layer.



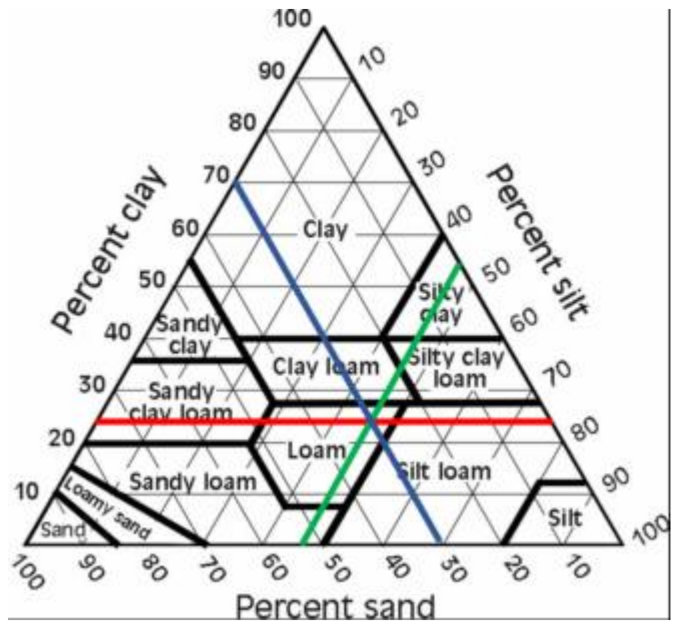
Jar showing the clay layer.
Andrew “Drew” Jeffers, ©2018, Clemson Extension

12. Using a ruler, measure and record the height of each layer, and the total height of all three layers. Use the soil texture analysis worksheet below to record results.

Using a ruler, measure and record the height of each layer, and the total height of all three layers. Andrew “Drew” Jeffers, ©2018, Clemson Extension

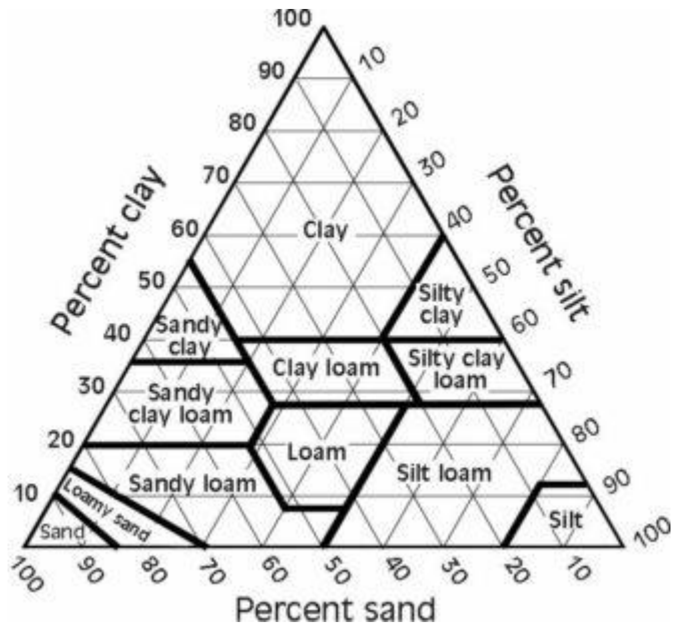
Procedure for using a soil texture triangle to estimate the soil type:

1. Use the soil texture triangle to estimate the soil type for the site.
2. The clay percentages are listed on the left side of the triangle. Lines corresponding to clay percentages extend from the percentages reading left to right (see red line).
3. The silt percentage is on the right side, with lines extending downwardly, diagonally right to left (see green line).
4. The sand percentage is on the right side, with lines extending upwardly, diagonally right to left (see blue line).
5. Track the lines with the percentages measured and find the spot on the triangle where all three lines intersect. The region where these lines intersect indicates the soil type present. The example shown represents a loam soil texture.



Soil Texture Analysis “The Jar Test” Worksheet:

Insert your measurements from the jar in the spaces below:



Height of sand layer _______inches / cm

Height of silt layer _______inches / cm

Height of clay layer _______inches / cm

Total height of layers _______inches / cm

% SAND=(sand height)/(total height) x 100 =__________ % SAND

% SILT=(silt height)/(total height) x 100 =___________ % SILT

% CLAY=(clay height)/(total height) x 100 =___________ % SILT

Adapted from: Soil Texture Analysis “The Jar Test” Procedure by Andrew "Drew" Jeffers, Spartanburg Cooperative Extension, Horticulture and Natural Resource Agent, Clemson University

Note: the lesson can be paused here for the day.

How to Determine the Size Factor of Your Rain Garden:

1. Locate the soil type of your rain garden on the left hand column of the table below.
2. Locate the depth you calculated for your rain garden in the second row of the table below.
3. Identify where the soil type and depth intersect in the table to find the proper size factor for your garden.
4. Use this number in the equation below to determine the appropriate size of your rain garden.

Soil Type	Depth		
	3-5 inches	6-7 inches	8+ inches
Sand	0.19	0.15	0.08
Silt	0.34	0.25	0.16
Clay	0.43	0.32	0.20

How to Determine the Size of Your Rain Garden:

Size Factor x Drainage Area = Rain Garden Area

Example: Suppose a rain garden was determined to have a drainage area of 1,000ft^2. It has a slope of 5%, requires a depth of 6-7 inches, and has clay soil. To determine the recommended size of the rain garden: 0.32 (Size Factor) x 1,000 ft^2 (Drainage Area) = 320ft^2 (Rain Garden Size)

ELABORATE:

Students continue to work in groups to plan out their rain garden. Have students plan the size of their rain garden and select plants. They can map out their garden using graph paper. Graph paper also comes in poster size, and can be used by students to create a larger scale plan. The design of the garden can be varied between students but should include the following components:

1. Ponding area or depression. To help capture runoff, the garden base should be shaped like a saucer with the middle deeper than the edges. The land leveling between the middle (generally 6" deep) and edges should be gradual so that water is spread out throughout the garden. Because of this shape, the edges of the garden will usually be drier than the middle which will need to be considered when selecting plant materials.
2. Well-draining soil. Well-draining soil is important to ensure quick absorption of runoff. During planting and maintenance, it is important to avoid compacting the soil, which will decrease its effectiveness.

3. Tough plants. Plants chosen for the rain garden must be able to tolerate extremes of wet and dry soil. Rain gardens are typically planted with shrubs and perennials. Because the rain garden functions better with deep rooting plants, annuals are not part of the usual design. Native plants are often the best choices because they will be well suited to the environmental conditions of your climate.
4. Mulch. Mulch is needed to protect the soil from erosion and insulate the garden from extreme wet and dry conditions. Shredded bark mulch is preferable because it does not wash away as easily as lighter bark chips.
5. A grass buffer strip. A grass buffer strip around the garden is important to slow the speed at which the runoff enters the garden and to decrease soil erosion.
6. A berm. A berm made from at least six inches of soil or rocks helps to keep the runoff in the garden long enough to allow it to be absorbed into the soil. Make sure that if your garden does overflow, the overflow will head to storm drains rather than towards structures.

Students may use this list as a resource to select suitable plants for rain gardens in the Gulf South. Information from Mississippi State University Extension.

Small and Large Trees			**Perennials**	
Common name	**Scientific name**		**Common name**	**Scientific name**
Swamp red maple	*Acer rubrum var. drummondii*		Joe pye weed	*Eupatorium fisulosum*
Bald cypress	*Taxodium distichum*		Cardinal flower	*Lobelia cardinalis*
Green ash	*Fraxinus pennsylvanica*		Stokes aster	*Stokesia laevis*
Swamp black gum	*Nyssa sylvatica var. biflora*		Rose mallow	*Hibiscus lasiocarpus*
Willow oak	*Quercus phellos*		Texas star hibiscus	*Hibiscus coccinea*
Black willow	*Salix nigra*		Louisiana iris	*Iris spp*
Sweet bay magnolia	*Magnolia virginiana*		Boltonia	*Boltonia asteroids*
Pond cypress	*Taxodium ascendens*		Coreopsis	*Coreopsis lanceolata*
Mayhaw	*Crataegus opaca*		Swamp sunflower	*Helianthus angustifolius*
Ironwood	*Carpinus caroliniana*		Blue flag iris	*Iris virginica*
Wax myrtle	*Myrica cerifera*		Blazing star	*Liatris spicata*
			Cinnamon fern	*Osmunda cinnomomea*
Shrubs			Royal fern	*Osmunda regalis*
Gallberry holly	*Ilex glabra*		Goldenrod	*Solidago canadensis*
Yaupon holly	*Ilex vomitoria*		Ironweed	*Vernonia spp.*
Dwarf palmetto	*Sabal minor*		Obedient plant	*Physostegia virginiana*
Chokeberry	*Aronia arbutifolia*		Horsetail	*Equisetum hyemale*
Buttonbush	*Cephalanthus occidentalis*			

Summersweet	*Clethra alnifolia*		**Grasses and Sedges**	
Sweetspire	*Itea virginica*		River oats	*Chasmanthium latifolium*
Titi	*Cyrilla racemiflora*		Blue sedge	*Carex glauca*
Buckwheat tree	*Cliftonia monophylla*		Woolgrass	*Scirpus cyperinus*
			Muhly grass	*Muhlenbergia capillaries*
			Panic grass	*Panicum virgatum*
			Little bluestem	*Andropogon virginicus*
			Spikerush	*Eleocharis spp.*

For any additional assistance needed for planning a rain garden please reach out to your local extension service. Mississippi educators can reach out to Christine E.H. Coker, Ph.D., GRP.

Email address: christine.coker@msstate.edu
Title: Associate Research and Extension Professor of Urban Horticulture
Mississippi State University Coastal Research and Extension Center
Beaumont Horticultural Unit

EVALUATE:

Students can present their rain garden design to the class, making sure to answer the following questions:

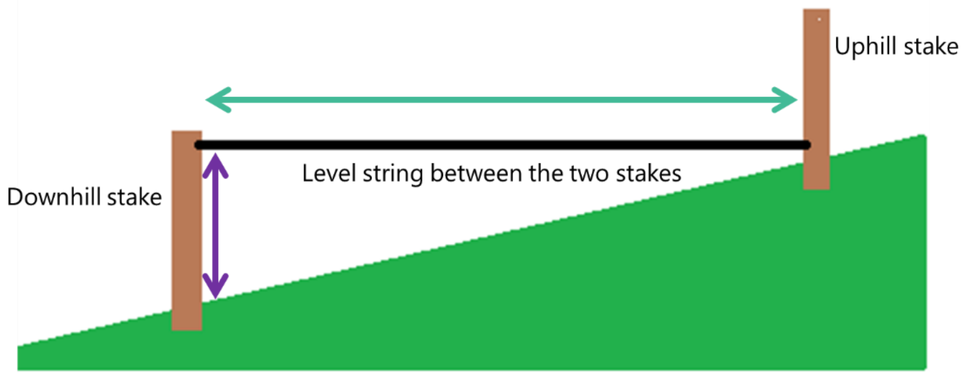
- What is the impact of stormwater on rivers, streams, and lakes?
- What are some ways each individual can reduce their impact on local waterways?
- State some reasons to mitigate stormwater runoff.
- State the purpose of rain gardens.
- State your scenario conclusions.
- Showcase your garden design.
- Showcase a listing of selected plants and why they were selected for use in the rain garden.

How to Calculate Drainage Area:

To determine the size of the area that will drain into the rain garden, measure the amount of impervious surfaces surrounding the location of your rain garden. *Make sure to pay attention to units.*

length (ft) x width (ft) = ____________ft ^{2} (drainage area)

How to Determine the Slope or Necessary Depth of the Rain Garden:



1. Place a stake at the uphill end for the rain garden and another at the downhill end.
2. Level the string between the two stakes.
3. Measure the total length of the string (teal arrow) and height of the string at the downhill stake (purple arrow) in inches.
4. Divide the height by the length of the string and multiply the result by 100. This is the slope as a percentage.

Slope = (height/length) x 100

The slope into the rain garden will help you figure out how deep the soil in your garden needs to be. Once you have calculated the slope, use the chart to identify the appropriate soil depth for your rain garden.

Slope	Depth
<4%	3-5 inches
5-7%	6-7 inches
8-12%	8+ inches

How to Determine the Soil Type in Your Rain Garden:

1. Grab a handful of moist soil and roll it into a ball in your hand.
2. Place the ball of soil between your thumb and the side of your forefinger and gently push the soil forward with your thumb, squeezing it upwards to form a ribbon about ¼" thick.
3. Try to keep the ribbon with a uniform thickness and width. Repeat the motion to lengthen the ribbon until it breaks under its own weight. Measure the ribbon and evaluate according to these specifications:
    a. Sand: soil does not form a ribbon at all
    b. Silt: soil forms a weak ribbon <1.5" before breaking
    c. Clay: soil forms a ribbon >1.5" long

How to Determine the Size Factor of Your Rain Garden:

1. Locate the soil type of your rain garden on the left hand column of the table below: Sand, Silt, or Clay.
2. Locate the depth you calculated for your rain garden in the second row of the table below: 3-5 inches, 6-7 inches, or 8+ inches.
3. Identify where the soil type and depth intersect in the table to find the proper size factor for your garden.
4. Use this number in the equation below to determine the appropriate size of your rain garden.

Soil Type	Depth		
	3-5 inches	6-7 inches	8+ inches
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DO NOW:

Compare the benefits of living shorelines and bulkheads.

EXIT TICKET:

How do plants help reduce flooding?