Student Handout

Name: ___________________________________

Background: The stability of the shoreline is dependent on many different factors. However, it is often desirable to simplify complex processes to numerical values that can easily be compared and ranked. The ability to rank locations with high or low risk factors allows them to be managed more efficiently by directing resources to the areas that are at the highest risk. The U.S. Geological Survey has created a rating system to assess the vulnerability of our shorelines to future rises in sea level based on 6 variables- geomorphology, slope, relative sea-level change, erosion/accretion rates, tide range, and wave height (Thieler and Hammar-Klose 1999). Each factor is briefly described below. The ranking is called the Coastal Vulnerability Index or CVI. A high score identifies areas at risk for erosion and a low score identifies areas that are stable. Throughout this exercise you will use this model as a framework to evaluate the vulnerability of different sites to future erosion.

CVI Variables

Geomorphology: Coastlines are made of many different materials and have varying shapes. These differences make some regions more vulnerable to erosion by waves and sea level rise. Coastlines with coarse sand or cobbles are more resistant to erosion than sandy beaches. Large waves can easily wash over low-lying barrier islands during a storm; whereas, a high, rock cliff will stabilize the shoreline.

Coastal Slope: The slope of the coast affects how quickly the area will be flooded as sea level rises. Beaches with a low slope (nearly flat) will retreat landward quickly as sea level rises. The shoreline will retreat more slowly if the coastal slope is steep (high) (Figure 1).

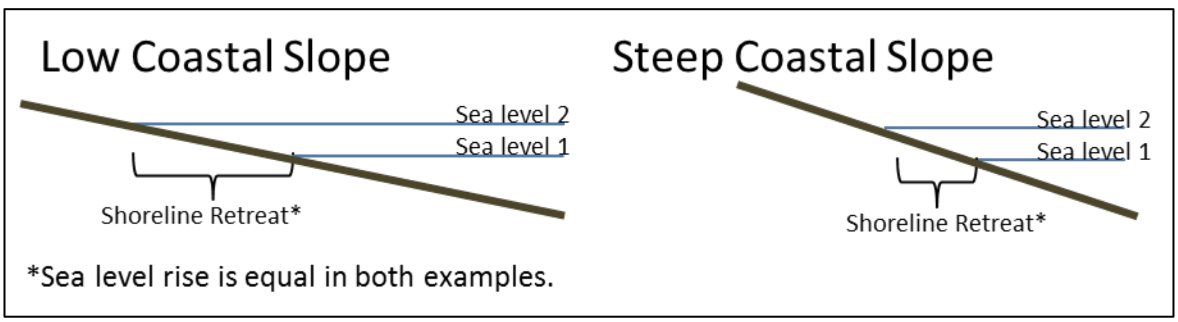

Figure 1. Example of the impact of coastal slope on erosion caused by sea level rise.

Relative Sea Level: High rates of relative sea level will flood low-lying areas rapidly. Accelerated rates of sea level rise also put vulnerable habitats, such as marshes, at risk.

Erosion/Accretion Rate: Historical changes in the shoreline are a good indication of what may happen in the future. Regions with high erosion rates will likely continue to experience high rates or erosion.

Tide Range: Regions with a small tidal range are more sensitive to erosion during storms. In areas with a small tidal range, the typical sea level is relatively stable. Even small increases in sea level caused by the storm surge can have a large impact because the waves will reach areas generally not flooded (Figure 2). In areas with a large tidal range, there is a chance the storm surge will arrive during low tide and the storm surge water elevation will not exceed the typical high tide water level. This will help protect the beach.

Wave Height: Larger waves have more energy than smaller waves and have the ability to move more sand offshore. This will cause more erosion.

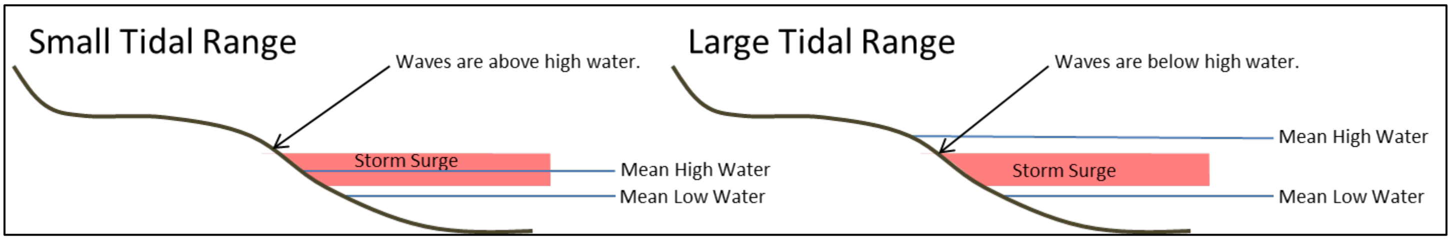

Figure 2. Example of the impact of tidal range on erosion.

Objective: Compare two coastal sites, calculate the erosion rate, and examine the variables that affect the shoreline stability in each location.

Data Layers

Wave Height	National Data Buoy Center http://www.ndbc.noaa.gov/
Tide Range and Rate of Sea Level Rise	NOAA Tides and Currents http://tidesandcurrents.noaa.gov/
Historical Shorelines	The National Assessment of Shoreline Change: A GIS Compilation of Vector Shorelines and Associated Shoreline Change Data for the New England and Mid-Atlantic Coasts: http://pubs.usgs.gov/of/2010/1119/data_catalog.html

Getting Started

Download and open the associated Google Earth File.

Data Collection and Analysis

1. Begin by collecting the data needed for Virginia. The first variable in the CVI is geomorphology. Double-click on the Virginia placemark to navigate to the area. Examine the area using Google Earth. Choose a geomorphology category described in Table 1. Your choices are:
   - *Rocky, cliffed coast*
   - *Medium cliffed coast, indented shoreline*
   - *Low cliffs*
   - *Cobble beach, estuary, or lagoon*
   - *Barrier beach, sand beach, salt marsh, mud flat, delta, mangrove, or coral reef*

   Recorded the value (description) and ranking (1-5) in Table 2.
2. The next variable is coastal slope. The figure 3 shows the offshore bathymetry for Virginia. Use this data to calculate coastal slope. The slope is calculated as:

$$\text{slope}(\%) = \frac{\text{change in elevation}}{\text{distance}} * 100$$

   The units must all be the same. Record the percent slope in Table 2 under 'value'. Use Table 1 to determine the coastal slope *ranking*. Record ranking in Table 3 under 'ranking'.

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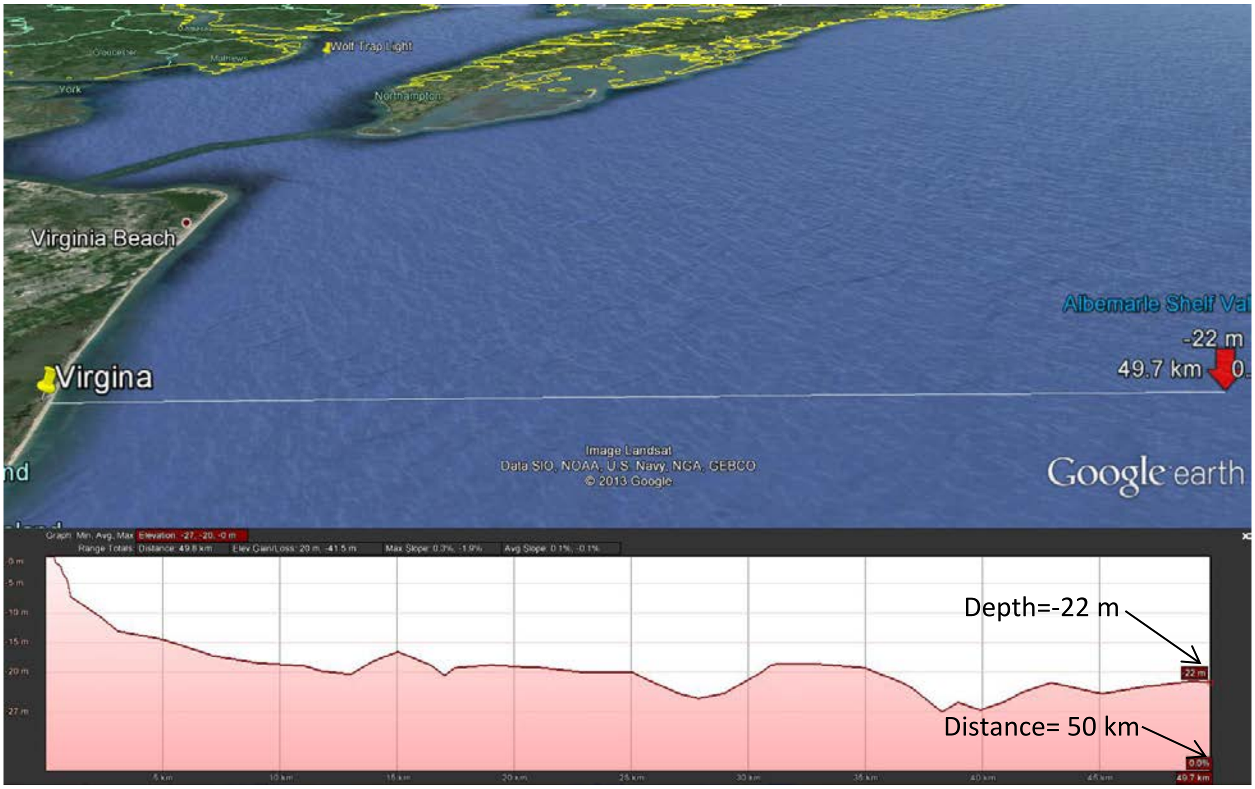

Figure 3. Virginia Offshore Profile

3. Locate the two NOAA tide stations closest to the site. You will need to zoom out to see the tide stations. It may help to expand the NOAA Tide Stations folder so you know what symbol to look for. The site is almost equidistance from the tide station on the Chesapeake Bay Bridge and at Duck NC. Click on the Station and follow the link. The mean tide range is listed on this page in feet. Find the tidal range for the Chesapeake Bay Bridge and at Duck NC. Because the site in in between the two stations average the values. Convert the value to meters (feet* 0.3048=meters) and record the range in Table 2 under 'value' and then record the 'ranking'.
4. Next, you will find the sea level rise at the two tide Stations. Follow the link to the tide station and click the 'Tides/Water Levels' tab. From the drop-down menu select 'Sea Level Trends'. This page will show you the rate of sea level rise. Average the rate of sea level rise just like you did for the tide range. Record the values and ranking in Table 1.
5. Return to the map. Locate the Chesapeake Light wave buoy (CHLV2) offshore of Virginia Beach (the red triangle). If you are having trouble locating the buoy, double-click on the place marker in 'my places'. The wave buoy is in the NBDC Wave Station folder. Click on the buoy and follow the link to the data. Scroll all the way to the bottom of the page and follow the hyperlink for 'Historical Data & Climatic Summaries'. Choose the climatic summary table for '*significant wave height*'. This graph shows the monthly average wave height. For each month the maximum/minimum wave height (the upper/lower most data point), the mean wave height (the center data point), and 1 standard deviation (the red bar) are shown. Estimate the mean annual wave height from the chart. Record the value and rankings in Table 1.
6. The next step is to calculate the erosion/accretion rate. The rate of shoreline change is the change in shoreline location measured as a distance divided by the time.

$$\frac{\text{Change in Location (m)}}{\text{Time (yrs)}} = \text{rate of change (m/yr)}$$

Zoom to the place marker for Virginia. Turn on the VA USGS Shoreline Data. There should be a legend in the bottom left-hand corner. Zoom on close enough to see the individual shorelines. Measure the distance between the location of the shoreline in 1859 and 1997 using the ruler tool. You can check the dates by clicking on the shoreline. Measure the distance in meters. When you record the rate of change note the direction the shoreline is migrating. If it is migrating landward, the beach is eroding and the rate is negative. If the shoreline is moving seaward, the beach is growing and the rate is positive. Calculate the rate of change and record the value in Table 2. Add in the ranking also.

7. Repeat the data collection process for Kennebunkport, ME. Double-click on the placemark for Kennebunkport to zoom to the location.
    a. Use Figure 4 to calculate the slope.
    b. Use the Wells tide station (8419317) for the tide range. It is south of Kennebunkport along the coast. You will need to zoom out to see it.
    c. Use the Portland tide station (8418150) for the sea level trend. It is north of Kennebunkport.
    d. Use the Portland wave buoy (station 44007) for the wave data. You may need to zoom out to see the buoy.
    e. Find the rate of shoreline change between 1870 (black) and 2000 (red).

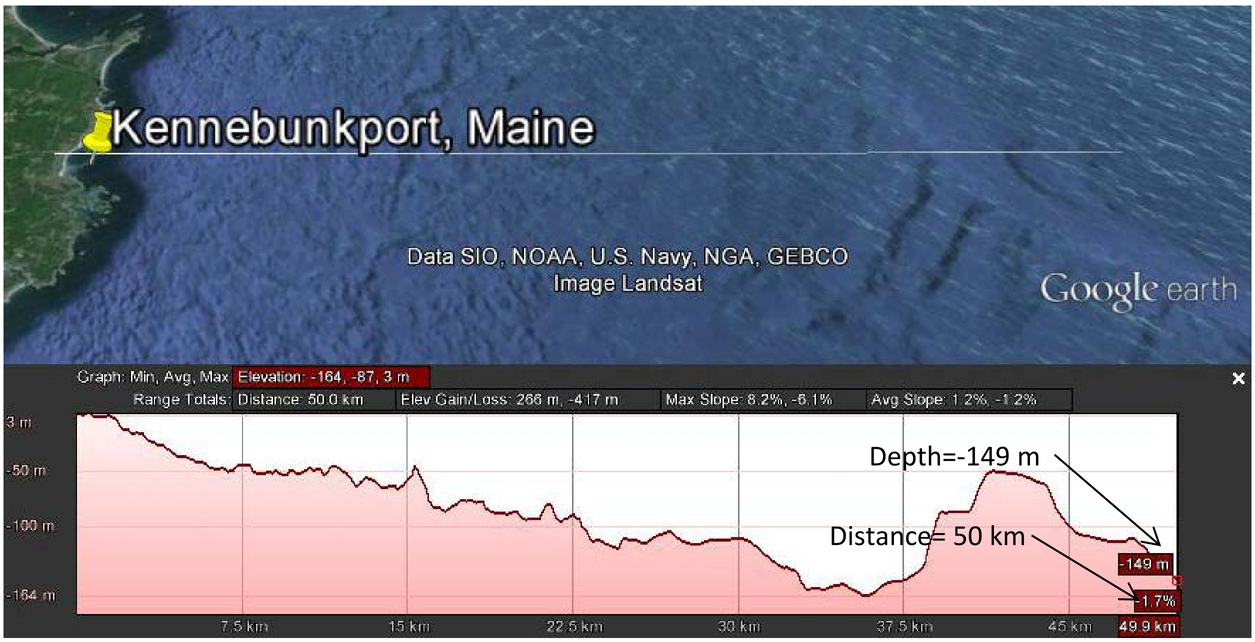

Figure 4. Kennebunkport Offshore Profile

8. Once Table 2 is complete, calculate the CVI for each site using the formula below:

$$\mathrm{CVI} = \sqrt{((a * b * c * d * e * f)/6)}$$

where,
- a = geomorphology
- b = coastal slope
- c = relative sea-level rise rate
- d = shoreline erosion/accretion rate
- e = mean tide range
- f = mean wave height

Table 2. CVI Ranking System (from Thieler and Hammar-Klose 1999)

	Very low	Low	Moderate	High	Very high
	Ranking of coastal vulnerability index				
VARIABLE	1	2	3	4	5
Geomorphology	Rocky, cliffed coasts Fiords Fiards	Medium cliffs Indented coasts	Low cliffs Glacial drift Alluvial plains	Cobble beaches Estuary Lagoon	Barrier beaches Sand Beaches Salt marsh Mud flats Deltas Mangrove Coral reefs
Coastal Slope (%)	> .2	.2 – .07	.07 – .04	.04 – .025	< .025
Relative sea-level change (mm/yr)	< 1.8	1.8 – 2.5	2.5 – 2.95	2.95 – 3.16	> 3.16
Shoreline erosion/ accretion (m/yr)	>2.0 Accretion	1.0 – 2.0	-1.0 – +1.0 Stable	-1.1– -2.0	< - 2.0 Erosion
Mean tide range (m)	> 6.0	4.1 – 6.0	2.0 – 4.0	1.0 – 1.9	< 1.0
Mean wave height (m)	<.55	.55 – .85	.85 – 1.05	1.05 – 1.25	>1.25

Table 3. CVI for Virginia Beach and Kennebunkport

Variable	**Virginia**		**Kennebunkport, Maine**	
	Value	*Ranking*	*Value*	*Ranking*
Geomorphology				
Coastal Slope				
Relative Sea Level Rise				
Erosion/Accretion				
Mean Tide Range				
Mean Wave Height				
	Overall CVI		**Overall CVI**	

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Summary Questions

1. Explain how each of the variables below affects shoreline stability.

   Geomorphology

   Coastal Slope

   Relative Sea Level

   Historical Erosion/Accretion

   Tide Range

   Wave Height

2. Which location, Virginia or Kennebunkport, is more stable?

3. Which parameter(s) made Virginia most vulnerable to erosion?

4. The wave height is similar at both locations but Virginia has experienced more erosion. Why?

5. Explain why it is useful to provide a numerical ranking for coastal vulnerability to shoreline erosion.

References

Thieler, E. Robert and Erika S. Hammar-Klose. 1999. *National Assessment of Coastal Vulnerability to Sea-Level Rise: Preliminary Results for the U.S. Atlantic Coast, U.S. Geological Survey Open-File Report 99-593*. Woodshole, MA: U.S. Geological Survey. http://pubs.usgs.gov/of/1999/of99-593/