

Coastal Landforms, Waves, and Tides

Goals: After completing this lab, you will be able to:

- Using Google Earth, identify and explain processes associated with coastal landforms and processes.
- Identify the component portions and areas of ocean waveforms.
- Explain the difference between a deep-water wave and a shallow-water wave.
- Classify a wave as a deep-water, shallow-water, or in-transition wave by calculating the ratio of its wavelength to water depth.
- Calculate deep-water wave velocities using periods and wavelengths.
- Calculate shallow-water wave velocities using ocean depths.
- Calculate arrival times for a tsunami for various locations around the Indian Ocean.
- Distinguish between Mean Lower Low Water (MLLW) and Mean Sea Level (MSL) in reference to tidal datums.
- Build tidal prediction graphs for Bar Harbor, Maine, and describe the plotted tidal patterns.

Key terms and concepts:

- | | | |
|---------------------|-------------------------------|------------------|
| • barrier island | • marine terrace | • tombolo |
| • baymouth bar | • Mean Lower Low Water (MLLW) | • wave crest |
| • deep-water wave | • Mean Sea Level (MSL) | • wave-cut bench |
| • embayment | • sandspit | • wave height |
| • emergent coast | • sea stack | • wavelength |
| • groin | • seawall | • wave period |
| • headland | • shallow-water wave | • wave trough |
| • jetty | • submergent coast | |
| • longshore current | • tide | |
| • longshore drift | | |

Required materials:

- Calculator
- High-speed Internet connection (for Module 1) and Google Earth (free download at <http://www.google.com/earth/download/ge/agree.html>)
- Textbook: *Living Physical Geography*, by Bruce Gervais



Problem-Solving Module #1: Coastal Landforms

Download the following file from the textbook companion site and open it within Google Earth:

- Coastal Landforms.kmz

Use the above Google Earth file to answer questions 1–13.

1. Fly to location marker A. What is this landform called, and what can we say about the rock's resistance to erosion compared to adjacent locations?

2. Fly to location marker B. Name this coastal landform, and explain how it is different from a tombolo.

3. Fly to location marker C. What is this landform called, and what protects it on two sides?

4. Fly to location marker D. This is a seawall in Japan. What is it designed to do?

5. Fly to location marker E. What is this landform called, and what is it designed to do?

6. Fly to location marker F. What is this landform, and how is it related to a sea arch?

7. Fly to location marker G. What is this landform called, and what is it designed to do?

8. Fly to location marker H. This is a marine terrace. What does its presence indicate has happened to the coastline?

9. Fly to location marker I. What is this landform, and how did it form?

10. Fly to location marker J. What is this landform called, and what four physical geographic conditions must be met in order for it to form? *Hint: See textbook, Section 19.2.*

11. Fly to location marker K. What is this landform called, and how is it formed? What has formed behind this landform?

12. Fly to location marker L. This is a wave-cut bench. What tectonic process will allow it to become a marine terrace? *Hint: See textbook, Section 19.2.*

13. Fly to location marker M. This is a sea arch (click on the photo links to see various images). How was this formed, and what will it become when it collapses?

Problem-Solving Module #2: Waves

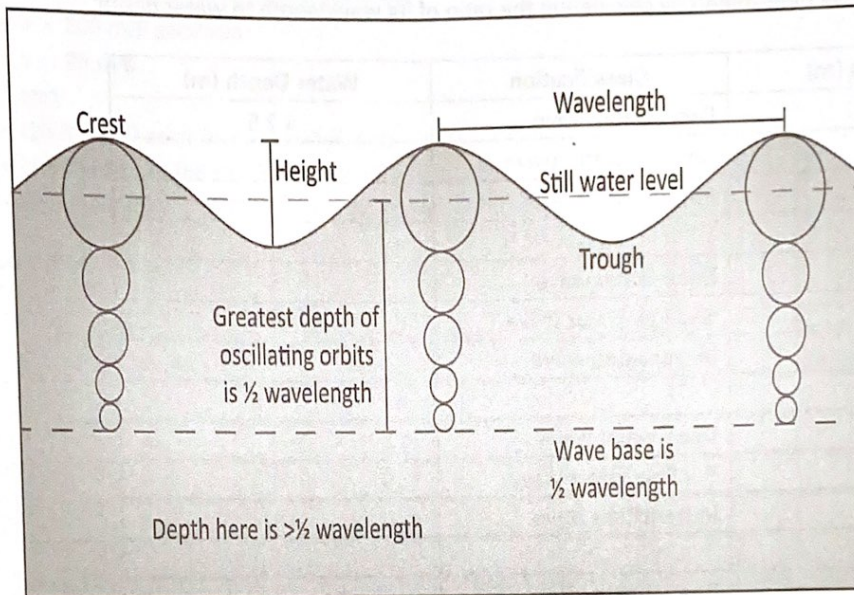


FIGURE 2-1

Use Figure 2-1 to define the following terms in your own words.

1. Wave height

2. Wavelength

3. Crest

4. Trough

A deep-water wave is a wave in water deeper than $\frac{1}{2}$ its wavelength. Figure 2-1 shows deep-water waves. A shallow-water wave is a wave in water shallower than $\frac{1}{20}$ th (0.05) of its wavelength. Shallow-water waves begin to "feel bottom" as their lowest oscillating orbits are flattened by the rising ocean floor as a wave approaches a coastline. For example, consider a wave with a wavelength of 18 meters:

- In water > 9 meters deep, this is a deep-water wave ($18/2 = 9$).
- In water < 90 cm deep, this is a shallow-water wave ($18 \times 0.05 = 0.9$ of a meter, or 90 cm).
- In water between 9 meters and 90 cm deep, it is in-transition as it approaches a coastline.

5. Complete Table 2-1. Remember that classifying a wave as deep-water, shallow-water, or in-transition is always determined by calculating the ratio of its wavelength to water depth.

Wavelength (m)	Classification	Water Depth (m)
5	Deep-water wave	> 2.5
5	Shallow-water wave	
5	In-transition wave	
78	Deep-water wave	
78	Shallow-water wave	
78	In-transition wave	
14	Deep-water wave	
14	Shallow-water wave	
14	In-transition wave	
103	Deep-water wave	
103	Shallow-water wave	
103	In-transition wave	

TABLE 2-1

Tsunamis are waves generated by the sudden displacement of water. They have wavelengths between 10 to 500 kilometers, travel at jet-speed, and obliterate coastal communities when they come ashore. Given these characteristics, it may seem odd that tsunamis are classified as "shallow-water waves."

6. Complete Table 2-2.

Tsunami Wavelength (km)	Tsunami Wavelength (m)	Depth of Water Required for Deep-Water Classification (m)	Average Ocean Depth (m)
	50,000		4,267
77			4,267
	143,000		4,267
200			4,267

TABLE 2-2

7. Why is it impossible to classify tsunamis as "deep-water waves"?

A wave's period is the time for consecutive crests to pass a fixed point. Wave period is normally measured in seconds. If we know a deep-water wave's period (T) and its wavelength (L), recorded in meters, we can calculate its velocity in meters/second using the formula below. In the formula, remember that " V " means velocity in meters per second.

$$V = L / T$$

For example, a deep-water wave has a period of 8 seconds and a wavelength of 200 meters. The velocity of this wave is 25 m/s, or 90 km/hr, because:

- $V = 200 \text{ m} / 8 \text{ seconds}$
- $V = 25 \text{ m/s}$
- and
- $(25 \text{ m/s})(60 \text{ sec/min}) = 1,500 \text{ m/min}$
- $(1,500 \text{ m/min})(60 \text{ min/hr}) = 90,000 \text{ m/hr}$
- $(90,000 \text{ m/hr}) / (1,000 \text{ m/km}) = 90 \text{ km/hr}$

8. Complete Table 2-3.

Deep-Water Wave Wavelength (L)	Deep-Water Wave Period (T)	Deep-Water Wave Velocity (m/s)	Deep-Water Wave Velocity (km/hr)
10	2		
95	7.2		
290	13.6		
452	16.3		

TABLE 2-3

9. Describe the general relationship between the values in the first two columns in Table 2-3.

Determining the velocity of shallow-water waves requires using a different formula. All we need to know is a wave's depth (d) in meters. In the formula, remember that 3.13 is a constant and that "V" means velocity in meters per second.

$$V = 3.13 \sqrt{d}$$

For example, a shallow-water wave in 3.5 m deep water has a velocity is 5.9 m/s, or 21.2 km/h, because:

- the square root of 3.5 = 1.87, so
- $V = 3.13 \times 1.87$
- $V = 5.9 \text{ m/s}$
- and
- $(5.9 \text{ m/s})(60 \text{ sec/min}) = 354 \text{ m/min}$
- $(354 \text{ m/min})(60 \text{ min/hr}) = 21,240 \text{ m/hr}$
- $(21,240 \text{ m/hr}) / (1,000 \text{ m/km}) = 21.2 \text{ km/hr}$

10. Complete Table 2-4.

Shallow-Water Wave Depth (d)	Shallow-Water Wave Velocity (m/s)	Shallow-Water Wave Velocity (km/hr)
1.7		
2.6		
3		
3.2		
4		

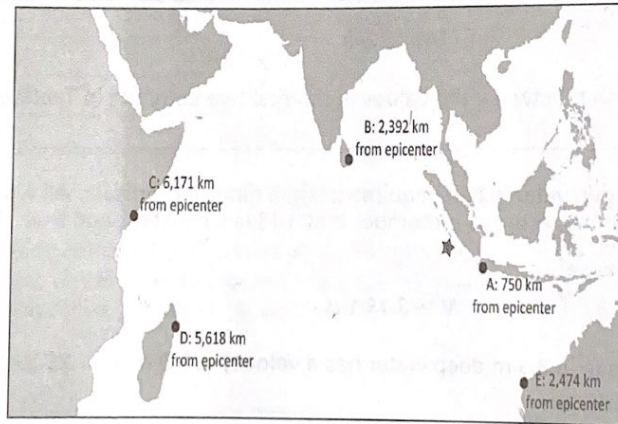
TABLE 2-4

11. Describe the general relationship between the values in the first two columns in Table 2-4.
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Assume you work as an oceanographer at a tsunami warning center. Your job is to warn coastal communities of approaching tsunamis so evacuations can begin. One afternoon a very large earthquake occurs along the Great Sumatran Fault. Buoys in the Indian Ocean sense a tsunami and transmit the data to satellites and then to you. You need to call your colleagues around the Indian Ocean to tell them how much time they have before the tsunami strikes their coastlines. *Note: For this exercise, assume the Indian Ocean's depth is the average depth of Earth's oceans.*

12. What formula should you use to calculate the velocity of this tsunami?
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13. How fast is this tsunami traveling in m/s and km/hr? Be sure to show your work.
Hint: See Table 2-2 for Earth's average ocean depth.
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Research from NOAA

FIGURE 2-2

14. A Boeing 747-400 has a cruise speed of 920 km/hr. In percentage terms, how fast is the tsunami compared to the cruising speed of a Boeing 747-400?
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15. Use an atlas and the information on Figure 2-2 to complete Table 2-5.

Location	Country	Hours and Minutes Before Tsunami Arrives
A		
B		
C		
D	Madagascar	7 h, 38 m
E		

TABLE 2-5

Problem-Solving Module #3: Tidal Datums

The National Ocean Service uses a 19-year-long temporal window (called a Tidal Datum Epoch) to observe tidal heights and reduce these data to obtain mean values for tidal datums. Tidal datums are standard elevations. They are determined by recording and calculating elevations for specific phases of a tide. There are over a dozen tidal datums available, but two common ones are Mean Lower Low Water (MLLW) and Mean Sea Level (MSL). The following definitions are taken directly from NOAA.

- **Mean Lower Low Water (MLLW):** "The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch"
- **Mean Sea Level (MSL):** "The arithmetic mean of hourly heights observed over the National Tidal Datum Epoch"

1. Tables 3-1 and 3-2 present real, future NOAA tide predictions (in meters) for Bar Harbor, Maine, on October 6 and 7, 2015. Notice that the data in Table 3-1 are relative to the Mean Lower Low Water (MLLW) datum, while the data in Table 3-2 are relative to the Mean Sea Level (MSL) datum. For Tables 3-1 and 3-2, identify if a tide is "High" or "Low" in the last column of each table.

Date	Day	Time	Prediction (m)	High or Low
October 6, 2015	Tuesday	12:12 a.m.	0.13	
October 6, 2015	Tuesday	6:27 a.m.	3.09	
October 6, 2015	Tuesday	12:37 p.m.	0.37	
October 6, 2015	Tuesday	6:49 p.m.	3.26	
October 7, 2015	Wednesday	1:14 a.m.	0.18	
October 7, 2015	Wednesday	7:28 a.m.	3.09	
October 7, 2015	Wednesday	1:38 p.m.	0.36	
October 7, 2015	Wednesday	7:49 p.m.	3.24	

TABLE 3-1: Tide Predictions for Bar Harbor, Maine, October 6 and 7, 2015
(Meters Relative to the Mean Lower Low Water—MLLW—Datum)

Date	Day	Time	Prediction (m)	High or Low
October 6, 2015	Tuesday	12:12 a.m.	-1.6	
October 6, 2015	Tuesday	6:27 a.m.	1.36	
October 6, 2015	Tuesday	12:37 p.m.	-1.36	
October 6, 2015	Tuesday	6:49 p.m.	1.53	
October 7, 2015	Wednesday	1:14 a.m.	-1.55	
October 7, 2015	Wednesday	7:28 a.m.	1.36	
October 7, 2015	Wednesday	1:38 p.m.	-1.36	
October 7, 2015	Wednesday	7:49 p.m.	1.51	

TABLE 3-2: Tide Predictions for Bar Harbor, Maine, October 6 and 7, 2015
(Meters Relative to the Mean Sea Level—MSL—Datum)

2. How many high tides and low tides does Bar Harbor, Maine experience on a daily basis?

3. If you make a graph of Table 3-1 (tides relative to the MLLW datum), would you place the "0 meters" value at the bottom, middle, or top of the y-axis?

4. If you make a graph of Table 3-2 (tides relative to the MSL datum), would you place the "0 meters" value at the bottom, middle, or top of the y-axis?

5. On Figure 3-1, create a graph of the data on Table 3-1. Be sure to demarcate and label the y-axis.

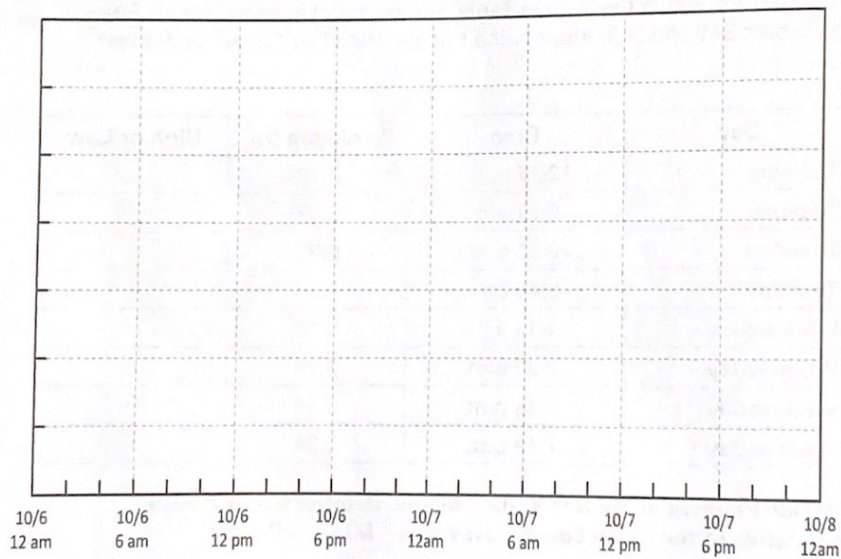


FIGURE 3-1: Tide Prediction Graph for Bar Harbor, Maine, October 6 and 7, 2015 (Meters Relative to Mean Lower Low Water—MLLW)

6. Describe the tidal pattern that you graphed in Figure 3-1.

7. On Figure 3-2, create a graph of the data on Table 3-2. Be sure to demarcate and label the x- and y- axes.

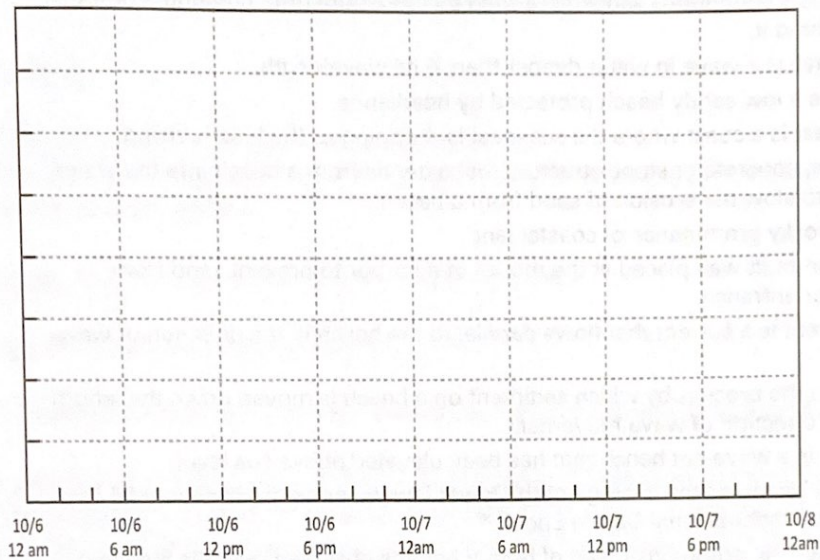


FIGURE 3-2: Tide Prediction Graph for Bar Harbor, Maine, October 6 and 7, 2015 (Meters Relative to Mean Sea Level—MSL)

8. Describe the tidal pattern that you graphed in Figure 3-2.

9. Explain what "0 meters" means for the MLLW tidal datum compared to the MSL tidal datum and which one illustrates a low water level that is physically lowest. Which tidal datum would you rely on if you were a boat captain in Bar Harbor, Maine and wanted to avoid running aground? Explain why.

Summary of Key Terms and Concepts:

- A barrier island is an offshore sand bar that runs parallel to the coast.
- A baymouth bar is a continuous sandspit formed by longshore drift, creating a brackish water lagoon behind it.
- A deep-water wave is a wave in water deeper than $\frac{1}{2}$ its wavelength.
- An embayment is a low sandy beach protected by headlands.
- An emergent coast is a coast where the sea level is dropping or the land is rising.
- A groin is a linear, concrete or stone structure that extends from a beach into the water and is designed to slow the erosion of sand from a beach.
- A headland is a rocky prominence of coastal land.
- A jetty is a human-built wall placed at the mouth of a harbor to prevent sand from closing the harbor entrance.
- A longshore current is a current that flows parallel to the beach in the direction of wave movement.
- Longshore drift is the process by which sediment on a beach is moved down the length of a beach in the direction of wave movement.
- A marine terrace is a wave-cut bench that has been elevated above sea level.
- Mean Lower Low Water is "the average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch."
- Mean Sea Level is "the arithmetic mean of hourly heights observed over the National Tidal Datum Epoch."
- A sandspit is an elongated dry bar of sand that extends from a beach out into the water usually parallel with the shore.
- A sea stack is a steep or vertical column of rock found near coasts.
- A sea wall is a concrete wall designed to protect backshore environments from wave erosion during large storms.
- A shallow-water wave is a wave in water shallower than $\frac{1}{20}$ th (0.05) of its wavelength.
- A submergent coast is where sea level is rising or the land is sinking.
- Tides are the rise and fall of sea level due to the gravitational effects of the Sun and Moon and centrifugal force by Earth's rotation.
- A tombolo is a sand bar that connects an island to the mainland or to another island.
- A wave-cut bench is a flat coastal platform created by erosion from waves and exposed at low tide.
- A wave crest is the highest part of a wave above the still water line.
- Wavelength is the horizontal distance between successive wave crests.
- Wave height is the vertical distance between a wave's crest and trough.
- A wave trough is the lowest part of a wave below the still water line.
- A wave's period is the time for consecutive crests to pass a fixed point and is normally measured in seconds.