Sea Rise Hazards + Ocean Waves Field Trip

We will meet on the **Oceanside Pier** where the wooden part of the pier begins above the beach. (Gather where the asphalt ends and the wooden part of the pier begins.)

Map location: **301 The Strand North, Oceanside, CA 92054**

Please don't be late. Travel time is about 20 minutes from Oceanside campus, and about 30 minutes from San Elijo campus.

There are restrooms down along the beach a short distance south of the pier.

Parking near the pier is **pay parking**, either at meters or at payment kiosks in the parking lots at street level above the pier.

Name ___________________________________

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Part 1: Sea Rise Hazards

In the pre-lab exercise you learned about potential **tsunami hazards** for our coast. Tsunamis, however, are just one of three potential sea rise hazards we will consider in this exercise. The others are **storm surges** and sea rise from long-term **climate change**. Although storm surges from hurricanes are rare in Southern California, such surges have caused major damage and fatalities in other areas of the U.S., and could potentially do so here in the event of a major hurricane. Sea rise from climate change, although comparatively slow, appears to be inevitable and will likely have devastating impacts on our future coastline.

South of the Oceanside Pier is a set of steps and benches. The paved area at the base is approximately 2 meters above sea level at high tide. Your starting point for all your measurements will therefore begin at +2 meters from the base of the steps upward. Each step is 14 cm high, which translates to about 7 steps per 1 meter of rise. Using a meter stick and the 7 steps/meter guide, work with your group to accurately place the markers at the heights of sea rise for the following scenarios:

Tsunamis *(Note: The projected run-ups below are from several different computer-modeling studies; references are listed in the Tsunami pre-lab exercise.)*

3.6 m – projected tsunami run-up based on computer modeling of a 7.6 magnitude earthquake on the Catalina Fault by Catalina Island.

3.5 m – projected run-up based on computer modeling of a 7.5 magnitude earthquake on the Coronado Bank Fault west of San Diego.

4.0 m – projected run-up based on computer modeling of a large undersea landslide in Coronado Canyon or Thirty-Mile Bank.

6.0 m – projected run-up based on computer modeling of a large undersea landslide on the San Pedro Escarpment offshore of the Palos Verdes Peninsula.

10 m – not likely here, but this is the run-up measured from the Japan tsunami of March 2011 along many miles of the Japan coast. (Some areas had run-ups of more than 30 meters!)

Storm Surges

6.0 m – storm surge from 1989 Hurricane Hugo, coast of South Carolina.

6.1 m – storm surge from 2008 Hurricane Ike, Galveston Island, Texas.

7.3 m – storm surge from 1995 Hurricane Opal, Pensacola Beach, Florida.

7.4 m – storm surge from 1969 Hurricane Camille, coast of Mississippi.

8.5 m – storm surge from 2005 Hurricane Katrina, coast of Louisiana and Mississippi.

3.0 m – highest likely storm surge estimated for the Northern San Diego coastline.

Past and Future Sea Rise due to Climate Change

8.0 m – sea level during the last interglacial period 125,000 years ago when average global temperatures were 1 to 2 degrees C warmer than today.

2.6 m – estimated sea level rise by year 2150.

4.9 m – estimated sea level rise by year 2200.

6.8 m – estimated sea level rise by year 2250.

8.0 m – estimated sea level rise by year 2300.

10.5m – estimated sea level rise by year 2350.

Note: The estimates above are from the United Nations International Panel on Climate Change, 2018, based on Antarctic ice melting projections and global warming associated with greenhouse gas emissions.

Questions

Step well back from the steps, look north and south, and imagine the sea reaching the levels indicated by the markers. Describe the effects and damage you would predict from the following levels of sea rise if they were to happen today.

1) 3- to 4-meter rise. What features at beach level would be inundated/swept away? List at least five.

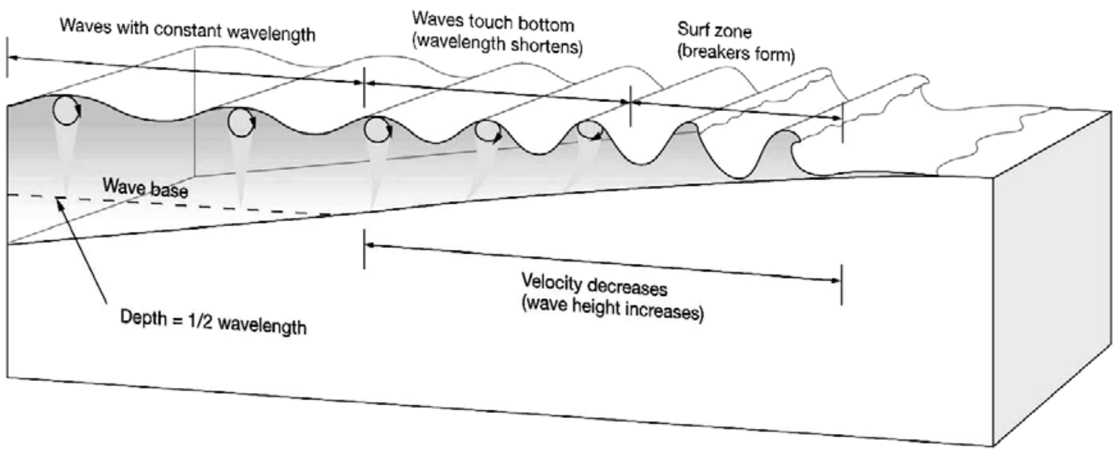
2) 6- to 7-meter rise. How high would the water reach on the buildings at beach level (first floor, second floor, roof)? How high would it reach on the pier?

3) 9- to 10-meter rise. Would the water overtop the pier? Would it reach the street above the beach? What would be the effects on coastal homes and businesses?

Part 2: Measuring Ocean Waves

Ocean waves can be categorized as either **deep water waves** or **shallow water waves.**

Deep water waves: When a wave moves across the ocean surface in deep water, the water doesn't move with the wave. Rather, the water moves in a circle called a **wave orbit** (see figure below). The circular motion of the water near the surface influences the water below it, so the water below also moves in a circular orbit, but with a smaller diameter than the one above. This circular motion becomes smaller and smaller with increasing depth, until it reaches zero at a depth equal to half the wavelength of the wave. This depth is called the **wave base**, and it is <u>always equal to half of the wavelength</u>. Any wave traveling in water <u>deeper</u> than half of its wavelength is called a **deep water wave**. The orbital motion of the wave does not reach the sea floor. Therefore, the wave moves independently of the sea floor, and its speed depends entirely on its wavelength and its period; waves with longer wavelengths and longer periods travel faster than waves with shorter wavelengths and shorter periods.



From Trujillo and Thurman, Essentials of Oceanography

Shallow water waves: Any wave, if it travels far enough, will eventually encounter shallow water near shore. Once the wave enters water where the depth is less than the wave base (i.e. less than half the wavelength of the wave), the wave begins to slow down as the orbital motion of the water below the wave makes contact with the sea floor. Any wave traveling in <u>water shallower than wave base</u> is called a **shallow water wave**. The shallower the water, the slower the wave goes. As waves approach the beach, the waves that are closer to the beach slow down more than those behind them. This causes the waves to "bunch up;" in other words, the wavelengths decrease, which causes the waves heights to increase. Beyond a critical ratio of wave height to wavelength (about 1:7), the waves topple over toward the shore, forming breakers.

Wave variables that you will be measuring in this exercise:
V = wave speed: the speed of the wave, measured in meters per second.
T = wave period: the time between two adjacent crests of the same wave, in seconds.
L = wavelength: the distance between two adjacent crests (or troughs) of the same wave, in meters.

To do the exercise you will need:

- Stopwatch [or any digital watch]
- Markers to track the movement of the waves, such as regularly spaced posts of the pier.
- 30-meter measuring tape

Be sure to measure all distances in <u>meters</u>, and all times in <u>seconds</u>.

1. Pick a start point and end point. The start point must be in an area where the crests are clearly visible. The end point must be in the area before the waves break. Make sure the two points are at least 30 meters apart. Measure the distance between these two points.

   Distance between start point and end point = _______________ meters

2. Follow a wave crest as it passes the pier posts. **Start** the stopwatch as the crest passes the first pier post. **Stop** timing when the crest reaches the second pier post. If the wave breaks before reaching the second post, discard the reading. Repeat measurements for a total of five good wave readings.

	Wave #1	#2	#3	#4	#5	Total
Time [sec]	_______	______	_______	______	______	_____

   Average time taken to travel the distance **s** = Total / 5 ___________ seconds

3. Calculate the **speed** (**V**) of the waves from the numbers in steps 1 and 2 above.

   Average wave speed (V) = **distance** / **average time** = ____________ meters per second

4. Measure the **wave period**. Wait until you see several distinct wave crests coming one after another. **Start** the stop watch when one wave crest passes you. **Stop** the watch when the next crest passes you. Repeat for five different waves.

	#1	#2	#3	#4	#5	Total
Period [sec]	_______	_______	_______	______	______	_____

   Average wave period, **T** = Total / 5 = _____________ seconds

5. Calculate the **wavelength** (**L**) of the waves using the numbers from steps 3 and 4 above.

   Wavelength (L) = **T** x **V** = __________x__________ = _______________ meters

6. The water where we are at the pier is probably no more than <u>three meters deep</u>. Based on the wavelength (**L**) from step 5 above:

   a. Would the waves here be classified as <u>shallow water waves</u> or <u>deep water waves</u>? Explain.

   b. How deep would the water need to be for waves of this wavelength to be considered deep water waves?

   c. What is happening to the following as these waves pass into even shallower water?

      wave speed:

      wavelength:

      wave height:

When waves go from deep water into shallow water, their speed, wavelength and height all change. But one thing that does not change is the **period (T)**.

The fact that the wave period (**T**) stays constant between deep water and shallow water is useful, because the period, speed, and wavelength of deepwater waves correlate closely with one other. By knowing the period (in seconds) we can figure out both the speed (in meters per second) and the wavelength (in meters) of these waves when they were formed by storm winds far out at sea in deep water, as follows:

Deepwater wavelength (L_{deep}) in meters = **$1.56 \times T^2$**

Deepwater speed (V_{deep}) in meters per second = **$L_{deep} \div T$**

7. Using your value of the **period (T)** from step 4 and the formula above, calculate the wavelength of these waves when they were in deep water:

   L_{deep} = _____________ meters

8. Compare the **wavelength** of the waves now (**L** from step 5) to their wavelength when they were in deep water (**L_{deep}** above). How do the values differ, and why do they differ? *Hint: think back to the pre-lab exercise, and/or consider the information about deep water versus shallow water waves on the first page here.*

9. Based on **L_{deep}** above, at what water depth did these waves become shallow water waves as they approached the pier?

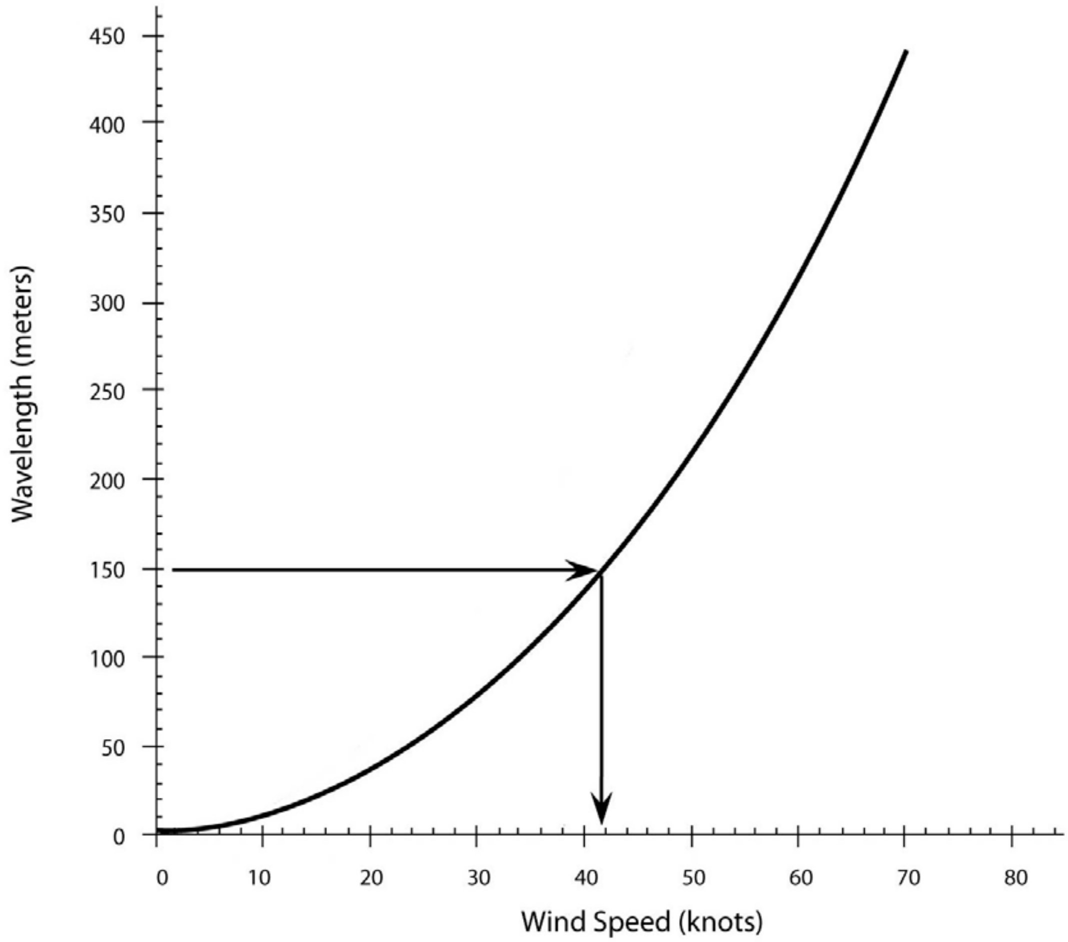
10. Use the formula above and your values of **L_{deep}** and **T** to calculate the speed of these waves when they were in deep water:

    V_{deep} = _____________ meters per second

11. Compare the **speed** of the waves now (**V** from step 3) to their speed when they were in deep water (**V_{deep}**). How do the values differ, and why do they differ? *Hint: think back to the pre-lab exercise, and/or consider the information about deep water versus shallow water waves on the first page here.*

In general, the wavelength, period, and speed of waves in deep water relates to the wind speed that generated the waves. If the fetch and duration of the wind is constant, then stronger winds generate longer waves with longer periods and greater speeds. Use the graph on the next page to estimate **the speed of the wind that generated these waves**, based on your value of wavelength (**L_{deep}**) above.

12. Speed of the wind that generated these waves = _____________ knots



Example (see arrows above): Waves with a 150-meter wavelength can be formed by winds blowing steadily for several days at 42 knots across the open ocean.

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Longshore Current Measurement

Distance that you tracked objects moving with the longshore current: _______________ meters

To calculate the speed of the longshore current, do at least three trials and take the average value.

	trial #1	trial #2	trial #3	Average time [sec]
Time [seconds]	_______	______	_______	__________

Speed of the longshore current in meters per second =
distance (meters) / average elapsed time (in seconds) = ________________ m / sec

Convert the speed above into miles per hour. Take the speed in meters per second, multiply by 3600 seconds/hour and then divide by 1609 meters/mile.

Speed of the longshore current in miles per hour = ________________ mi / hr