Geography Key Stage 3

Investigating waves at Dawlish, Devon: a GIS activity

How are waves formed?

Sea waves are formed by the wind blowing over the sea. Friction with the surface of the water causes ripples to form and these develop into waves. As the waves approach land, the shallowing water causes the waves to grow in height. Eventually they topple and break at the coast.

Why are waves a hazard?

When waves break at the coast, they can cause erosion of natural cliffs or beaches and impact artificial structures such as sea walls causing wave overtopping – fast jests or dense plumes of spray that shoot over the top. At Dawlish, a sea wall has been constructed to protect the mainline railway that connects south-west England to London. On the map below, locate Dawlish between Exmouth and Torquay. Can you spot the railway line (black line)?

The location of Dawlish

Source: **Digimap for Schools**

The Dawlish train line, walkway and sea wall

Source: National Oceanography Centre, CreamT research project 2020

Occasionally, during storms, waves can overtop the sea wall creating dangerous conditions and result in the closure of the railway. In the past, overtopping has resulted in flooding.

In 2014, Storm Petra whipped up powerful waves along the south coast of England. The existing sea defences at Dawlish were breached and the railway line was left dangling in mid-air! It took engineers two months to repair the line during which time the south-west rail network of England was cut off from the rest of the UK.

Damaged railway lines at Dawlish, 2014

Source: Network Rail, https://www.bbc.co.uk/news/uk-england-devon-55939197

How can waves be monitored?

Waves can be monitored using offshore buoys that are tethered to the seabed. They can measure several wave characteristics such as wave height, frequency and direction. Some also measure and record weather information such as wind direction and wind speed. There is a wave buoy just off the coast at Dawlish and a nearby land based met station, in Exmouth, which measures the weather.

A buoy used for monitoring waves

Source: South West Coastal Monitoring

Activities

1. Access real time data for the buoy at Dawlish at https://coastalmonitoring.org/realtimedata/?chart=103 .
   (a) Complete the following table to record some of the information.

Date and time	Wave height (m)	Max. wave height (m)	Peak direction* (degrees)	Sea temperature (C)

**this is the wave direction given in degrees, where north is 0 degrees and south is 180 degrees*

   (b) When was the highest significant wave height* recorded this year and what was its height? **Hs is the significant wave height, which is calculated as the average wave height of the highest one-third of the waves*

   Date: ______________________ Wave height: __________ m

   (c) Scroll down to the graph showing wave height. Describe the pattern of wave heights during the last 24-hours.

   (d) What is the 'storm alert threshold'* when damaging waves are likely to occur?
   ___________ m **This is the Hs with a probability of occurring 4 times a year.*

Why is wave height important?

Wave height is often linked to overtopping – the higher the wave, the greater the likelihood of overtopping. Wave height is determined by three main factors:

- Wind speed
- Wind duration
- Fetch (distance of water over which the wind has blown)

The higher the wind speed, the longer the duration of strong winds and the greater the fetch . . . the higher the waves and the more likely that overtopping will occur.

How can wave overtopping be monitored?

In 2018 the National Oceanography Centre constructed a new measurement system to collect information about waves overtopping structures such as sea walls. The WireWall uses a series of electrical wires to monitor and measure spray from waves, recording the speed and volume of a plume of water as it passes through the structure.

Take a look at how water passes through the system at https://youtu.be/O1MK8WV4S-k.

The WireWall

Source: National Oceanography Centre, WireWall research project 2018/2019

Activities

2. Watch the Wirewall project video at https://youtu.be/a5Y33SWdNU4.
   (a) Why is it important to test WireWall in a laboratory?

(b) How can WireWall help engineers in the design of coastal defences?

(c) How can WireWall be used to give alerts of hazardous conditions?

The CreamT research project, monitoring wave hazard in Dawlish

WireWall was installed on top of the sea wall at Dawlish (where the railway line collapsed in 2014) to study wave overtopping for a year from March 2021 – March 2022. Alongside WireWall the University of Plymouth installed a camera to provide visual information about the overtopping conditions. This research was part of a project called 'CreamT', which stands for "Coastal Resistance: Alerts and Monitoring Techniques". The aim was to test the technology, linking it to live data from wave buoys and thereby creating a hazard alert system.

The research will enable scientists to see how the different combinations of waves, winds and tides interact to change the overtopping hazard to pedestrians walking along the sea wall at Dawlish and the train service running on the track just inland of the walkway. This new understanding will allow Network Rail to refine their hazard response protocols, which is when they apply speed restrictions to the trains, use only the inland rail track and cancel services. When conditions exist that have been known to result in hazardous overtopping, warnings are issued, and action taken.

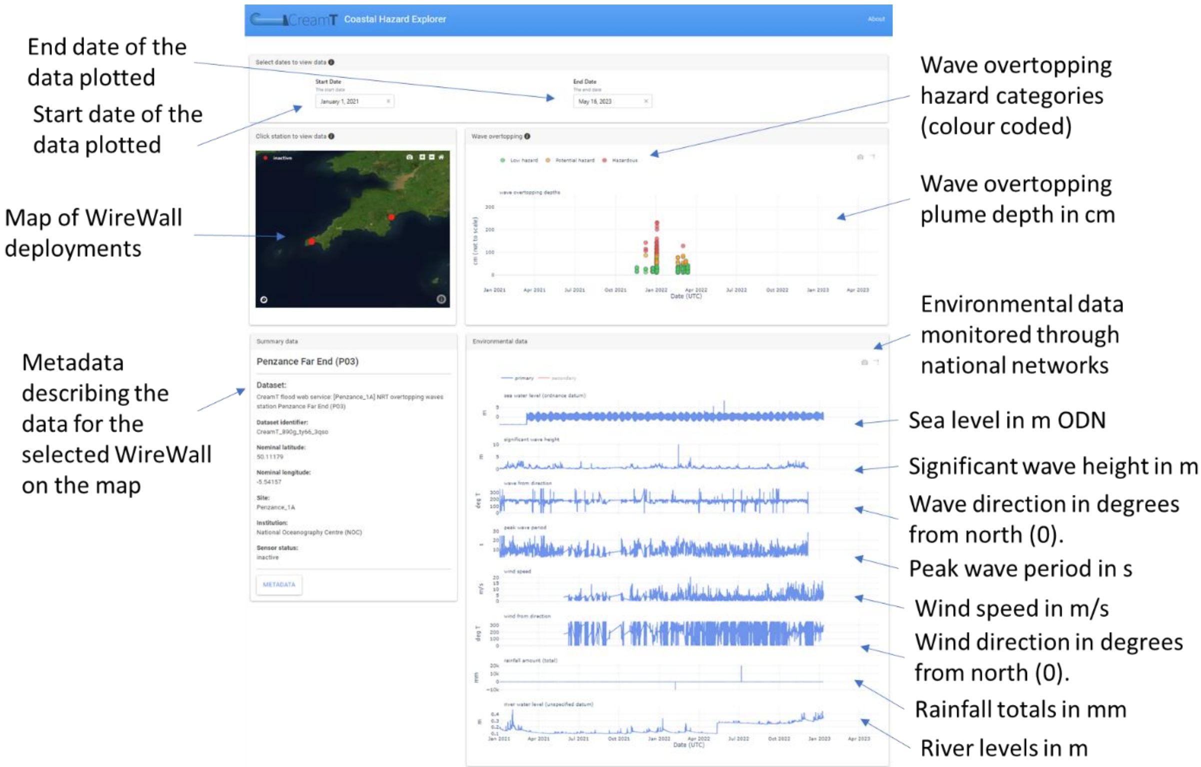
Activities

3. Look at the system in operation during windy conditions at Dawlish at: https://youtu.be/82h0HCcQLkQ. Capture a screenshot of a wave as it overtops the sea wall and paste it below.

Investigating data from the Dawlish WireWall research project

The WireWall data can be accessed at https://coastalhazards.app.noc.ac.uk/. The data dashboard pulls together additional coastal, river and weather information from a variety of sources including the National Network of Regional Coastal Monitoring and the Environment Agency.

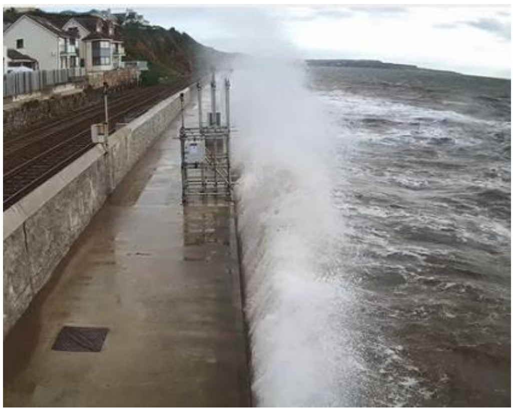
Load the Coastal Hazards Explorer dashboard at https://coastalhazards.app.noc.ac.uk/. Use the following annotated image to help you to explore the site.



Wave overtopping at Dawlish, 7-8 March 2022

In the following activities, you will investigate data on two consecutive days (7-8th March 2022) when overtopping occurred. The University of Plymouth's camera captured the following images at high tide on the mornings of March 7 and March 8.

Overtopping at Dawlish, 7th March 2022



Overtopping at Dawlish, 8th March 2022

Source: University of Plymouth, CreamT research project 2022

Notice that on March 7, the curved return lip of the sea wall was effective in deflecting most of the spray back out to sea. However, on March 8 a lot more spray passed over the sea wall towards the railway line. Let's consider how environmental data can explain why this happened?

Activities

4. Load the Coastal Hazards Explorer dashboard at https://coastalhazards.app.noc.ac.uk/. In the dashboard we need to select the WireWall systems for Dawlish.
   - Zoom in on Dawlish using the map in the left-hand corner of the dashboard. Keep zooming to reveal four red dots in Dawlish representing the different WireWall systems deployed here.
   - Use the mouse to hover over the dots so their names come up. Click on the dot that represents the system at the edge of the sea wall 'Dawlish crest (D03)'. The term 'crest' is the name given to the highest point in the sea wall profile, close to the seaward edge of the wall which has a lip or return curve to direct the uprush from the waves back out to sea.

   - Having clicked the 'Dawlish crest (D03)' dot, the data will load for this location.
   - Set the start date to 1 March 2022 and the end date to 15 March 2022. To look at the environmental data you can hover the mouse over the graph lines and data points to read off the values.

Notice that there are several occasions when overtopping occurs from March 1 to March 3. Then, from the March 4 to the March 6, the wave height becomes very low and overtopping stops (no data are plotted).

(a) Use the mouse to hover over the overtopping data points to find the date when the first **'potential hazard'** overtopping data point occurs after March 5.

Date/time: ___________________ March 6 10:26

Wave overtopping depth*: ____ cm 62.1cm

** Wave overtopping depth is the sum of the individual depths of each individual water droplet in the plume of spray connecting with a WireWall wire. This represents the total depth of the aerated plume of water that is traveling through the air over the sea wall and through WireWall.*

- Without changing the dates, now select the WireWall sensor that is positioned on the wall between the railway line and the walkway 'Dawlish Wall (D02)'. This measures the wave overtopping spray that is traveling across the walkway and potentially impacting passing trains.

Notice that the depth of most of the wave plumes measured are lower. The spray is falling under the influence of gravity as it travels inland. Not all of the water overtopping the crest of the sea wall will reach the railway line wall. This is why there are fewer columns of data points, during some high tides there are no data inland, while there are data at the crest. Let's examine the data more closely.

- Change the start date to the 7 March 2022 and the end date to the 9 March 2022 (don't change the sensor).

(b) Hover over the overtopping data. What is the maximum wave overtopping depth at the railway line wall? When did this occur?

Depth: ______ cm 246.8cm Date/time: ______________________ March 7 20:24

Notice that on the morning of March 7 less overtopping was reaching the railway line wall than in the evening of March 7 and the morning of March 8. The increased overtopping during the second two periods shown on the graph threatened the railway line. Look back to the photos earlier to see overtopping on the mornings of March 7 and March 8.

(c) Use the mouse to hover over the overtopping data. At what time does the maximum depth in the overtopping waves occur during the two periods:
March 7 (06:00 – 12:00) _______ 10:56
March 8 (06:00 – 12:00) _______ 08:39

The reasons for the difference in patterns of overtopping were the result of changes in the environmental (wave and weather) conditions which cause overtopping. Now let's find out how the environmental conditions differed between these two dates.

- Scroll down the hazard dashboard to see several graphs describing the environmental conditions during this period. Notice that they are all drawn to the same scale so they can be directly compared as you scroll up and down.
- Notice that if you hover over each graph, you can see the recorded data values.

(d) Carefully hover over each graph to complete the table below for the times of maximum overtopping on the mornings of March 7 and March 8. This will enable you to compare the environmental conditions associated with each overtopping event.

	March 7 (am)	March 8 (am)
Time of maximum wave overtopping depth	10:56	08:39
Sea water level (m)	1.357m	1.423m
Is the water level close to high tide or low tide?	High	High
Significant wave height (m)	1.4m	1.92m
Wind speed (m/sec)	6.1m/s	6.2m/s
Wind direction	113 degrees (E/SE)	188 degrees (S)

[Note: data is recorded at regular intervals, for example every 15 or 30 mins. Select the data that was recorded closest to the two times of maximum wave overtopping depth]

(e) Calculate the difference in wave height between the two dates?
______ (date) was higher by ______ m March 8 higher by 0.52m

(f) Explain how the difference in wave height accounted for the difference in overtopping between the two dates.

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Higher wave height on March 8 accounts for greater overtopping

Extension activity

You have discovered that wave height can be directly linked to wave overtopping. But what environmental factors may have been responsible for the increased wave height on the morning of March 8?

Wave height is mostly affected by wind speed, wind duration and fetch. Generally, the higher the wind speed, the longer the duration of strong winds and the longer the fetch . . . the higher the waves. At Dawlish, an additional factor is the interference of waves caused by headlands and the shallowing of the seabed, which reduces wave height. The changing water levels due to the tides also change the depth influencing wave breaking.

At Dawlish, the dominant wind direction is from the south-west. Despite the long fetch, waves from this direction lose energy and height due to interference from coastal headlands and seabed shallowing due to nearshore and offshore sand banks. In contrast, when waves approach from the south or south-east, they do so unimpeded and so tend to have more height.

[Source: https://www.scopac.org.uk/sts/ho-sp-literature-review.html]

Using the data, suggest which factors may have resulted in higher waves (and more overtopping) on March 8.