What are storm surges?

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The specification

AQA A Level 3.1.3.4 Coastal management. Sustainable approaches to coastal flood risk.

Edexcel A Level Option 2B.9 Coastal flooding is a significant and increasing risk for some.

OCR A Level 1.a. Coastal landscapes can be viewed as systems.

WJEC A Level 1.1.8 Variations in coastal processes, coastal landforms and landscapes over different time scales

This resource has been produced to mark the 70th anniversary of the 1953 storm surge. It is described as one of the worst peacetime natural disasters of the twentieth century. 307 people died, with some estimates putting the total cost of the damage at approximately £1 billion in today's money.

What are storm surges?

A storm surge is a dangerous rise in sea level which leads to coastal flooding. They are described as deadly because roughly half of the world's 8 billion people live within 100 kilometres of the coast. The UN Millennium Ecosystem Assessment, initiated in 2001, first identified this coastal 'zone' with a distance threshold of 100 kilometres and a 50-metre elevation threshold, choosing whichever was closer to the sea. Increasingly this zone is 'built-up' or urban, natural coastal ecosystems are diminishing (which once acted as a buffer to coastal storms), and impermeable surfaces are increasing.

Key coastal areas are labelled Large Marine Ecosystems (LMEs). In 2010, the 10 most populous (and therefore the most at-risk) were: the Bay of Bengal, South China Sea, Mediterranean Sea, Arabian Sea, Indonesian Sea, Yellow Sea, East China Sea, Kuroshio Current, Caribbean Sea and the Sulu–Celebes Sea.

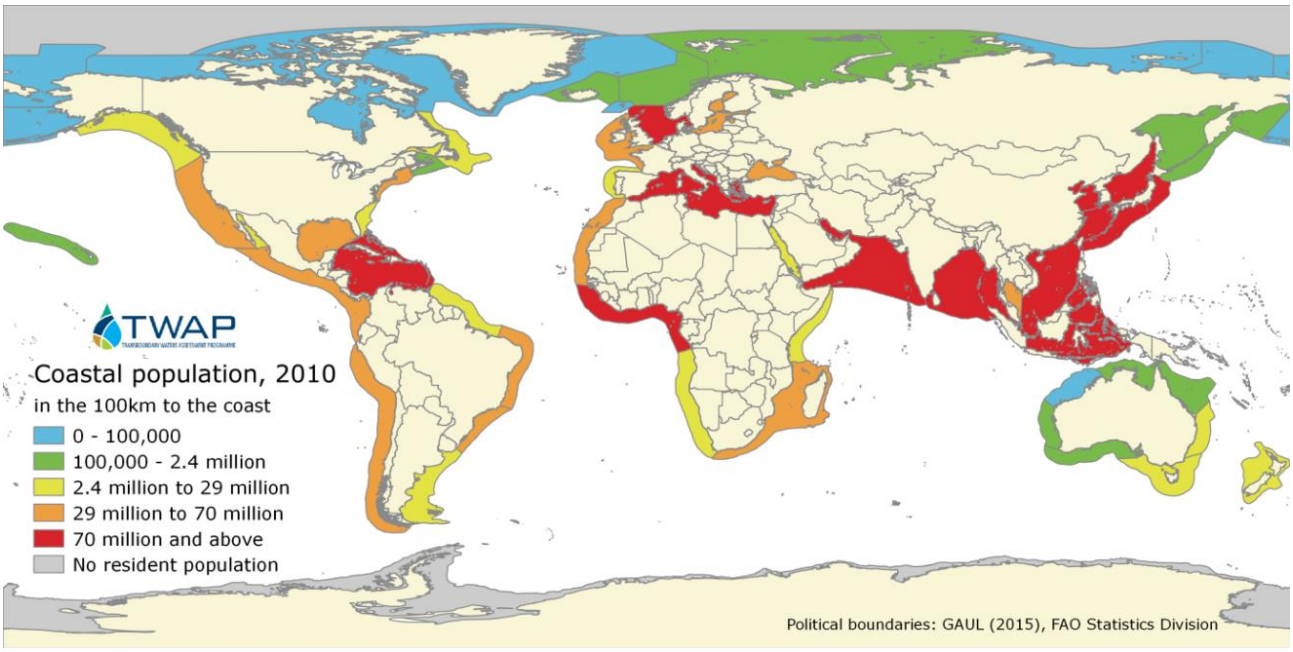

Figure 1 a coastal population world map © TWAP Indicators global maps, 2015

As an island nation, Great Britain has a long coastline. Including islands, there are 31,368km of coast, with the mainland making up 17,819km of that total. Due to low-lying land, particularly in the

east and south-east, some of the country is vulnerable to coastal flooding and storm surges. As a result of this relief, arguably the worst post-war natural disaster occurred in 1953.

What happened in 1953?

Warning signs began on the 31st of January as a low-pressure system moved across the Irish Sea. Sailors reported winds of up to 135 miles per hour, whipping up waves 60 feet high (18m). Tragically, a ferry called the Princess Victoria, which operated between Stranraer and Larne, sank as the stern doors were breached, flooding the car-deck. 133 people drowned.

Over the course of that Saturday night the sea reached a height of 8 metres along the coast of East Anglia. The low-pressure system continued across Great Britain with weather and tidal conditions together creating a storm surge which would later strike the Norfolk, Suffolk, Essex and Kent coastlines the following day, on the 1st of February.

The storm surge claimed the lives of 307 people along England's east coast and made a further 40,000 people homeless. The ultimate reason for such devastation was a lack of preparedness at the national level. At this time, weather forecasting was delivered without satellite information and there was no instantaneous internet communication offering 'real-time' data. Services such as the BBC Shipping Forecast and Met Office were the best source of information for vessels at sea.

Other storm events

Since 1953, there have been multiple low-pressure systems and storm surges around Great Britain. Particularly dangerous events occurred in 1978, 2007, 2013, and 2017. They were all prevented from becoming disasters by sea defences and tidal barriers.

Table 1 shows the barometric data for Manston in Kent for these four low pressure systems. Barometric data is the measurement of air pressure in the atmosphere and is a strong indication of active weather i.e., wind and rain. Storm surges occur from high winds pushing water towards the coast, causing it to pile up there.

As low pressure moves overhead it also creates a phenomenon called 'the inverse barometer effect'. This describes the storm 'pulling up' the water level at a rate of approximately 1cm for every 1 millibar change in pressure, further adding to the storm surge.

In 1982 the Thames barrier was built to protect London from storm surges. The barrier is a retractable defence against high (usually spring) tides, tidal surges, or a high river flow level. In Figure 2, you can clearly see the inverse barometer effect by the difference in water level on either side of the Thames barrier.

The Colne Barrier on the River Colne in Essex is another example of a tidal defence. This structure was installed to protect Colchester upstream.

Both the Thames and Colne successfully withstood the 2013 storm surge which, on 5-6 December 2013, produced the highest still water levels on record at tidal gauges up and down the east coast. This was an event comparable in magnitude to the 1953 storm surge with water levels south of the Humber estuary and on the north-facing Norfolk coast being higher than mid-century. The 2013 event damaged infrastructure, led to localised flooding, and tested sea defences – which held strong.

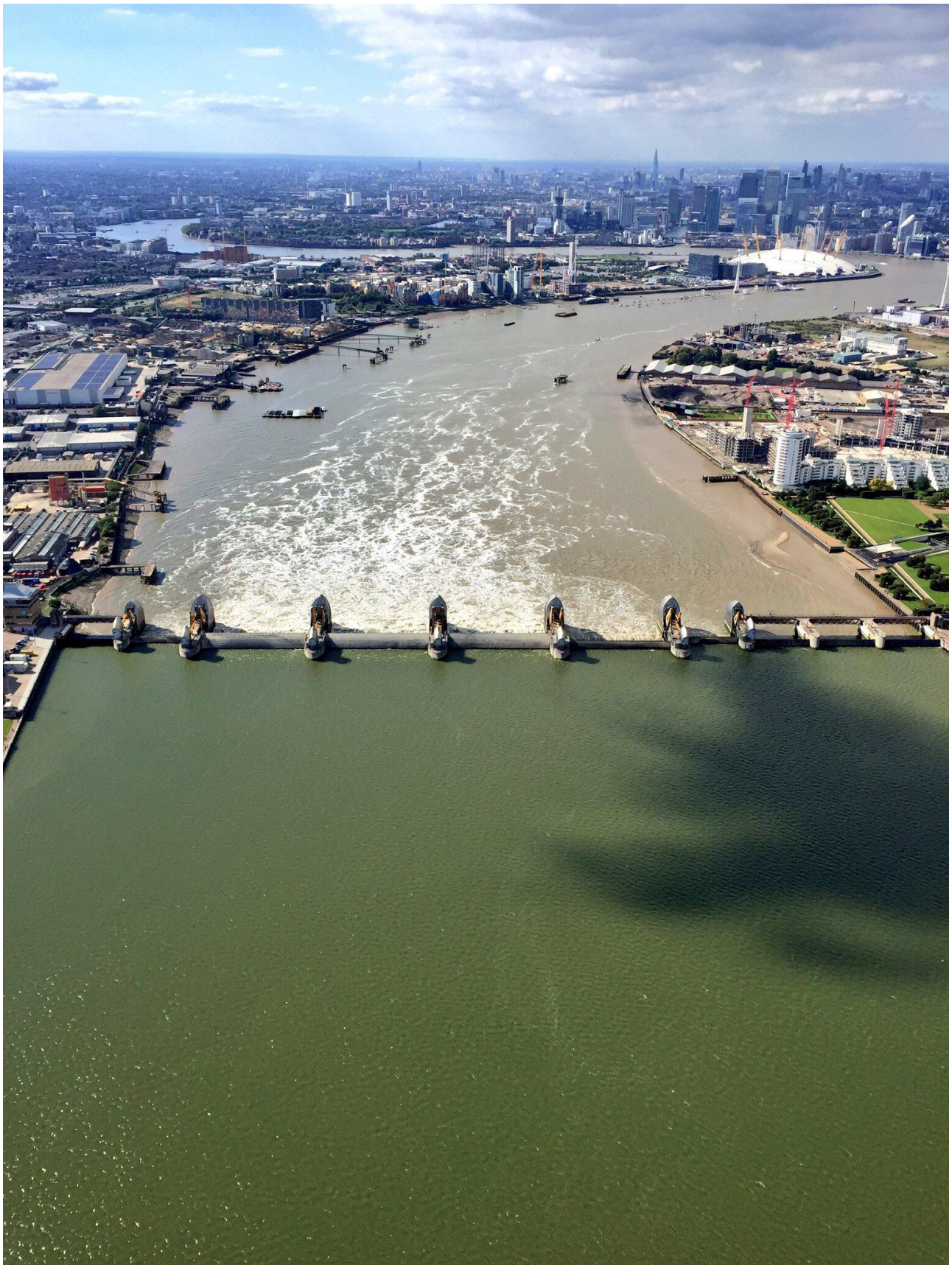

Figure 2 a view of the Thames barrier holding back the 2017 surge © NPAS South East Region

An example of a coastal defence in Essex: the Colne barrier

In spite of the UK weather systems typically approaching from the west and southwest, it is the east coast that has the potential to experience significant or severe coastal flooding. After the 1953 storm surge there has been regular investment in flood defences up England's east coast.

The Colne barrier, on the River Colne in Essex, is an example of coastal engineering. Since 1994, the tidal defence has protected Colchester, further upstream on the River Colne, from storm surges.

Figure 4 the Colne barrier at Wivenhoe © John Fielding Flickr

The urban area of Colchester covers approximately 125 square miles, containing a population estimated at 192,700 (as of 2021). The city population increased by 11.3% (from 173,100) from the 2011 census highlighting the growing popularity of the area – and the need to adequately protect it from the North Sea.

In 1994 it was estimated that the Colne Barrier would close 12 times a year. However, since then the barrier controller at Wivenhoe has been forced to close the gates more than 20 times per annum. In one particularly bad year the record was 70 closures. This is because spring tides are increasing in occurrence, due to global warming. As the planet warms there are more low-pressure systems arriving over the North Sea, triggering high tides and storm surges.

Approximately 2,900 homes are now protected by the barrier in the River Colne catchment, estimated at more than £80 million worth of property.

Figure 5 the Colne barrier looking inland © EA

Figure 6 the sluice gates at Colne barrier © EA

Figure 7 Colne barrier gates © EA

Activity

1. Listen to the testimonials from survivors of the storm surge. Describe the scene which caused one survivor in Sea Palling to exclaim, “I have never forgotten it, whenever the winds blow, it’s the night of the flood again.”

2. Watch the Savage Planet Documentary 1953 Floods until 10:00 and between 16:40-23:08 to answer the following questions.

    a. How many miles of coastline were affected? 0:28
    b. How many people lost their lives? 3:07
    c. What did the U.S. Air Force airman, Reis Leming, do to assist? 4:55
    d. Which two areas were attacked by the storm surge? 9:50
    e. What was the tragedy in Essex? 17:17

3. Using Table 1 in Appendix A, create a line graph for the 4 storm surges that have struck Great Britain over the past 70 years.

4. Study your line graph from question 3. Low atmospheric pressure allows sea level to rise. During day 1, which event saw the fastest drop in hourly pressure?

5. In 2013 a low-pressure system brought particularly bad weather to Great Britain (storm Xaver created a tidal surge and force 12 winds). Does the line graph support this assertion?

6. The Colne Barrier is an example of a tidal defence in Essex. What is a surge barrier?

7. Visit topographic-map.com. Explain why the Colne Barrier is so important in this part of England.

8. Study the 1953 east coast flood charts. A key geographical skill in GCSE geography is the ability to construct, interpret and extract data from different types of maps, graphs, and charts. Can you track the centre of the low-pressure system?

Further reading

- Watch What is a Storm Surge by the Met Office
- NOAA What is a storm surge
- The Loss of the Princess Victoria, Historic UK
- The 1953 Floods in Norfolk, the Cromer Museum
- The Conversation 1953 storm surge: how Britain's worst natural disaster kicked off the debate on climate change
- ScienceDirect Southern North Sea storm surge event of 5 December 2013: Water levels, waves and coastal impacts
- The Guardian Devastation on England's east coast after 1953's 'Big Flood' – in pictures | Environment | The Guardian
- The devastating storm of 1953 The History Press | The devastating Storm of 1953
- The EA Colne Barrier leaflet
- Britannica Natural disaster | Causes, Types, & Facts | Britannica
- BBC 1953 How the UK defences compare with the Netherlands 1953 flood: How UK defences compare with the Netherlands - BBC News
- Lessons of the 1953 storm surge on flood defences Lessons of 1953 spurred spending on flood defences | UK news | The Guardian
- The Daily Echo How Colne Barrier helps protect thousands from flooding
- The Met Office Saturday 31 January 1953 historical weather factsheet pdf
- The Met Office Floods and flooding
- The Met Office National Meteorological Library and Archive n.b. these suggestions are not scanned, and copyright still applies
- SurgeWatch The 2007 storm event
- The Met Office National Climate Information Centre 2013 Historical Weather write up
- The Met Office Shipping Forecasts

- Access The Met Office Daily Weather Reports for 1953, 1978, 2007, 2013 and 2017

Appendix A

		Storm surges			
Duration	Hour	1978 Hourly Pressure at Mean Sea Level (hPa)	2007 Hourly Pressure at Mean Sea Level (hPa)	2013 Hourly Pressure at Mean Sea Level (hPa)	2017 Hourly Pressure at Mean Sea Level (hPa)
Day 1	0.0	996.7	1023.5	1031.9	996.9
Day 1	1.0	n/a	1022.9	1031.2	998.1
Day 1	2.0	n/a	1022.2	1031.0	999.4
Day 1	3.0	990.3	1021.6	1030.2	1000.9
Day 1	4.0	n/a	1021.3	1029.6	1002.4
Day 1	5.0	n/a	1020.8	1028.7	1003.9
Day 1	6.0	982.1	1020.5	1027.3	1004.9
Day 1	7.0	n/a	1020.2	1025.9	1005.9
Day 1	8.0	n/a	1019.5	1025.2	1006.7
Day 1	9.0	981.7	1019.1	1023.6	1007.6
Day 1	10.0	n/a	1018.0	1021.8	1008.9
Day 1	11.0	n/a	1016.7	1019.8	1009.4
Day 1	12.0	981.7	1015.7	1017.6	1009.9
Day 1	13.0	n/a	1014.5	1016.9	1009.8
Day 1	14.0	n/a	1013.1	1015.9	1010.0
Day 1	15.0	981.8	1012.2	1015.4	1010.8
Day 1	16.0	n/a	1011.1	1015.5	1010.9
Day 1	17.0	n/a	1012.3	1018.2	1011.3
Day 1	18.0	984.3	1011.9	1019.5	1011.2
Day 1	19.0	n/a	1011.5	1020.5	1011.0
Day 1	20.0	n/a	1012.6	1021.1	1010.9
Day 1	21.0	990.3	1013.3	1021.6	1010.1
Day 1	22.0	n/a	1014.6	1021.7	1009.1
Day 1	23.0	n/a	1015.4	1022.4	1008.3
Day 2	0.0	996.8	1016.2	1022.9	1007.3
Day 2	1.0	n/a	1016.8	1023.3	1006.1
Day 2	2.0	n/a	1017.6	1023.8	1004.7
Day 2	3.0	1003.3	1018.1	1024.5	1003.4
Day 2	4.0	n/a	1018.3	1024.8	1002.1
Day 2	5.0	n/a	1019.0	1025.2	1000.8
Day 2	6.0	1009.3	1019.7	1025.4	1000.0
Day 2	7.0	n/a	1020.5	1025.8	999.7
Day 2	8.0	n/a	1021.6	1026.5	1000.2
Day 2	9.0	1013.9	1022.5	1026.7	1000.4
Day 2	10.0	n/a	1023.4	1027.6	1000.0
Day 2	11.0	n/a	1024.2	1027.7	999.4
Day 2	12.0	1018.0	1024.5	1027.7	998.0
Day 2	13.0	n/a	1025.0	1028.1	996.1
Day 2	14.0	n/a	1025.1	1028.2	994.5
Day 2	15.0	1022.2	1025.6	1028.4	992.3
Day 2	16.0	n/a	1025.6	1028.4	990.8
Day 2	17.0	n/a	1026.2	1028.3	990.3
Day 2	18.0	1024.8	1026.4	1028.5	990.3

Day 2	19.0	n/a	1026.2	1028.5	991.2
Day 2	20.0	n/a	1025.9	1028.7	991.4
Day 2	21.0	1027.6	1025.3	1028.8	990.6
Day 2	22.0	n/a	1025.0	1028.5	989.6
Day 2	23.0	n/a	1024.3	1028.4	989.3
Day 3	0.0			1028.1	990.2
Day 3	1.0			1027.9	991.7
Day 3	2.0			1027.7	992.9
Day 3	3.0			1027.5	993.4
Day 3	4.0			1026.9	993.3
Day 3	5.0			1026.8	993.3
Day 3	6.0			1026.9	993.2
Day 3	7.0			1026.8	993.1
Day 3	8.0			1026.7	993.0
Day 3	9.0			1026.9	993.1
Day 3	10.0			1026.9	993.0
Day 3	11.0			1026.9	992.8
Day 3	12.0			1026.6	992.2
Day 3	13.0			1026.0	991.3
Day 3	14.0			1025.7	990.6
Day 3	15.0			1025.5	989.8
Day 3	16.0			1025.7	989.5
Day 3	17.0			1025.5	989.3
Day 3	18.0			1025.6	989.1
Day 3	19.0			1025.6	989.3
Day 3	20.0			1025.7	989.6
Day 3	21.0			1025.9	989.6
Day 3	22.0			1025.7	989.1
Day 3	23.0			1025.5	989.0
Average					

Table 1 Meteorological data for Manston in Kent © The Met Office

Answers

1. There were terrific winds which were so strong residents could not stand up in them. Water rose up through the drains. The storm surge was fast and overwhelmed communities, rising rapidly in the space of 15-minutes between a quarter to 9 and 9 o'clock.

2. The answers are below.

    a. 1,000 miles of British coastline were affected.
    b. 133 people lost their lives on board the Princess Victoria.
    c. He and other American airmen who were stationed in Britain at the time, rescued survivors around Hunstanton using a dinghy.
    d. East Anglia and the low-lying Dutch coast.
    e. The people of Canvey Island in Essex was completely flooded, overcome by the storm surge, killing 58 people.

3. Line graph drawn below.

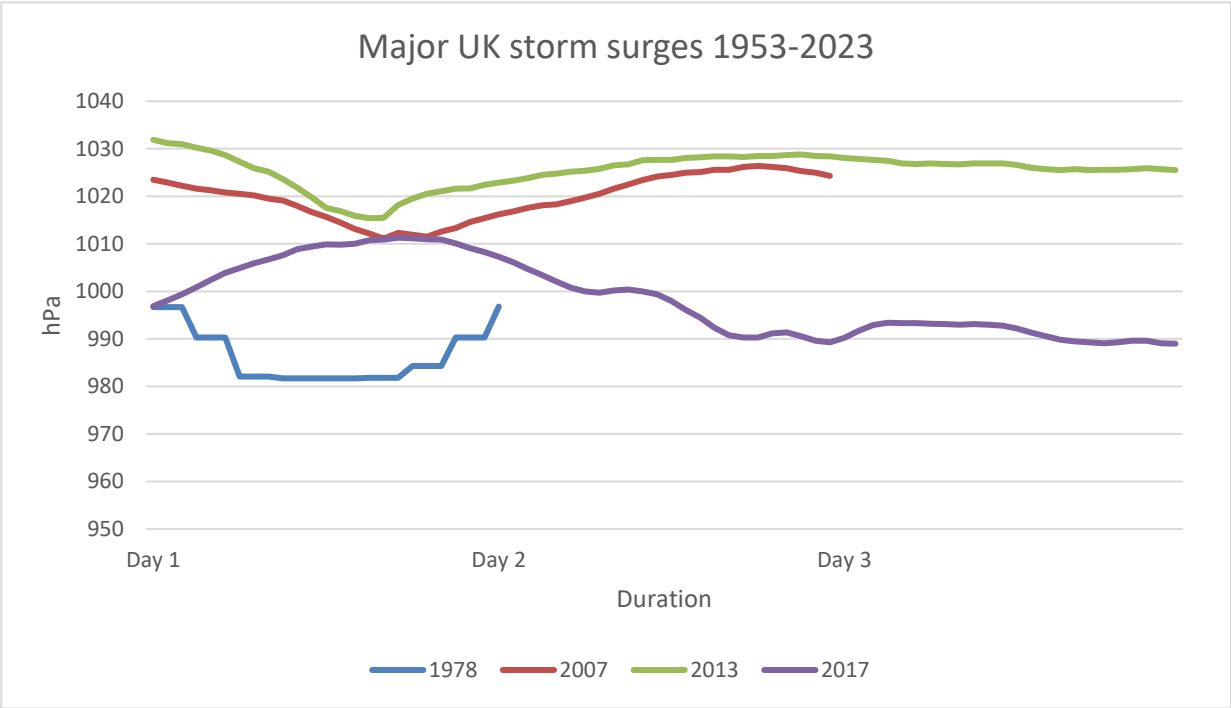

Figure 8 major UK storm surges, by hourly pressure at mean sea level (hPa) over the past 70 years

* The 1978 line will look slightly more angular as data collection only occurred every 3-hours.

4. The event with the fastest drop in hourly pressure was the 2013 storm surge with a 9.5 hPa drop in pressure from 1031.9 to 1022.4 hPa.

5. Yes, it does. The 2013 data clearly shows a long 3-day storm duration with an exceptionally high atmospheric pressure level which unusually drops a second time during day 2.

6. A tidal surge barrier is a form of hard engineering. It is designed to prevent high surge tides from reaching the river upstream (often the site of key residential, commercial, and industrial land).

7. The Colne Barrier is crucial due to the value of the land in the river catchment. 2,900 households are protected by it. The river is in danger of storm surges because of the topography of the land which, between Wivenhoe and Colchester, is in places only 2m above sea level. For example, in Rowhedge, a riverbank village opposite Wivenhoe, the topography does not climb above 19m. It would be very vulnerable to flooding where it not for the Colne Barrier.