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NEW REALISTIC STORM SURGE SCENARIOS FOR UK INSURERS

Exactly 70 years on from the devastating 1953 North Sea floods, new joint research by the Gallagher Research Centre (GRC) and HR Wallingford highlights that 60,000 households may be at risk from a UK storm surge event, with climate change driven sea-level rise exposing a further 17,000 (20%) more properties by 2050.

These new Realistic Disaster Scenarios (RDS) will support UK insurers in helping stress test their exposure to coastal flood risk, while helping explore the impacts of potential UK flood defence breaching and how this risk will increase with climate change. Scenarios have been created for both the east and west coasts of the UK.

Scope of study

This joint study was undertaken between the GRC and research partners HR Wallingford to help determine what the realistic impact of potential flood defence breaching could mean for heavily insured areas along the UK coastline, both for the present day and in 2050. By exploring a range of potential breach scenarios it can help insurers assess their own portfolio exposure as well as explore how climate change materially impacts this risk in the future.

Two extreme but plausible UK storm surge scenarios were developed separately for the East and West coasts of the UK. The choice of scenario regions was based on a combination of historic surge activity (Table 1) and potential insurance impact. Presented here are the methodology and summary findings of this study.

The high-resolution flood footprints are intended to be used for UK storm surge stress tests to assess insured portfolios. An additional analysis of the same events estimated the impact of climate change on these events in 2050 through an RCP 4.5 emissions scenario.*

Historical losses

The UK has experienced several notable coastal floods over the last century. As Table 1 shows, the most devastating of these was the North Sea floods of 1953 which resulted in 307 fatalities and damage to 24,000 properties (see inset story '1953 North Sea Floods: 70 years on' for further details).

*A Representative Concentration Pathway (RCP) is a greenhouse gas concentration (not emissions) trajectory adopted by the IPCC. The pathways describe different climate futures, all of which are considered possible depending on the volume of greenhouse gases (GHG) emitted in the years to come.

Year	Storm name/cause	Result
1953	North Sea Flood	2m high storm surge, 307 people dead, 24,000 homes damaged and 1,000km^2 of land flooded. Caused the building of the Thames Barrier, protecting London from a 1 in 1,000 year storm surge.
1978	Greenland low pressure system	1,400 homes flooded, one death, 22 children evacuated from hospital, multiple defences breached. In some areas storm surge was higher than in 1953.
1990	Storm Vivian	One of the most severe costal floods in the UK. 3,000 properties flooded, up to 50 deaths linked to flood. 50% of houses uninsured. GBP1.4 billion insured loss
2005	Storm Gero + Icelandic low pressure system	Storm surge between 0.5–1.5m. 5 deaths, 1,800 properties flooded and 60,000 power affected, GBP600 million insured loss
2013	Storm Xaver	2,800 properties flooded, GBP314M insured loss, around 50 defence breaches

Table 1: Notable North Sea floods

Source: The Ivan D. Haigh database: https://www.nature.com/articles

Though UK surge events in recent years have been mitigated by effective flood protection, the 2013/2014 UK winter season resulted in GBP0.5 billion[1] of damage as 50 flood defence breaches occurred and 2,800 properties were flooded.[1] One of the key elements of uncertainty explored in this study was the potential impacts of flood breach scenarios across highly exposed regions of coastline.

1953 North Sea floods: 70 years on

On the 28 January, 1953, a storm southeast of Greenland developed and moved eastwards, tracking above the UK and then south-eastward into the enclosed and relatively shallow North Sea. As the central pressure dropped to 964 mbar, a devastating storm surge developed that brought widespread flooding to the UK's East coast.

The 1953 North Sea flood remains the single biggest loss of life from flooding in the UK and Europe in the 20th century. Taking place on the evening of 31 January, 1953, a European windstorm in the North Sea caused levels of damage that today would cost over GBP1 billion (adjusted to 2023). Coastal flood waters reached 4.9m above mean sea level[2] as a devastating combination of a high spring tide, low pressure and wind-driven waves pushed a surge of water against the UK's east coast. Some 2,551 people lost their life and over 47,000 buildings were either damaged or destroyed as widespread flooding occurred across the UK, Belgium and Netherlands.[2]

In the aftermath of the event, it was clear that post-war Britain was unprepared in terms of coastal flood risk management. The 1,200 breaches of UK flood defence[2] highlighted a lack of disaster preparedness and with weather forecasting still in its infancy, it was a wake-up call to the UK government that further action was needed. In the intervening years, the UK and Netherlands governments invested heavily in improving coastal flood defences, including embankments, sea walls and the creation of the Thames barrier in 1984 to protect London.

Figure 1: Flooding during the 1953 North Sea floods

Origin of UK Storm Surges

To simulate UK storm surges, it is important to firstly understand how these events occur. In the Northern Hemisphere winter months, it is common for low pressure synoptic weather systems to track across the North Atlantic to Europe. Often termed Extratropical Cyclones (ETC), these systems bring wet and windy weather from December through to February each year. The combination of a low centre of pressure, diurnal tidal ranges and wind-driven waves can lead to large masses of water being pushed against UK coastlines. The phenomenon is commonly termed a storm surge and can result in flooding as water levels far exceed expected tidal ranges.

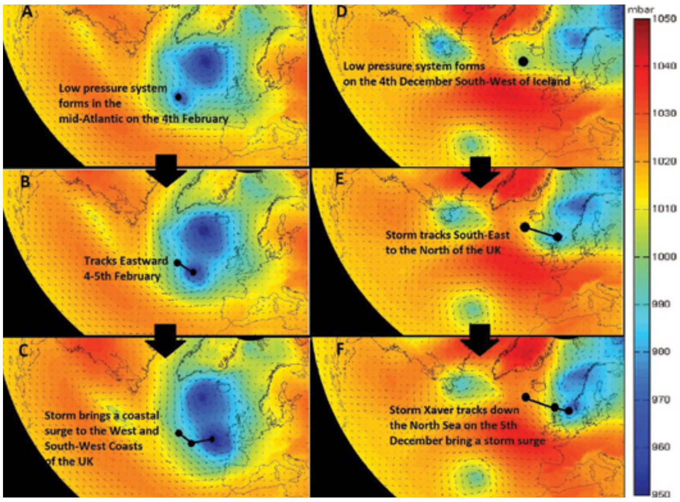

Figure 2: ERA5 surface pressure data 2013–2014. Illustration shows east and west UK storm surges that developed during 2013/2014 winter season. A-C highlights the development of a west coast surge between 5–7 February, 2014 and D-F highlights how the 5 December, 2013 Storm Xaver resulted in an east coast surge. (Image Arthur J. Gallagher, Data: HR Wallingford)

As Figure 2 highlights, the risk posed to different coastlines of the UK is often caused by the track approach of storms and its relative interaction with local astronomic tides (particularly spring tides†) and coastal bathymetry, that can amplify the effect. The North Sea is particularly susceptible to large tidal surges as wind, atmospheric pressure and tidal actions can combine at the same time along the length of the East Coast.

†A Spring tide refers to the "springing forth" of a tide during the new and full moons.

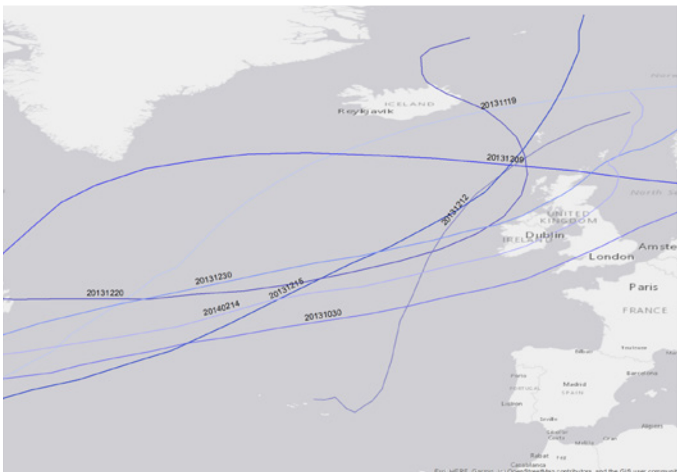

Figure 3: Clustering of storm tracks from European windstorms between October 2013- February 2014 (Image: Arthur J. Gallagher, Data: CS3 Storm Track Database)

As Figure 3 shows, the 2013–2014 winter season proved a particularly active winter as a cluster of storms followed in quick succession to bring widespread coastal flooding to different areas of the UK. Figure 3 also highlights the diversity of track approach with most storms approaching from the south-west and north-east directions. The storm surges of 2013 and 1953 were both caused by low pressure systems that tracked into the North Sea from northern latitudes. As Figure 4 shows below, the track direction as storms approach UK shorelines greatly dictates which coastline may be more likely to experience a coastal surge.

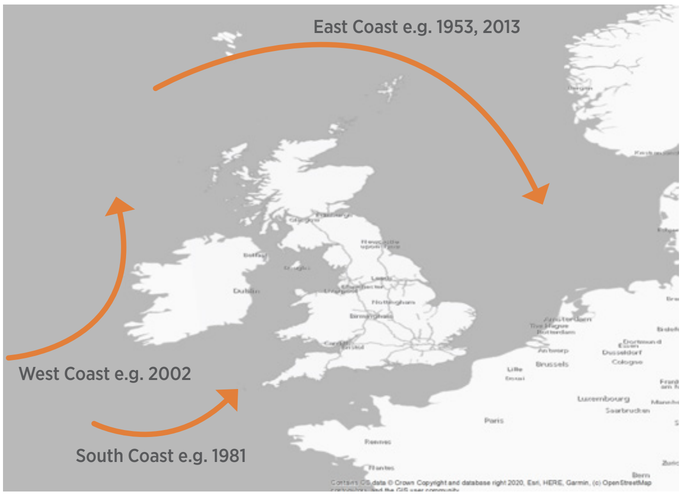

Figure 4: Common low-pressure storm track trajectories around the UK coastline and respective coastlines impacted and corresponding years of significant surge (Image: Arthur J. Gallagher)

Exposure dataset

A geospatial residential and commercial property level database was used for the spatial location of properties at risk. Insured values were then disaggregated from a Gallagher Re UK market portfolio to assign residential and commercial insured values within the property portfolio. Low-lying areas of the UK coastline are particularly at risk of storm surge. By aggregating the exposure database within areas that have an elevation ranging between 0 and 8m above sea level, it showed that 13% of households in the UK may be at risk of coastal flooding, with a significant concentration along the east and west Coasts.

Hazard Simulation

Scenarios were chosen from a stochastic event catalogue of extreme surge events. A subset of events for the east and west coasts were chosen due to both the severity and potential impact they could have on heavily exposed coastlines (Figure 5). The next step was to take the initial sea-state (surge) of the events selected and simulate their interaction with the coastal regions using 2D hydrodynamic modelling. This process of inundation modelling was undertaken by HR Wallingford using high-resolution LiDAR data on the modelling domain (Figure 6).

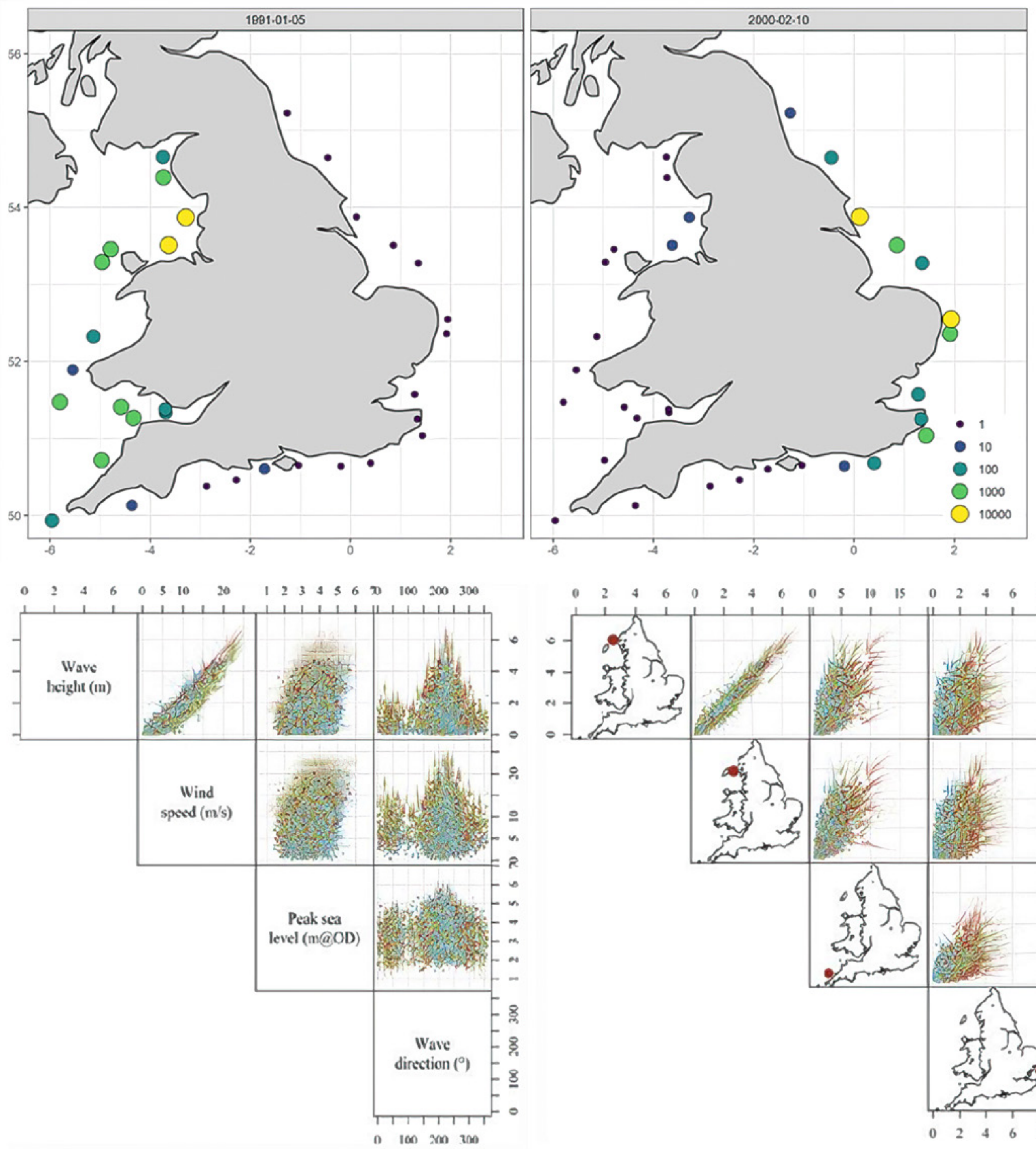

Figure 5: Statistical modelling of extreme tidal surge levels from stochastic event set (Clockwise from top left: West coast scenario, east coast scenario, multivariate plots of storm surge input parameters (source: HR Wallingford)

Flood breaching was based upon flood defence reliability analysis comprised within a national set of fragility curves created by HR Wallingford's flood defence RELIABLE model.[5] The analysis was implemented across a number of known flood defence locations with alternative widths and sections breaching in different model simulations (Figure 6).

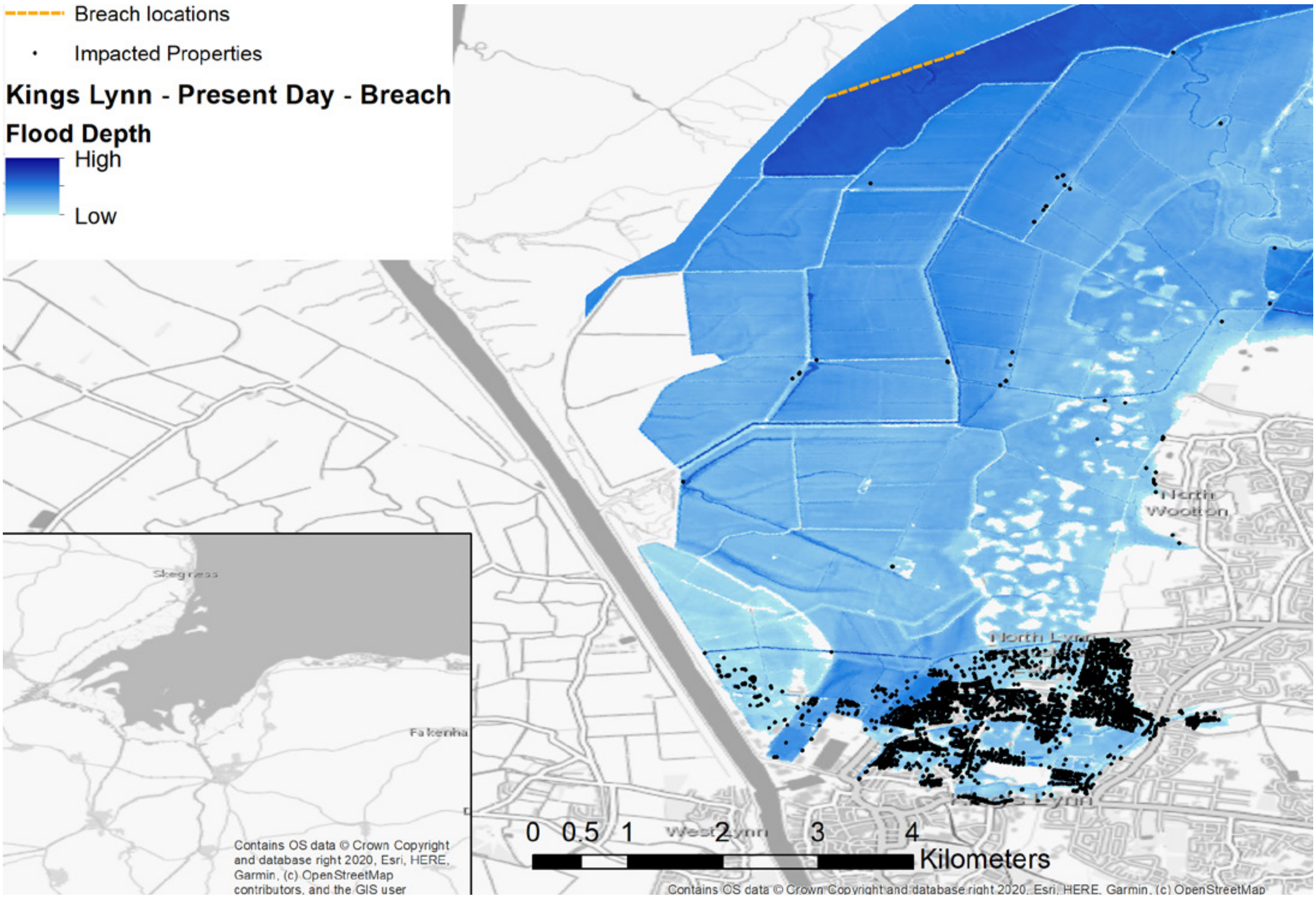

Figure 6: Coastal flood inundation of Kings Lynn showing potential breach location (orange) (source: HR Wallingford)

To account for climate change, the UKCP[6] (UK climate projections) were used to assign the projected RCP 4.5 sea level rise estimates for 2050. This scenario was selected as it most closely matches the CBES regulatory requirements of climate stress test scenarios for the UK.

Results

The simulated flood footprints were then compared to Gallagher Re's insured market portfolio and UK coastal flood vulnerability curves to determine the loss potential of each scenario. Figure 7 provides a summary of the number of impacted properties for each scenario.

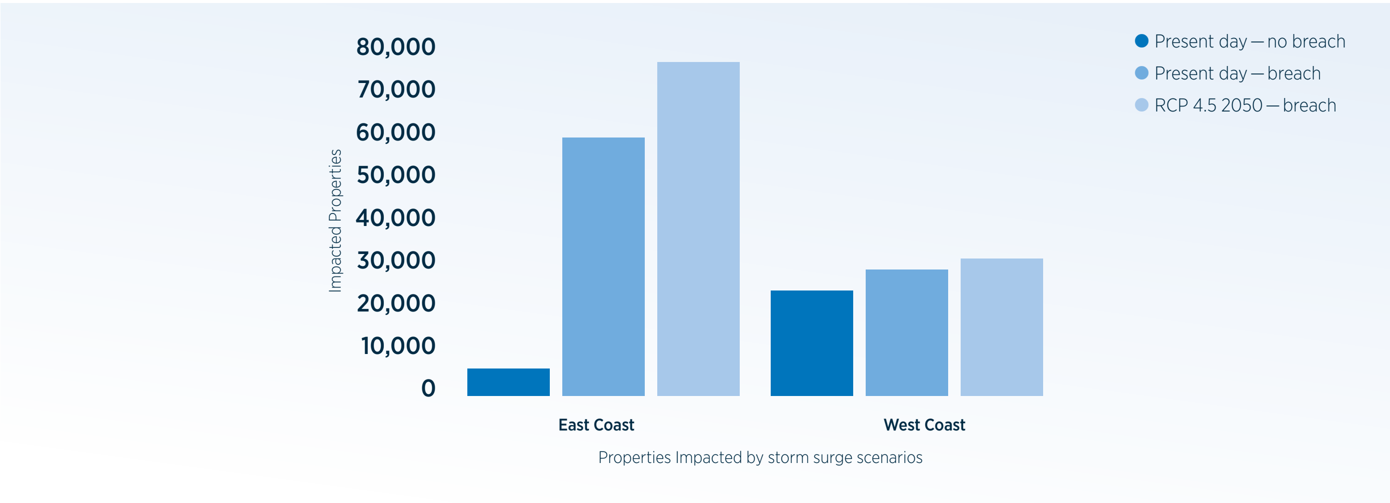

Figure 7: Properties Impacted by the east and west coast storm surge scenarios (Source: Arthur J. Gallagher)

Figure 7 highlights the significant impact that any breaching of flood defences could have on the number of affected properties. In both scenarios, climate change only further increases the impact of storm surge risk. The worst-case scenario of breaching for the east coast of the UK was shown to result in a 10x increase in the number of flooded properties. The west coast event shows a similar trend but as defences are lower on the west coast of the UK, the impact of breaching of defences is less pronounced.

Figure 8 provides an overview of the eight different areas inundated in the flood scenarios. Impacted areas of the west coast scenario include Blackpool (Lancashire) and Bristol, while the East Coast event impacts Hull (Yorkshire), Skegness (Lincolnshire), Kings Lynn (Norfolk), Southend (Essex) and Sandwich (Kent).

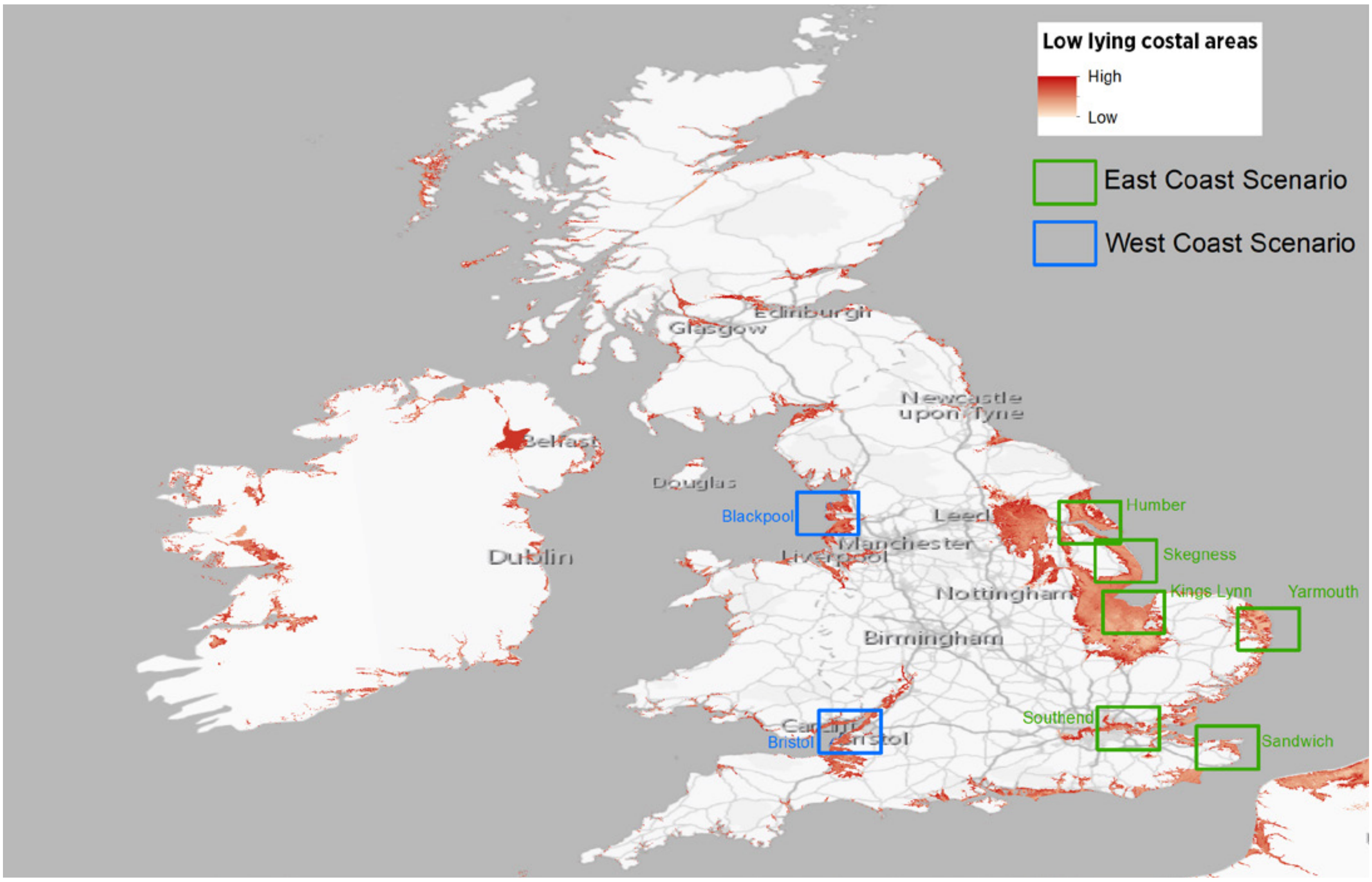

Figure 8: Low-lying properties to coastal flood risk around the UK Areas impacted by the scenarios are highlighted for the West (blue) and East Coast (green).

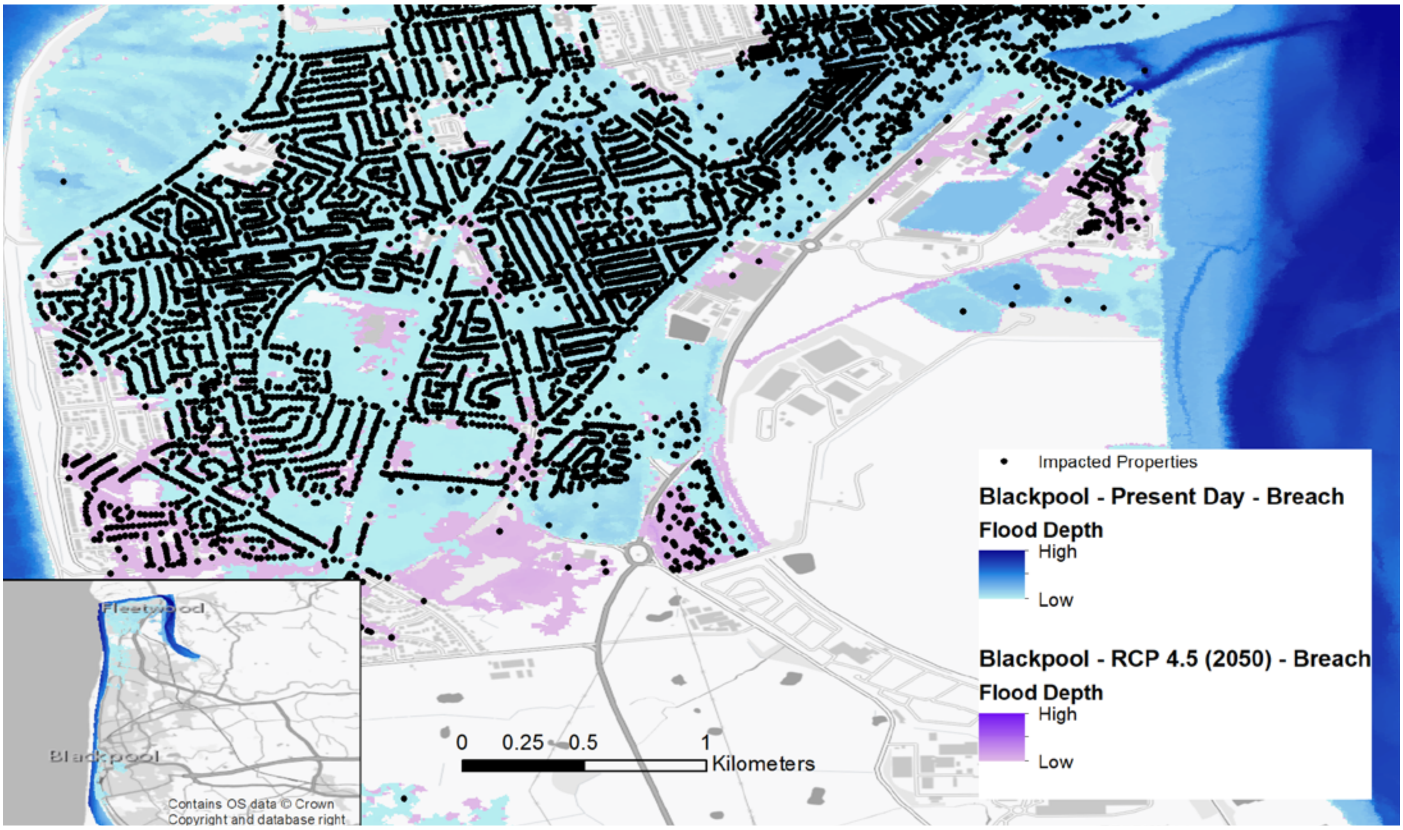

Figure 9: West coast — flood extent and hazard for the West coast scenario in the town of Blackpool. The illustration highlights that a large surge event could result in thousands of flooded properties. Climate Change impacts (purple) further increases the number of properties at risk.

A significant portion of the flooding in the east coast breach scenario relates to the potential failure of the river Hull barrier in the upper bank of the Humber estuary. The barrier is designed to prevent the water from the sea moving upstream through the river Humber during surge tide (Figure 10). Similarly, a 1,000m failure along the sea bank around the Wash, which is effectively a grass covered embankment designed to prevent the water from the sea to penetrate inland, could lead to widespread flooding. These breaches could cause damage to an additional 40,000 insured properties in the city of Hull and 6,000 insured properties in King's Lynn, respectively.

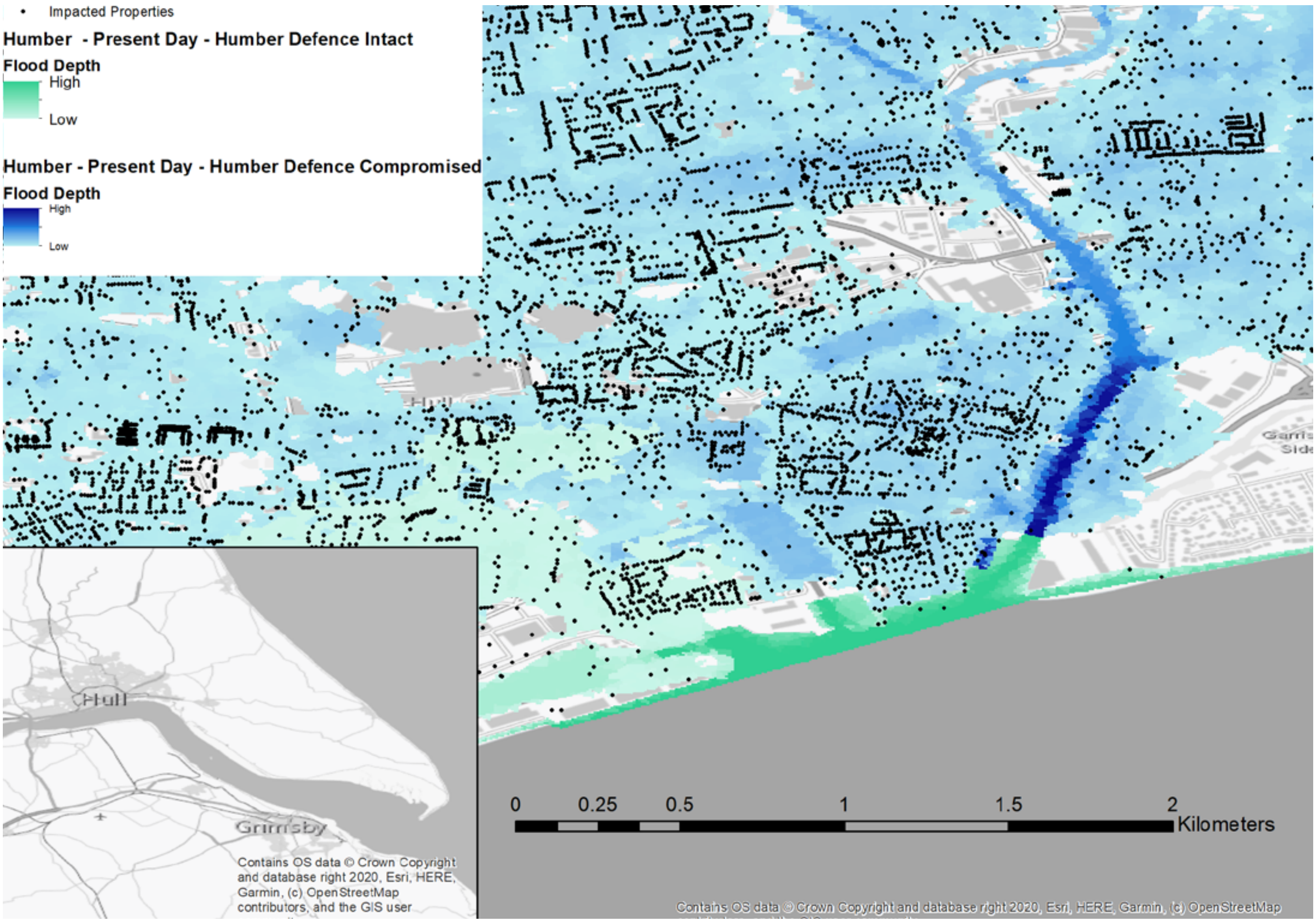

Figure 10: East coast flood breaching in Hull with the Humber barrier fully intact (green) and with the defence failure (blue).

Climate change

The storm surge scenarios also provide a valuable tool for simulating the effects of climate change on UK coastal flood risk for insurers. The research shows how anticipated sea level rise by 2050, which has been ongoing throughout the last century, will only increase loss potential from UK storm surges. Based on the RCP 4.5, 2050 Climate Scenario, an additional 16,000 insured properties could be impacted on the East coast. As shown in Figure 10, climate change significantly increases the flood footprint across towns such as Great Yarmouth and Hull (Humber).

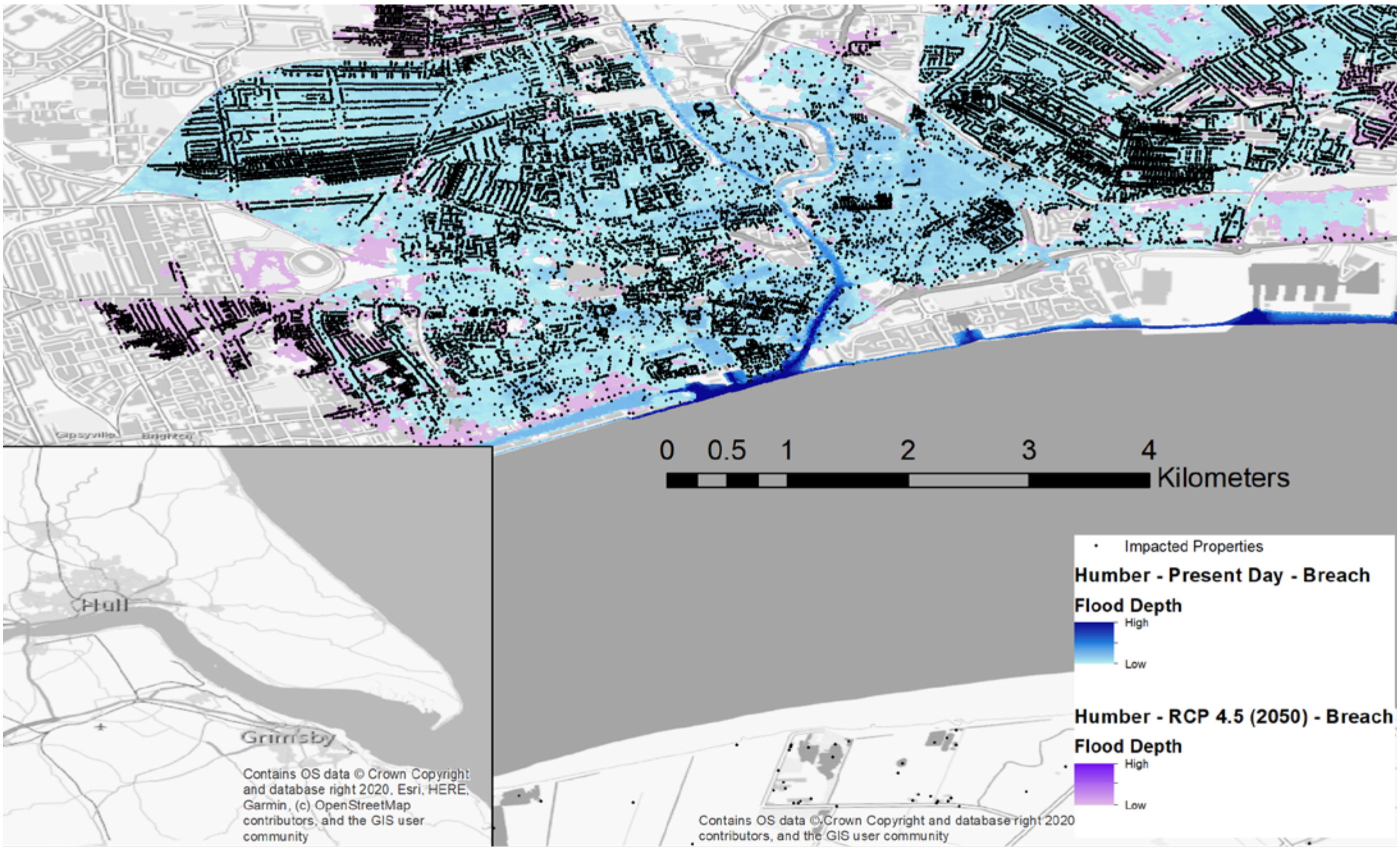

Figure 11. Present day breach east coast flood extent (blue) and additional RCP 4.5–2050 breach flood extent (purple) in Hull (Humber) and Yarmouth. The additional properties impacted are highlighted in black.

It is important to note that climate change has two impacts: it impacts the number of properties flooded, but also the depth of flooding experienced by properties already at risk — further exacerbating losses. Figure 12 compares the distribution of flood depths for the cumulative exposure impacted in the present day and in the RCP 4.5, 2050 scenarios. It is estimated that an additional 24% and 6% of the exposure will be flooded with a depth >0.5m and 1m, respectively.

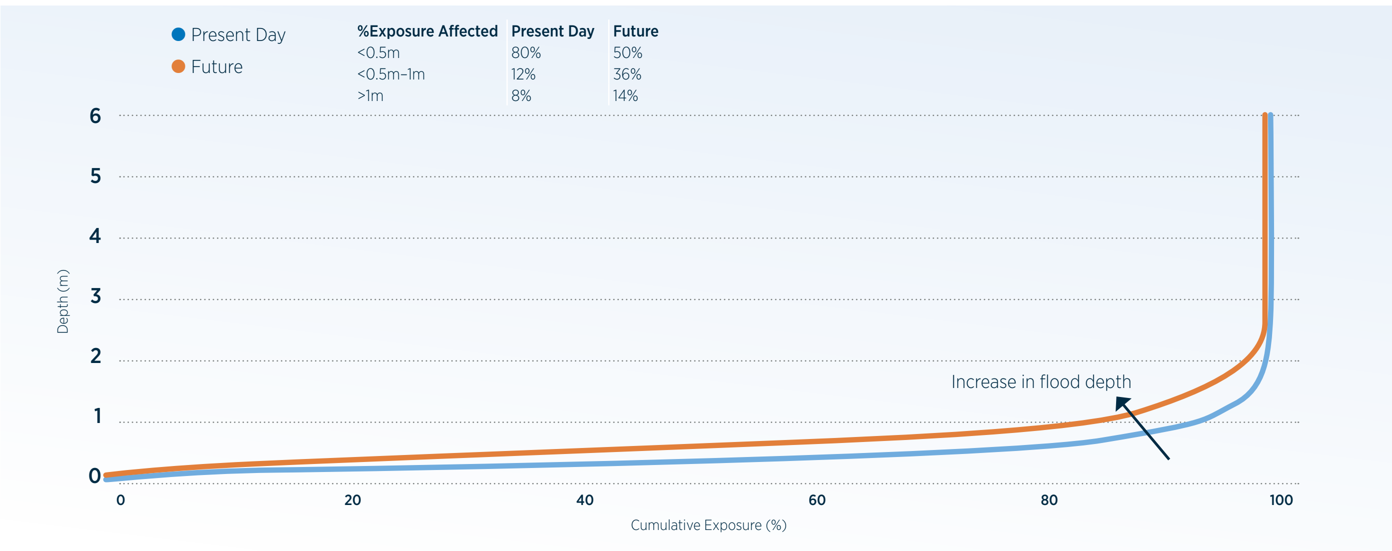

Figure 12. Distribution of flood depth for the cumulative exposure impacted in a present day breach scenario (blue) and future breach scenario (red).

Source: Gallagher Re. (Results obtained after aggregating the Gallagher Re insured market portfolio and the footprint for the two different scenarios).

The pressure of increasing sea level rise on UK flood defences

Post-1953 significant UK government investment led to the development of comprehensive flood defences around the UK coastline. Along with improvements in weather forecasting and a public greater awareness, flood defence measures have proved largely successful in minimising flood damage since 1953. One significant development was the safeguarding of Greater London through the construction of the Thames Barrier. Operational since 1982, the barrier protects central London from extreme tidal surges as well as the combination of the high river levels and high tides at the same time.

Closures of the Thames Barrier Flood Defence1982–2023

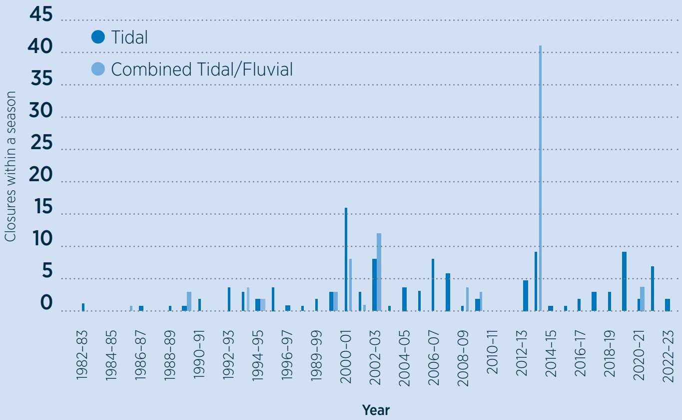

Figure 13: Increasing closures of the Thames barrier flood defence. Note the clustering of closures in the 2013–2014 season (Data: Environment Agency)

Since it began operating, the barrier has closed a total of 208 times to protect London. As Figure 13 highlights though, while the barrier only closed ten times within the first decade of operation, in the last ten years (2013–2023) it has closed 84 times. While some variance can be explained by potential multidecadal cycles and the natural variability associated with European windstorm activity, climate change driven sea level rise also plays an increasing role in coastal flood risk.

The Sheerness tidal gauge is located on the banks of the Thames Estuary and provides a rich record of tidal measurements that dates back to the 1840s. As Figure 14 highlights, the long-term averages show a clear rising trend in tidal levels of nearly 0.5m over the last 180 years.

While the Thames Barrier and other UK defences continue to mitigate flood risk, it is important to factor in that their relative standard of protection (e.g., the Thames barrier is designed for a 1-in-a-1,000 year event) will gradually decline in the coming decades as sea levels continue to rise. It remains imperative that UK flood defences are maintained in the coming decades to further mitigate UK storm surge losses.

Sheerness — Mean Monthly Sea Level 1842–2022

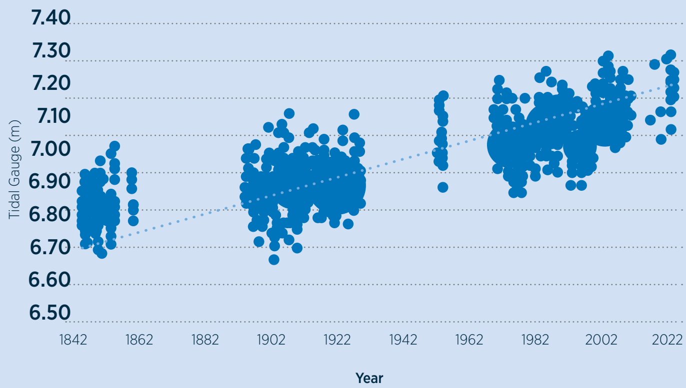

Figure 14: Increasing impact of climate change sea level rise — mean monthly tide levels, Sheerness, Thames Estuary, UK (Data: NOC,[4] PMSL)

How can we help?

Gallagher Re's Global Analytics and Advisory team are making the new UK storm surge scenarios available for portfolio and regulatory climate stress testing on the Vortex catastrophe modelling platform. Please contact your UK client representative if you would like to know more or request modelling support.

References

[1]https://www.surgewatch.org/

[2]Hall, A. (2013). The north sea flood of 1953. *Arcadia*, 5, 148.

[3]Swindles, G. T., Galloway, J. M., Macumber, A. L., Croudace, I. W., Emery, A. R., Woulds, C., ... & Barlow, N. L. (2018). Sedimentary records of coastal storm surges: Evidence of the 1953 North Sea event. *Marine Geology*, 403, 262-270.

[4]NOC (National Oceanographic Centre) Permanent Service for Mean Sea Level: https://psmsl.org/

[5]Simm, J.D., Gouldby, B.P., Sayers, P., Flikweert, J., Wersching, S. and Bramley, M., 2008. Representing fragility of flood and coastal defences: getting into the detail.

[6]https://www.metoffice.gov.uk/research/approach/collaboration/ukcp

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