1953 U.K. Floods

50-year Retrospective

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SUMMARY

The storm surge that struck the east coast of England and the southwest coast of the Netherlands during the night of Saturday 31 January, 1953 caused the worst natural disaster in northern Europe over the past two centuries. The surge was generated by an intense, rapidly moving, low-pressure weather system which travelled southeast across the North Sea, producing very high winds over an offshore region from northeast Scotland to the Netherlands. In combination with a high tide, the surge swept southwards, overwhelming flood defences in both countries. Over 600 square kilometers (150,000 acres) of land were flooded and 307 lives lost in the U.K., while in the Netherlands over 1,800 people were drowned. The resulting damage in both countries remains the worst seen since the Second World War. While the causes of the flood are well recognized, the cost and likelihood of such an event re-occurring today are not as well understood. Fifty years after the event, this retrospective reviews the impact of the catastrophe at the time, and assesses the cost that would be associated with a repeat of a similar surge today.

Figure 1. Coastal flooding affected 1,600 km of the east coast of England (Courtesy Professor Wolf)

Development of the Storm Surge

A storm surge is defined as the difference between the predicted astronomical tide and the actual height of the tide when it arrives. Two factors drive significant storm surges: the low pressure at the centre of a storm causes the sea level to bulge upwards, and more importantly, the high winds associated with a large and persistent pressure gradient can drive the water towards the shore. On 31 January 1953, one of the strongest North Sea windstorms of the 20th century produced the highest storm surge ever recorded along much of the eastern coast of England. As the tide rose that evening, water levels reached heights not seen during at least the previous 250 years. The storm that caused the surge began to develop around midday on Thursday, 29 January as a low-pressure system located to the southwest of Iceland, with a central pressure of 1003 mb. The system proceeded to move to the northeast over the following 30 hours, deepening rapidly by 24 mb and was located to the northwest of Scotland by 6 pm GMT on Friday, 30 January.

Instead of continuing on the same path, the system became influenced by the circulation around a strong anticyclone located to the west of Ireland and turned to the southeast. It entered the North Sea during the morning of 31 January, where it attained its lowest pressure of around 966 mb. The contrast in pressures between the low-pressure system and the anticyclone led to very high winds to the southwest of the storm centre, and a gust of 125 mph (56 m/s) was recorded at Costa Hill (altitude 15 m) in Orkney, the highest recorded land windspeed in the U.K. to that date. The winds caused significant damage to property and the destruction of forests in northeast Scotland, felling more trees than the annual timber-harvest.

As the storm system moved down the North Sea during the remainder of Saturday 31, high pressure continued to build over the eastern North Atlantic. Although the system was filling at the time, encroachment of the high pressure increased the pressure gradient over the North Sea, effectively squeezing the system and tightening the isobars. The strong winds pushed water into the North Sea from the Atlantic and southwards, generating the surge. The water was driven on-shore as the coasts of eastern England and the Netherlands funnel together and the sea becomes shallower, amplifying the surge along the east coast of England and then against the southwest coast of the Netherlands where it arrived during the early hours of Sunday, 1 February.

The storm crossed the North Sea just two days after the full Moon, interacting with the spring tides (when the gravitational pull of the Sun and Moon combines to create the highest tide of the lunar cycle). Higher spring tides than those of the end of January 1953 are possible though, and in fact were due just two weeks later. A similar combination of spring tides and a major storm surge (driven by the easterly winds from a near-stationary low-pressure system in the southern North Sea) coincided in January 1978, again flooding areas of coast from the Humber to Kent. Fortunately, however, warning systems and evacuation plans were successful, and there were no casualties. Improved flood defences also helped by limiting the area of land that was inundated.

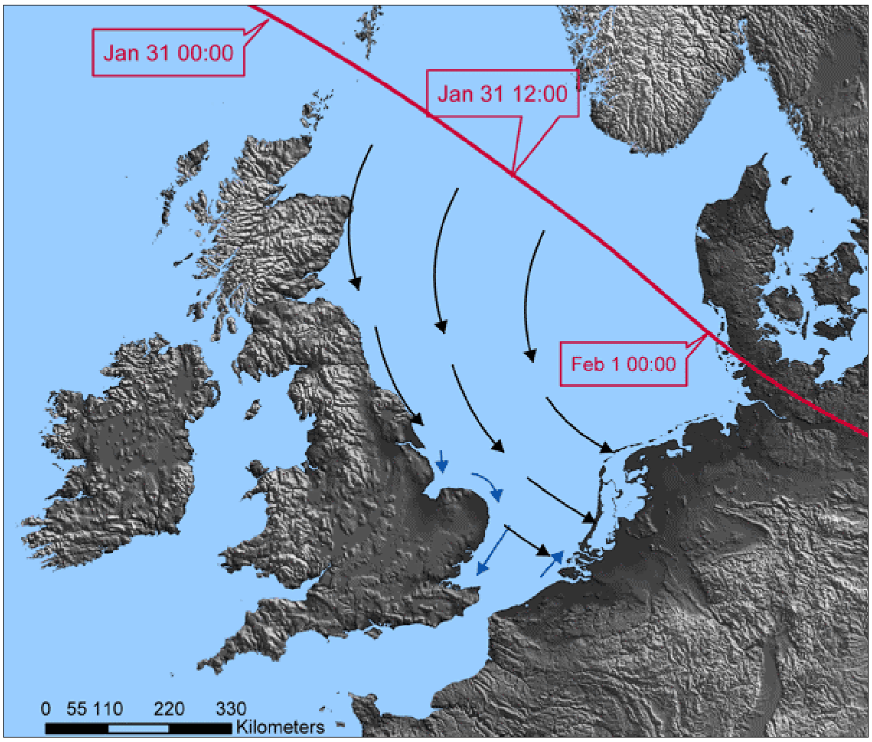

Figure 2. Track of the low pressure system over the North Sea with the wind direction on Saturday midnight indicated by the black arrows and the direction of the storm surge during the night by the blue arrows

Damage Along the East Coast of England

The high water levels and accompanying waves overwhelmed and broke through flood defences and walls all along the east coast of England during the night of Saturday 31 January. On Friday 30 January, once it was clear that a severe storm was developing, the U.K. Meteorological Office issued its first weather warnings. On Saturday 31 in the morning, the storm claimed its first casualties when the Princess Victoria ferry, on passage from Stranraer in Scotland to Larne in Ireland, sank with the loss of 133 lives. Flood warnings for the east coast were issued late that morning, however there was no national coordinated system for distributing these warnings at the time. The danger mark on the Norfolk coast of 2.5 m (8 feet) above mean sea level was surpassed at 6 pm and within half an hour the sea level had risen a further 1 m (3 feet). The sea level rose up to 0.6 m (2 feet) higher than recorded during the previous 80 years and for many sections of coast it remains the highest recorded surge in the North Sea.

A government inquiry into the causes of the floods identified that along the 1,600 km (1,000 miles) of east coast affected there were 1,200 flood defence breaches, 647 square kilometers (160,000 acres) of land flooded, 307 people died and 24,000 houses were damaged, of which 500 were totally destroyed. Around 200 industrial facilities were also damaged by floodwater. On the positive side, over 32,000 people were safely evacuated. A massive military assistance exercise was immediately mobilised to rescue inhabitants from the floodwaters, and to temporarily repair and stabilise the damaged defences. At the peak of the exercise on 12 February, 30,000 emergency workers were operating.

The first breaches were recorded on the Northumberland coast at 5 pm on Saturday and spread southwards over the following 8 hours during the night. It was not until daybreak the following day that the full extent of the devastation was realised. The human impact of the disaster was exacerbated by disruption to telephone and radio services, so that many of those affected received no warning, and were unaware of the scale of the disaster.

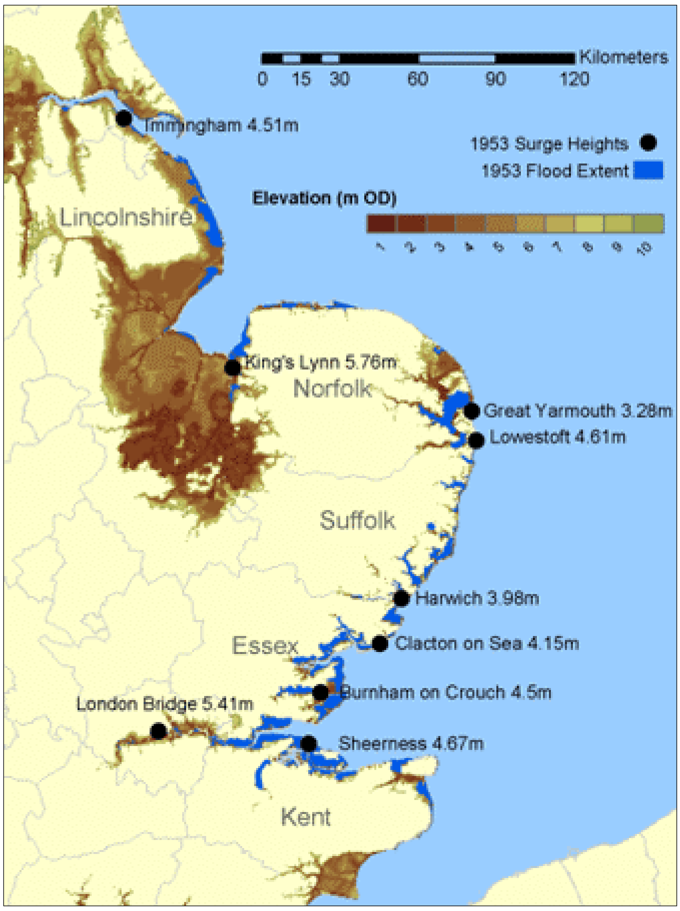

Figure 3. Extent of flooding along the east coast of England with measurements of the surge height recorded in 1957 and land below 10m elevation above the ordnance datum

Among the worst affected areas was the low-lying Canvey Island in the Thames Estuary, which was completely inundated, the death toll was later confirmed at 58. Water flooded up to 8 km (4 miles) inland around Cley on the north Norfolk coast, and to a depth of 1.8 m (6 feet) in the town centre of Kings Lynn. It was not just coastal communities that were at risk, as the surge travelled inland from The Wash along the Rivers Ouse and Nene, causing both rivers to overflow and break their banks. Along the south bank of the River Thames defences were breached, and the floodwater reached the top of embankments in the City and through Westminster.

The overall financial cost of the disaster at the time is difficult to quantify, as accurate records were not collated. A month after the flood, the Home Secretary, Sir David Maxwell Fyfe, estimated the material cost of the damage to be £40 - £50 million: equivalent to around £1 billion in 2003 values. However this does not include the impact of interrupted business activity or the costs of relocation. Flood was not a general insurance coverage at the time, and therefore the proportion of costs repaid by insurance was very small. Financial aid for those affected came mainly from the Lord Mayor's Flood and Tempest Distress Fund, a disaster fund which received donations from all around the world. The Government matched the donations given to it to aid the victims. Within a week the fund had grown to £125,000 and within a month to £1.9 million.

Flood Defence Failures

The high water levels associated with the combination of storm surge and tide had not been foreseen in the design of coastal flood defences, which were unable to hold back the water in many places. Several mechanisms contributed to the defences' failure. In some cases the powerful surge and associated waves scoured the seaward face of the defences while water that had overtopped or flowed through cracks and permeable layers eroded the inland face, leading to damage and collapse. Elsewhere, sand and earth fillings were washed out, undermining the embankments and again leading to collapse. At a number of locations properties were subjected to the repeated entry of the tides for days and weeks as seawater continued to flow through the breaches. However the huge repair and recovery operation meant that around 90% of the breaches in England were closed within a month. Photographs taken shortly after the disaster by Professor P. Wolf during a survey of the coastal defences in Lincolnshire and Norfolk reveal the extent and nature of the damage.

Figure 4. Hard engineered walls and concrete defences were severely damaged by the pounding waves (Courtesy Professor Wolf)

Figure 5. Seawater washed over and broke through walls and earth dikes (Courtesy Professor Wolf)

Figure 6. Sand was washed from beaches revealing the underlying clay as on the left hand side and transported inland where it half buried properties such as the bungalow on the right hand side (Courtesy Professor Wolf)

The catastrophe revealed the inadequacy of coastal defences then in place and led to Britain's largest sea defence improvement program. All the damaged defences were repaired temporarily in the weeks immediately following the floods, before permanent renovation. In the following years, defences were raised by up to 2 m (6.5 feet) and strengthened around the principle concentrations of population and exposure to protect against storm surges with a return period of up to 1 in 1,000 years. The spectre of a major storm surge flood in London led to the construction of the Thames Flood Barrier near Woolwich, which became operational in 1982. The barrier was initially designed to protect against extreme tidal surge events with a return period of up to 1 in 1,000 years until 2030. In addition, the Storm Tide Warning Service, a national flood-warning organisation, was created to improve the accuracy and efficiency of coastal surge warnings to the public as well as the authorities. As part of this effort, a network of tidal gauges was installed around the British Isles coastline to provide accurate water height measurements and connect weather forecasts with tidal movements.

DAMAGE IN THE NETHERLANDS

The devastation was even worse in Zeeland, in the southwest Netherlands. A total of 1,783 people died and 1,335 square kilometers (330,000 acres) of land were inundated, much of it prime agricultural land. Although the flood defences were built to a height of 4 to 8 m (3 to 26 feet) above mean sea level, hundreds of breaks and breaches allowed the water in. Three hundred miles, or 45% of the dikes in southwest Netherlands were damaged. The floodwaters inundated 47,300 buildings, of which 9,215 were destroyed. A large quantity of livestock was killed, and infrastructure was severely disrupted with many roads submerged and damaged. The Dutch Surge Warning Service, in place since 1916, successfully predicted the surge, but the poor state of repair, and inadequate height of many of the defences, converted the surge into an even worse human disaster, than in the U.K.

Most of the defence breaks, over 500, were plugged relatively easily during the following weeks. However, 67 more substantial breaches where the tide flowed freely in and out, required more significant engineering repairs. Eleven of these were still open in mid April, and the last gap was not sealed until 1 November, 1953.

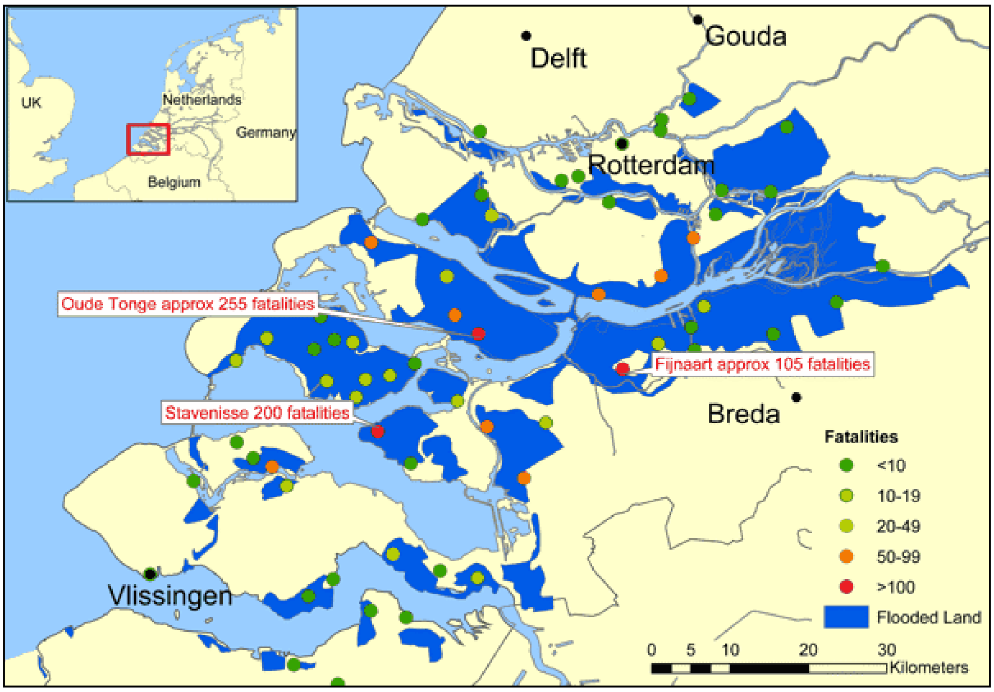

Figure 7. Extent of flooding in the Netherlands with locations of major fatalities

Damage in the Netherlands was estimated at the time to be 1 billion guilders (250 million Euro), with 350 million guilders (90 million Euro) damage caused to the flood defences. The disaster prompted the Dutch Government to launch a massive flood protection plan, called the Delta Works, consisting of a network of huge dikes, locks and dams. The new defences were designed to protect against surges with a return period of 1 in 4,000 or 1 in 10,000 years. The project was not finished until 1997, when the final storm surge barrier was erected to protect Rotterdam and its environs.

What if the 1953 Floods Occurred Today?

Since 1953, increases in population and wealth have significantly increased the amount and value of property within the area flooded on 31 January 1953. In addition, flood coverage is now included as standard in residential and commercial insurance policies in the U.K. (although remains completely unavailable in the Netherlands). A repeat of the 1953 flooding would therefore create one of the most expensive natural disasters for the insurance industry in the U.K.

In order to estimate the insured loss from a repeat of the 1953 storm surge flood extent in the U.K., RMS digitally recreated the outline of areas flooded and draped this flood extent over a 50 m cell size digital terrain model, with enhanced topography down to 0.1 m resolution. This allowed the depth of flooding in all postcode units within the flood boundary to be calculated. Estimates of 2003 value insured exposures for commercial, residential and industrial lines of business developed by RMS were then combined with the flood depths using appropriate vulnerability functions (differentiated by buildings or contents cover for each line of business) to derive losses for each postcode unit, and across the whole extent of the flooding.

Using this procedure, RMS calculates the insured property loss that would occur today with the same extent of flooding as in 1953 would be £5.5 billion, split approximately equally between losses to residential buildings and contents, and to the large portfolio of commercial and industrial properties. Around 59,000 residential properties lie within the '53 flood footprint. Excluding postcode units which are now protected by the Thames Barrier, the insured loss from a repeat of the 1953 flood extent would be 10% lower, meaning that the Thames Barrier would reduce losses by around £0.5 billion. This estimate does not include the cost of business interruption on commercial policies or additional living expenses on residential policies, which would be likely to add another £1.5 billion to the overall insurance costs.

Of course improvements to coastal flood defences since 1953 mean that if the storm surge of 31 January were to happen again, the flooding would not be nearly as extensive – particularly in areas of high exposure concentrations. In order to estimate the likely losses given these improvements, a series of events with combined surge-tide heights comparable to that of 1953 were selected from the 2,280 stochastic events in the RMS™ U.K. Storm Surge probabilistic catastrophe analysis model. The analysis explored a range of alternative combinations of tides arriving with the surge, including high tides even higher than those experienced on the night of 31 January 1953.

The RMS U.K. Storm Surge model treats defence failures probabilistically, assessing the potential failure of any particular section of defence according to surge height and wave action, using fragility curves appropriate to the construction type, height, quality of repair and foreshore condition of that defence. A single surge may lead to very different flood outcomes according to which coastal defences fail. This can only be explored by assessing a large range of potential outcomes.

Combining these scenarios allowed estimates of possible flood event losses to be derived, each with their associated relative probabilities. The events under consideration include a number in which the higher tides accompanying the surge give a significantly increased risk of flooding than a direct repeat of the 1953 sea-levels. Events in the sample were weighted for their relative probability of occurrence, contingent on a repeat of the meteorology of the 1953 surge. The same exposure estimates were used as in modelling the losses from the same flood footprint as in 1953.

The insured property loss from all these possible scenarios, involving different states of tide and defence failure scenarios, ranges from £5 million to more than £2 billion. The probability-weighted average 'expected' loss is £470 million, representing flooding to 9,500 residential properties.

Business interruption and additional living expenses add a further 20% to this figure, giving a weighted average loss of £580 million. Figure 8 shows the probability weighted 'expected loss' from a repeat of the 1953 storm surge in association with a range of states of high-tide, broken down by postcode sector. It is important in any consideration of this kind, in which the impact of flood extent is so sensitive to the performance of individual sections of defences, to consider a wide range of possible outcomes probabilistically.

Improvements to coastal flood defences since 1953 have significantly reduced the risk of such a flood occurring again today. A £470 million property loss from an east coast storm surge event is assessed as having a return period of 40 years from the RMS™ U.K. Storm Surge catastrophe analysis model. This represents a significant reduction from the return period of loss reconstructed from the 1953 flood footprint, which is 750 years. However, rising sea-levels and continued subsidence of the southeast corner of England, associated with the recovery of land-levels after the Ice Age, act to increase the risk of storm surge flooding year on year. In addition, the programme of defence upgrades and maintenance along the U.K. east coast remains patchy, and the potential for a catastrophic storm surge flood to the low-lying communities is ever present.

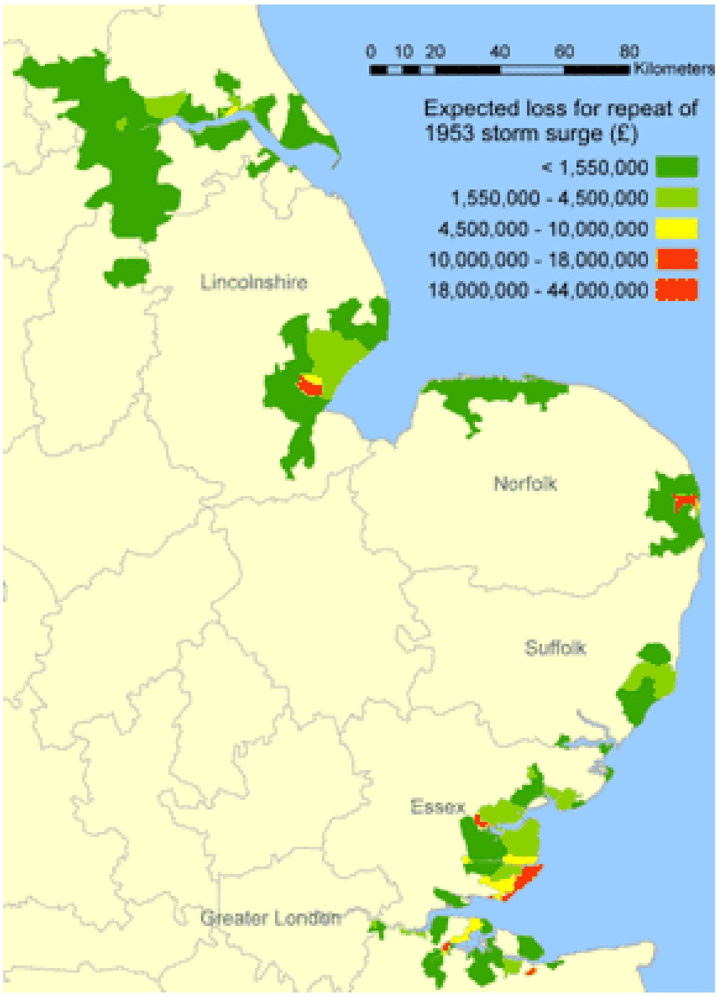

Figure 8. Expected loss for a repeat of the 1953 storm surge heights

References and Acknowledgements

References

Home Office, Scottish Office, Ministry of Housing and Local Government, Ministry of Agriculture and Fisheries. Report of the Departmental Committee on Coastal Flooding. May 1954. Her Majesty's Stationary Office, London.

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