UNUSUAL WAVES ON EUROPEAN COASTS, FEBRUARY 1979

by

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and

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ABSTRACT

A depression in mid North Atlantic moved at a speed such that it generated high waves of unusually long period and large wavelength. These waves travelled in precisely the right direction to carry them into the English Channel, where they arrived during a time of spring tides and when low barometric pressure contributed to long waves impinging high on the foreshore, causing appreciable damage to sea defences and property.

OBSERVED EFFECTS

Unusually high wave activity, which caused considerable damage, occurred along the central and western coasts of The English Channel at about the time of high tide during the morning of Tuesday, 13 February 1979. Locations mentioned are shown on the map. Damage was particularly severe at Chiswell on the Isle of Portland, where waves over-topped Chesil Beach, the crest of which is about 12 metres above high tide level, causing extensive flooding and necessitating virtual rebuilding of parts of the Beach and settlement (Fig. 1). Eye witnesses described a considerable amount of water flooding through the beach, adding to the flooding due to overtopping. Chesil Beach is a narrow spit and is unusual in that the pebbles are graded in size over its ten-mile length, being smallest at the west and largest at the east.

The damage, on a south-westerly facing beach, took place at a time when the local wind was easterly of about 10 knots. This is in contrast to several times Chiswell has been flooded in the past, when

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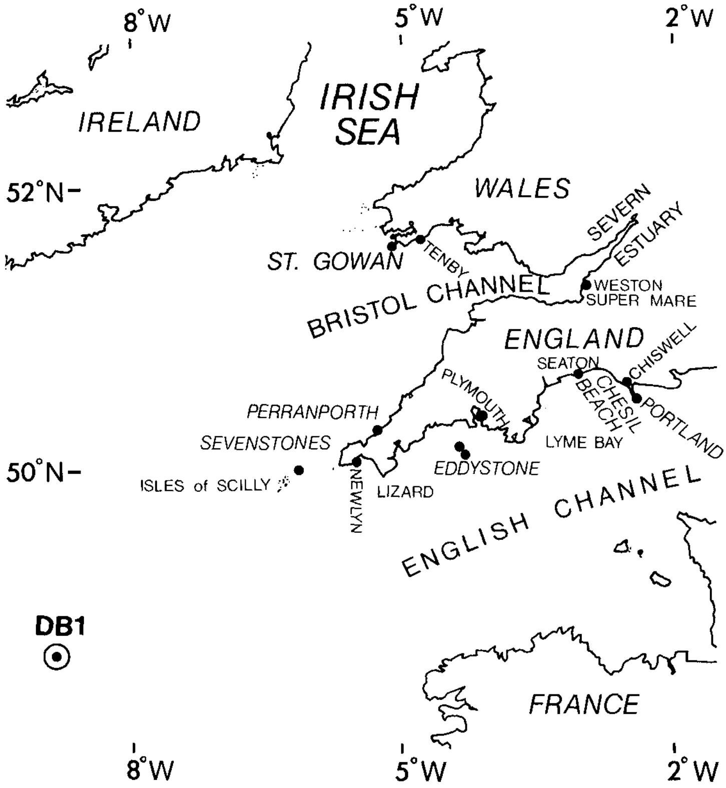

Location Map

Figure 1 Chesil Beach at Chiswell two days after the flooding. Much material had already been bull-dozed back up to the top of the bank. The sea is to the left.

PHOTOGRAPHIC SECTION HMS OSPREY CROWN COPYRIGHT PHOTOGRAPH the damage was directly attributable to strong winds in the local area which resulted in overtopping of and percolation through the beach. (The most recent previous occasion of this was a strong southerly gale on 13 December 1978.)

In February 1979 there was damage all along the southern English coasts. In harbour in The Isles of Scilly the ship Scillonian tore her mooring bollard off the deck and ripped up her shore moorings. In Plymouth harbour the long waves arrived around 0500hr, high water was at 0700 and the peak activity occurred around 0800. When the dock gates were opened, craft broke moorings until the gates jammed shut. Spray from the waves broke over the breakwater light at the seaward side of Plymouth Sound at 19m. An RAF craft reported that sailing parallel to the crests was like having enormously long walls of sea either side, but that with such a great wavelength no difficulty was experienced.

At Seaton, further up-Channel, coastal structures were badly damaged, and even at Hayling Island, to the east and in the lee of the Isle of Wight, very long length swell waves caused flooding.

Elsewhere, in South Wales these waves caused damage, for example by breaking over the fore-shore at Tenby, and at Sines in Portugal the massive breakwater under construction, and already damaged by previous wave attack, again suffered considerably. Nearby, Leixoes also suffered damage.

An interesting observation of the contrast between effects of the storms of 13 December 1978 and 13 February 1979 was made by Lt. Cdr. J. Roberts, Meteorological Officer of HMS Osprey, Portland. In the former storm the seaward side of the remaining shingle was much too steep to climb up, the pebbles looking as though they had been shovelled out by the sea, leaving a cliff, whilst in the latter case the bank looked like a huge rounded whale-back. In the first case the damage was consistent with attack from short, steep waves, characteristic of locally-generated storm waves, or "sea", which destroy beaches and rip out sand and pebbles from a beach. In the second case, damage was consistent with attack from waves which are very long compared with their height, and are termed "swell", which carry sea-bed material towards the shore and build beaches.

OCEANOGRAPHIC ASPECTS

As the local wind could not have been responsible for generating any waves approaching from a westerly direction, the source of the wave energy must have lain in the Atlantic. Portland subtends only a small angle to the Atlantic, with an arc from perhaps 230 degrees to 260 degrees, so that any wind source must therefore lie within this "window". However, the "window" is not a simple "optical" one, because refraction, which itself will depend on wavelength and therefore ultimately on wind strength, and also on the direction of the original wind, will allow a displacement of the generating zone into areas adjacent to those in the "optical window". There is, therefore, a range of conditions which could result in a wave orthogonal leading to Portland.

Probably the most important single parameter is the wave period; the periods of the waves at the time of the disaster lay outside the range of periods associated with substantial wave energy ever recorded in many years of wave recording in waters around the British Isles or of the North Atlantic.

WAVE DATA SOURCES

The Taunton laboratory of the Institute of Oceanographic Sciences maintains several wave recorders off the west coasts of the UK for climatological purposes. It has been possible to obtain and analyse data for the relevant times from a recorder on the Sevenstones Light Vessel off Land's End, one near Eddystone Lighthouse and another on the St. Gowan Light Vessel in the Bristol Channel south of Pembroke. The UK Data Buoy DB1 located 120 miles south west of The Isles of Scilly at 48°42'N, 8°58'W, was operated by the Departments of Energy and Industry and the United Kingdom Offshore Operators' Association, and measured meteorological and oceanographic parameters, including wave conditions, and transmitted the data by radio to EMI (Woking). A Waverider was maintained by the Hydraulics Research Station, Wallingford, off Perranporth, on the western Cornish coast south of Newquay; it was exposed to waves approaching from the west. Another was operating well up the Bristol Channel. Elsewhere, a Waverider was operating off the port of Sines in Portugal.

A SEARCH FOR THE GENERATING AREA

In order to find a possible generating area which could be the source of this wave energy and which lies within the "window", it is necessary to study the previous few days' North Atlantic synoptic weather charts. The chart for 1200 on 10 February 1979 shows a new depression (Low 992) south of Newfoundland. This depression deepened rapidly as it moved eastwards and by 0000hr GMT on 11 February it can be seen (Fig. 2) as low H, having deepened to 952 mb. The westerly winds on its southern flank were estimated to be of 50-60 knots. Such wind speeds are by no means uncommon in an Atlantic storm.

By 12 February the depression was incorporated as the southern part of a low pressure system having filled to 968 mb. Finally, by 0600 on 13 February the depression was centred approximately 120 nm south west of Land's End at 970 mb. In general, the longer-period waves generated by an Atlantic depression usually travel faster than the storm and so move out of the storm area, and the storms tend to move on a curved path. In this case the depression moved with roughly the same speed (30 knots) and in the same direction as that of the wave components of about 18-20 seconds which it had generated, and so

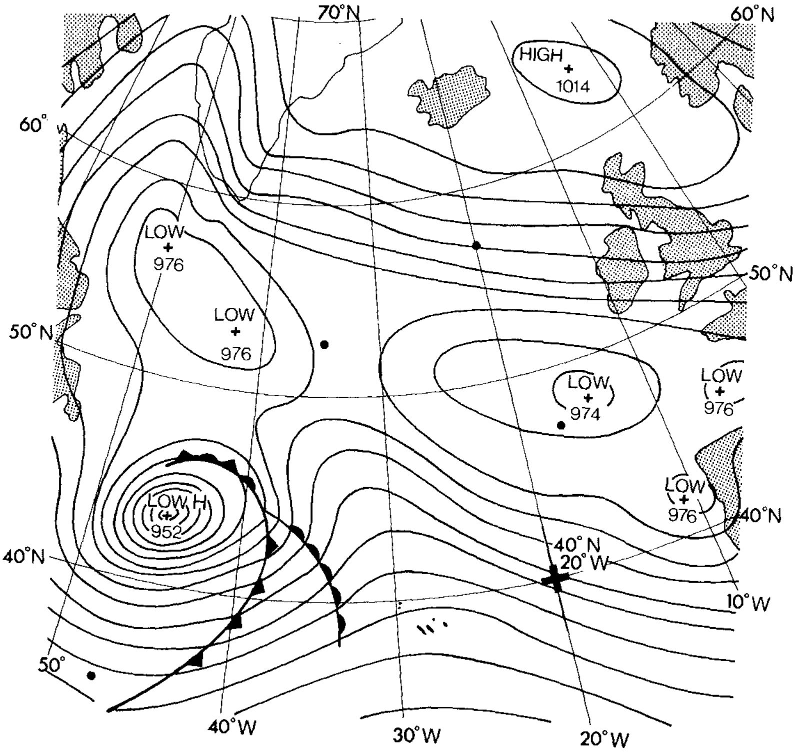

Figure 2 Meteorological Chart for 0000hr GMT 11 February 1979, showing the storm which generated the unusual wave conditions.

continued to input energy preferentially into this longer-period part of the wave spectrum for a considerable time, creating high and unusually long period sea waves. This is the primary cause of the problems at Portland.

A similar event occurred in the South Atlantic in July 1980, but the energy approaching the South African coast on that occasion, when the significant wave height was 3 metres, was only about a fifth of the energy present in the waves described in this paper. That event was described in a careful spectral study and interpretation by Shillington (1981).

THE WAVES ON EURDPEAN COASTS

The depression in mid-Atlantic filled rapidly, but the packet of wave energy it had produced continued eastwards as a swell at about 30 knots, and was detected at about 2400hr on 12 February by DB1 in the western Approaches to The Channel. During 12 February DB1 had consistently recorded waves with a zero-crossing period (T_Z) of around 12 seconds and a significant height (H_S) of about 4 metres, but by midnight the wave period had increased rapidly to nearly 17 seconds and by D100 13 February to over 18 seconds with a significant height of 7 metres. It continued to record these high values until about noon on 13 February. In Figure 3, parameters from DB1 for this storm are superimposed on a scatter diagram for Ocean Weather Station INDIA (59°N, 19°W), the most exposed IDS wave climatology station in one of the roughest oceans. This wave climatology is representative of conditions in the eastern Atlantic from about 45°N to 60°N. The 13 February 1979 conditions are outside the envelope of all data from over 40 previous instrument-years of measurements in all parts of UK waters; about 10 of these have been in locations well exposed to Atlantic conditions. According to the UK Meteorological Office ship routeing wave prediction model, these unusual wave conditions did not extend as far north as station LIMA (57°N 20°W), and this is confirmed by its measurements. (LIMA replaced INDIA in 1976.) (The wave period referred to in this report is the zero-up-crossing wave period, symbolized by T_Z. It is the average interval between successive crossings in the upward direction through the still-water level. The significant wave height, H_S, is the average value of the height of the highest one third of all the waves.) Captain Warren, Master of the oil rig Atlantic I working close to DB1, reported visual estimates of swells of up to 9 metres with periods of over 15 seconds, at times reported to be as high as 20-25 seconds.

Although there was no wave recorder operating at that time off The Isles of Scilly, the tide recorder at St. Mary's showed considerable disturbances starting at about 2200hr on 12 February and continuing until the early afternoon of 13 February. The period is difficult to determine due to heavy filtering by the tide recorder, but a period of about 1D minutes is detectable on the recorder. It seems probable that a local oscillation was induced by the storm waves.

WAVES AT OCEAN WEATHER STATION INDIA

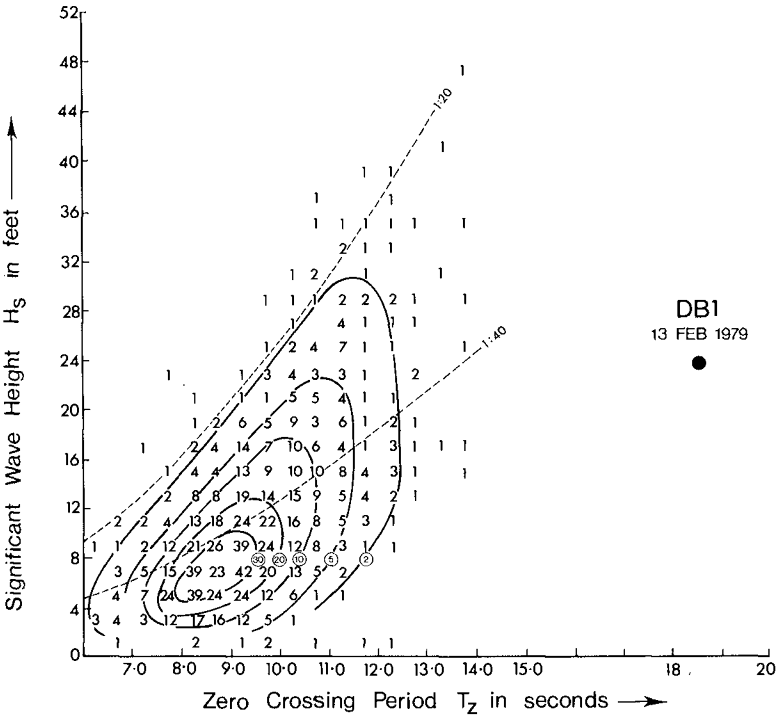

Figure 3 Wave Climatology for the eastern Atlantic as measured at Ocean Weather Station INDIA (59°N 19°W). These data are representative of the eastern Atlantic between about 45°N to 6D°N. The most severe of the parameters measured at DB1 on 13 February 1979 are plotted to show their unusual characteristics. (The wave climate at DB1 is still under confidentiality imposed by the UK Offshore Operators' Association and therefore not available for publication.) The 13 February 1979 conditions are outside the envelope of data from over 40 previous instrument-years of measurements in all parts of UK waters. According to the UK Meteorological Office ship-routeing wave prediction model, these unusual wave conditions did not extend as far north as station LIMA (57°N 20°W), and this is confirmed by its measurements (LIMA replaced INDIA in 1976).

A Shipborne Wave Recorder on the Sevenstones Light Vessel, between Land's End and The Isles of Scilly, measured waves with a significant height of around 3 metres and a zero-crossing period around 10 seconds during the evening of 12 February, but by 0600hr on 13 February the waves increased to over 5 metres in height and over 13 seconds in period. This Light Vessel is partially sheltered from such waves by The Isles of Scilly.

Off Perranporth, the significant height had been about 1 metre on 12 February, gradually increasing to about 1.5m by 2100hr, and then more than doubled by 0300hr on 13 February, staying around 3 metres until 0900 and then decreasing to somewhat over 2 metres by midnight. The direction of approach of these waves was such that they travelled almost parallel to the Perranporth coast, so that their height at the recorder would have been less than that further out at sea. The zero-crossing periods were around 8 or 9 seconds on the 12th until the arrival of the swell late in the day, and in the morning of the 13th reached 13.5 seconds, falling back by noon to 8 or 9 seconds again. Chart records show swell groups of 20 seconds period at Perranporth, and at the Severn Estuary site near Weston-super-Mare, also recorded by HRS.

At Eddystone, which is somewhat sheltered by The Lizard, the wave period had increased considerably by 0300hr on 13 February, and more so by 0600hr with an increase in wave height. The wave heights are lower than at OB1 because of the sheltering. The timing is consistent with the passage of the wave energy past the DB1 location. At St. Gowan in the Bristol Channel, a site well exposed to the source of this wave energy, records show that the wave period (T_Z) there increased to 15-16 seconds by 0300hr on 13 February (a value in excess of anything recorded previously in over a year's measurements) and stayed high for at least six hours afterwards. Visual inspection of records from both these sites reveals considerable energy content at around 15 to 20 seconds period. At the NMI research tower in a relatively sheltered position in Christchurch Bay just northwest of the Isle of Wight, off the map to the east, these waves achieved a significant height of over 2 metres. At Hayling Island, to the north east of the Isle of Wight, the attenuated and refracted waves were still 1.5 metres in height at the coast.

The Waverider off Sines, south of Lisbon, experienced unusual conditions and recorded one wave with a height of 17.2 metres and a zero-crossing period of 20 seconds at 0340hr on 13 February. The significant height was 9.4 metres; these waves must have been generated by this same storm.

The ship-routeing wave prediction model run in real time by the UK Meteorological Office had forecast the heavy swell correctly for the morning of the 13th and again forecast heavy swell for mid-Channel for the evening, but apparently at the evening high tide the waves did not have a damaging effect at Chesil Beach. The correctness of the forecast is borne out by the measurements at DB1. However, the most likely explanation of the failure of the swell to arrive at Chesil on the evening tide of the 13th is that the angle of approach had changed sufficiently (perhaps by only 10 degrees) to place Chesil in the shadow of the south western headlands.

THE APPROACH UP THE ENGLISH CHANNEL

A series of refraction diagrams has been constructed based on the approach of a broad front of waves travelling in directions appropriate to those generated in this storm, approximately towards the east north east. These show that waves of 20 seconds period can come to a focus in the middle of Lyme Bay, those of 18 seconds period focus almost directly onto the Isle of Portland and somewhat shorter period waves come to a real focus further east in The Channel or to a virtual focus inland. Clearly, Portland is particularly vulnerable to the approach of such long period swell coming up-Channel, and in the early hours of 13 February conditions were just right for the waves to make their land-fall in force.

SEA LEVELS

Although the incident occurred at the top of a spring tide predicted for 0740hr at Portland, it was not an unusually high astronomical tide; in fact in the first three months of that year at Portland over forty tides of the value expected for the morning of 13 February, or higher, were predicted, the highest being 0.6 metre higher. However, there was a surge in The Channel that morning, possibly connected with the low pressure centre over the western Channel at that time. At Newlyn, sea level was 0.85 metre above prediction, at Devonport (Plymouth) 0.6 metre and inside Portland harbour 0.52 metre.

The Bidston Laboratory of the Institute of Oceanographic Sciences has analysed surge levels at various ports in the UK and the highest value of surge recorded at Newlyn over an 18-year period was 0.88 metre. Such a surge as occurred on 13 February is unlikely to recur there, on average, more often than once in three years.

In addition to mean water level changes caused by tides and surges, on coasts exposed to wave action the ocean level can be lifted by wave set-up, a mechanism by which the momentum of subsequent waves holds the water carried up the beach by breaking waves and results in an even higher water level at the beach. This effect is not likely to have contributed to the surge levels measured in Newlyn or Portland harbours, but it has been estimated that with these extremely long waves it could perhaps have added about 1 metre to the near-beach water depth at places such as Chesil Beach.

RARITY OF THE EVENT

It seems possible that the situation on 13 February was near to the optimum for severity of effect at Portland. If the speed of the depression had been lower, waves of shorter period would have been enhanced, and focussing, if it occurred at all, would have given enhanced waves but probably further east and in mid-Channel. If the speed of the depression had been higher the enhancement would have taken place for waves of longer period with focussing further west, but the actual total energy at such periods, being even further down the tail of the energy distribution, would have been smaller than actually occurred on 13 February so that the effect at Chesil, and anywhere else in The Channel, would probably have been less.

Without a prolonged historical study of meteorological conditions over the whole Atlantic, it is virtually impossible to ascribe a number to the average return period of such an event. The occasional floodings of Chesil seem to be due to two causes: one, the most likely, occurs when there is a severe local southerly storm coincident with a high tide, and this seems to be the most common. The second, and the cause behind the 13 February 1979 flooding, appears to be a most unusual combination of events; its impact is very much greater because its real-time prediction is orders of magnitude more difficult and expensive, and so far its occurrence has come completely by surprise to the local population, almost literally "out of the blue".

CONCLUSIONS

It is obvious that the coastal damage came about as a result of the compounding of a number of improbable events. Although waves of these heights are likely to occur in the Western Approaches several times each year, it is the coupling with the long wave period which is the most destructive element in this phenomenon. This coupling, which would be directly responsible for wave set-up at an exposed coast, occurring together with a surge and a moderately high tide, is the basic cause of the destruction. At this time it is not possible, or possibly not even sensible, to attempt to quantify the probability of occurrence of such an event, but bearing in mind that the most likely cause of flooding is a local southerly storm, which is predictable, an unheralded flood caused by the factors which caused this one seems purely, on a hunch, to be of the order of a century or longer. This does not, however, mean that it cannot occur again next week; similar but not so severe events may well occur in most years.

The observations made by Lt. Cdr. J. Roberts, Meteorological Officer of HMS Osprey, Portland, of the shapes of the beach in the two floodings of December 1978 and February 1979 are consistent with the known wave conditions and their effects on beaches, and illustrate the completely different nature of the waves on the two occasions.

Needless to say, the effects on the local community were disastrously similar.

The most important engineering implication seems to be that, when an installation is being planned on or near an exposed eastern Atlantic coast, and probably other oceanic coasts as well, the susceptibility to heavy swells with wave periods of around 20 seconds and possibly longer must be considered, because the mechanism for their generation does seem to exist and, by rare chance, occur outside the envelope of all wave measurements covering over 40 instrument years in this part of the North East Atlantic. If inundation from such waves would be disastrous, then the possibility of their occurrence within the typical lifetime of many engineering structures must be considered.

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REFERENCE

Shillington, F.A., 1981
Low frequency 0.045-H_Z swell from the southern ocean.
Nature <u>290</u>, No. 5802, pp 123-125, 12 March.