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Institute of Oceanographic Sciences
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July 1983.

NATURAL ENVIRONMENT RESEARCH COUNCIL

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1. Introduction

Estimates of extreme still water level (swl) at Newhaven were computed by Graff and Blackman for the Southern Water Authority in 1977. The surge event of 02 February 1983 caused a peak level markedly in excess of their predicted figures, and the Ministry of Agriculture, Fisheries and Food (MAFF), has asked IOS to update these estimates.

We have recomputed the estimates of return period levels using both the annual maxima method and the joint probability method, and have derived best estimates based on the reliability of the two methods and the quality of the data available. A detailed discussion of the methods used is given in the quoted references.

2. Annual maxima method

Graff and Blackman (1977, and Blackman and Graff, 1978) fitted and extrapolated an extreme value curve to 60 annual maxima data from 1913-1976, using Jenkinson's method. Their "port diagram curve" is replotted as curve A on Figure 1 and estimated "return period" levels (to Ordnance Datum Newlyn) are given in Table 1. Only return periods up to 250 y are given as the method does not warrant extrapolation to periods longer than four times the data length (NERC, 1975).

We have added the observed peak level of 4.25 m ODN occurring on 02 February 1983 to the data set and applied the method to yield curve B and corresponding return period levels, Table 1. The estimates have increased by approximately 0.10 m and this illustrates the sensitivity of the results to the length of data record used; a point discussed in detail by Graff (1981). This problem is highlighted by our computation of return period levels using subsets of the annual maxima data. The lower and upper bounding curves, B1 and B2, given in Figure 1 are from computations using annual maxima from 1913, 1916-1919, 1921-1924, 1926; and 1968-1976, 1983 respectively. The 100 y return period levels estimated from these curves are approximately 0.30m above and below the value of 4.11 m from the total data set. Curves A, B and B2 are of Fisher-Tippett Type 3, ie bounded above; but curve B1 is FT-2 and is unbounded above, predicting infinite levels at very long return periods.

A further problem is the significant trend (of 6mm y^{-1}) in the Newhaven annual maxima data. The statistical theory of the method assumes that the data are stochastically stationary, ie random and uncorrelated. The method can still be applied provided that the annual maxima are reduced to a standard epoch and the trend removed; and this was done using 1980 as the reference year. Curve C on Figure 1 was obtained with corresponding return period estimates given in Table 1, these are approximately 0.12 m higher than those from curve B. It is difficult to ascertain if the trend is due to oceanographic-meteorological effects or to the suspect quality of the data. Part 2 of the original report to the SWA (Blackman and Brown 1977) details the many problems with assessing the quality of the data from both the British Rail and the SWA's tide gauges. Many annual maxima during 1913-54, obtained from the BR gauge were considered to be of doubtful quality and no information was available on which to base a sound assessment. The data from 1955-76 from the SWA gauge was considered more reliable but the gauge was plagued by frequent mechanical problems, power cuts, and siltation of the well. The history of the tide gauge site shows evidence of gradually subsidence and land slip, culminating in the removal of the gauge in 1976. All these factors must raise questions about the reliability of the data and its trend, and therefore the reliability of any estimates obtained using the annual maxima method.

3. Joint probability method

A new tide gauge was installed by the Tide Gauge Inspectorate (TGI) of the National Committee on Tide Gauges in May 1982. We have processed one year of hourly data from 26 May 1982 to 25 May 1983, and analysed the record using the Extended Harmonic Method (EHM) to yield harmonic constituents of the tide. The analysis was used to predict hourly values of the astronomical tide over the period, and surge residuals computed as the difference between observed and predicted levels.

The frequency distributions of tide and surge levels were computed and combined to give the probabilities of occurrence of total swl. The cumulative distribution function was computed and used to find the probability of exceeding particular levels (Pugh and Vassie, 1979, 1980).

Curve D of Figure 2 is the probability curve for exceedance of high water levels at Newhaven, return period levels are given in Table 1. The new gauge has not yet been officially levelled to ODN by the Ordnance Survey and therefore the levels are quoted to an unofficial ODN computed by TGI; any difference is unlikely to exceed 0.01 m.

The joint probability method assumes that the tide and surge are independent and we have found this to be a satisfactory assumption for Newhaven. Another assumption is that the frequency distribution of surge levels over the given period is taken to be representative of the probability density function for the population of all surges - past and future. As we only have 1 year of data and as the 02 February surge seems to have been an exceptional event, we omitted it from the surge distribution and recomputed the probabilities, to yield curve E on Figure 2 and return period estimates given in Table 1.

Pugh and Vassie (1979, 1980) investigated the stability and reliability of the joint probability method by comparing results using subsets of 1 year of data with the result using the whole set of 18 years data at Newlyn. The mean of the values of the 100 y return period level from the subsets was 0.04 m lower than the value from the 18 y data set, and the standard error was 0.02 m. Maximum and minimum differences of individual 1 y values from the mean value were 0.14 m and 0.20 m respectively. The method therefore gives stable results but estimates based on only 1 year's data are liable to have error bounds of approximately ±0.20 m.

4. Discussion

It is necessary to choose the best estimates of return period levels from the wide range of values available to us!

In view of the significant trend in the annual maxima data, we do not have much confidence in the estimates derived from curves A and B. Estimates from curve C, obtained from detrended data, are considered more reliable but because of the suspect quality of the data and the problems in using the annual maxima method, they should be treated with extreme caution.

Estimates obtained from the joint probability method using all the year's data, curve D, are likely to be extremely conservative for two reasons. Firstly the joint probability method gives more conservative estimates than the annual maxima method because it assumes that any surge level can combine with any tide level; whereas in practice an extreme total level is most likely to occur with a large tide and a large surge together, rather than with an extreme of either component (Pugh and Vassie, 1981). Secondly, our limited population of surges contains the extreme surge event of 02 February 1983 and this will bias the surge statistics.

We therefore consider estimates derived from curve E, computed without the 02 February surge, to be the more reliable of the two sets. A comparison of estimates from curves C and E shows good agreement and our final best estimates are taken as the mean of these values and given in Table 2. Note that the 500 y return period level given is that from the joint probability curve E as the annual maxima data set does not warrant extrapolating the extreme value curve beyond the 250 y level.

The joint probability method does not involve any extrapolation beyond the range of observed tide and surge. The longest return period from curve E is 719 y (4.30 m); that from curve D is 2893 y (4.50 m) and the 1000 y return period level is 4.43 m. We have not included these values in Table 2 because we think that the length of data available, 1 year, does not justify quoting levels beyond the 500 y return period.

Finally, we would like to point out that the return period is the average time between occurrences of an event, and that there is a finite risk that one such event will occur during a period equal to the return period. This risk (ri) is related to the return period (rp) and design life of the structure (L) by

$$ri = 1 - (1 - 1/rp)^L,$$

and is tabulated for various rp and L in Table 3. Note that if L = rp, then ri = 0.63, ie there is a 63% probability that the return period event will occur during the life of the structure; the risk can be reduced by choosing a return period greater than the effective lifetime of the structure.

5. Conclusion

We consider that the estimates of extreme still water levels at Newhaven given in Table 2 are the best available now, but stress the importance of collecting, processing and analysing more high-quality data in order to apply the joint probability method to more than 1 year of data.

We acknowledge the considerable efforts of our colleagues Sheila Shaw and Joyce Richards in processing the tide gauge data.

6. References

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Figure 1: Port diagram curves for Newhaven, using annual maxima method.

Figure 2: Return period curves of high still water level at Newhaven, using joint probability method.

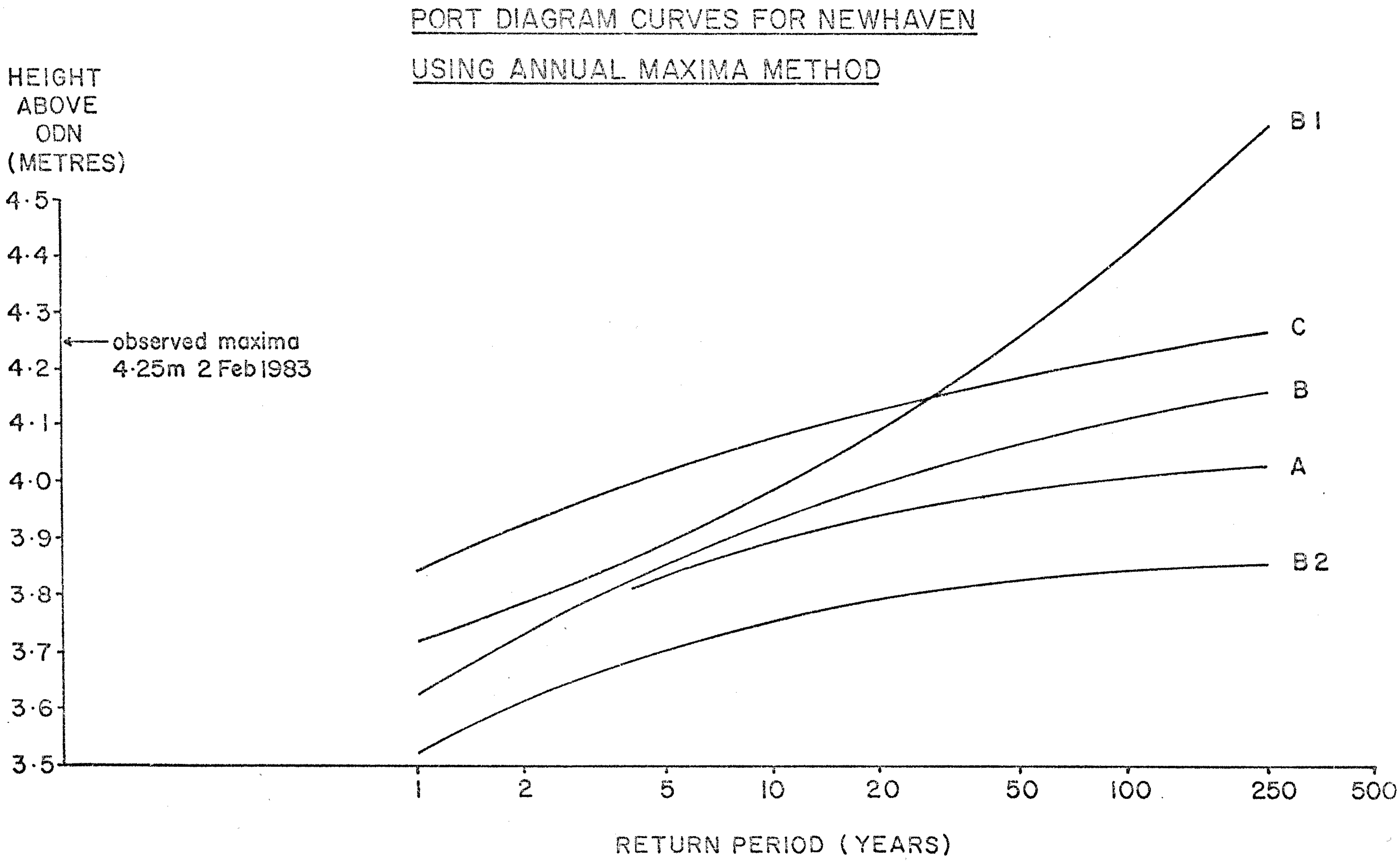
PORT DIAGRAM CURVES FOR NEWHAVEN
USING ANNUAL MAXIMA METHOD
HEIGHT ABOVE ODN (METRES)
4·5
4·4
4·3
4·2
4·1
4·0
3·9
3·8
3·7
3·6
3·5
observed maxima
4·25m 2 Feb 1983
B 1
C
B
A
B 2
1
2
5
10
20
50
100
250
500
RETURN PERIOD (YEARS)

FIG. 1

RETURN PERIOD CURVES OF HIGH STILL WATER LEVEL AT NEWHAVEN USING JOINT PROBABILITY METHOD

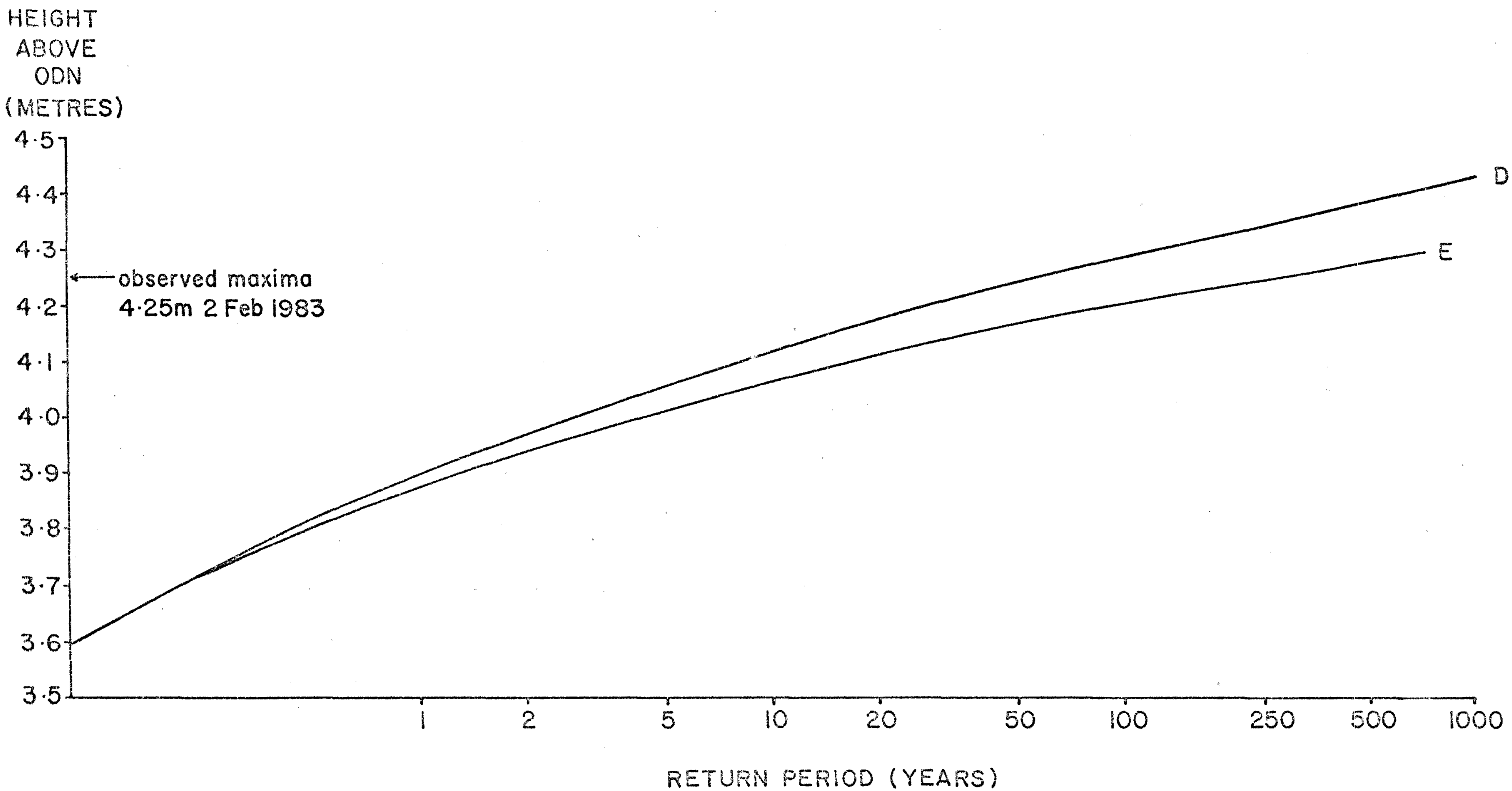

FIG. 2

		Return period levels (m to ODN)				Rp. of 4.25m ODN (y)
		50y	100y	250y	500y	
A.	Ann. max 1913-1976	3.98	4.01	4.03	--	
B.	Ann. max 1913-1976, 1983	4.07	4.11	4.16	--	1100
C.	As B, but detrended data	4.19	4.23	4.27	--	167
E.	Joint probability, 1982/83 surge of 02 February excluded	4.16	4.20	4.25	4.28	406
D.	As E but all surges included	4.25	4.30	4.35	4.39	50

Table 1 - Estimates of return period levels at Newhaven.

Return period level, (m to ODN)			
50y	100y	250y	500y
4.17	4.22	4.26	4.28

Table 2 - Best estimates of return period levels at Newhaven.

Design life L	Design return period, rp 50	100	250	500
50	0.636	0.395	0.182	0.095
100	0.867	0.634	0.330	0.181
250	0.994	0.919	0.633	0.394
500	0.999	0.993	0.865	0.632

Table 3 Risk of event occurring as a function of design life and design return period.