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WAVES MEASURED AT HELWICK LIGHT VESSEL
BRISTOL CHANNEL

L DRAPER

DATA FOR AUGUST 1960 TO JULY 1961
AT POSITION 51°30.5′N 4°25.5′W

REPORT NO 58
1978

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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L. Draper

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1. INTRODUCTION

Waves have been recorded by a Shipborne Wave Recorder (Tucker, 1956) placed on the Helwick Light Vessel, which is stationed approximately five miles south-west of Worms Head at the west of the Gower Peninsula. The depth of water under the vessel is about 90 feet (28m) at low tide with deepening water south westwards to the Atlantic. The mean spring tidal range is about 28 feet (8.5m). Wave recording started in late August 1960 and continued until mid July 1961. The records for this period of operation from August 1960 have been analysed, mainly following the method developed by Tucker (1961) from theoretical studies by Cartwright and Longuet-Higgins (1956) (see paragraph on Missing Data, Page 4). The form of presentation is that recommended for data for engineering purposes (Draper, 1966). The methods of analysis and presentation and the definitions used in this Report have been reviewed by Tann (1976). The instrument was calibrated in feet and these units have been retained throughout the analysis (1 metre = 3.28 feet).

2. RECORDING ROUTINE AND ANALYSIS

Records were taken for 15 minutes at three-hourly intervals, and the analysis of the first 12 minutes of each record yields the following parameters:

2.1 Parameters and definitions

(a) H_1 = The sum of the distances of the highest crest and the lowest trough from the mean water level. (See (h) Calm, below)

(b) H_2 = The sum of the distances of the second highest crest and the second lowest trough from the mean water level.

(c) T_z = The mean zero-crossing period, obtained by dividing the duration of the record (in seconds) by the number of occasions the trace passes in an upward direction through the mean water level.

(d) T_c = The mean crest period.

The expected values of H_1 and H_2 are a function of the significant wave height and of the number of zero-up-crossing waves in the analysed record. These values of H_1 and H_2 have been corrected for the depth below the surface of the pressure sensors by the formula, using T_z as the period parameter, given by M. Darbyshire (1961). (Her equation 1 with $K = 2.5$). The depths of the pressure sensors were assumed constant at 5.0 feet. From these measured parameters the following values have been calculated, after allowing for instrumental reponse:

(e) H_s = The significant wave height (mean height of the highest one-third of the waves): this is calculated separately from both H_1 and H_2, and an average taken. The relationship between the parameters is: $H_s = F.H_1$ where f is a function of the number of zero-crossings in the record (Tucker, 1963). A similar equation is used for the calculation of H_s from H_2.

(f) $H_{max(3\ hours)}$ = The most probable value of the height of the highest wave which occurred in the recording interval of 3 hours (Draper, 1963). (The recording interval is the time elapsed between the starts of successive records.)

(g) ε = The spectral width parameter, which is calculated from T_z and T_c (Tucker, 1961):

$$\varepsilon^2 = 1 - (T_c/T_z)^2$$

(h) Calm Any record where the sum of the highest crest plus the lowest trough (H_1) is less than 1 foot is classified as Calm.

2.2 Treatment of missing data

There are two major gaps in this data set, they are of 9 days in March and of 47 days in July and August. In neither case are data available for the same periods in another year, so the gaps are filled by substitution, using an equal amount of data from before and after the gap. This is probably the best available approximation which can be achieved to simulate a complete year. To avoid unnecessary discontinuities in the persistence diagram the adjacent data have been inserted in reverse order from before and after the discontinuities, i.e. the first missing figure is a repeat of the last measured one, the second missing figure is a repeat of the last-but-one measured figure, and so on until the mid point is reached. Similarly with the second half of the gap, the last missing figure is replaced by the first one measured after the re-start and so on. In this way there is only one abrupt discontinuity. In the first gap it is of 2.5 ft in measured height (H_1) whilst the difference between the two previous actually-measured values is 2.6 feet, so it is not a change which will be noticeable in the persistence diagram. In the second gap the discontinuity is 1.1 foot, which is negligible. Six other one-record gaps and one of three records have been filled by interpolation.

3. PRESENTATION

The results of these measurements are expressed graphically, divided into seasons thus:

Winter:	January	February	March
Spring:	April	May	June
Summer:	July	August	September
Autumn:	October	November	December

For each season a graph (Figures 1-4) shows the cumulative distributions of significant wave height H_s and of the most probable value of the heights of the highest wave in the recording interval, $H_{max(3\ hours)}$, whilst Figure 5 is for the whole year.

The distribution of zero-crossing period is given for each season (Figures 6-9), whilst Figure 10 is for the whole year.

The distribution of the spectral width parameter is given for the whole year (Figure 11).

Figure 12 is a scatter diagram relating significant wave height to zero-crossing period.

Figure 13 is a persistence of calms diagram for the whole year.

Figure 14 is a persistence of storms diagram for the whole year.

Figures 15 and 16 enable 'Lifetime' wave predictions to be made using log-normal and Weibull distributions.

4. WIND CONDITIONS during the year of recording compared with the long-term average

The Meteorological Office has analysed wind conditions at Rhoose, Swansea, which is the most suitable site in the vicinity of Helwick at which to assess the normality of the wind (and therefore wave) conditions during the year of wave recording. The winds used were those which blew from between 180^{0} and 290^{0}, the principal directions for the generation of waves at Helwick. The local winds are likely to be responsible for the higher and steeper seas but of course they are not likely to be correlated with the swell which reaches the site. The long term average wind speed from 1959 to 1976 was 12.2 knots, whereas the average wind speed from August 1960 to July 1961 was 10.8 knots, only 89% of the normal speed.

5. INTERPRETATION AND DISCUSSION

5.1 Highest Waves

The highest recorded individual wave, 33 feet crest to trough, occurred on 31 January, with a zero-up-crossing period of the whole record of 9.73 seconds. Waves of almost that height also occurred in November, but in this case they were of slightly longer period.

5.2 Percentage exceedance

From Figures 1-4 may be determined the proportion of time for which H_s or $H_{max(3\ hours)}$ exceeded any given height. For example, in winter the significant height exceeded 5 feet for 65 percent of the time whilst in the summer it was exceeded for only 28 percent of the time.

5.3 Zero-up-crossing period

The distribution of zero-crossing period, Figures 6-10, do not show marked differences from season to season. In the autumn and winter the most common is about 8 seconds whilst in the spring and summer it is about 6 seconds. Each season shows a spread of from about 3.5 seconds to 11 seconds but in the winter it exceeds 12 seconds.

5.4 Spectral width parameter

Figure 11 shows the spectral width parameter to lie mainly between 0.4 and 0.8 with the most common values around 0.6. (A high value indicates a fully-developed sea and a low one indicates swell.)

5.5 Scatter diagram

The scatter diagram of Figure 12 relates the significant wave height to zero-crossing period, with the number of occurrences expressed in parts per thousand. There are nearly three thousand records taken in a full year, so that an asterisk *, which represents one occurrence, is equivalent to one part in three thousand, and a plus sign +, which represents two occurrences, is equivalent to two parts in three thousand. As an example, the most common wave conditions were those with a significant height of between 3 and 4 feet with a zero-crossing period of between 6 and 6.5 seconds, which occurred for 29 thousandths, or 2.9 percent, of the time. The rapid attenuation of the shorter waves with depth means that the instrument's pressure units, which are about 5.0 feet below the mean water level, do not record waves which have a period of less than approximately 3 seconds; this is the cause of the cut-off below that period.

A parameter which is sometimes of interest is the wave steepness, expressed as wave height: wave length. It should be noted that the steepness of a wave is not the same as the maximum slope of the water surface during the passage of a wave. Lines of constant steepness of 1:20 and 1:40 are drawn on Figure 12. (Wave length L was computed using the linear wave theory with period T in deep water, that is $L = gT^2/2\pi$.) The figure indicates a small proportion of significant wave heights steeper than 1:20. Individual wave heights can occasionally be expected to exceed about twice the significant wave height, approaching the theoretical limiting steepness of 1:7.

5.6 Persistence diagrams

5.6.1 Persistence of Calms

From the persistence of calms diagram, Figure 13, may be deduced the number and duration of occasions in 1 year on which waves persisted at or below a given height after they had fallen through the threshold value. For example, for a vessel able to operate in a significant height of up to 6 feet there were 80 separate occasions in the year when it would have been able to operate continuously for 12 hours or longer; on 55 of these occasions the calm would have lasted for 24 hours or longer and on 32 of these occasions it would have lasted for 50 hours or longer. On 10 occasions the calm would have lasted for 200 hours.

5.6.2 Persistence of Storms

From the persistence of storms diagram, Figure 14, may be deduced the number and duration of the occasions in 1 year on which waves persisted at or above a given height. For example, if the limit for a particular operation of a vessel is again a significant height of 6 feet, it would have been unable to operate for spells in excess of 10 hours on 60 separate occasions, or spells in excess of 24 hours on 32 of these separate occasions.

5.7 'Lifetime' wave prediction

Figures 15 and 16 are plots on probability paper of values of $H_{max(3\ hours)}$ and H_s respectively. The data on the log-normal plot (Figure 14) lie well along a smooth curve, the estimated value of the wave height at a 50 year average return period is about 58 feet, although the drawing of this curve is subjective. On the Weibull plot the data are quite well behaved and lie close to a straight line, the extrapolation of which yields a 50-year estimate of 57 feet. These estimates should be used with caution, especially so bearing in mind the comments made in the section on wind conditions (4) and Conclusions (6).

6. CONCLUSIONS

As the local winds responsible for wave generation at Helwick appeared to be lighter than average during the time in which wave recorder was operational, the locally-generated waves are likely to have been lower in height and period than those in an average year. The swell content, having originated over a much larger area, is less likely to have varied from the norm; it is not possible to make any estimate of its difference. If the assumption is made that wave height is related to wind speed to the power 1.5, and period to the power 0.5, it is reasonable to conclude that wave heights in a normal year can be estimated by multiplying the values presented in this Report by 1.15, and periods by multiplying by 1.05. As swell is responsible for only a smaller part of the wave heights, compared with those of the locally-generated waves, the application of these factors to all wave heights and periods should not significantly distort the results.

7. ACKNOWLEDGEMENTS

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8. REFERENCES

Cartwright, D.E. and Longuet-Higgins, M.S. 1956
The statistical distribution of the maxima of a random function.
Proc. roy. Soc. A 237, 212-232

Darbyshire, M. 1961
A method of calibration of Shipborne Wave Recorders
Deutsche Hydrographische Zeitschrift 14 (2) 56-63

Draper, L. 1963
The derivation of a 'design-wave' from instrumental measurements of sea waves.
Proc. Instn. civ. Engrs. 26, 291-304.

Draper, L. 1966
The analysis and presentation of wave data - a plea for uniformity.
Proc. 10 Conf. on Coastal Engineering, Tokyo, Chapters 1 and 2.

Tann, H.M. 1976
The estimation of wave parameters for the design of offshore structures.
IOS Report 23.

Tucker, M.J. 1956
A Shipborne Wave Recorder.
Trans. Instn. nav. Archit. Lond. 98, 236-250.

Tucker, M.J. 1961
Simple measurement of wave records.
Proc. Conf. Wave Recording for civ. Engrs. (NIO) 22-3.

HELWICK S.B W.R DATA. 1960/1961.

PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

WINTER - JANUARY TO MARCH

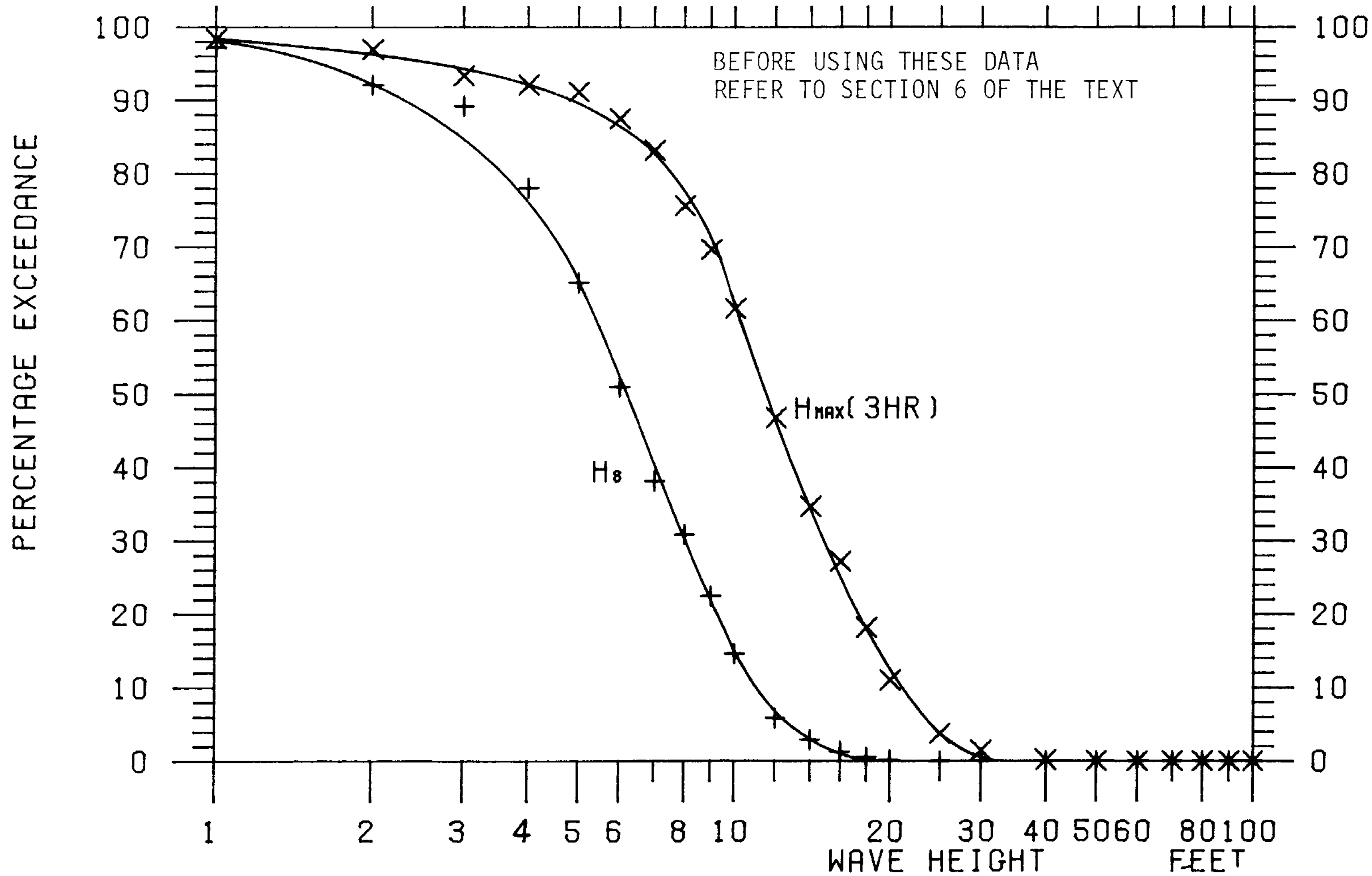


Fig.1

HELWICK S.B W.R DATA. 1960/1961.

PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

SPRING APRIL TO JUNE

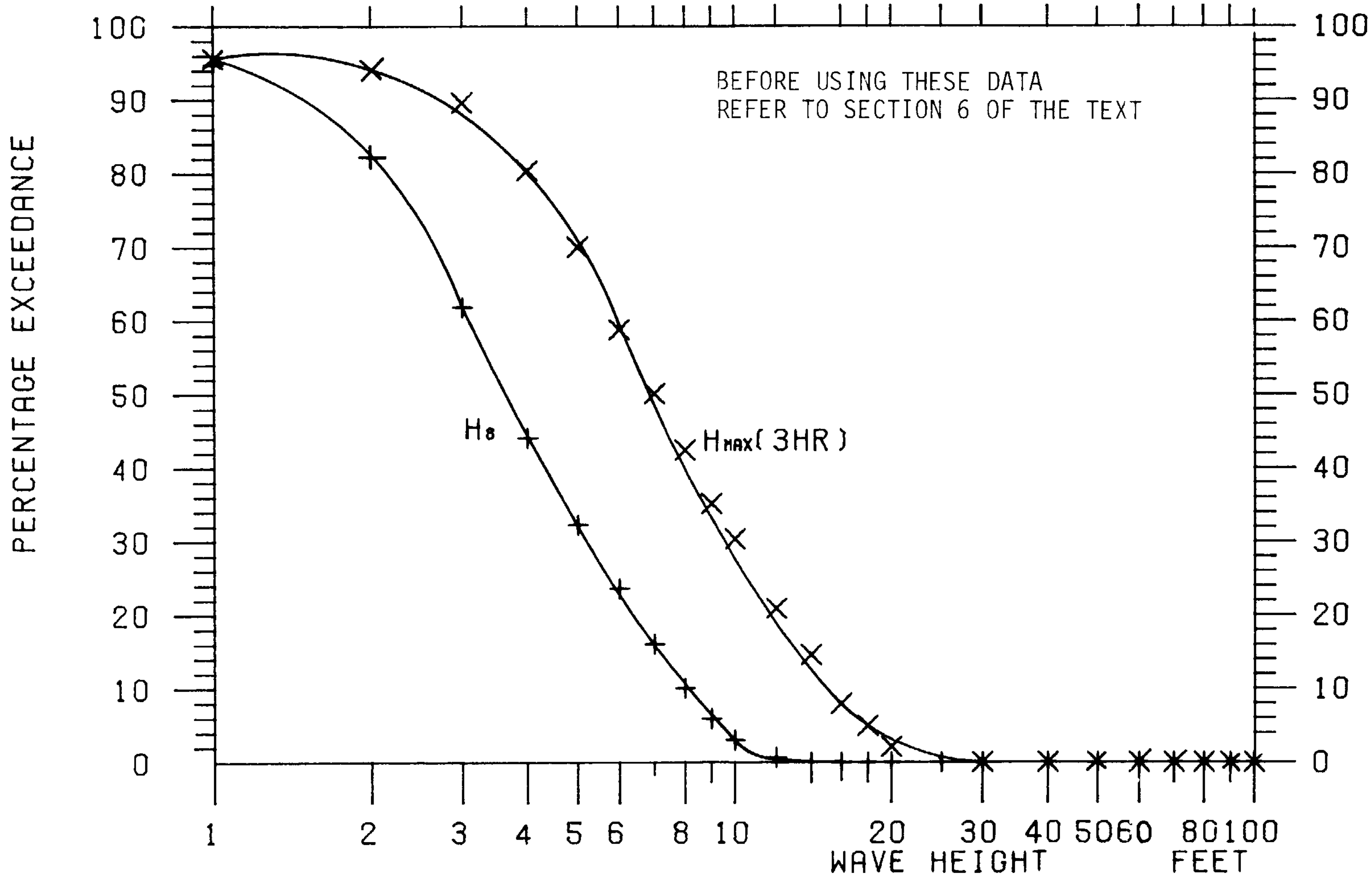


Fig.2

HELWICK S.B.W.R. DATA. 1960/1961.

PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

SUMMER - JULY TO SEPTEMBER

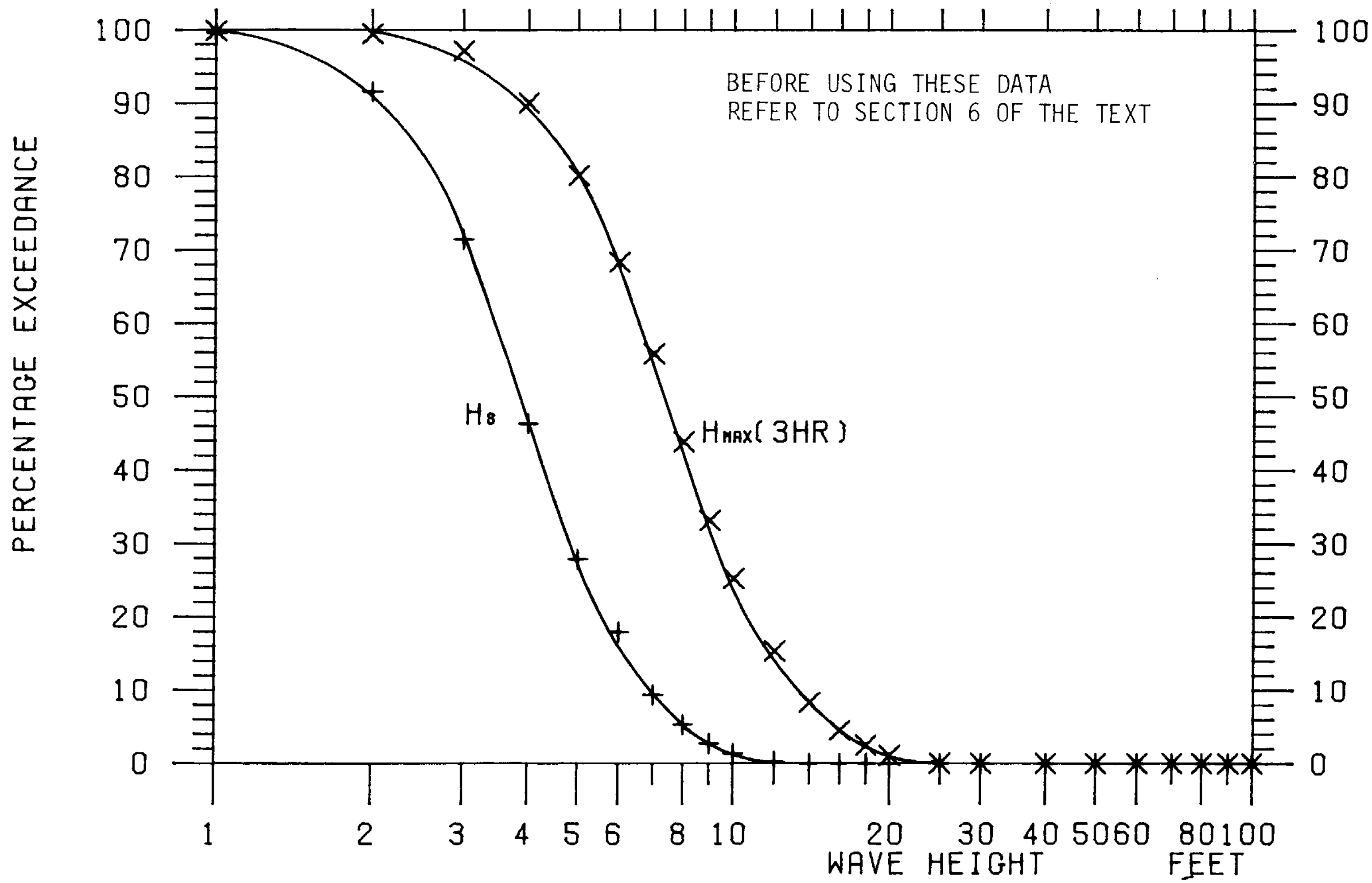


Fig. 3

HELWICK S.B.W.R. DATA. 1960/1961.

PERCENTAGE EXCEEDANCE OF H_s AND H_{MAX}

AUTUMN - OCTOBER TO DECEMBER

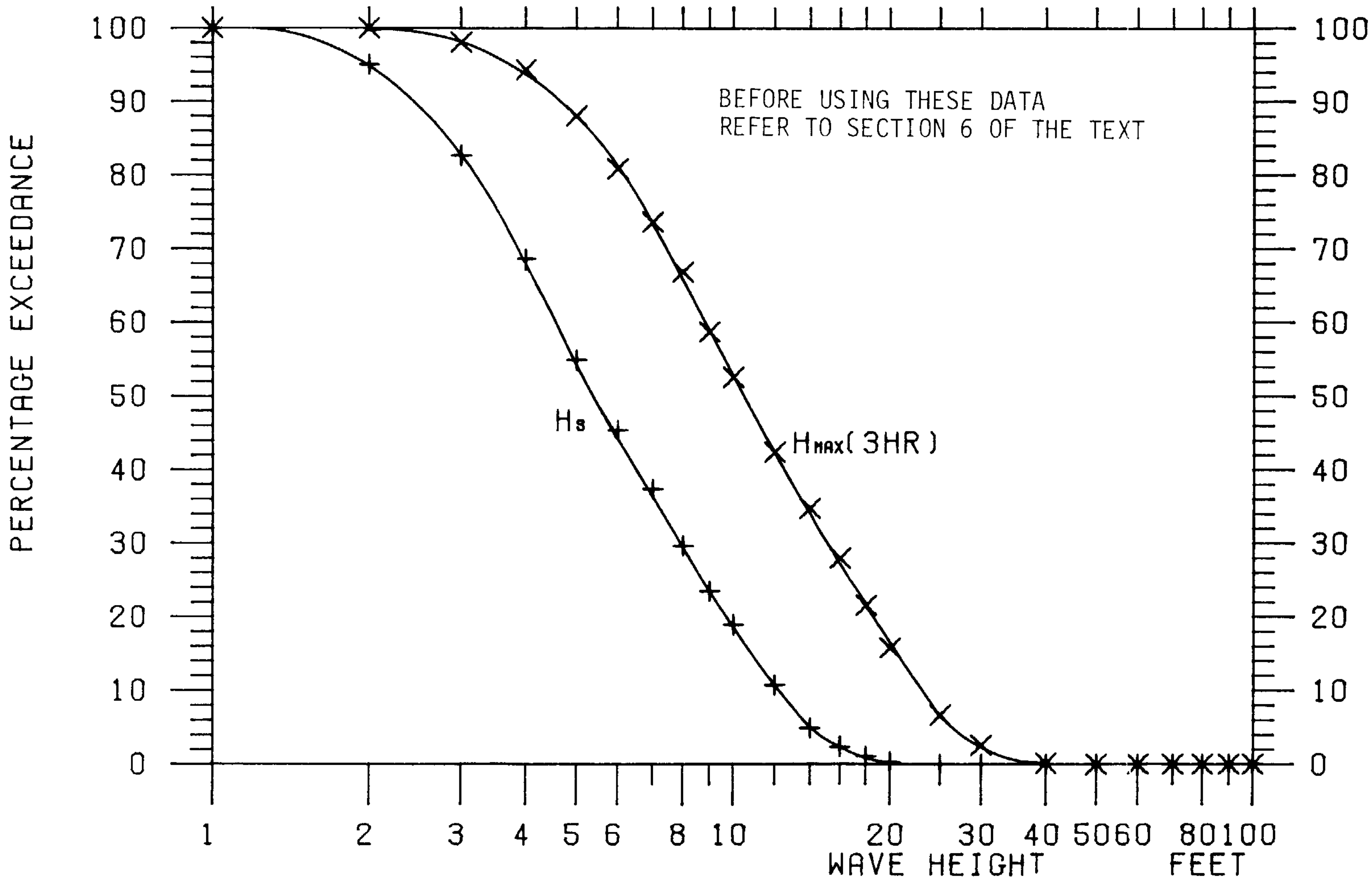


Fig. 4

HELWICK S.B.W.R. DATA. 1960/1961.

PERCENTAGE EXCEEDANCE OF H_s AND H_{max}

WHOLE YEAR

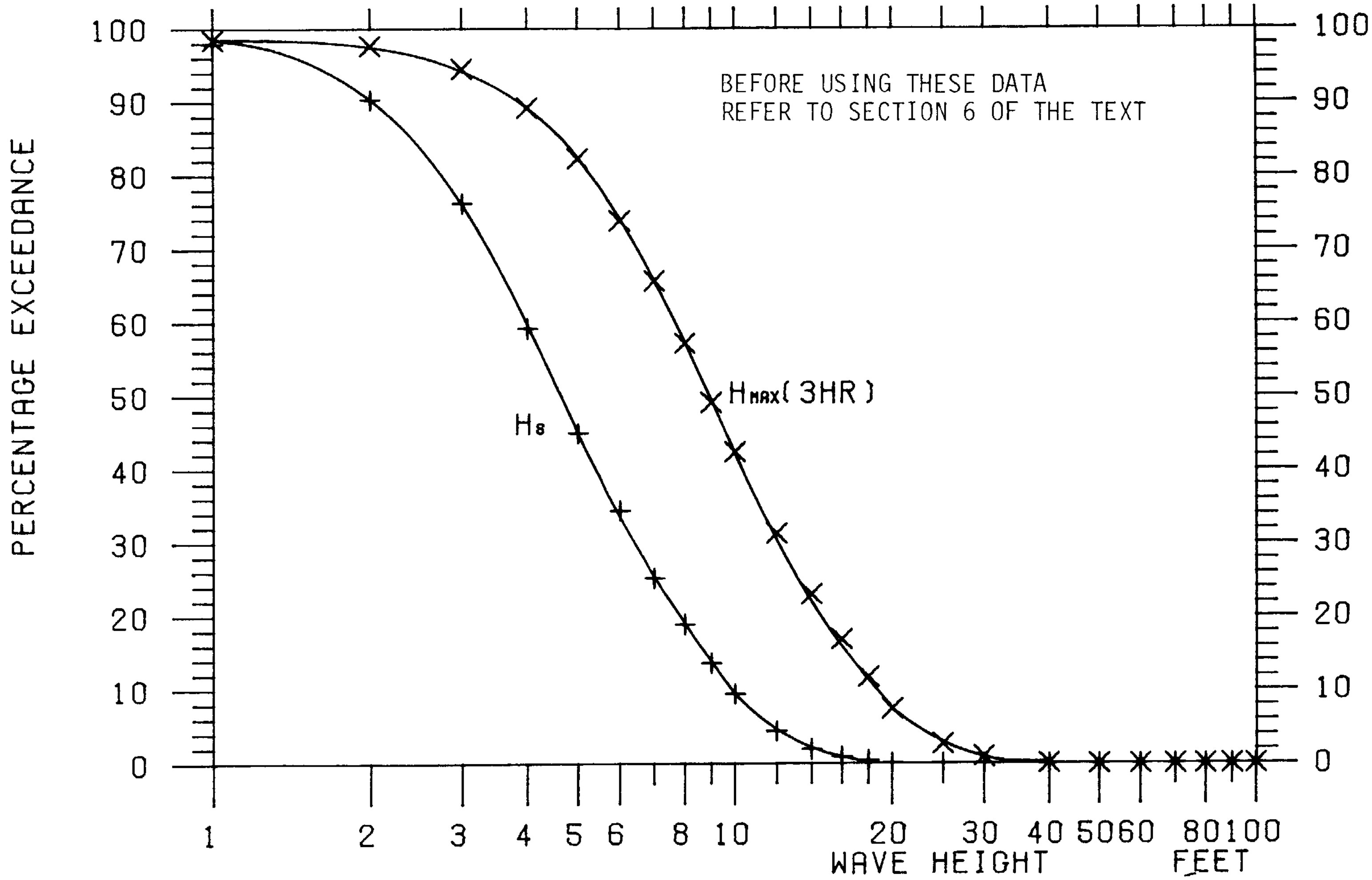


Fig.5

HELWICK S.B.W.R. DATA. 1960/1961.

PERCENTAGE OCCURRENCE OF T_z

WINTER - JANUARY TO MARCH

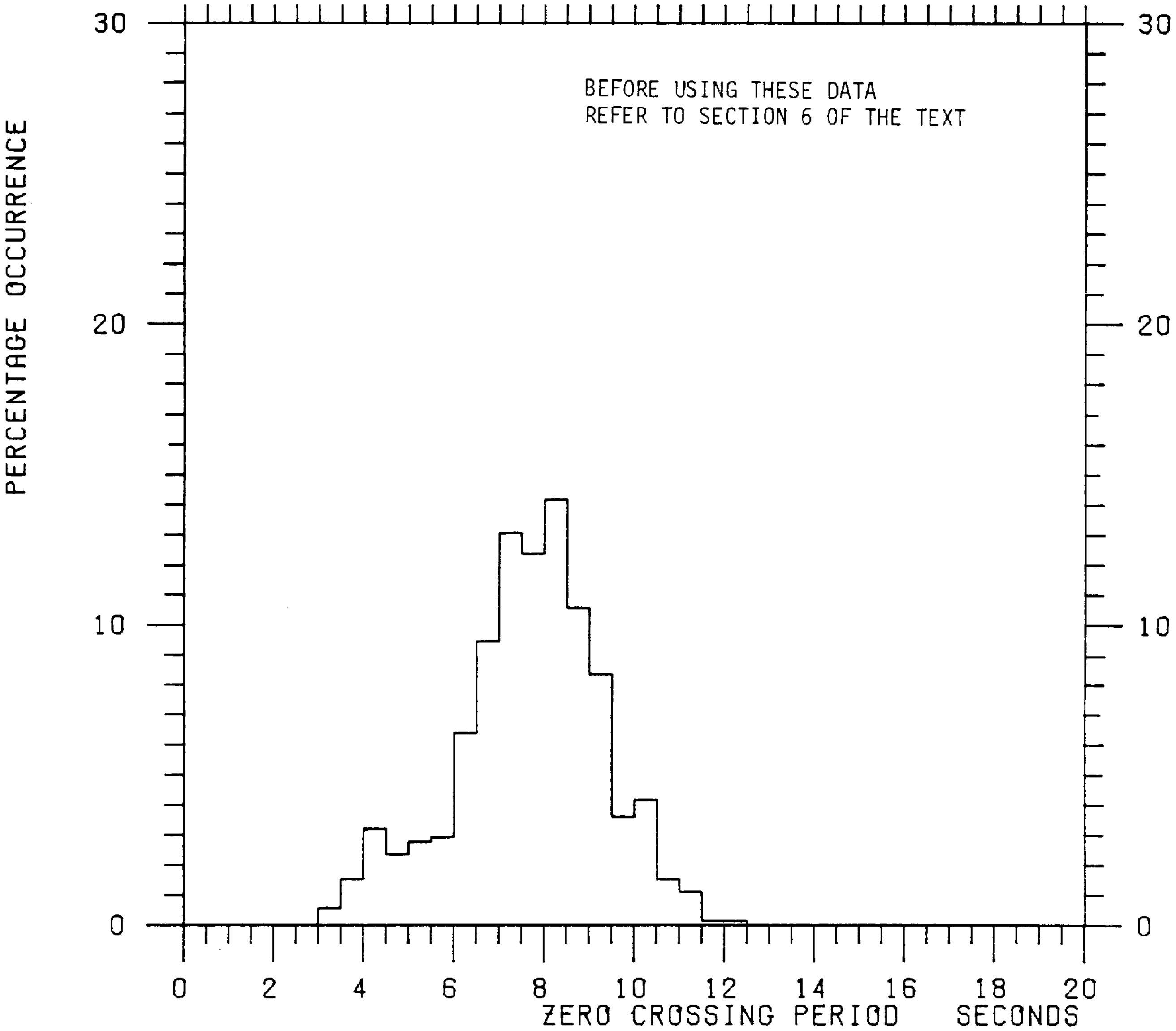


Fig. 6

CALM= 1.67 PER CENT

HELWICK S.B.W.R. DATA. 1960/1961.

PERCENTAGE OCCURRENCE OF T_z

SPRING - APRIL TO JUNE

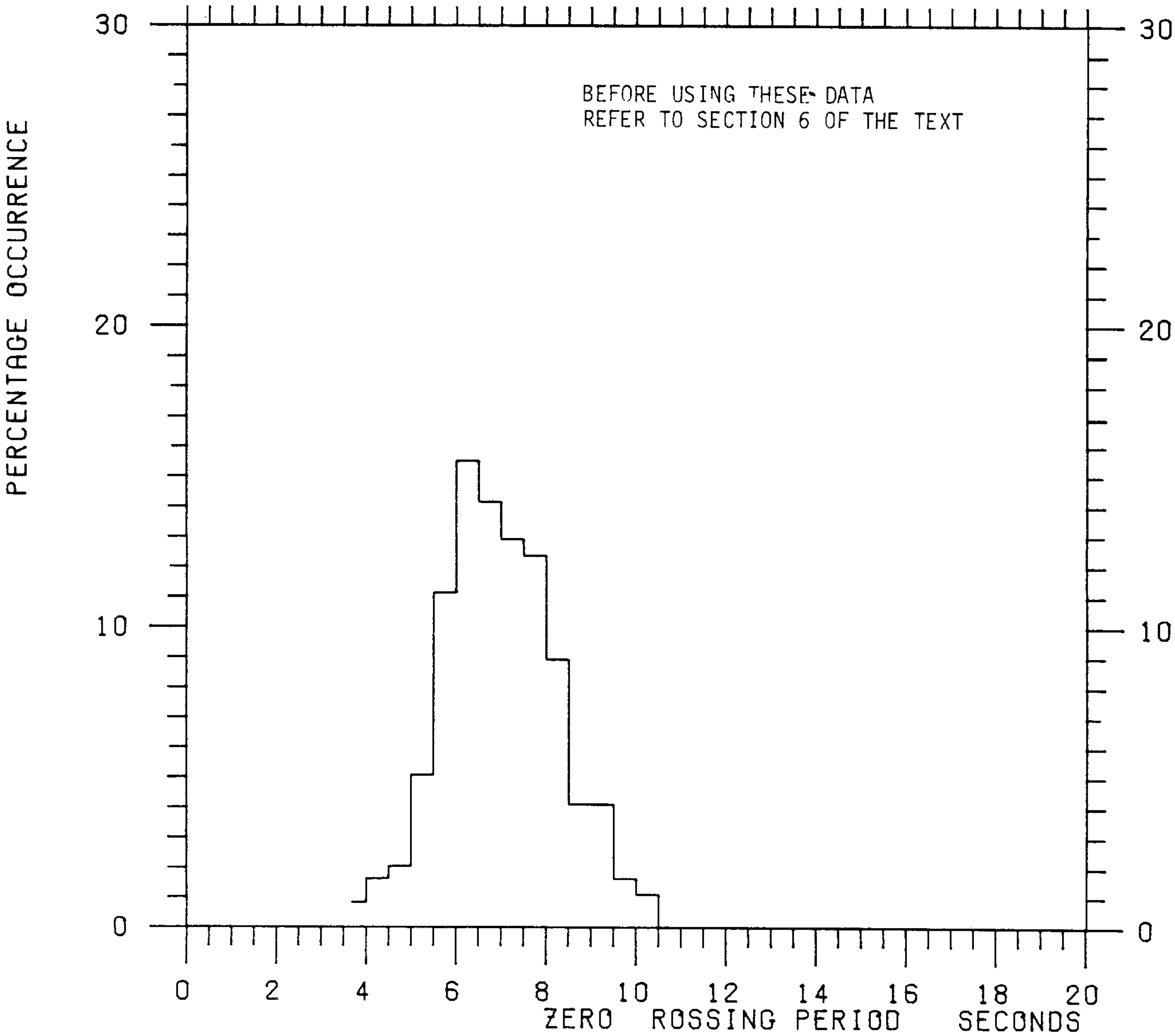


Fig.7

CALM= 4.40 PER CENT

HELWICK S.B.W.R. DATA. 1960/1961.

PERCENTAGE OCCURRENCE OF T_z

SUMMER - JULY TO SEPTEMBER

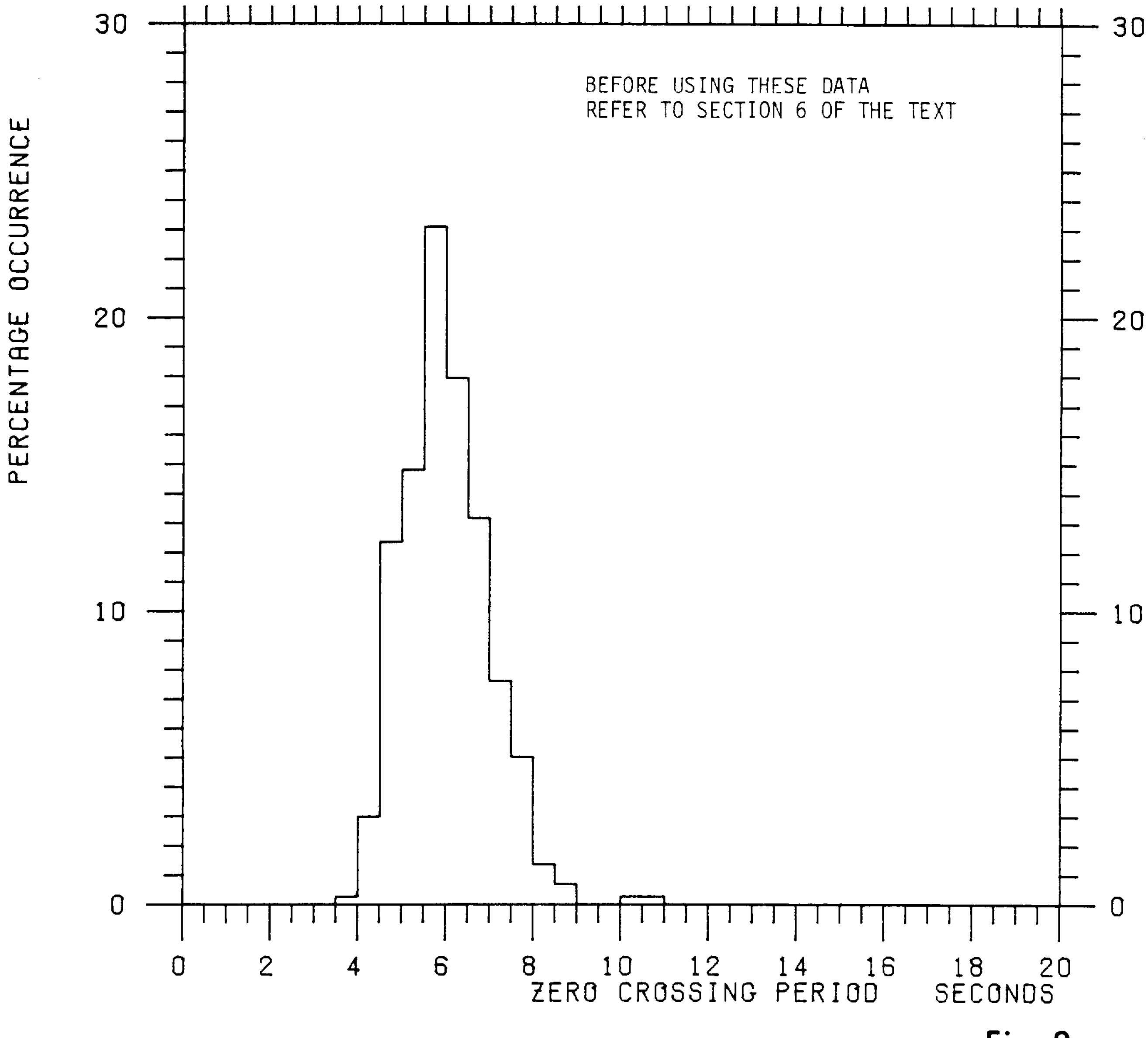


Fig. 8

CALM= 0.14 PER CENT

HELWICK S.B.W.R. DATA. 1960/1961.

PERCENTAGE OCCURRENCE OF T_z

AUTUMN - OCTOBER TO DECEMBER

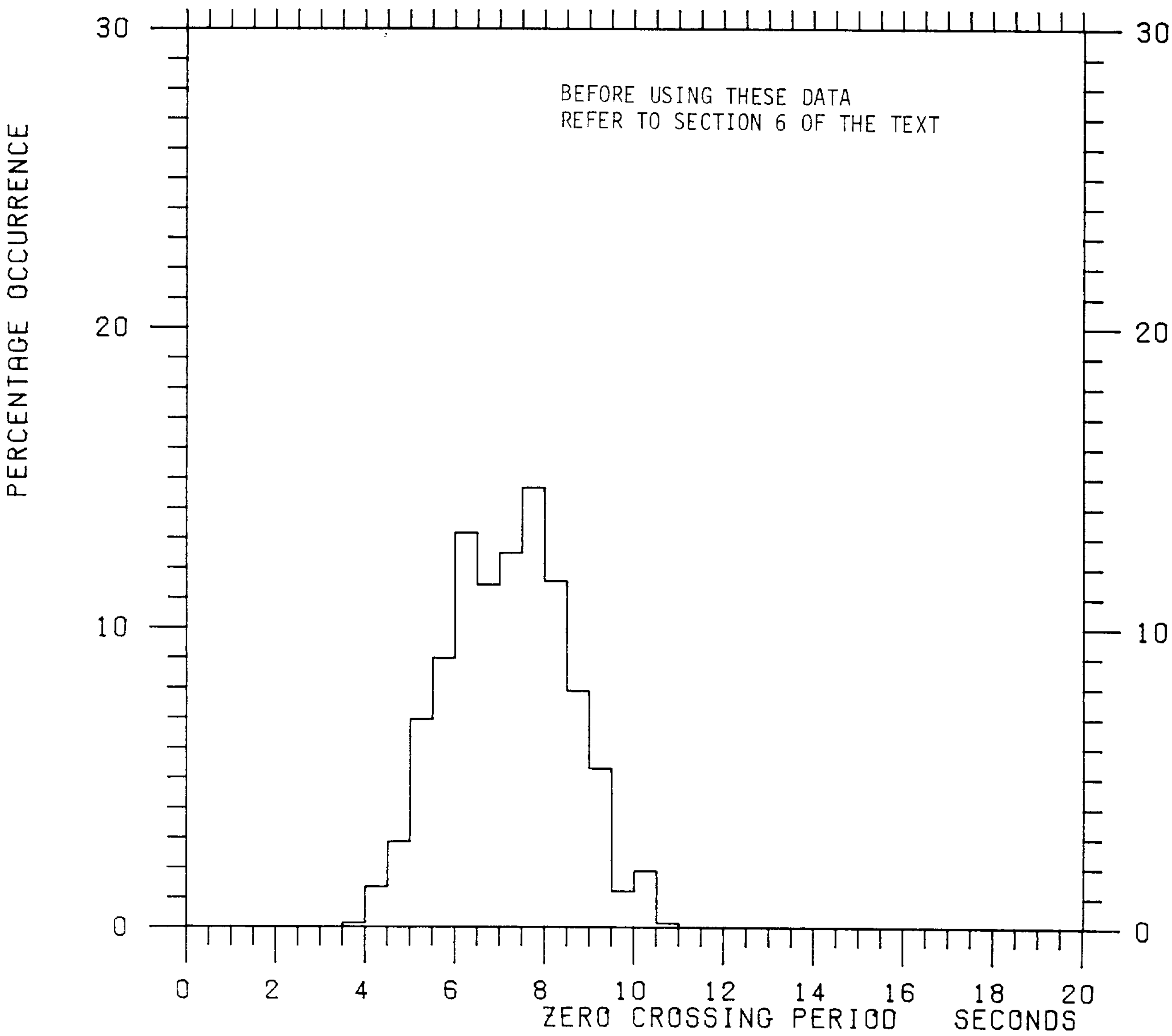


Fig. 9

CALM= 0.00 PER CENT

HELWICK S.B.W.R. DATA. 1960/1961.

PERCENTAGE OCCURRENCE OF T_z

WHOLE YEAR

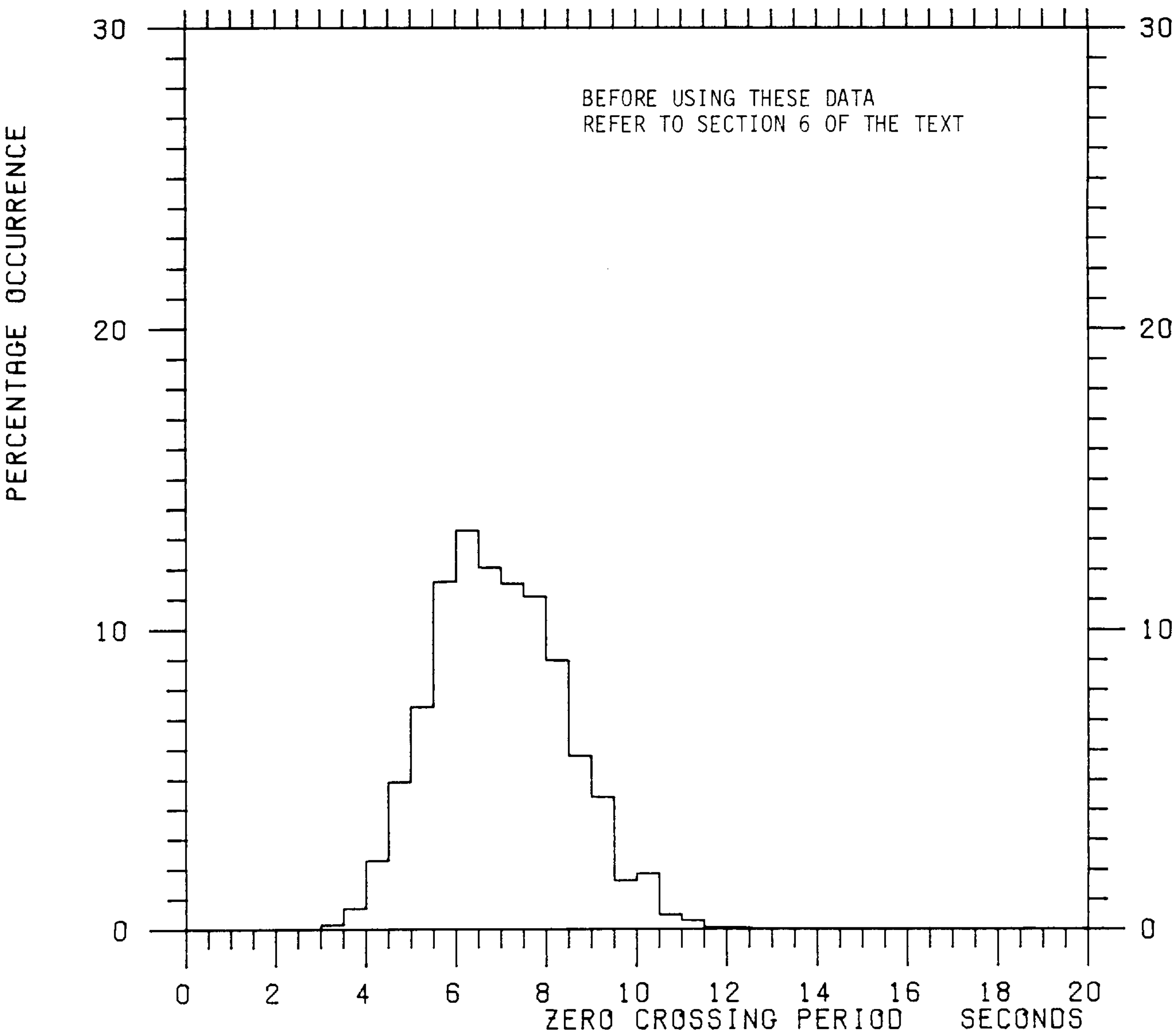


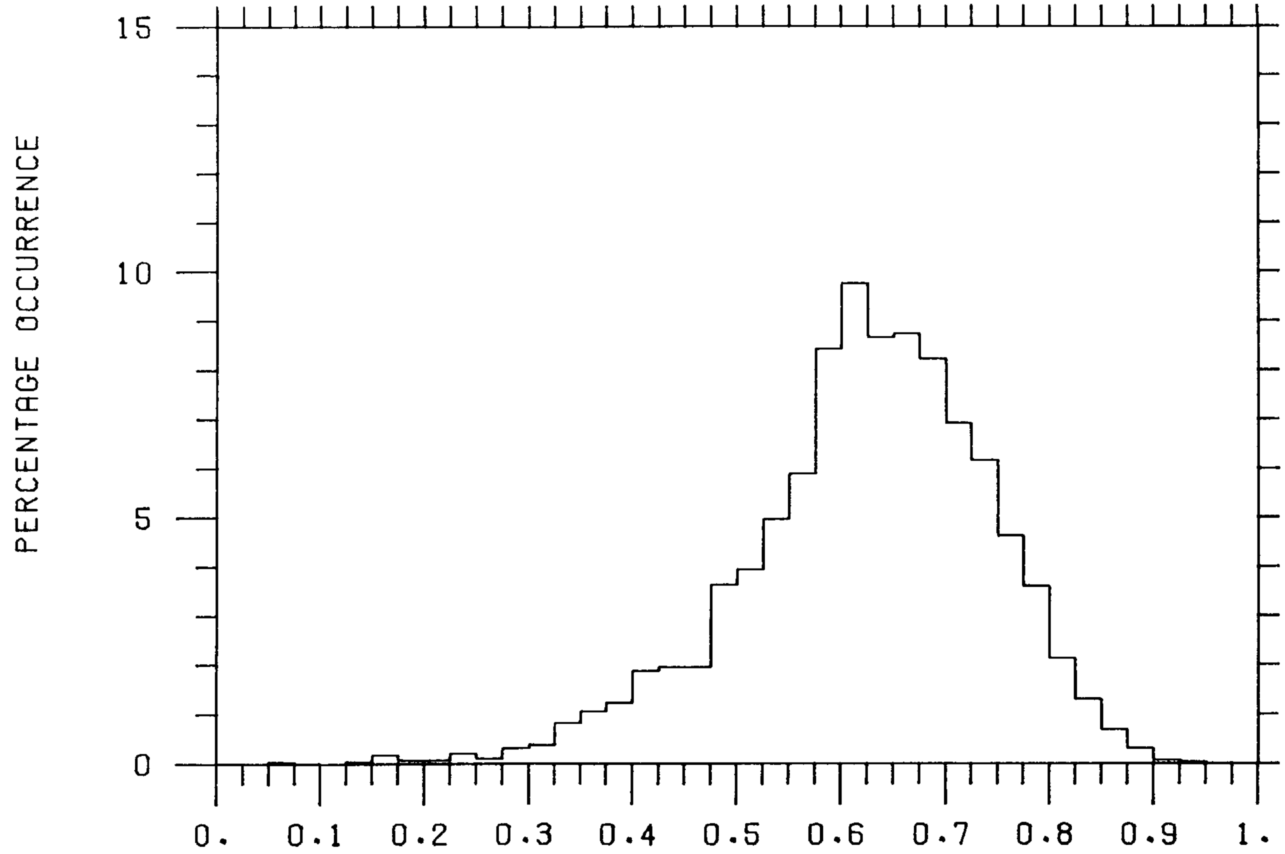
Fig.10

CALM= 1.54 PER CENT

HELWICK S.B.W.R. DATA. 1960/1961.

SPECTRAL WIDTH PARAMETER

WHOLE YEAR



CALM= 1.54 PER CENT

Fig.11

HELWICK S.B.W.R. DATA. 1960/1961.

SCATTER DIAGRAM FOR WHOLE YEAR

IN PARTS PER 1000 ✱=1 OCCURRENCE 0·3 PART +=2 OCCURRENCES 0·7 PART

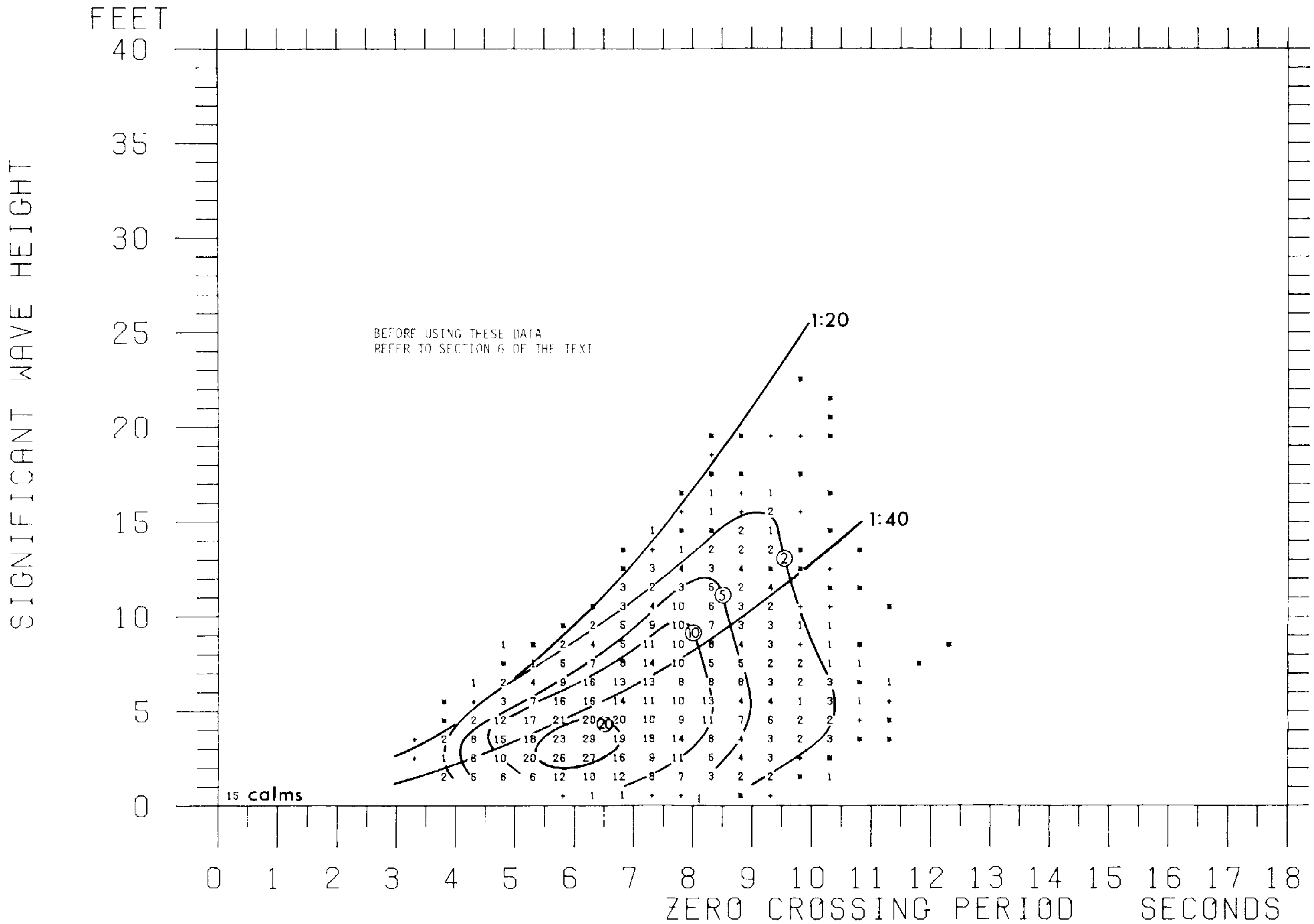


Fig. 12

HELWICK S.B.W.R. DATA. 1960 / 1961

WHOLE YEAR

PERSISTENCE OF CALMS

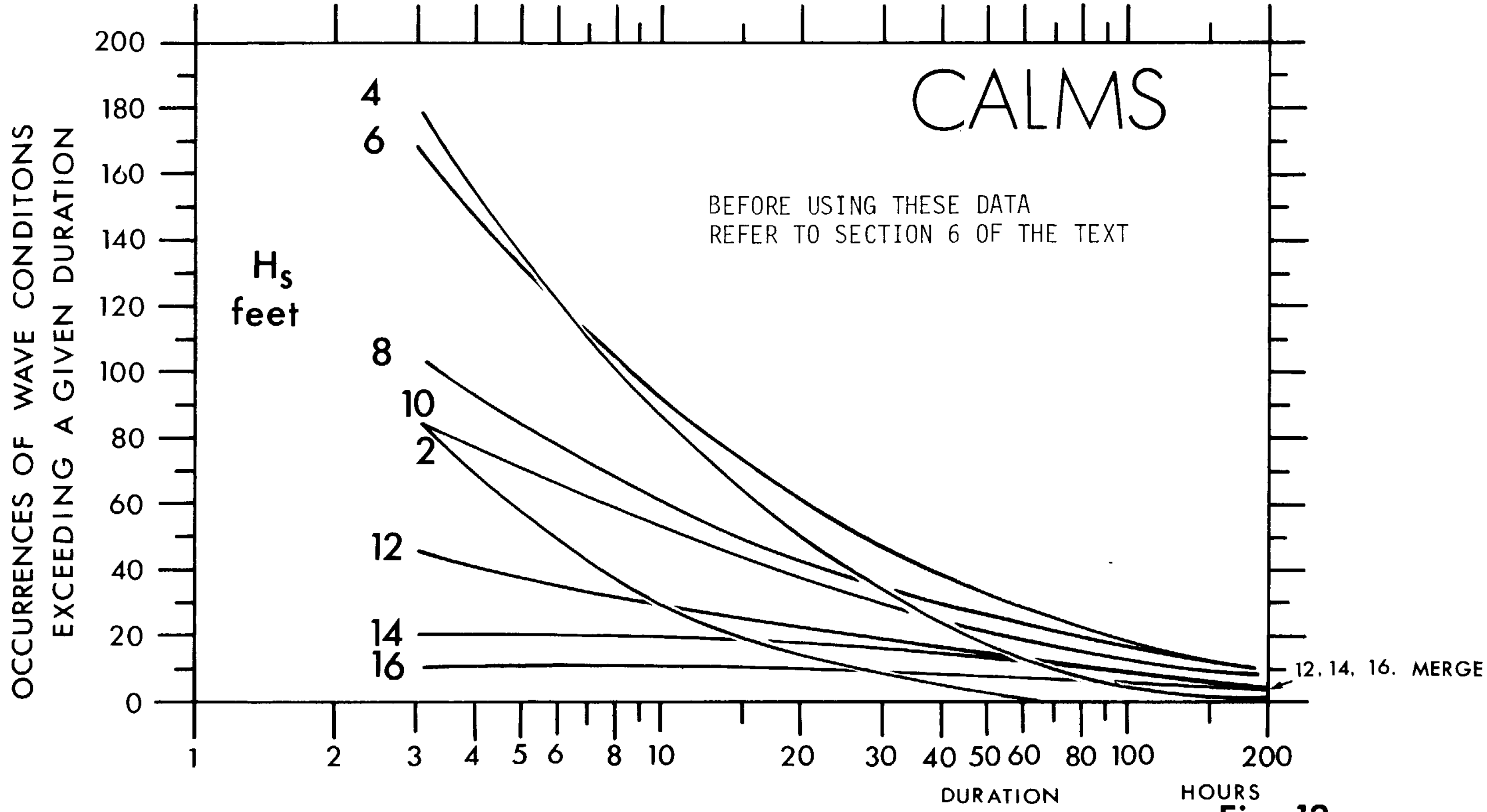


Fig. 13

HELWICK S.B.W.R. DATA 1960/1961

WHOLE YEAR

PERSISTENCE OF STORMS

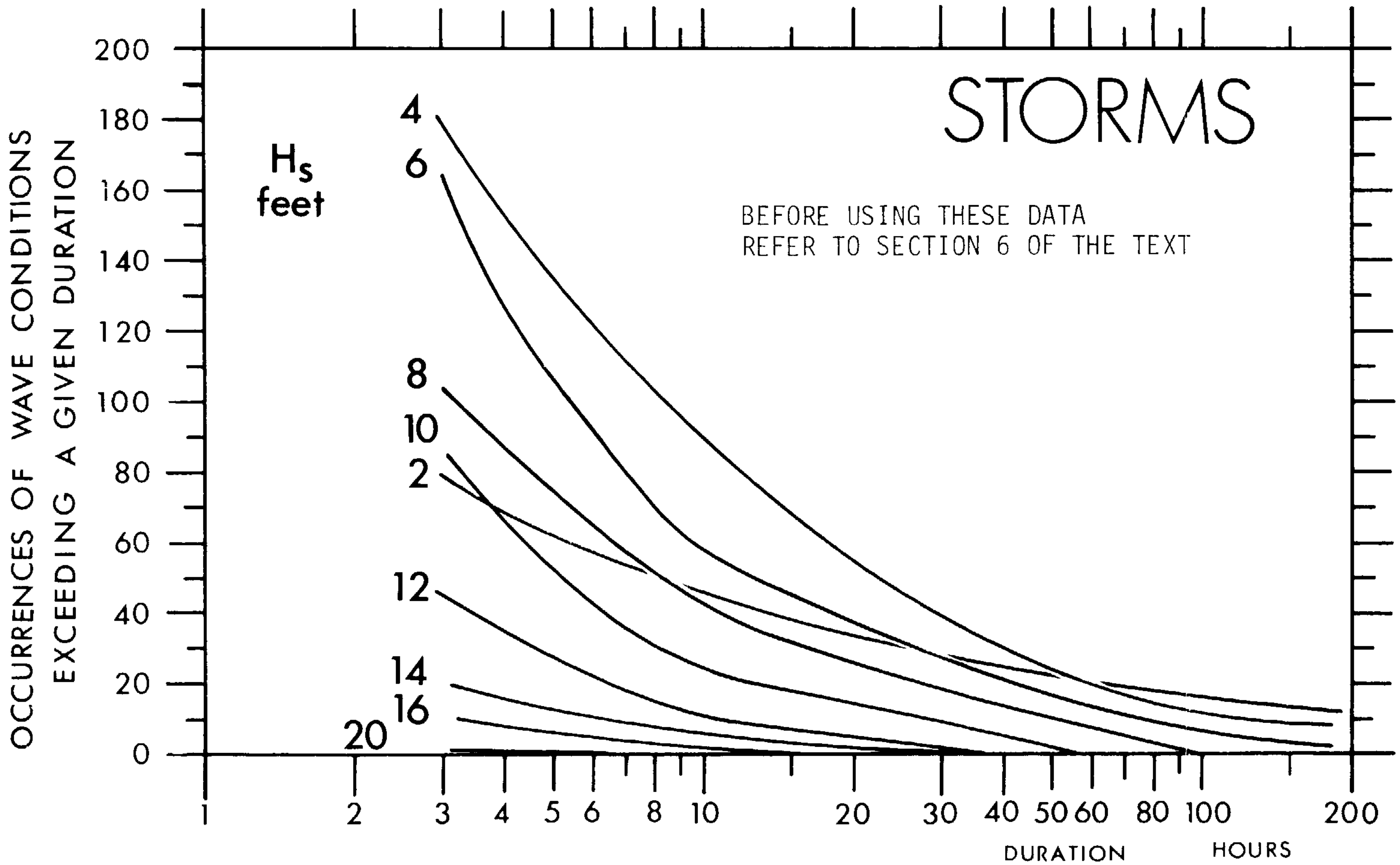


Fig. 14

HELWICK S.B.W.R. DATA 1960/1961

Lifetime Wave Prediction Log - normal

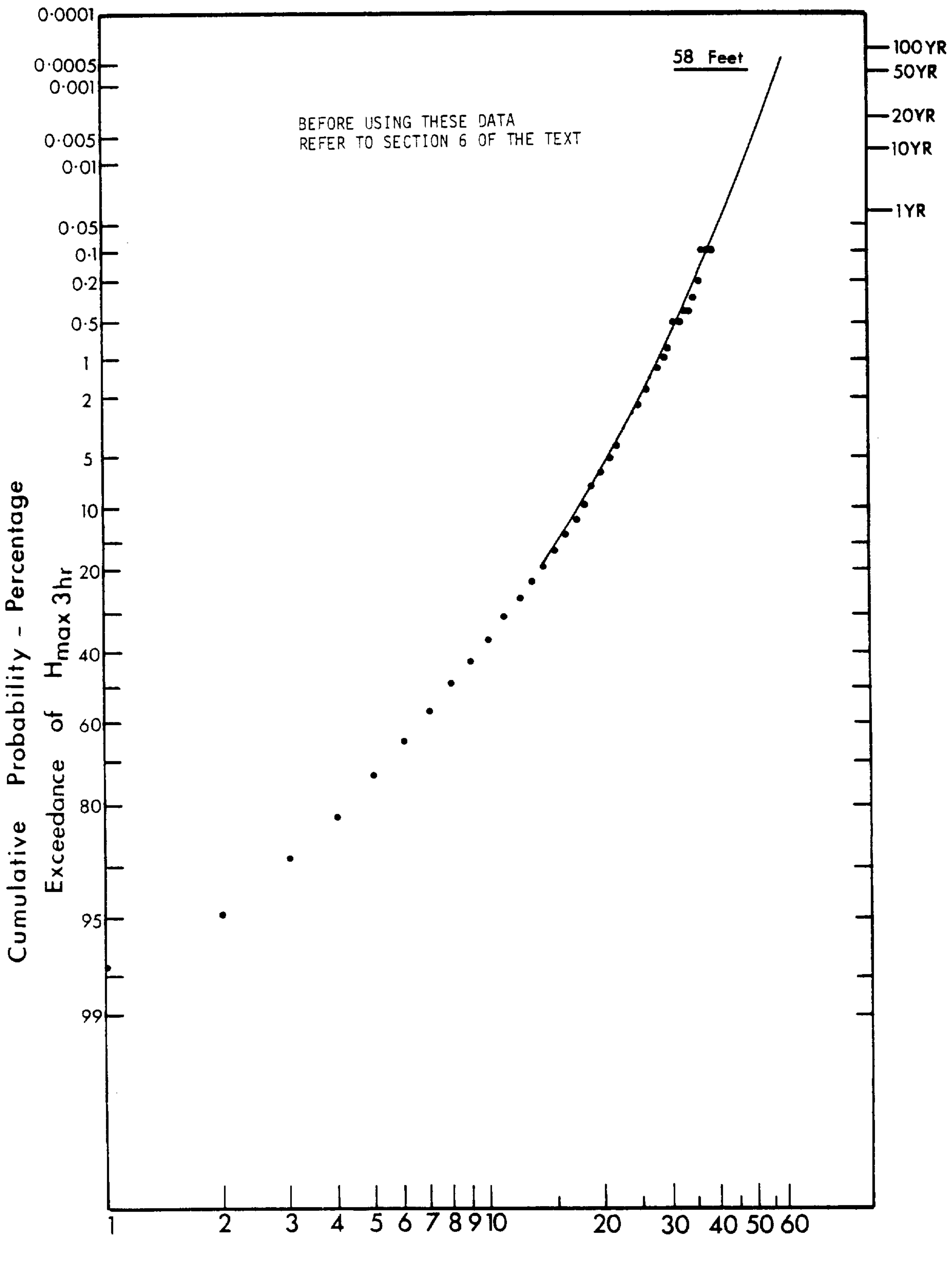


Fig. 15

HELWICK S.B.W.R. DATA 1960/1961

Lifetime Wave Prediction – WEIBULL

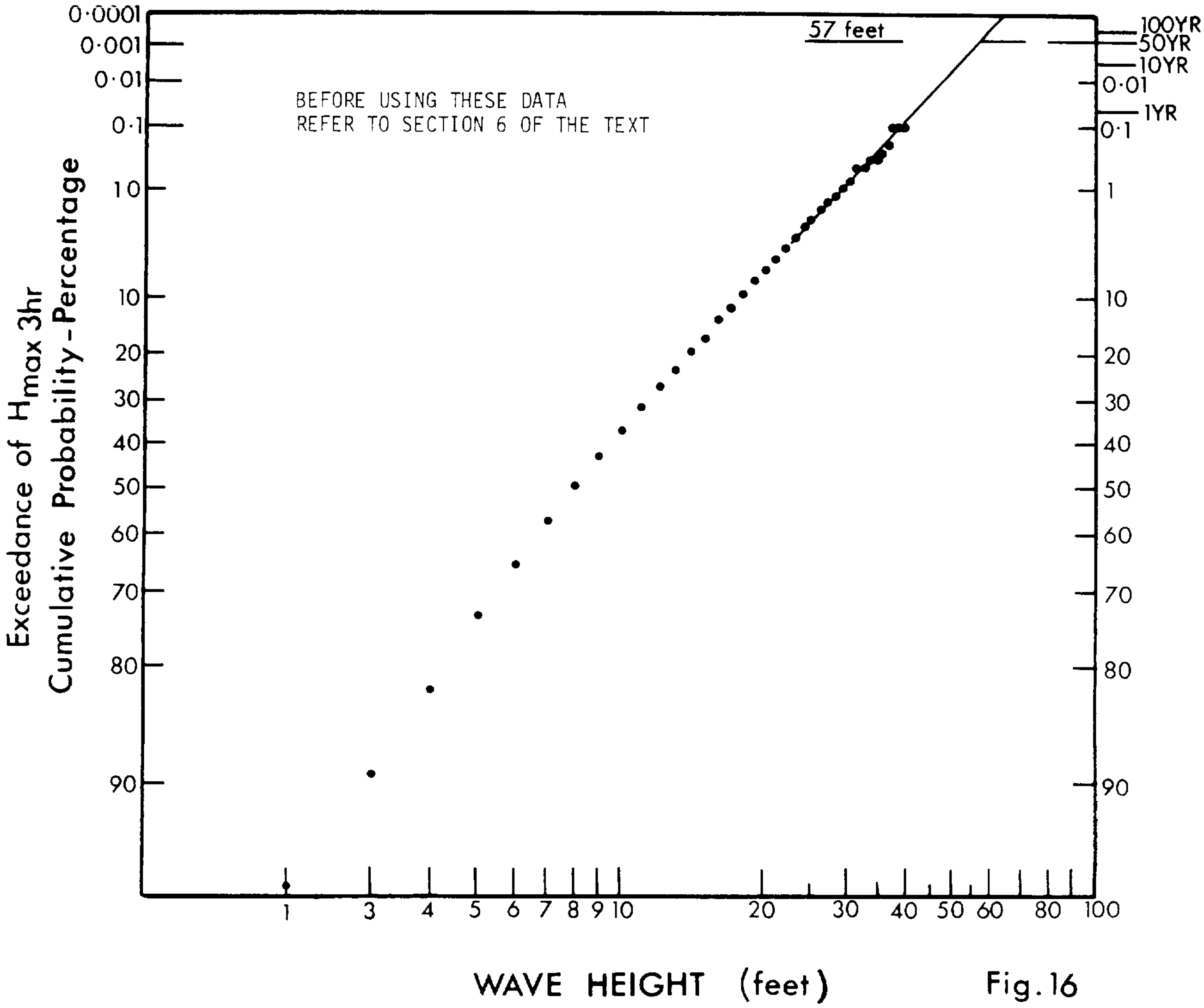


Fig. 16