

The probability of high current speeds at the Netherlands lightships

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New activities undertaken in the North Sea, and technical projects which are under consideration, have focused the attention on the influence of the marine environmental conditions, and especially on the risks of extreme situations.

One of the parameters that may be important is the current speed. The speed of the tidal current is rather well known (be it not in the most desirable detail), and maps exist of the maximum velocity of the tidal current [4]. The non-tidal part of the current, although usually small, may be in extreme conditions of the same magnitude as the tidal current. A statistical study of the probability of high current speeds is therefore deemed necessary.

The problem is, however, that data on the current over periods, long enough to give useful results, are scarce. The longest available time series are those of the lightships. In this paper the main results of a statistical investigation of a 10-year series of current observations (1954 ... 1963 (inclusive)) are presented; a more complete account is given elsewhere [3].

The data are the hourly means of the current speed at six metres (20 ft) depth; the observations have been made by hourly readings of a 'vertical log' current meter [1]. This is a very simple instrument, especially developed for operating from lightships under all kinds of weather conditions. With these instruments regular observations are made at the Netherlands lightships under auspices of the Royal Netherlands Meteorological Institute; the accuracy of the measurements is about

0.1 kn (5 cm/s) for normal weather conditions. It is not known, however, whether this is also valid for exceptional cases of high seas and strong winds. The mean positions of the lightships during the period of these observations and the mean directions of 'flood'- and 'ebb'-current were the following:

'Noord-Hinder':	51°39' N, 2°34' E; flood 40°, ebb 220°
'Goeree':	51°56' N, 3°40' E; flood 44°, ebb 224°
'Texel':	53°01' N, 4°22' E; flood 32°, ebb 212°
'Terschellingbank':	53°29' N, 5°08' E; flood 76°, ebb 256°

All the available current observations, irrespective of the phase of the tidal cycle, have been used. They have been divided into two categories: 'flood' and 'ebb', respectively, according to whether the corresponding direction of the current was nearest to the mean direction of the flood current, or to the mean direction of the ebb current, as just defined. An example of the frequency distribution of the current velocities for the 'flood'- and the 'ebb'-currents separately, is given in Fig. 1; cumulative frequency distributions are given in Figs. 2 and 3. An interesting point of Fig. 3, giving the cumulative frequency distribution for the lightship 'Texel', is the large difference between the distributions for flood- and for ebb-current. None of the other lightships shows such a large asymmetry between both phases of the tide.

It is obvious that the periodically varying tidal currents and

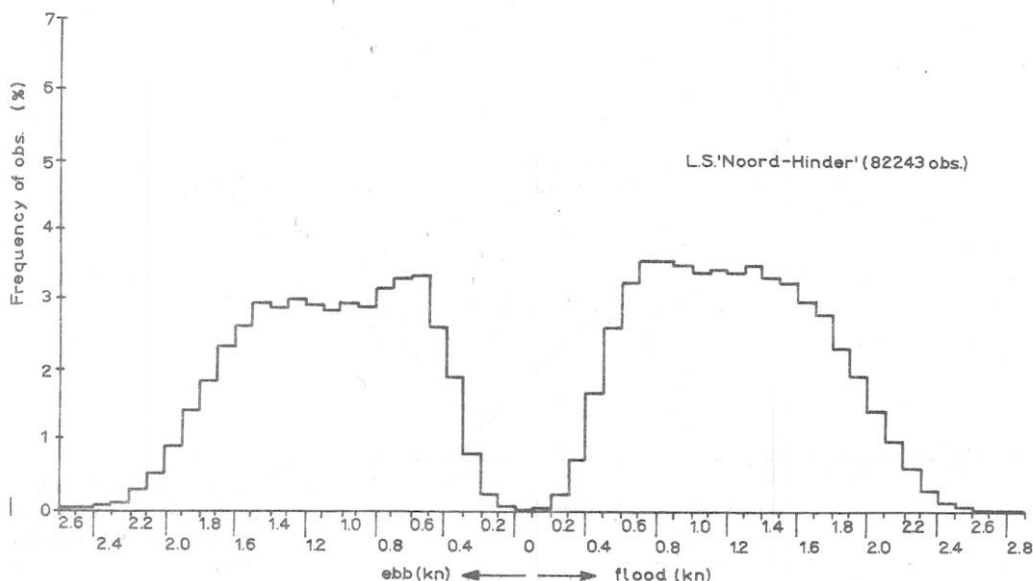


Fig. 1. Frequency distribution of current velocities at the lightship 'Noord-Hinder'.

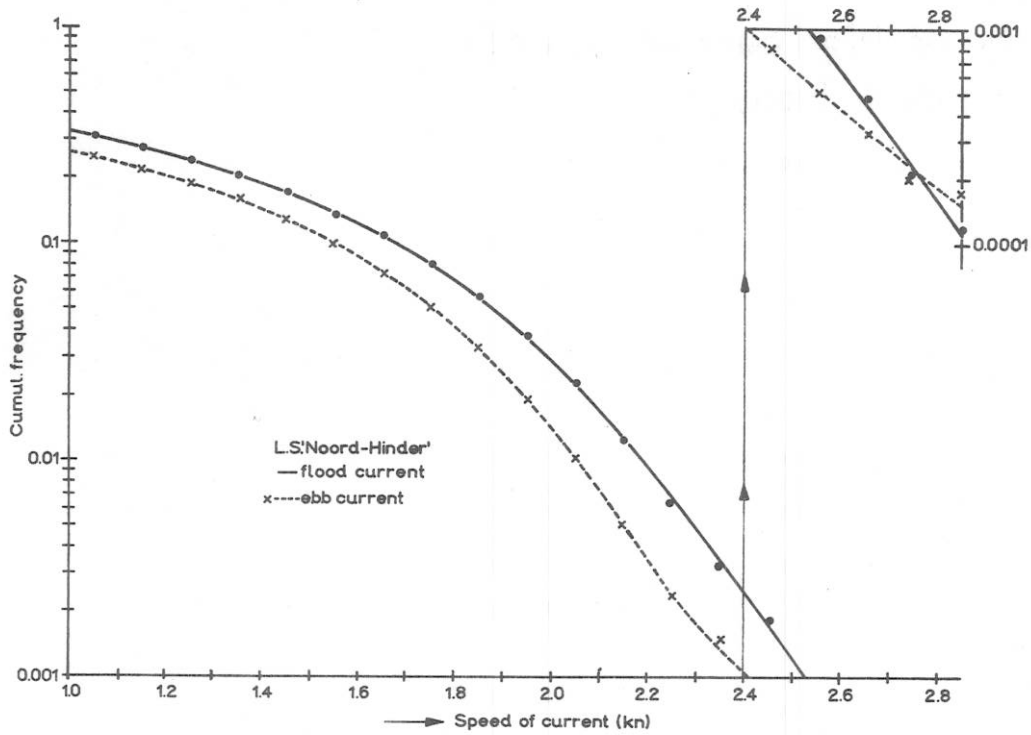


Fig. 2. Cumulative frequency distribution of current velocities at the lightship 'Noord-Hinder'.

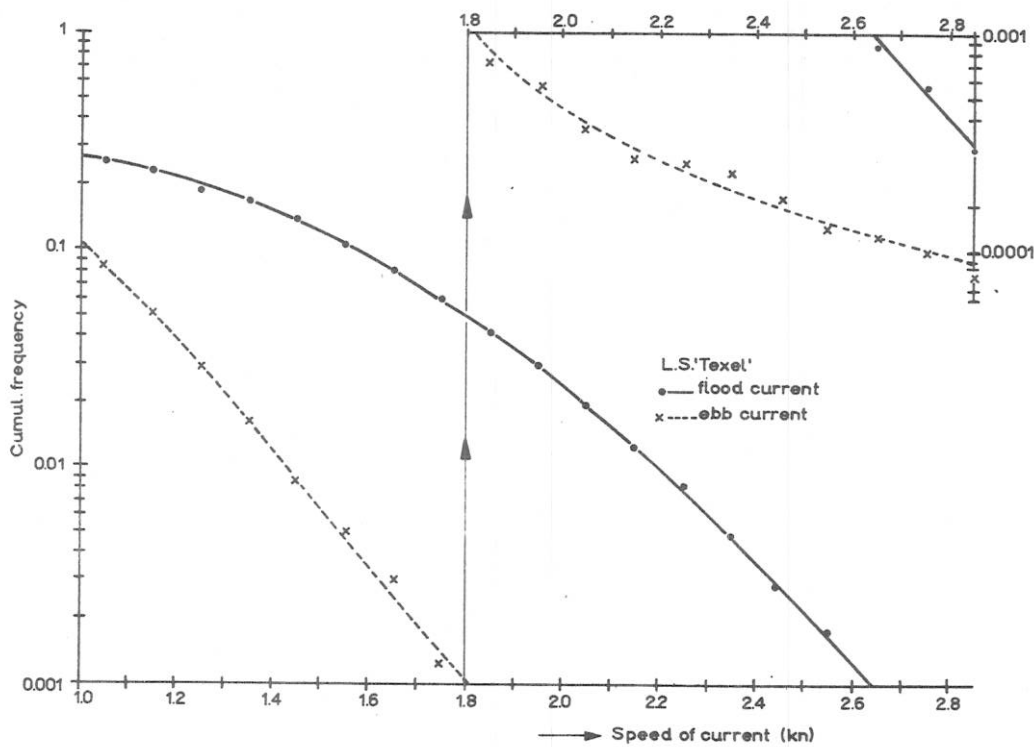


Fig. 3. Cumulative frequency distribution of current velocities at the lightship 'Texel'.

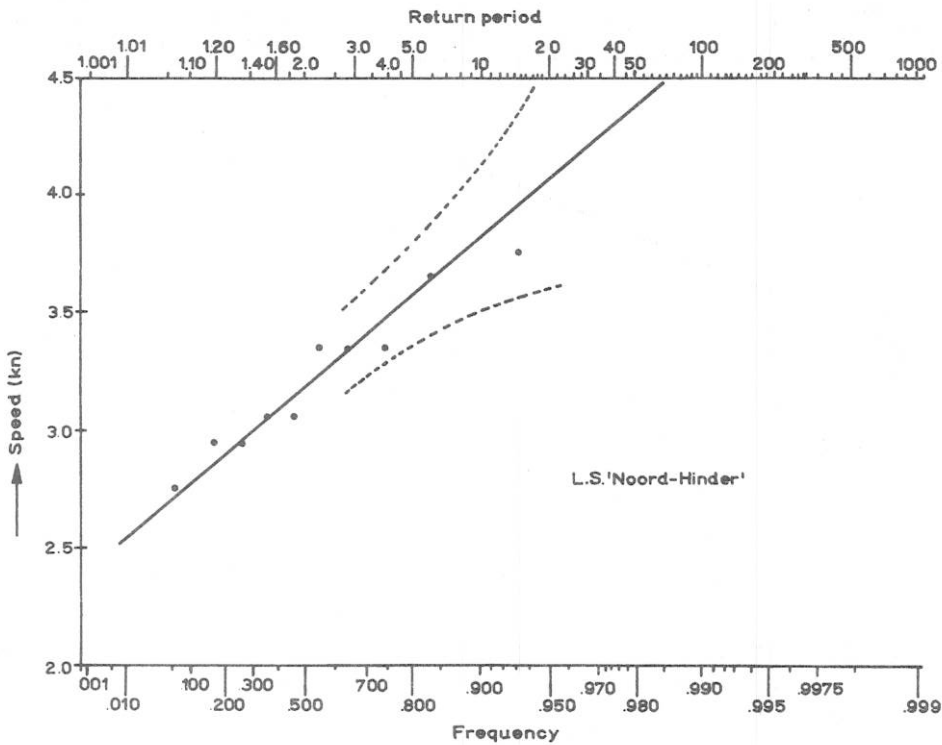
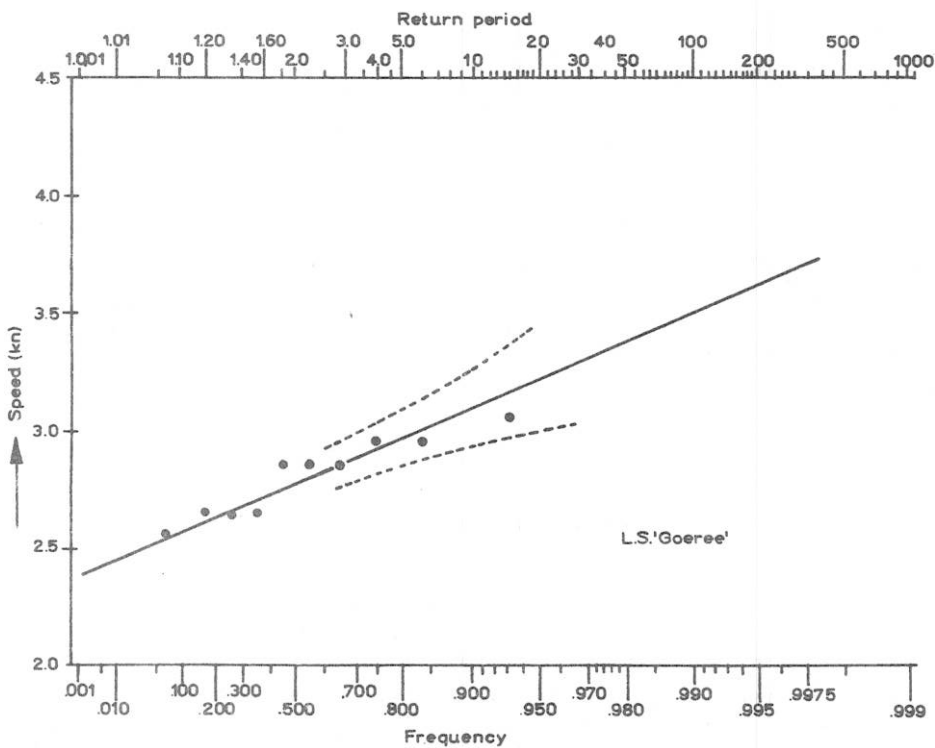


Fig. 4. Return period of annual maximum of the current velocity at the lightship 'Texel'.

(Courtesy of E.J.Gumbel)



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Fig. 5. Return period of annual maximum of the current velocity at the lightship 'Goeree'.

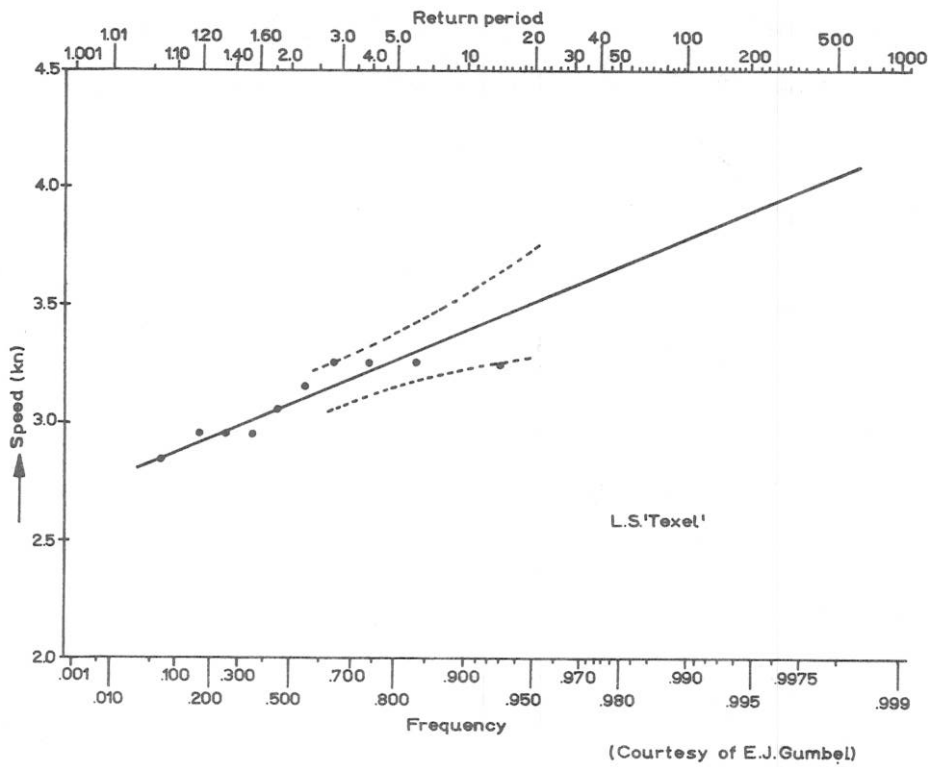


Fig. 6. Return period of annual maximum of the current velocity at the lightship 'Texel'.

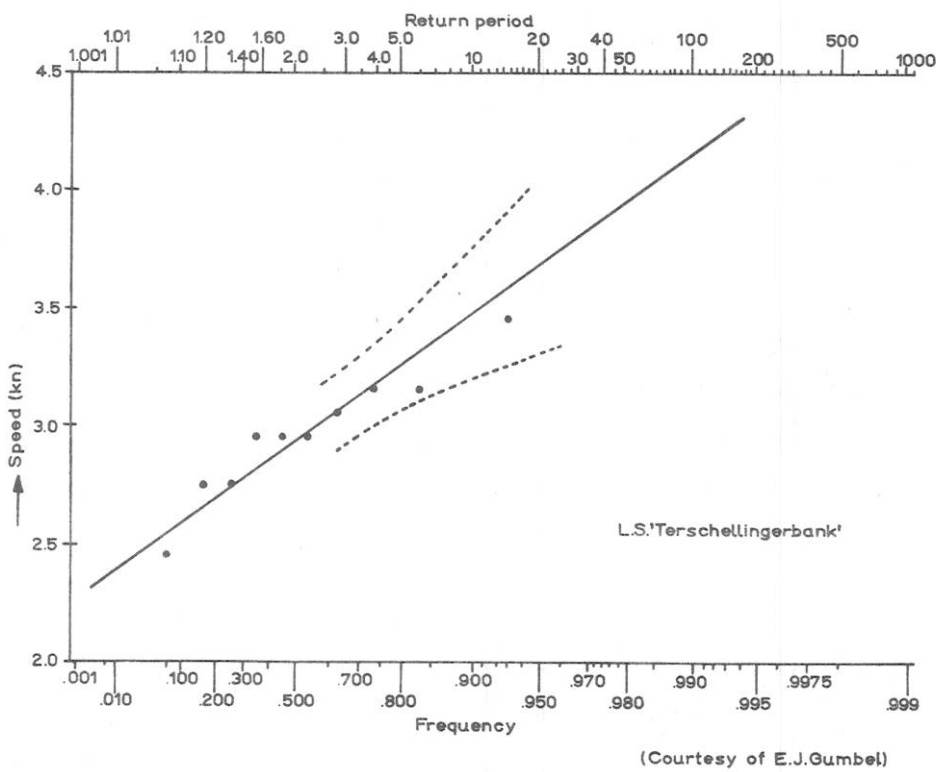


Fig. 7. Return period of annual maximum of the current velocity at the lightship 'Terschellingerbank'.

the irregularly varying residual currents remain unseparated in this presentation. By a theoretical method, however, it is possible to deduce from the cumulative frequency distribution of all data the cumulative frequency distribution of the maximum velocities per tidal cycle, if the amplitudes of the main tidal constituents (e.g. M_2 , S_2) are known. The probability of a certain high velocity to occur within a certain period may be estimated from the latter frequency distribution, as has been

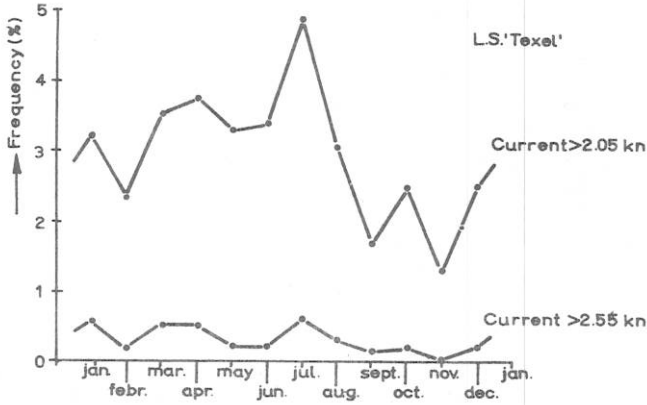
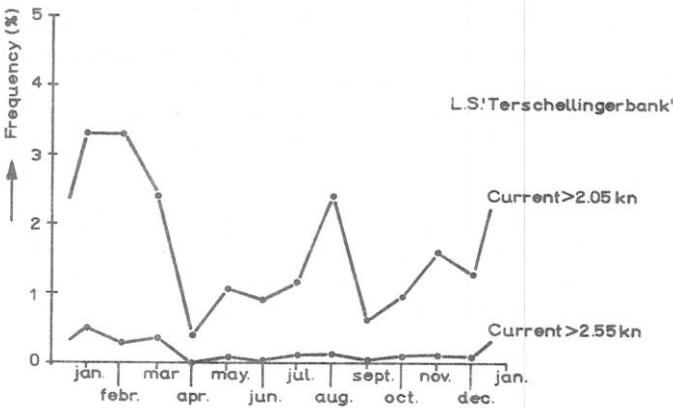


Fig. 8. Annual variation of the frequency of current velocities of over 2.05 and 2.55 kn at the lightship 'Texel'.



done in the report mentioned previously. Here we will present another approach. It should be mentioned that both methods give results that are only roughly comparable.

Table 1. Annual maxima of 'flood'- and 'ebb'-current at the Netherlands lightships (in knots).

Year	'N.-Hinder'		'Goeree'		'Texel'		'Terschellingbank'	
	flood	ebb	flood	ebb	flood	ebb	flood	ebb
1954	3.0	3.0	2.5	2.6	3.1	3.2	3.1	2.3
1955	2.9	2.7	2.9	2.9	2.9	3.0	2.7	2.2
1956	2.9	2.6	2.8	2.8	3.2	2.0	2.7	2.6
1957	3.0	3.0	2.7	3.0	2.9	2.8	2.9	3.0
1958	3.3	3.1	2.8	2.7	3.2	2.0	2.9	2.1
1959	2.5	3.3	2.9	2.2	2.9	2.8	2.9	2.3
1960	2.6	2.7	2.4	2.5	2.9	2.9	2.9	2.3
1961	3.0	3.3	2.6	2.5	3.2	2.1	3.4	2.2
1962	2.9	3.7	2.8	2.7	2.8	2.0	2.7	3.1
1963	3.6	3.0	2.6	2.6	2.9	3.1	≤ 2.4	2.4

For this second approach the annual maxima of the current velocity have been used, as given in Table 1. *Gumbel's* theory of extreme values now may be applied to these data (see for

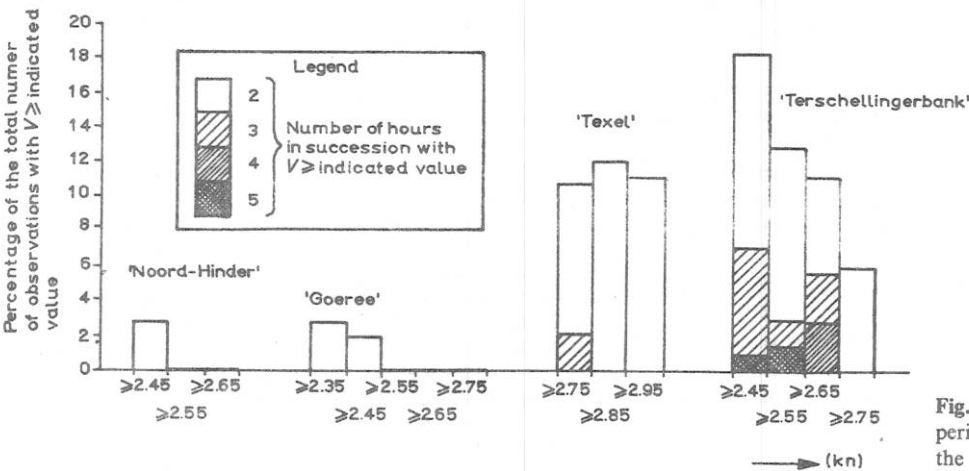


Fig. 10. Occurrence of long continuous periods with high current velocities at the different lightships.

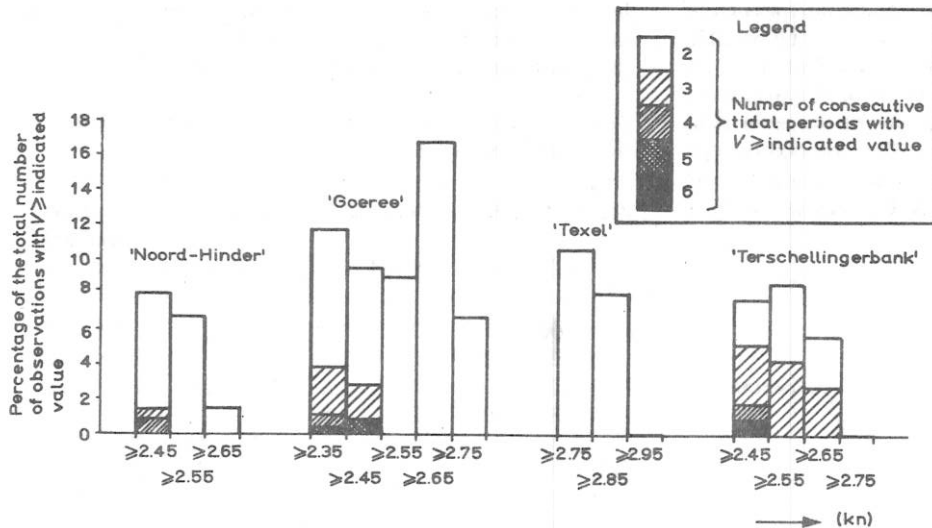


Fig. 11. Occurrence of long series of tidal periods with high current velocities at the different lightships.

practical applications of this theory [2]). The result is a graph of the return period of a certain current velocity, which may be extrapolated towards larger values of the current speed. In Figs. 4, 5, 6 and 7 these graphs are given, together with the $\frac{2}{3}$ -confidence limits. Because there are only ten annual maxima for each lightship, an extrapolation towards long return periods would bring about a rather large uncertainty. It should further be emphasized that the values given are hourly averages of the current speed; short-periodic variations of the current surely give higher instantaneous values of the velocity.

The question may be asked whether there is a seasonal variation in the occurrence of high speeds. Such a seasonal variation may result from variations in the maximum tidal current (e.g. by the changing phase difference between the S_2 and K_2 constituent) or from seasonal differences in the wind regime over the North Sea and resulting differences in the residual current pattern.

To investigate this problem a study has been made of the annual variation of the frequency in which the speeds of 2.05 kn and 2.55 kn, respectively, are exceeded. Examples of the results are given in Figs. 8 and 9 for two of the lightships. It is remarkable that the annual variation differs so much from one lightship to the other; apparently no general rule can be given for a seasonal variation.

Another point is the persistence of the situations with high current velocities. There are two ways in which this persistence may become manifest: several hours in succession the velocity may exceed a certain value, or during a consecutive number of tidal periods the maximum current may exceed a certain value each time. The frequency of occurrence of the first situation is illustrated in Fig. 10. At 'Noord-Hinder', for example (according to this figure) in 2.8% of the cases where $V \geq 2.45$ kn, such an observation is one of a group 2 consecutive observations of this kind. Current speeds of over 2.55 kn did occur as isolated observations only.

In Fig. 11 the frequency of occurrence is given of a consecutive number of tidal periods with a speed over a certain limit. For example, at 'Terschellingerbank' in 0.9% of all the observations with $V \geq 2.45$ kn the observation is part of a series of 6 consecutive tidal periods with a velocity surpassing this value, in

1.8% the observation is one of a series of at least 4, in 5.2% of a series of at least 3 and in 7.8% of a series of at least 2 such tidal periods.

It is remarkable that again there are marked differences between these frequency distributions for the different lightships. These differences, in any case, are a warning against too rash generalizations. Nevertheless, it is expected that the present data may help to come to better-founded decisions in a number of technical problems; for problems related with sand transport over the bottom these data may be useful too.

Presently different countries are expanding their programs of current observations in the North Sea, using anchored self-recording current meters. The observations from lightships, however, although only relative to a small number of points in the North Sea, are (notwithstanding their limitations in accuracy) of the utmost importance in the study of the current-regime of the North Sea, because of the relatively long time period covered in the regular collecting of such observational data.

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