

# DNMI - RAPPORT

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TITTEL

NEDSTRANDSFJORDEN  
EXTREME WINDS AND WAVES

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SAMMENDRAG

The extreme wind conditions in Nedstrandsfjorden are evaluated from extreme wind calculations for Sola Airport and the topography. The maximum 10 min mean speed with 100 years return period is estimated to 25 m/s for all year and 20 m/s for summer. Maximum wave height is calculated to 1.2 m.

UNDERSKRIFT

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## NEDSTRANDSFJORDEN. EXTREME WINDS AND WAVES

### 1. INTRODUCTION

The aims of the present report were formulated in a letter from Norwegian Contractors dated 20.03.1985 (appendix 1):

- "a. To evaluate extreme wind speeds and directions.
- b. To evaluate extreme significant wave heights and corresponding spectral peak periods.

The data shall be sorted on the seasons all year and summer (May - Aug).

The data shall also be sorted on the return periods 1, 10 and 100 years.

Please also document the expected accuracy of the analyses."

The main task was then to evaluate the wind speeds and thereafter use the computer program "FJORD-SEA" to calculate wind generated waves for the area.

The Norwegian Meteorological Institute (DNMI) in cooperation with The Norwegian Research Institute of Electricity Supply (EFI) has earlier prepared similar reports for Norwegian Contractors, latest for 3 positions in Gandsfjorden [1]. It was agreed that the present report should have about the same structure.

### 2. DESCRIPTION OF THE AREA

Nedstrandsfjorden is the name of the inner part of Boknafjorden north of Stavanger, see map in figure 1. The fjord area runs towards NE from the coast and Nedstrandsfjorden is about 30-50 km from the coast line.

On a local scale the fjord is surrounded by islands and hilly terrain except for Boknafjorden towards SW and the inlets of the narrow fjords Vindafjorden and Sandsfjorden towards N and NE.

On a regional scale the terrain rises up to 800-1000 masl within about 30 km towards NE-SE. Towards S there are numerous islands and hills up to 400-500 masl down to the Stavanger area, and hilly terrain up to 400-600 m further south. Towards W and NW there are also numerous hills about 200-400 masl.

### 3. METHODS AND ACCURACY

Due to the lack of data for the area, the wind conditions must be evaluated on the basis of available data from Sola, where DNMI has got relatively long homogeneous records of 10 minute mean (and gust) wind speeds. Calculated extremes with different return periods are given in [1].

Directional distributions of extremes have in Norway traditionally been based on evaluations of ordinary frequency distributions of concurrent wind forces and directions. This has not been considered to be fully satisfactory, but thorough studies of this kind would require time consuming manual readings of anemograms.

For this project a series of nearly 6 years of recordings of daily extremes of both mean and gust winds have been ready for computer treatment. The actual directions are included as well.

The procedure of the analysis has been as follows:

1. calculate extreme values for the 4 main sectors relative to all data for Sola based on the short period data,
2. apply these relative values to the extremes found earlier for all directions on Sola,
3. estimate reductions based on topographical effects from Sola to Nedstrandsfjorden for each sector, and
4. take the highest windspeed of the 4 sectors to represent "all directions" for that return period.

It is difficult to estimate the accuracy of such a method, but trials with different methods in similar projects indicate that the estimated wind speeds differ mostly within the order of  $\pm 2-3$  m/s.

#### 4. WIND EXTREMES FOR SOLA AIRPORT

The calculated extremes with return period 2, 10 and 100 years for Sola are given in table 1. (It should be noted that the Gumbel method is not defined for 1 year return period when yearly data are used. The values for 1 year return period will be about 1-2 m/s lower.)

Table 1. Calculated extremes of 10 min mean wind speed (given in m/s) for Sola based on 26 yearly extremes.

Season	Return period (years)		
	2	10	100
All year	21	25	31
Summer	14	17	20

A series of daily extremes for the period 04.66-12.71 is supposed to give basis for extracting monthly and yearly extremes of wind speeds within the 4 main sectors, N - E, E - S, S - W and W - N, with reasonable accuracy. Using Gumbel's 1. distribution of extremes, the relative values of extremes are calculated, and the results are listed in table 2 (the "extreme value" for all directions = 1.0).

Table 2. Relative extreme wind speeds for 4 sectors (all direction = 1.0) for Sola.

Sector	All year	May-August
all directions	1.0	1.0
N - E	0.6	0.7
E - S	0.8	0.9
S - W	0.8	1.0
W - N	1.0	1.0

For the directions N, E, S and W the highest value in table 2 should be chosen.

Combining the values in tables 1 and 2, we get the directional distribution for Sola given in table 3.

Table 3. Estimated extremes of 10 min mean wind speeds (m/s) for different sectors at Sola airport.

Season	Sector	Return period (years)		
		2	10	100
All year	All	21	25	31
	N - E	13	15	19
	E - S	17	20	25
	S - W	17	20	25
	W - N	21	25	31
May - August	All	14	17	20
	N - E	10	12	14
	E - S	13	15	18
	S - W	14	17	20
	W - N	14	17	20

The all year values in table 3 are comparable with the values evaluated earlier for the dock area (position 3) in Gandsfjorden [1].

## 5. EVALUATIONS FOR NEDSTRANDSFJORDEN

Due to the inland mountain range northwesterly winds will probably be significantly reduced in Nedstrandsfjorden compared with the coast (Sola). This reduction is estimated to be of the order 5 m/s. Around NE the wind will probably at least of the same magnitude as for Sola. Taking into account that the reduction factors given in table 2 probably are influenced by the stronger winds from E, the same wind speeds are concluded for Nedstrandsfjorden as for Sola.

Due to "corner effects" on a large scale, southeasterly winds are relatively strong at Sola, but dynamical effects may also strengthen such winds in Nedstrandsfjorden. However, a

reduction of 2-3 m/s is concluded for this sector.

The open area of Boknafjorden and the channels towards NE give reason to assume about the same wind speed as for Sola around SW.

These conclusions lead to the values given in table 4.

Table 4. Estimated extremes of 10 min mean wind speeds (m/s) for Nedstrandsfjorden.

Season	Sector	Return period (years)		
		2	10	100
All year	All	17	20	25
	N - E	13	15	20
	E - S	15	18	23
	S - W	17	20	25
	W - N	15	20	25
May-August	All	14	17	20
	N - E	10	12	14
	E - S	10	12	15
	S - W	14	17	20
	W - N	10	12	15

Comparing tables 3 and 4 it is seen that for all directions the wind speed is reduced with about 5 m/s from Sola to Nedstrandsfjorden for all-year, but no reduction appears in the summer. This difference is mainly due to northwesterly winds which dominates in winter, while in the summer the southwesterlies dominate the extremes.

The wind speeds given above are 10 min mean speeds. In [1] the factor 1.25 is used to estimate 1 min means in Gandsfjorden. Due to somewhat higher roughness around Nedstrandsfjorden, the corresponding factor may be chosen to 1.3.

## 6. WAVES

As indicated in [1] the wind must be relatively steady for at least 6 hours to generate the extreme waves. The average wind speed for such a long period in Nedstrandsfjorden will probably not exceed 80% of the 10 min means given in table 4.

Because of the open fjord towards SW this direction will produce the highest waves. The "FJORD-SEA" model has been applied for this direction ( $225^{\circ}$ ) for the wind speeds 13, 15, 18 and 20 m/s, and the model results for 6 and 9 hours are shown in the figures 2-9. The maximum significant wave heights ( $H_{1/3}$ ) calculated for Nedstrandsfjorden are shown in table 5.

Since we lack measurements of waves in waters like Nedstrandsfjord, it is difficult to estimate spectral parameters. However, experience with fetch-limited waves in other areas indicates that the spectral peak period in this case can be between 4 and 5 seconds. (See e.g. [2] or [3]).

Table 5. Maximum significant wave heights (m) calculated for Nedstrandsfjorden. Wind direction 225°.

Time (hours)	Wind speed (m/s)			
	13	15	18	20
6	0.5	0.5	0.7	0.9
9	0.6	0.7	0.9	1.2

REFERENCE

- [1] Fikke, S.M. and K. Johansen: Gandsfjorden. Extreme Wind and Wave Conditions EFI TR 3176/DNMI FR 8/85 KLIMA, 1985.
- [2] Titov, L.F: Wind-Driven Waves Israel Program for Scientific Translations Ltd., Jerusalem 1971.
- [3] Haver, Sverre: Wave Climate off Northern Norway xx Congress of the Inst.Ass.for Hydraulic Res., Moscow 1983.

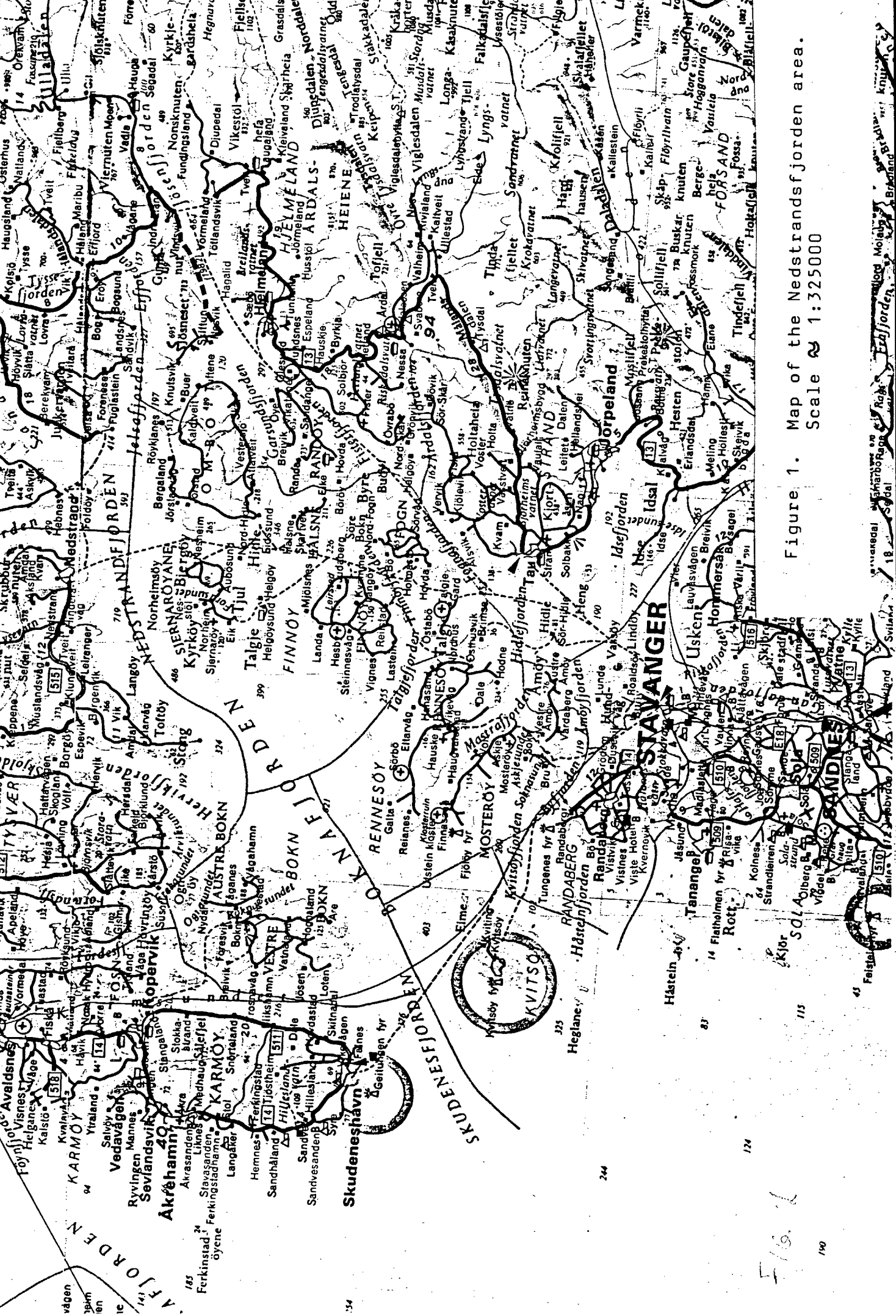


Figure 1. Map of the Nedstrandfjorden area. Scale  $\approx$  1:325000

Fig. 1

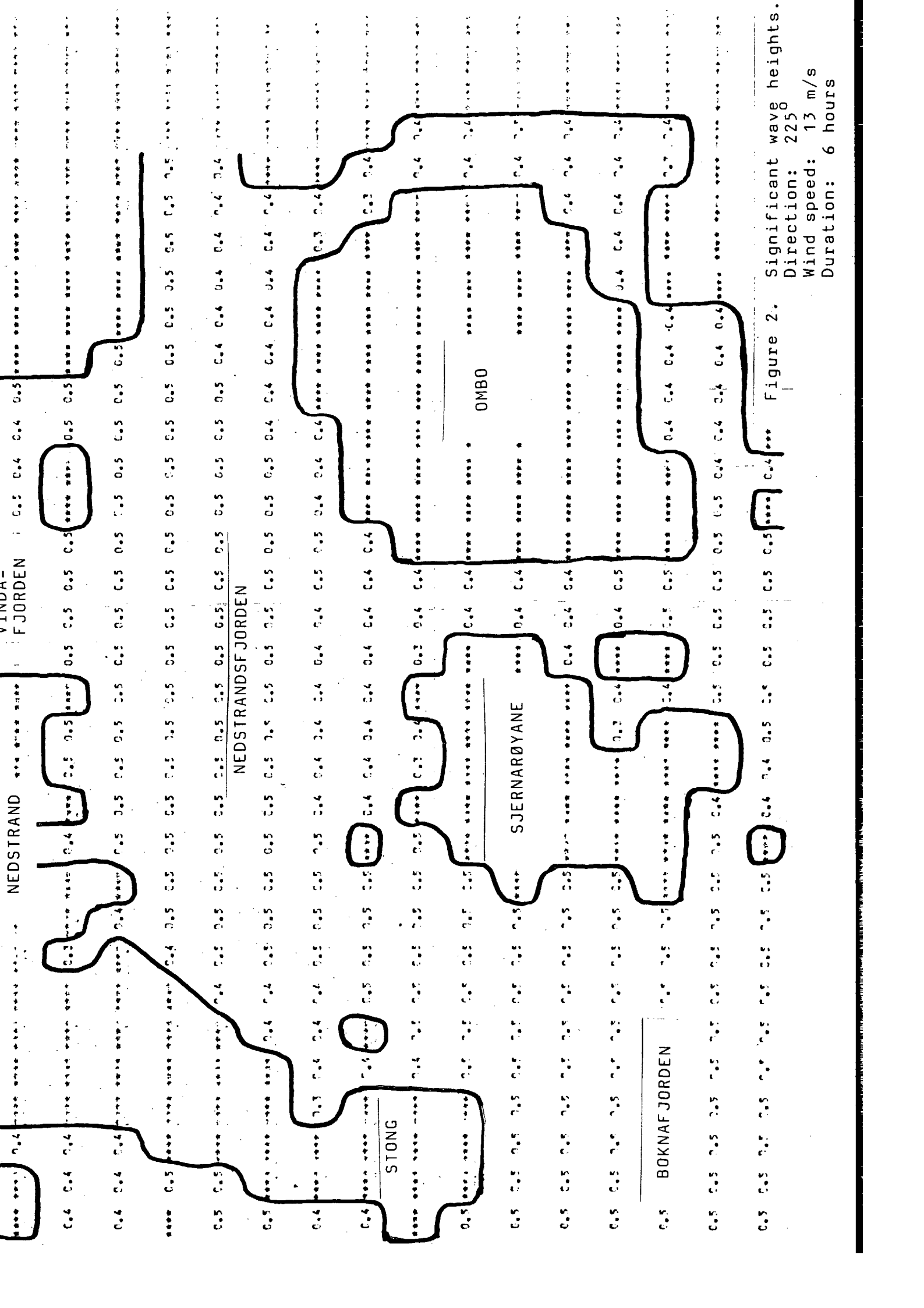
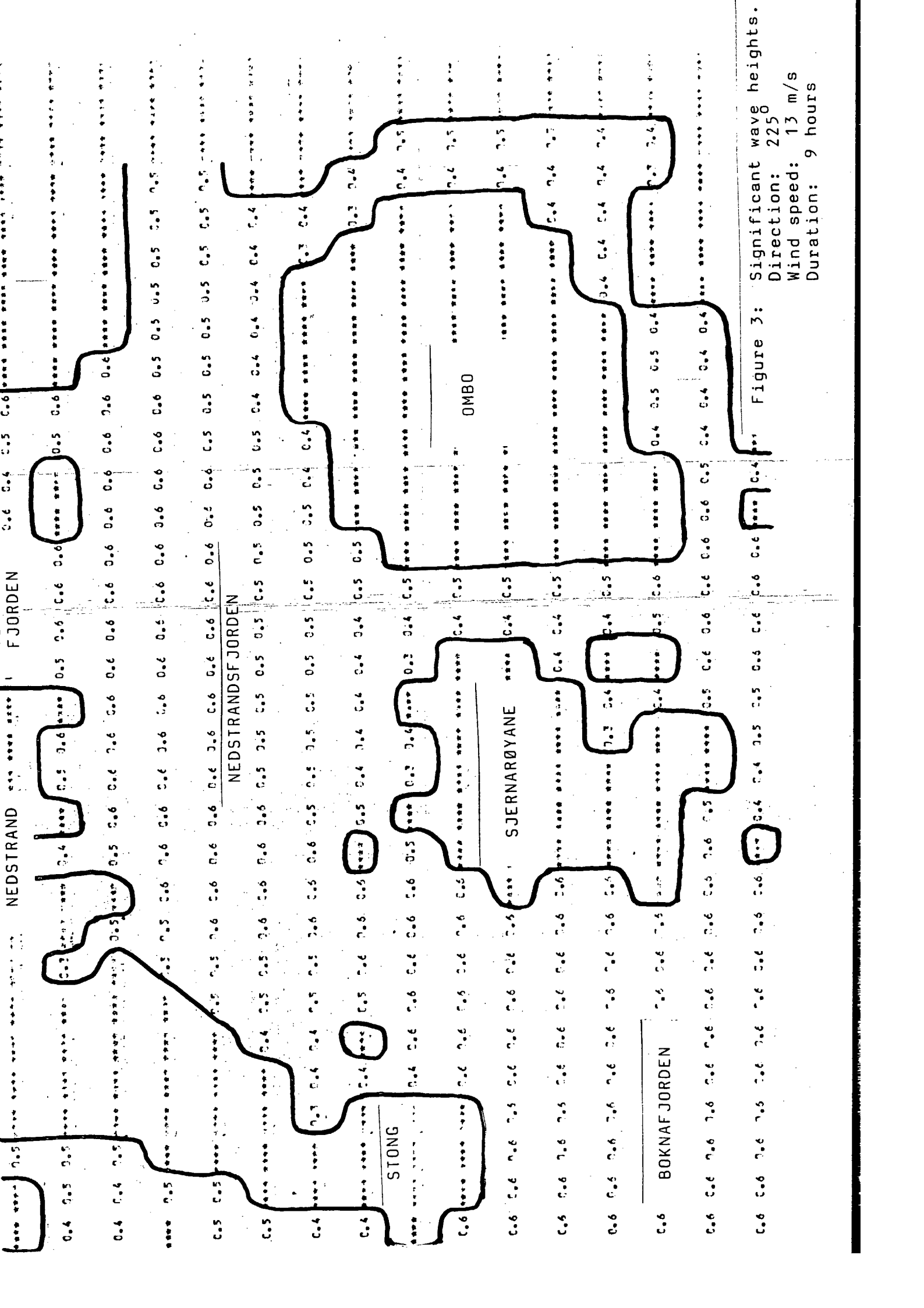
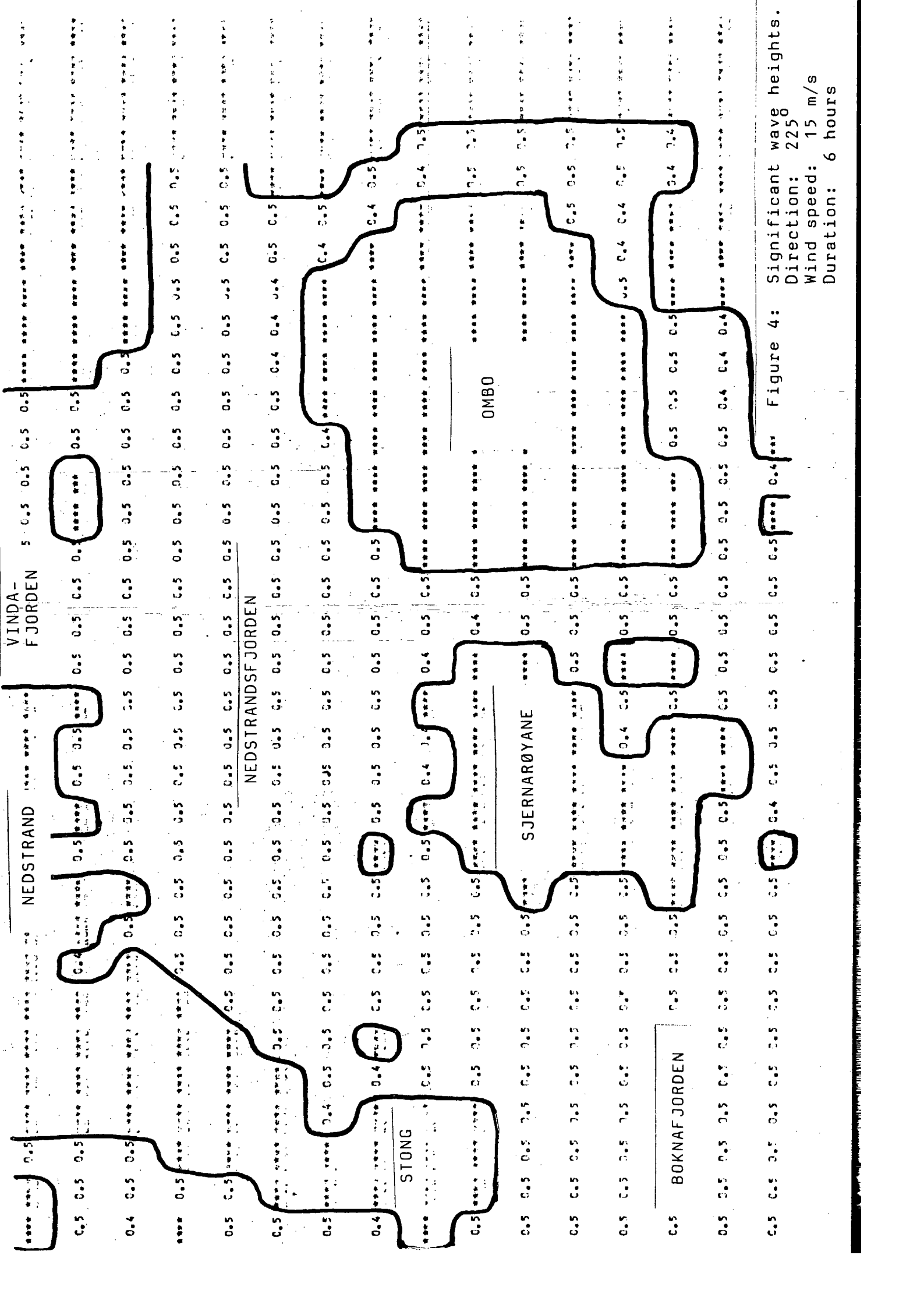


Figure 2. Significant wave heights.  
 Direction: 225°  
 Wind speed: 13 m/s  
 Duration: 6 hours







VINDA-FJORDEN

NEDSTRAND

NEDSTRANDSFJORDEN

STONG

SJERNARØYANE

BOKNAFJORDEN

OMBO

Figure 4: Significant wave heights.  
 Direction: 225  
 Wind speed: 15 m/s  
 Duration: 6 hours

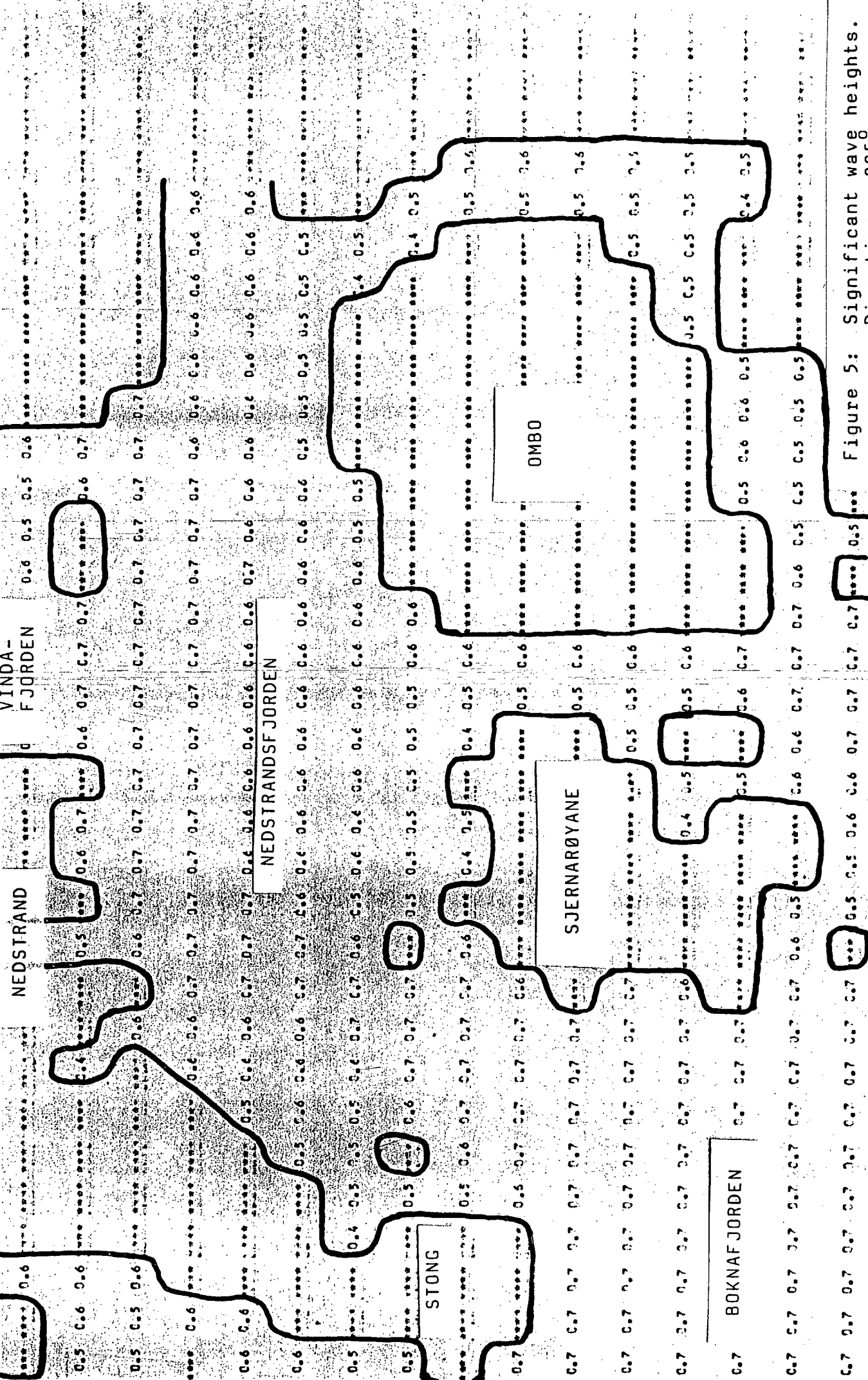


Figure 5: Significant wave heights.  
 Direction: 225°  
 Wind speed: 15 m/s  
 Duration: 9 hours

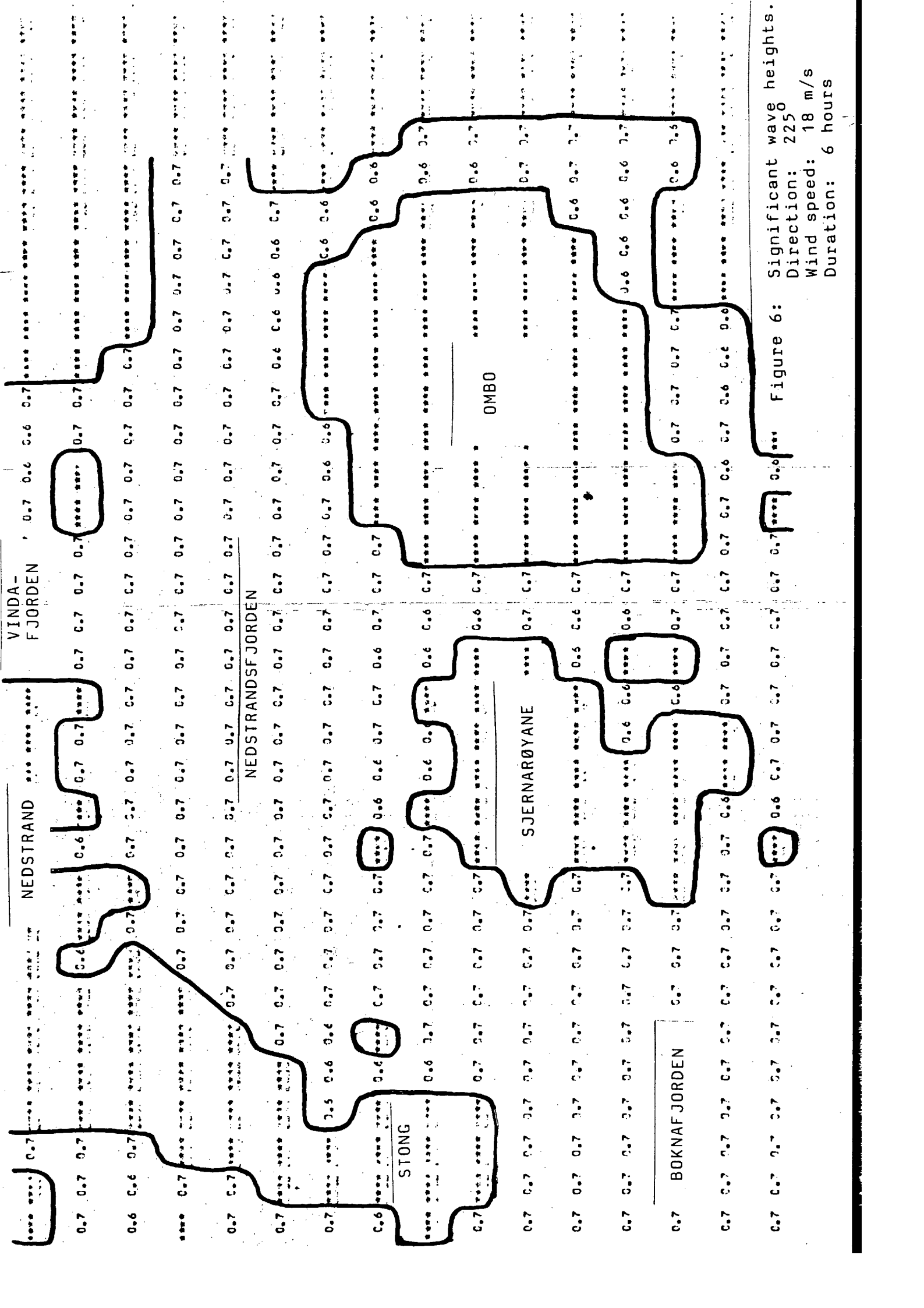
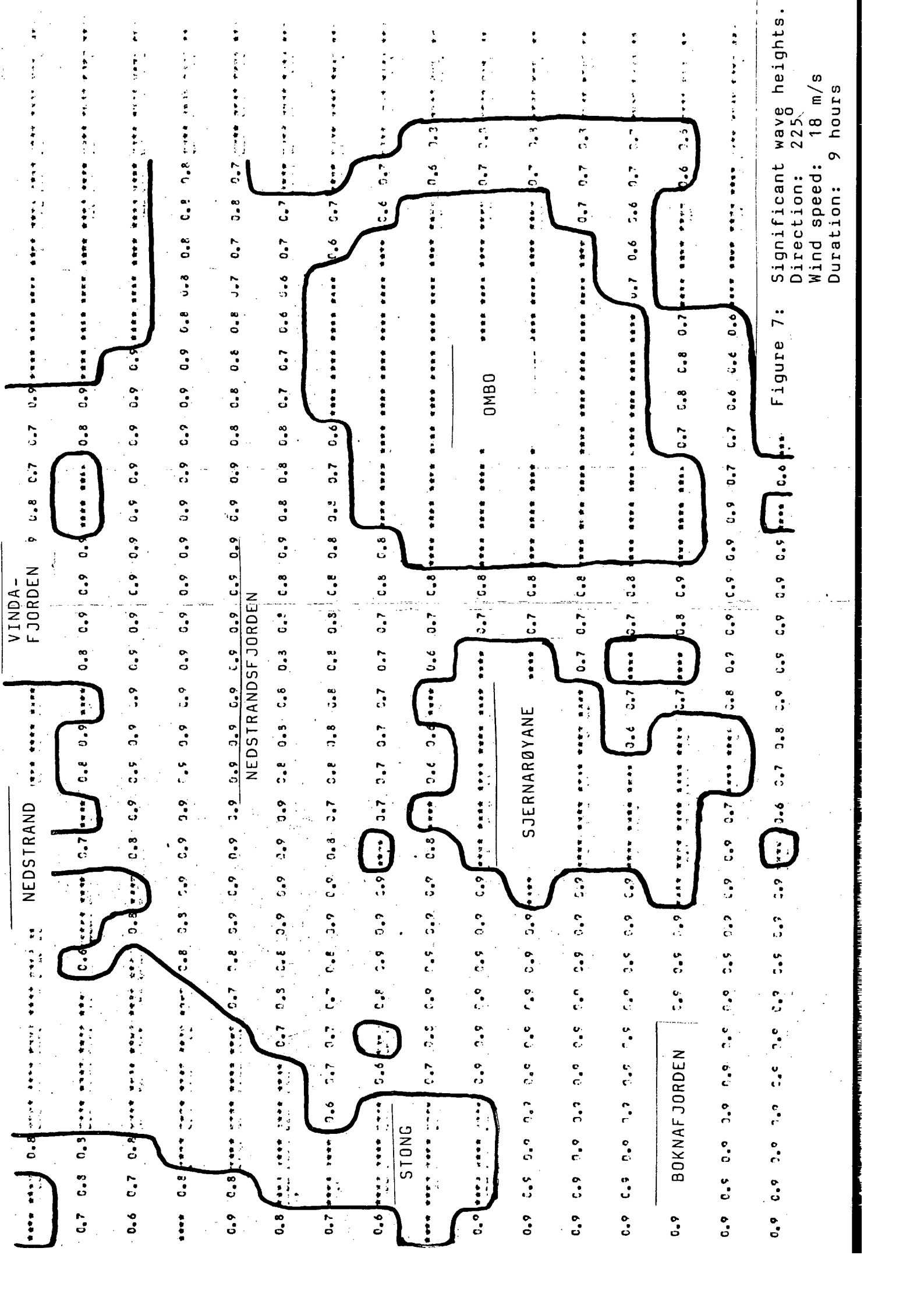


Figure 6: Significant wave heights.  
 Direction: 225  
 Wind speed: 18 m/s  
 Duration: 6 hours



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Figure 7: Significant wave heights.  
 Direction: 225°  
 Wind speed: 18 m/s  
 Duration: 9 hours

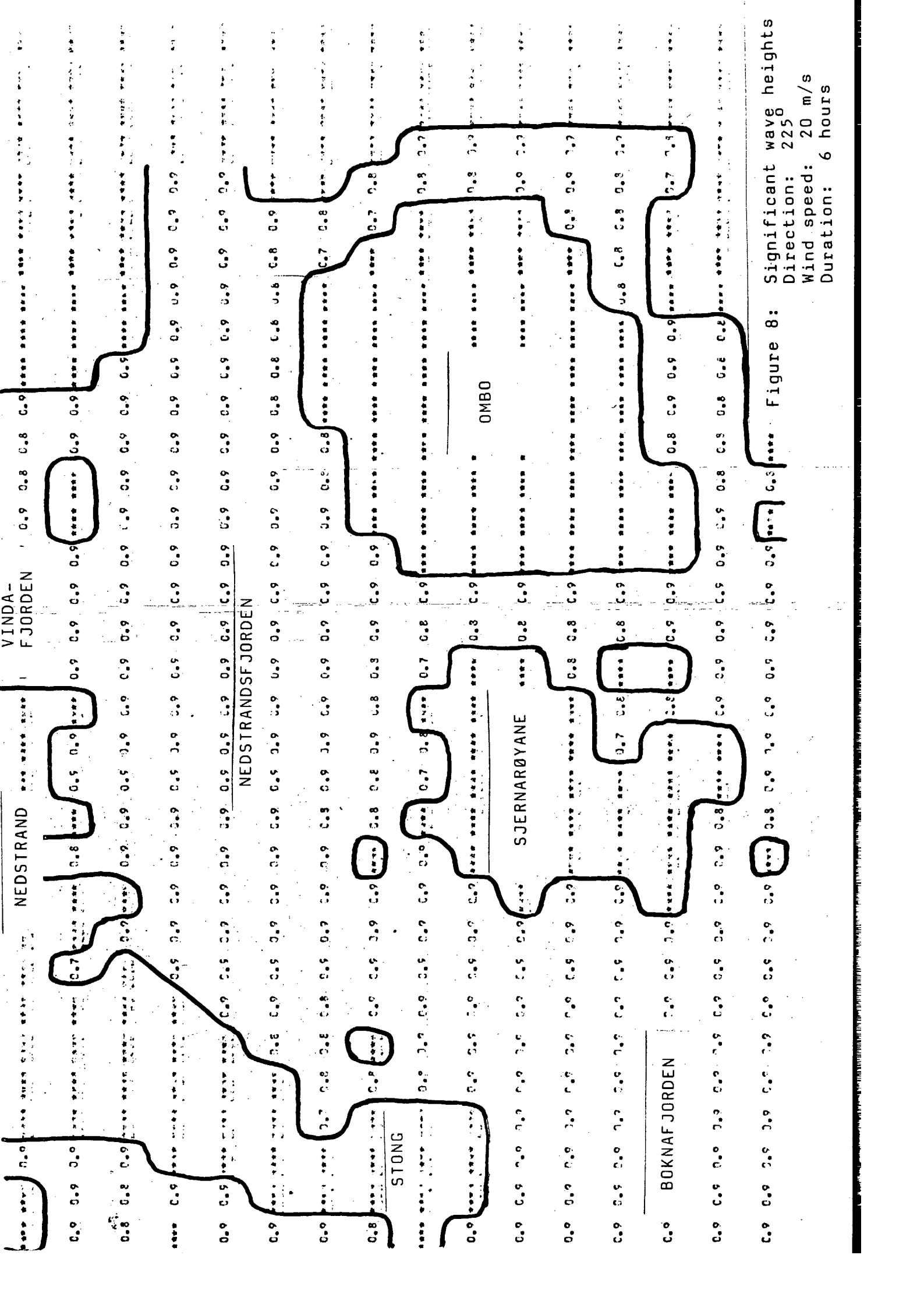
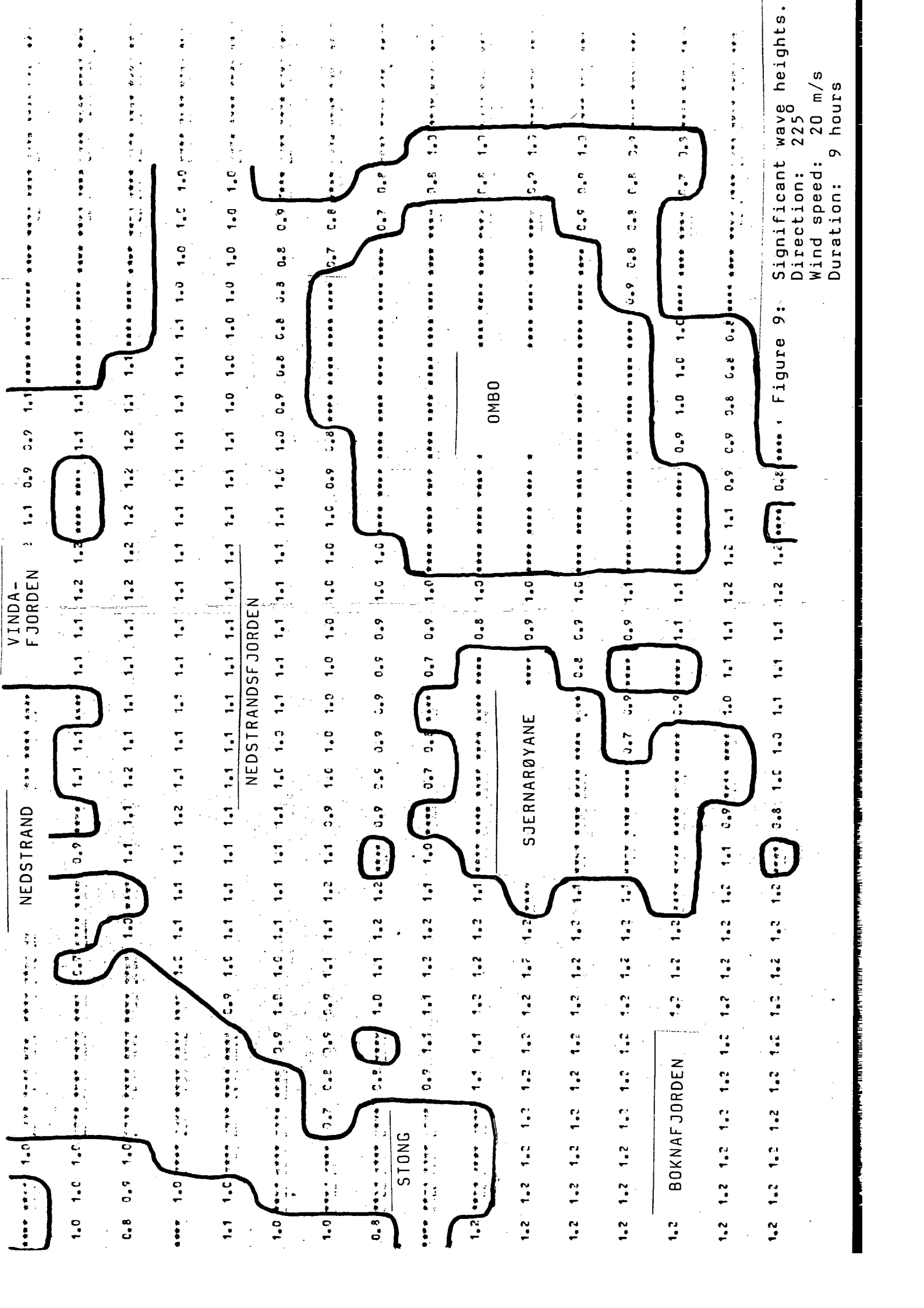


Figure 8: Significant wave heights  
 Direction: 225°  
 Wind speed: 20 m/s  
 Duration: 6 hours



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Figure 9: Significant wave heights.  
 Direction: 225°  
 Wind speed: 20 m/s  
 Duration: 9 hours

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1320 Stabekk, 20.3.1985

NEDSTRANDSFJORDEN, EXTREME WIND AND WAVE CONDITIONS

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With reference to telecon today we hereby ask you to perform the following work for Nedstrandsfjord:

- a. To evaluate extreme wind speeds and directions.
- b. To evaluate extreme significant wave heights and corresponding spectral peak periods.

The data shall be sorted on the seasons all year and summer (May -- Aug.)

The data shall also be sorted on the return periods 1,10 and 100 years.

Please also document the expected accuracy of the analyses.

Yours faithfully,  
for NORWEGIAN CONTRACTORS

*K. A. Nyhus*  
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