EFI Elektrisitetsforsyningens Forskningsinstitutt

7034 TRONDHEIM-NTH Tel. (07)597200 Telex 55513 efi n.

TEKNISK RAPPORT nr.
TR 3176

DNMI Det norske meteorologiske institutt

Boks 320 BLINDERN, 0314 OSLO 3 TLF. (02)605090 TELEX 11900

FAGRAPPORT nr.
8/85 KLIMA

REFERANSESIDE

Rapportens tittel:
GANDSFJORDEN.
EXTREME WIND AND WAVE CONDITIONS

Dato: 15.02.85

Rapporten er: Fortrolig

Saksbehandlere:
SVEIN M. FIKKE (project leader) Svein M. Fikke
KNUT JOHANSEN

Prosjektnr.: 280012
Arkivnr.: 8 2228 89
Antall sider: 15
Opplag: 15

Faglig ansvarlig:
BJØRN AUNE
(Head of Climatic Department) Bjørn Aune

Oppdragsgiver:
NORWEGIAN CONTRACTORS

Oppdragsgivers ref.:
HELGE RØRAAS

4 emneord à maksimum 23 karakterer

Sola	Gust
Mean wind extremes	Waves

Referat:
Extreme 1 min. and 10 min. mean wind speeds are estimated for 3 locations in Gandsfjorden. The FJORD-SEA wave model is used to calculate wave heights.

GANDSFJORDEN. EXTREME WIND AND WAVE CONDITIONS

1. INTRODUCTION

The first evaluations of extreme winds in Gandsfjorden were given in a letter to Norwegian Contractors dated 4 October 1977. Those evaluations were based upon extreme analysis of a 21 years record of monthly extremes of short periodic wind gusts (3-5s) from Stavanger airport, Sola.

Recently, an analysis of 26 years of annual extremes of 10 minutes mean wind recorded at Sola is performed. This is the main reason for reconsidering the wind values given for Gandsfjorden.

A map of the area is shown in figure 1. The three sites that will be evaluated are marked on the map.

2. WIND EXTREMES AT SOLA AIRPORT

Wind gusts (v_g) with return period 100 years for Sola based on a 21 years record are earlier calculated to 46 m/s. Additionally, 7 years of annual maxima are now available giving only minor changes in the calculated 100 years value (47 m/s), **see** table 1.

A record of 26 annual extremes (1959-84) of the 10 min. mean wind ($\bar{v}_{10}$) is analysed by the Gumbel type 1 method [1]. The results for various return periods are given in table 1.

In order to obtain as good independency as possible in the data, the "year" is defined from July to June. Thus, the autumn and the following winter belong to the same "year".

It is seen from table 1 that the ratio $v_g/\bar{v}_{10}$ is about 1.53-1.54. This is somewhat higher than expected for extremes in this area. This means that the 1 and 10 minutes averages stipulated earlier from gusts are higher than the present calculation gives reason for. With the roughness indicated by these values, the 1 min. wind speed should be near 25% higher than the 10 min. means according to [2]. The resulting 1 min. means are also given in

table 1.

The directional distribution of gusts shows that two sectors of 90^{o} sentered towards SE and NW have equal probability of extremes (37-38% of the total for each sector). However, looking at table 2 it is seen that forces 9 and 10 have occured only in the sector W-N during the years 1957-84. The high frequency of extreme gusts from SE is due to high gustiness, or turbulence, in this sector.

It is also seen in table 2 that 10 min. winds from SE do not exceed 20 m/s at Sola.

A complete analysis of extremes from different directions is not performed since this would presuppose a manual reading of the anemograms.

Table 1. Calculated extremes of different wind speeds at Stavanger Airport, Sola.

Return period (years)	2	10	50	100
3-5 s wind gust (m/s)	32	39	45	47
10 min. mean speed (m/s)	21	25	29	31
1 min. mean speed (m/s)	26	32	36	38

3. GANDSFJORDEN

In general, the wind conditions in Gandsfjorden are very well represented by Sola. However, east of the fjord the terrain rises up to above 200 m. These heights will cause some local effects, up to about 1 km from the eastern shore line. The main effects will be increased turbulence in SE-winds and a damping (reduction) of westerly and easterly winds near Lifjell and Flatafjell.

Based upon the arguments given above the estimated wind speeds with return periods of 10 and 100 years from all diections are given below for the three positions in question (see fig. 1).

From table 1 the ratio between the 100 and 10 years value can be found to 1.21.

	1 min. means		10 min. means	
Return period (year)	10	100	10	100
Direction				
Pos. 1 170^{o}-250^{o}	29	35	23	28
250^{o}-020^{o}	31	38	25	30
020^{o}-090^{o}	21	25	17	20
090^{o}-170^{o}	26	31	20	25
Pos. 2 150^{o}-240^{o}	29	35	23	28
240^{o}-310^{o}	26	31	20	25
310^{o}-020^{o}	31	38	25	30
020^{o}-150^{o}	21	25	17	20
Pos. 3 140^{o}-250^{o}	29	35	23	28
250^{o}-020^{o}	31	38	25	30
020^{o}-110^{o}	21	25	17	20
110^{o}-140^{o}	26	31	20	25

4. WAVES

The 10 min. mean wind speeds with return period 100 years are estimated to 28 and 30 m/s for the southern and west to north sectors respectively. In the extreme wave situation it is assumed that the wind must be relatively steady for at least 6 hours. The average for such a long period is estimated for both of these sectors to maximum 25 m/s for the 100 year return period and 20 m/s for the 10 year return period.

DNMIs "FJORD-SEA" wave model [3] is applied with the two wind speeds above from the directions south and northwest. The grid used in the model is shown in figure 1. The grid length is 500 m. Computer outprints after 6 and 9 hours duration of the wind are shown in figures 2-9. The maximum significant wave heights ($H_{1/3}$) calculated for Gandsfjorden for these 8 cases are:

Direction	South		Northwest	
Return period (years)	10	100	10	100
Wave heights (m) after:				
6 hours	0.9	1.4	0.9	1.3
9 hours	1.0	1.5	0.9	1.4

It should be noted that the FJORD-SEA model is not valid for shallow waters and inlets like the dock area (position 3).

REFERENCES:

[1] Gumbel, E.J.: Statistics of Extremes. Columbia University Press.

[2] Ghiocel, D. and D. Lungu: Wind, Snow and Temperature Effects on Structures Based on Probability. Abacus Press 1975

[3] Børresen, J.A. and K. Johansen: Computed and Measured Wind Waves for Statpipe Shore Approach. XX Congress of the Inst. Ass. for Hydraulic Res., Moscow 1983.

Table 2. Wind frequency distribution for Sola.

+ SOLA YEAR 1957 1984

HRS. 00,06,12,18 GMT N=40908 C= 8.9% VM= 4.4M/S FM=2.8 B

DD	F: 1	2	3	4	5	6	7	8	9	10	11	12	ND	FDM
36N	1.3	2.2	2.5	1.9	0.6	0.1	0.0	0.0		0.0			8.7	2.9
03	1.2	1.1	0.5	0.2	0.0	0.0	0.0						3.0	1.9
06	1.1	0.9	0.4	0.1	0.0								2.5	1.9
09E	1.2	1.0	0.8	0.8	0.2	0.1	0.0	0.0					4.0	2.6
12	2.6	2.5	2.3	2.0	0.9	0.5	0.1	0.0					10.9	2.8
15	2.2	2.5	2.8	3.3	1.7	0.7	0.2	0.0					13.5	3.2
18S	1.7	2.1	3.0	3.8	1.6	0.6	0.1	0.0					12.8	3.3
21	0.6	1.0	1.6	1.9	0.6	0.1	0.0	0.0					5.9	3.3
24	0.5	0.8	1.3	1.4	0.4	0.2	0.0	0.0					4.7	3.2
27W	0.6	1.1	1.5	1.3	0.5	0.3	0.1	0.0	0.0				5.4	3.2
30	1.0	1.9	2.6	2.1	0.6	0.3	0.1	0.0		0.0			8.7	3.1
33	0.8	1.7	2.9	3.5	1.3	0.5	0.1	0.0	0.0				10.9	3.4
NF	14.8	18.8	22.5	22.3	8.6	3.4	0.7	0.1	0.0	0.0				

FREQUENCY OF MAX WIND FORCE BETWEEN THE HOURS OF OBSERVATION

												C
19-01	4.1	17.2	24.2	28.2	14.8	8.2	2.4	0.6	0.1	0.0		0.1
01-07	9.6	19.7	22.8	23.9	13.1	7.4	2.2	0.7	0.1	0.0	0.0	0.5
07-13	2.9	10.8	23.8	31.1	17.8	9.6	3.0	0.8	0.1	0.0		0.1
13-19	1.6	8.0	21.4	34.0	19.8	11.3	3.0	0.7	0.1	0.0		0.1

Explanation to table

HRS	hours of observation in GMT
N	total number of observations
C	frequency of calm
VM	mean wind velocity in m/sec
FM	mean wind force in Beaufort
DD	wind direction in dekadegrees, rounded off to the nearest of 12 main directions: 35-01, 02-24 etc.
F	wind force in Beaufort
ND	frequency of each wind direction DD
FDM	mean wind force in Beaufort for each wind direction DD
NF	frequency of each wind force F

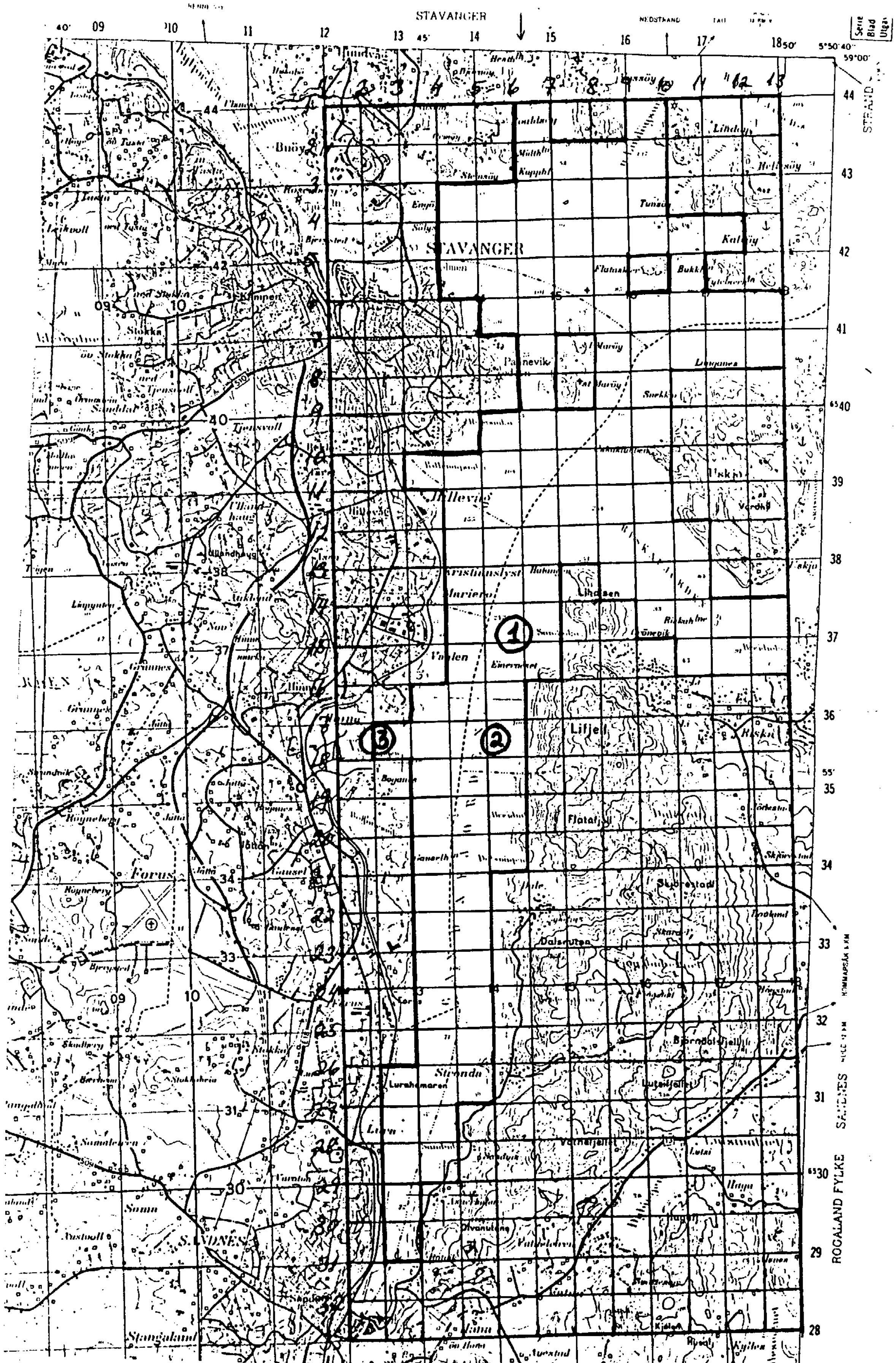

Figure 1. Map of Gandsfjorden with grid for the wave model. Grid width: 500 m

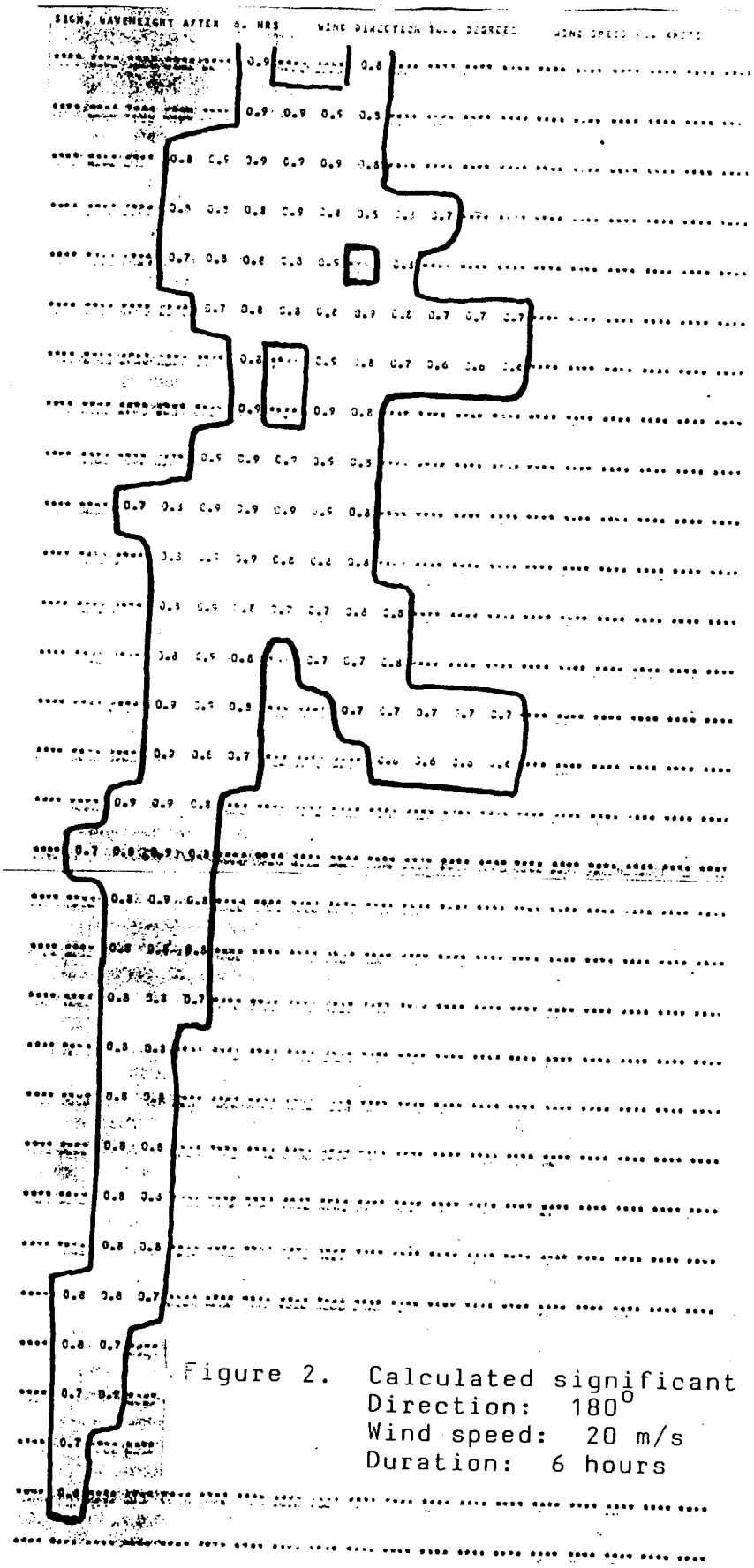

Figure 2. Calculated significant wave heights.
Direction: 180°
Wind speed: 20 m/s
Duration: 6 hours

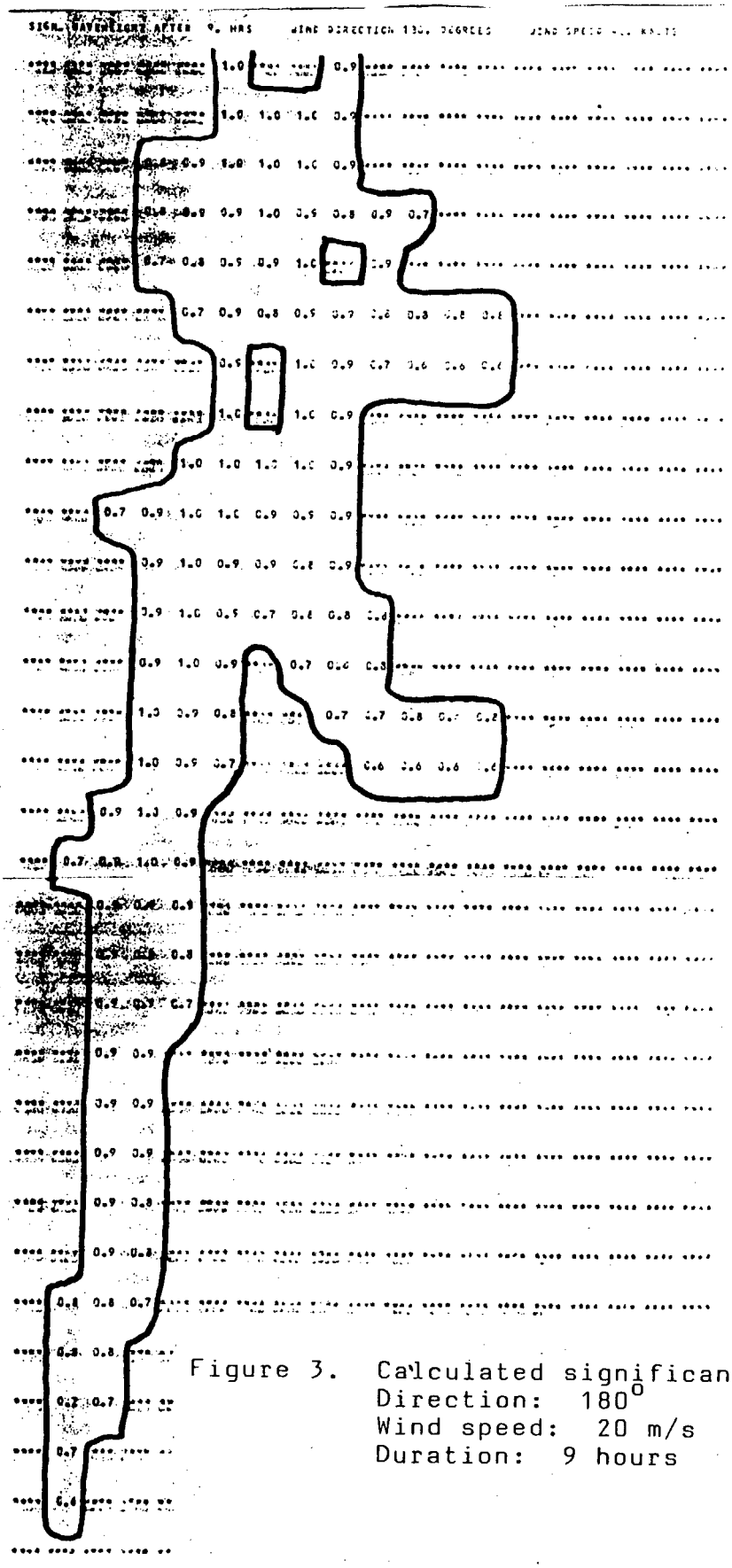

Figure 3. Calculated significant wave heights.
Direction: 180°
Wind speed: 20 m/s
Duration: 9 hours

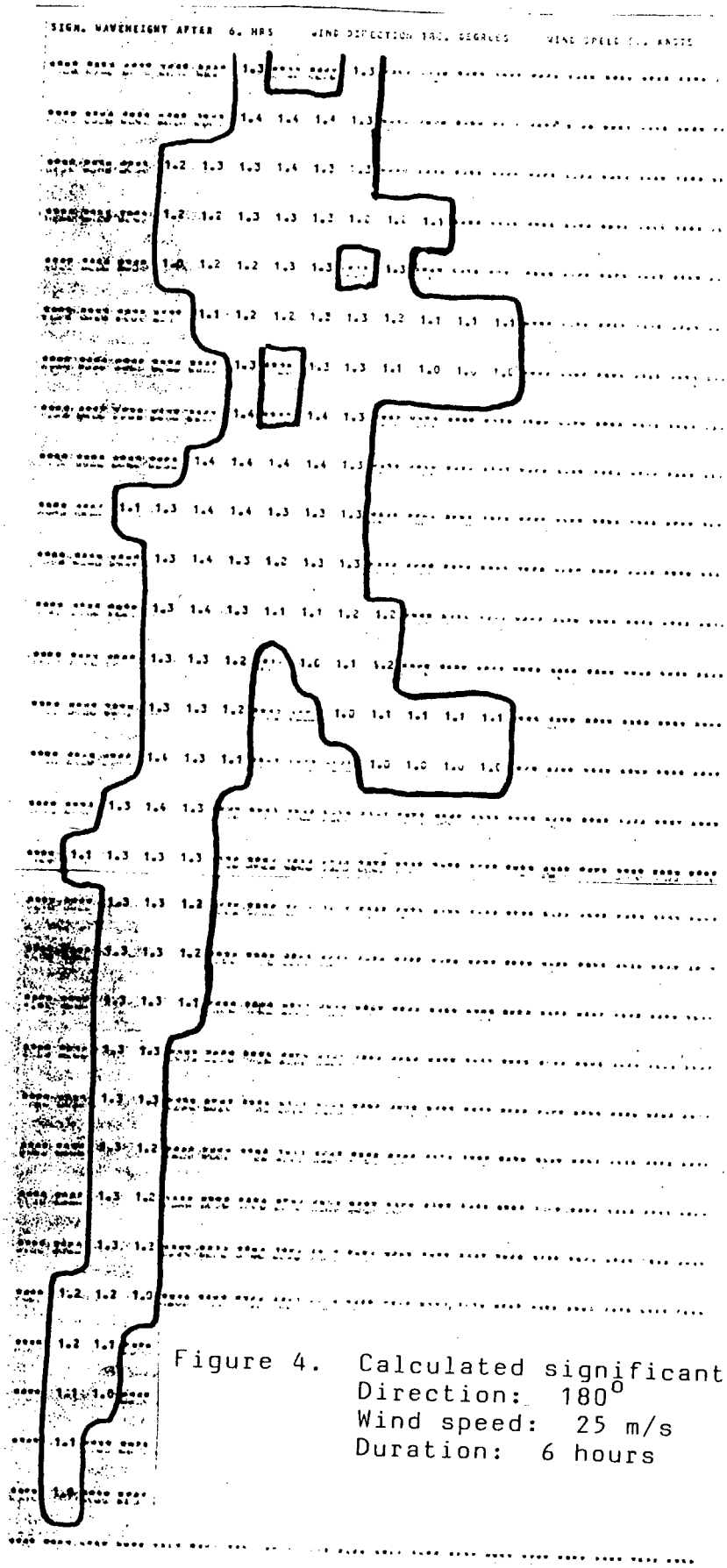

Figure 4. Calculated significant wave heights.
Direction: 180°
Wind speed: 25 m/s
Duration: 6 hours

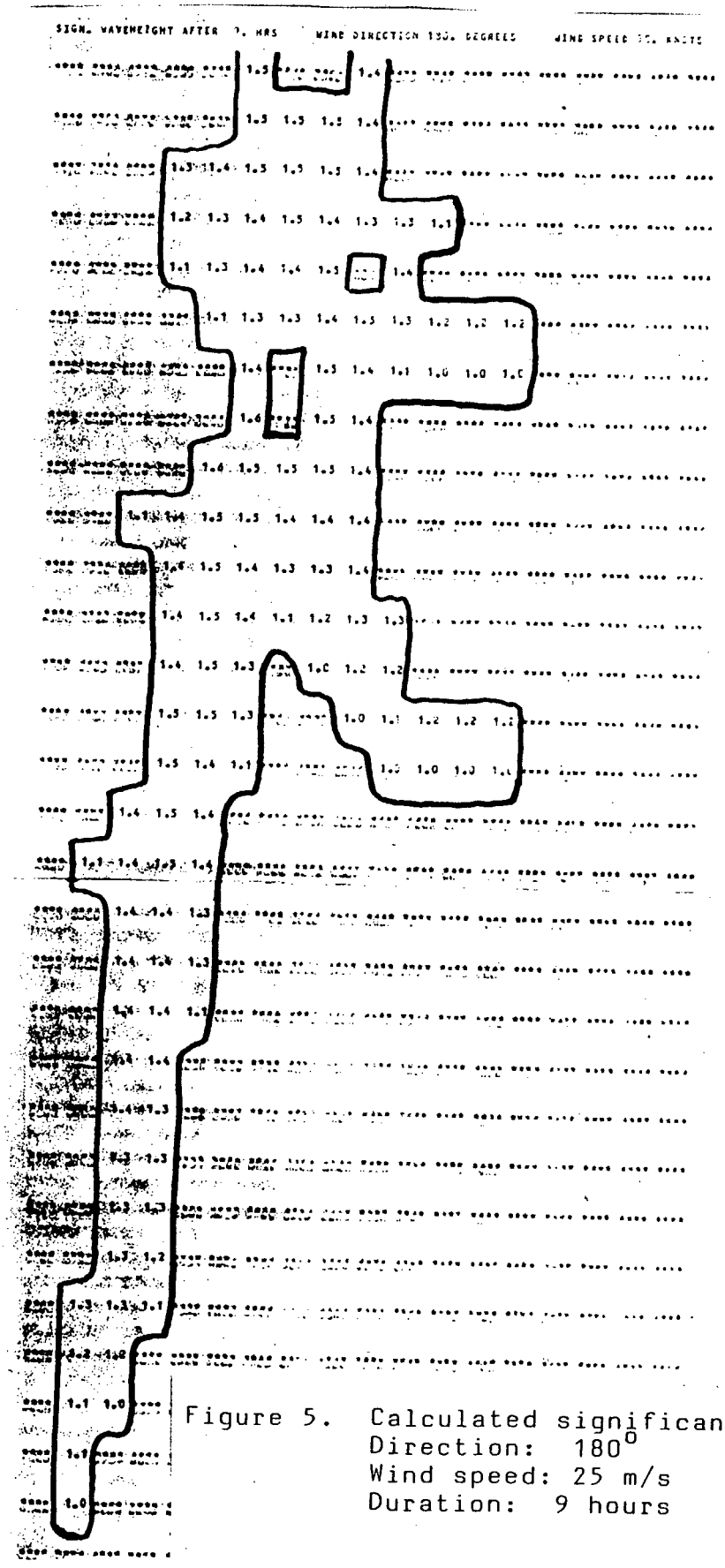

Figure 5. Calculated significant wave heights.
Direction: 180°
Wind speed: 25 m/s
Duration: 9 hours

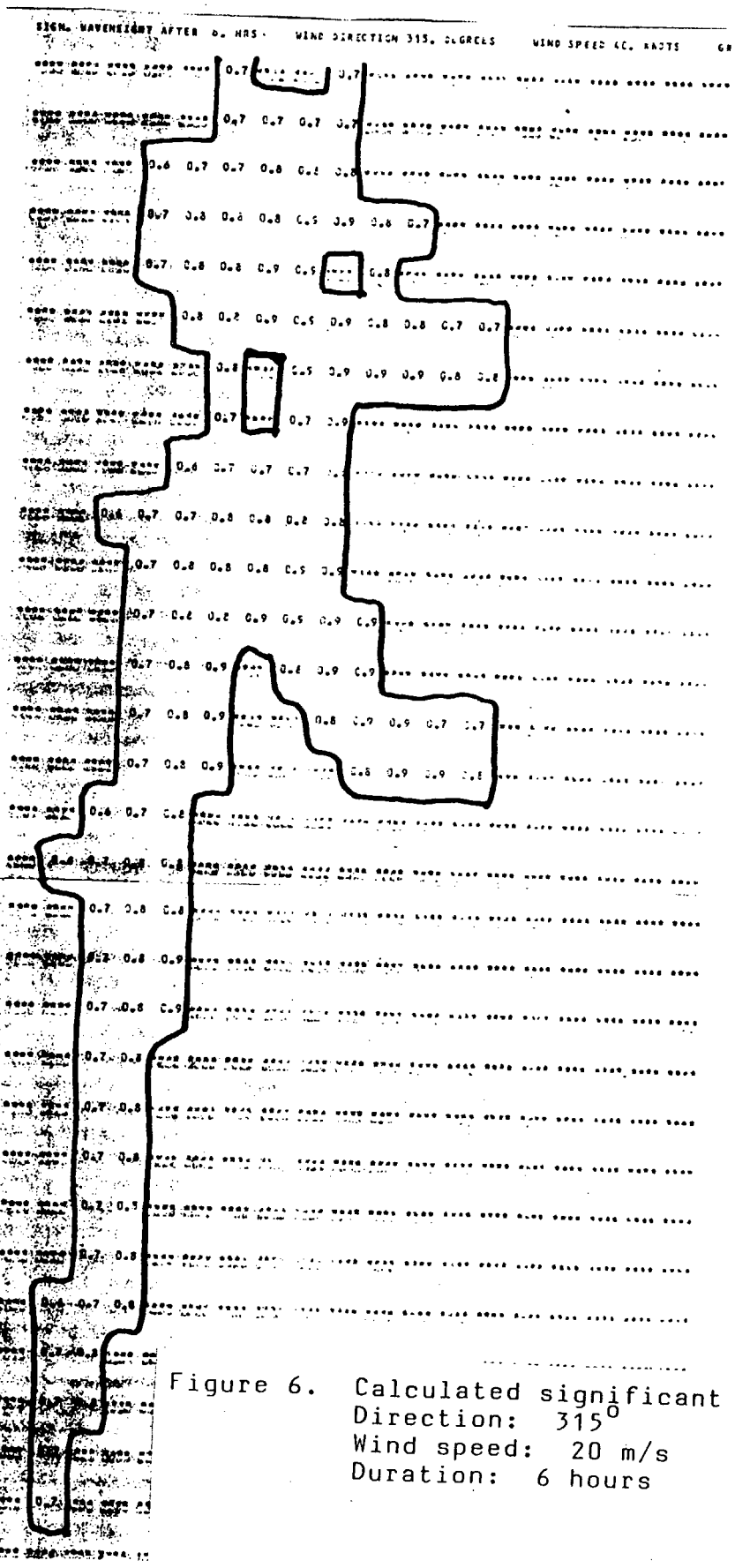

Figure 6. Calculated significant wave heights.
Direction: 315°
Wind speed: 20 m/s
Duration: 6 hours

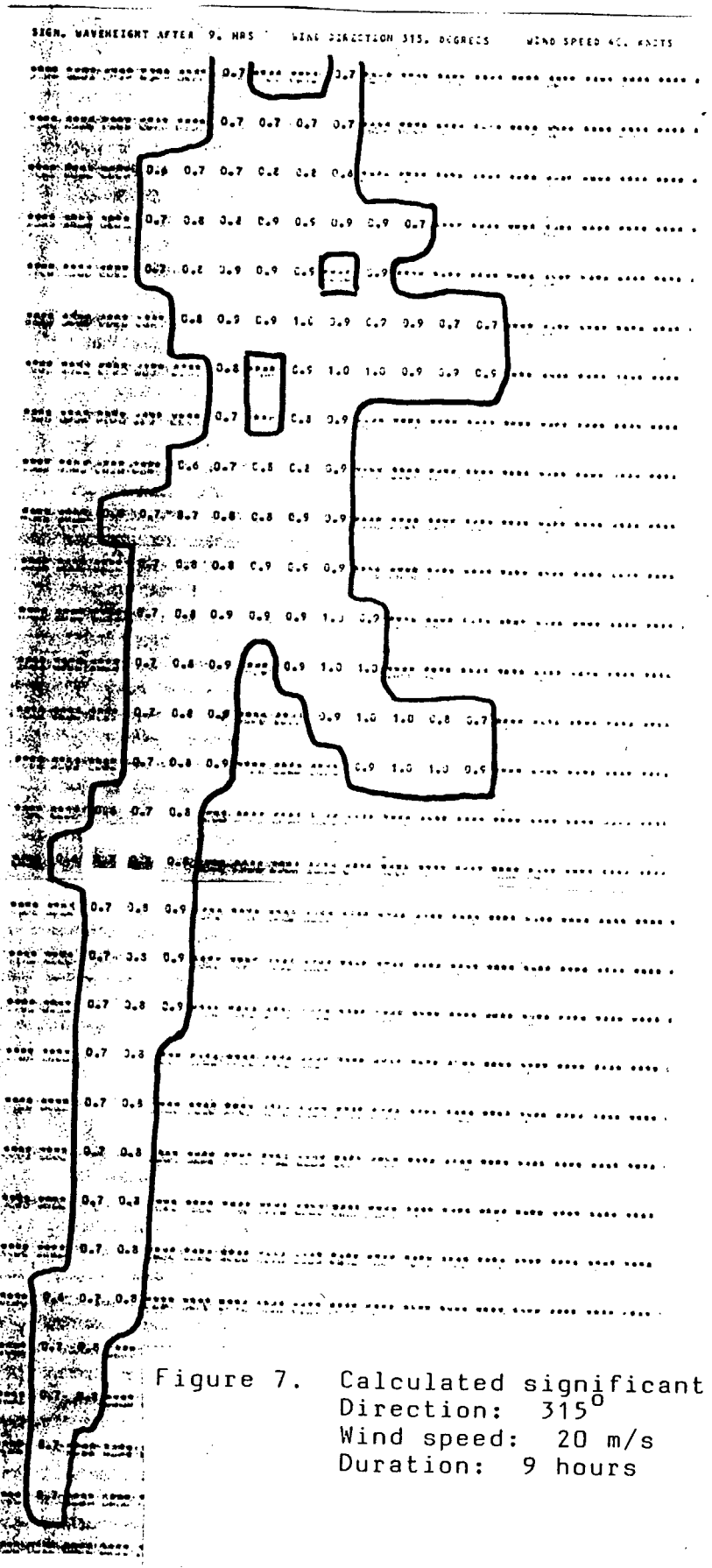

Figure 7. Calculated significant wave heights.
Direction: 315°
Wind speed: 20 m/s
Duration: 9 hours

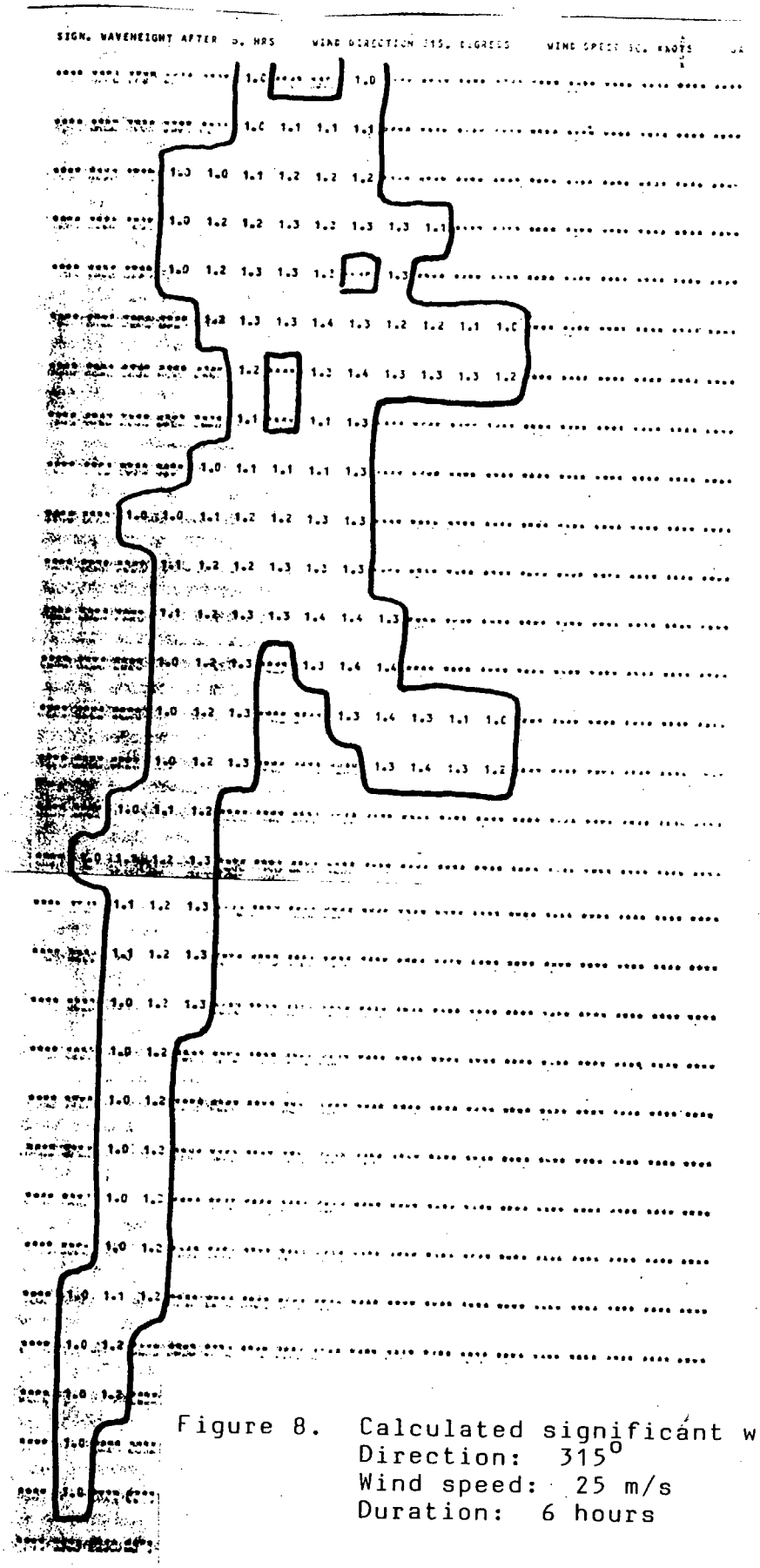

Figure 8. Calculated significant wave heights.
Direction: 315°
Wind speed: 25 m/s
Duration: 6 hours

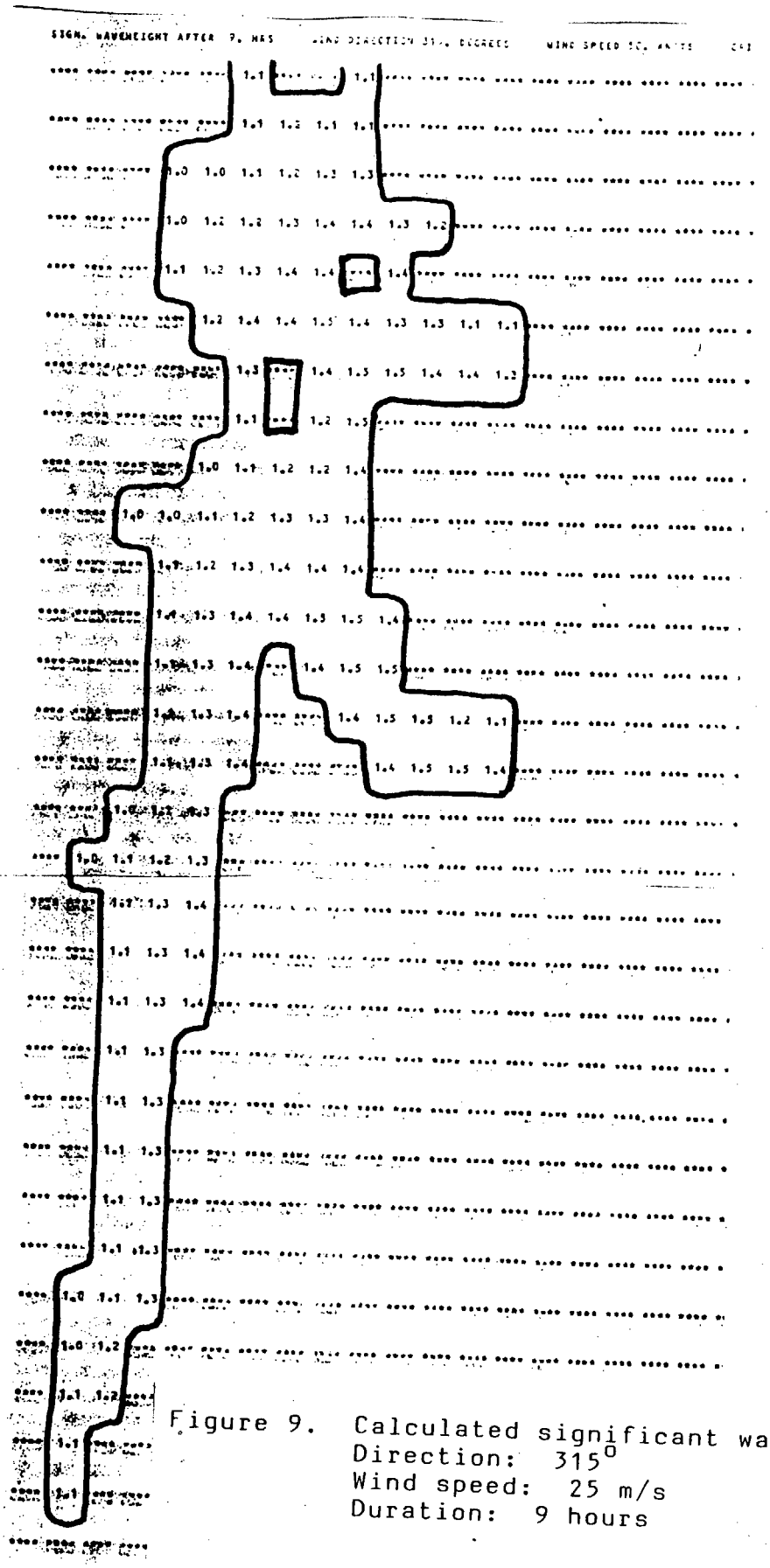

Figure 9. Calculated significant wave heights.
Direction: 315°
Wind speed: 25 m/s
Duration: 9 hours

DNMI-KLIMAAVDELINGENS FAGRAPPORTER

1/84 NORDLIE P E:
KLIMAGRANSKINGAR I NVE'S PROSJEKTOMRADE FOR KRAFTUTBYGGING
Statusrapportar 1983, administrativ del
Oppdragsgjevar: NVE - Statskraftverka

2/84 AUNE B:
ROGNMOEN GRUSTAK
Eventuelle lokale klimaendringer
08.06.1984
Oppdragsgiver: Statens vegvesen, Vegsjefen i Troms fylke

3/84 FØRLAND E J:
PÅREGNELIGE EKSTREME NEDBØRVERDIER
03.07.1984
Oppdragsgiver: NVE - Hydrologisk avdeling

4/84 FØRLAND E J og IDEN K A:
EKSTREM NEDBØR I LØPET AV 1 - 30 DØGN
Observerte og beregnede verdier for 49 stasjoner
03.07.1984
Oppdragsgiver: Vassdragsregulantenes Forening

5/84 NORDLIE P E:
E6 MOGREINA - BOKBRUD
Klimavurdering av konsekvensane ved kryssing av Andelva
05.07.1984
Oppdragsgjevar: Statens vegvesen, Vegsjefen i Akershus fylke

6/84 NORDLIE P E:
KLIMAENDRINGAR PA GRUNN AV IS I INDRE NORDFJORD
05.07.1984
Oppdragsgjevar: NVE - Statskraftverka

7/84 FIKKE S M:
KRAFTLEDNING TIL ILULISSAT/JAKOBSHAVN
Meteorologiske vurderinger
25.10.1984
Oppdragsgiver: Grønlands Tekniske Organisasjon

8/84 FIKKE S M:
KRAFTLEDNINGSTRASEER TIL ILULISSAT/JAKOBSHAVN
Reiserapport etter studietur 31.08-10.09.1984
25.10.1984
Oppdragsgiver: Grønlands Tekniske Organisasjon

9/84 FIKKE S M:
22kV KRAFTLEDNING TIL HAMNEFJELL RL-STASJON
Is- og vindlaster
09.11.1984
Oppdragsgiver: Tron Horn A/S for Teledirektoratet TBE

10/84 FIKKE S M:
22kV KRAFTLEDNING TIL ISKURAS RL-STASJON
Is- og vindlaster
09.11.1984
Oppdragsgiver: Tron Horn A/S for Teledirektoratet TBE

11/84 FIKKE S M:
300 kV KRAFTLEDNING DALE - FANA
Revurdering av is- og vindlaster
29.11.1984
Oppdragsgiver: Bergenshalvøens komm. Kraftselskap

12/84 FIKKE S M:
66 kV KRAFTLEDNING TROLLBERGET - BEIARN
Is- og vindlaster
07.12.1984
Oppdragsgiver: Tron Horn A/S for NVE-Statskraftverkene

13/84 FIKKE S M:
132 kV KRAFTLEDNING NADDVIK - ÅRDALSTANGEN
Is- og vindlaster
21.12.1984
Oppdragsgiver: ASV Nyset Steggje Kraft A/S

1/85 NORDLIE P E:
KLIMAGRANSKINGAR I NVE'S PROSJEKTOMRADE FOR KRAFTUTBYGGING
Statusrapportar 1984, administrativ del
15.01.1985
Oppdragsgjevar: NVE - Statskraftverka

2/85 FIKKE S M, ANDRESEN L, HARSTVEIT K, SUNDE A:
SKANEVIKFJORDEN. EXTREME WIND CONDITIONS.
25.01.1985
Oppdragsgiver: Neptun / Norwegian Contractors

3/85 FIKKE S M, ANDRESEN L:
ALFJORDEN. EXTREME WIND CONDITIONS.
07.02.1985
Oppdragsgiver: Haugesund Mekaniske Verksted A/S

4/85 FIKKE S M:
HAMNEFJELL RADIOLINJESTASJON
Vind- og islaster
11.02.1985
Oppdragsgiver: Siv.ing. Jørgen Madsen / Teledirektoratet

5/85 FIKKE S M:
RL - MASTER PÅ LAUVVIKFJELL OG TVERRFJELLET
Vind- og islaster
11.02.1985
Oppdragsgiver: Jarlse Fabrikker A/S

6/85 FIKKE S M, JOHANSEN K:
SKANEVIKFJORDEN. WAVE CONDITIONS.
13.02.1985
Oppdragsgiver: Neptun / Norwegian Contractors

7/85 FIKKE S M:
132 kV KRAFTLEDNING VARANGERBOTN - FINSKEGRENSEN
Vind- og islaster
15.02.1985
Oppdragsgiver: NVE - Statskraftverkene

8/85 FIKKE S M, JOHANSEN K:
SANDSFJORDEN. EXTREME WIND AND WAVE CONDITIONS.
15.02.1985
Oppdragsgiver: Norwegian Contractors