PORT AND OCEAN ENGINEERING UNDER ARCTIC CONDITIONS
TECHNICAL UNIVERSITY OF NORWAY

LONG PERIODIC OSCILLATIONS IN SØRVÆR HARBOUR, FINNMARK, NORWAY

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INTRODUCTION

In coastal engineering, considerable attention has been drawn to the subject of long periodic oscillations. The need of additional observations on this matter has been frequently mentioned by scientists and research engineers. This paper gives a description of long periodic oscillations observed at the port of Sørvær, Norway; not far from the North Cape. (Fig. 1). Also, the origin of these oscillations will be considered. Thirdly, a generating mechanism is suggested.

DESCRIPTION

First, consider the physical environments of the harbour. (Fig. 2). Upper right we can see the island of Sørvær, which is rather large; only a small part is included on the figure. Sørvær is exposed to sea and swell from south and west. There are no beaches on this part of the island; the coastline is mainly rocky and rather steep. Figure 3 shows the surroundings in more detail. The harbour is placed between some small islands. The Markeila bay might also be the cause of the oscillations in the harbour. This possibility will be discussed in a little more detail later.

The layout of the harbour is shown on fig. 4. The negative numbers are the depths in meters, the shaded contour is the shore, and the positive numbers are the heights above mean sea level. A non completed rubble-mound breakwater, some wooden piers and a tide gage, installed in the winter 1970-71, is also shown. The tide gage is of the type Leupold & Stevens recorder A 35. The length of the

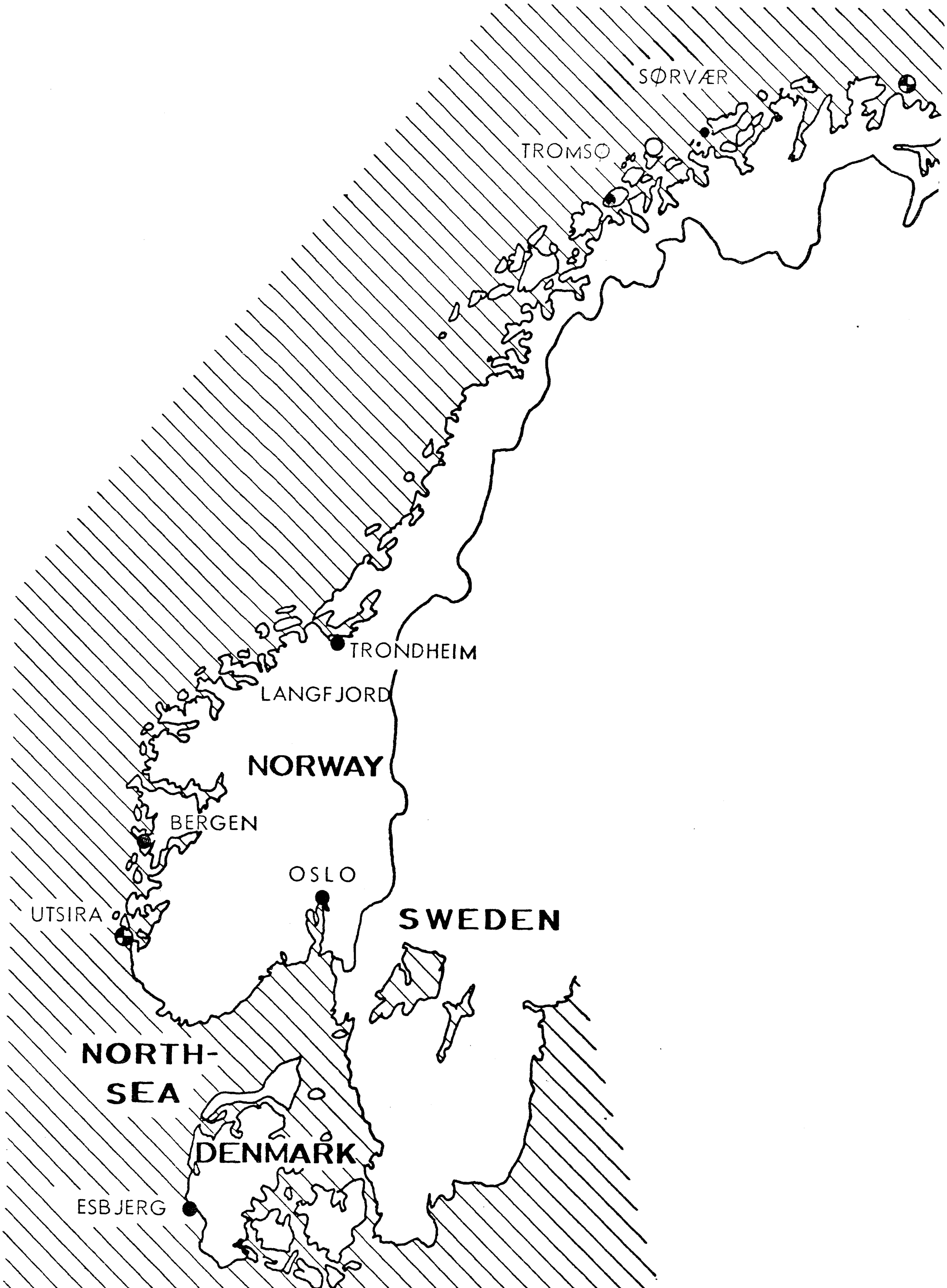

SØRVÆR
TROMSØ
TRONDHEIM
LANGFJORD
NORWAY
BERGEN
OSLO
UTSIRA
SWEDEN
NORTH-
SEA
DENMARK
ESBJERG

FIGURE 1


300
100
200
50
SØRVÆR
BREVIK
SØRØYA
HASVIK
SØRØYA
SCALE 1 : 200000
0 2 4 6 8 10km

FIGURE 2

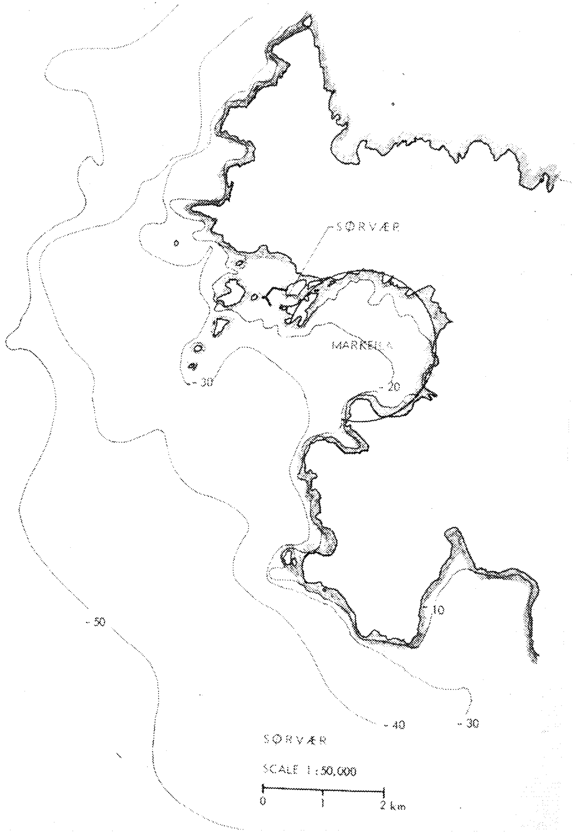


FIGURE 3

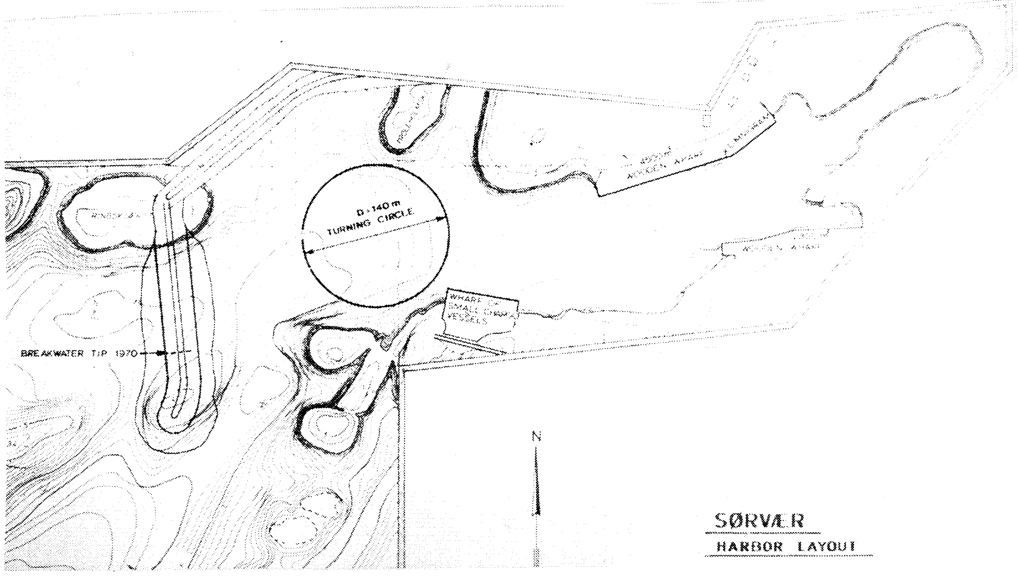


FIGURE 4

harbour is approximately 860 meters, so this is a relatively large basin.

Figure 5 shows long periodic oscillations recorded by the tide gage. During the winter, long periodic oscillations were recorded several times, and it was decided therefore to select 5 different recordings showing oscillating activity for further analysis.

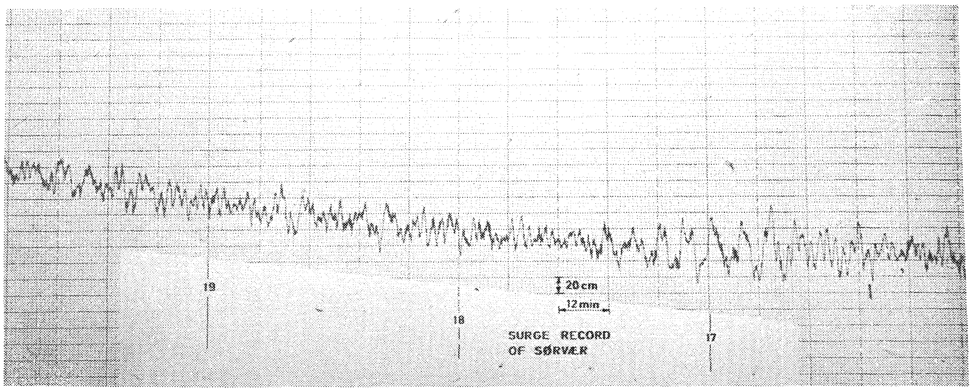


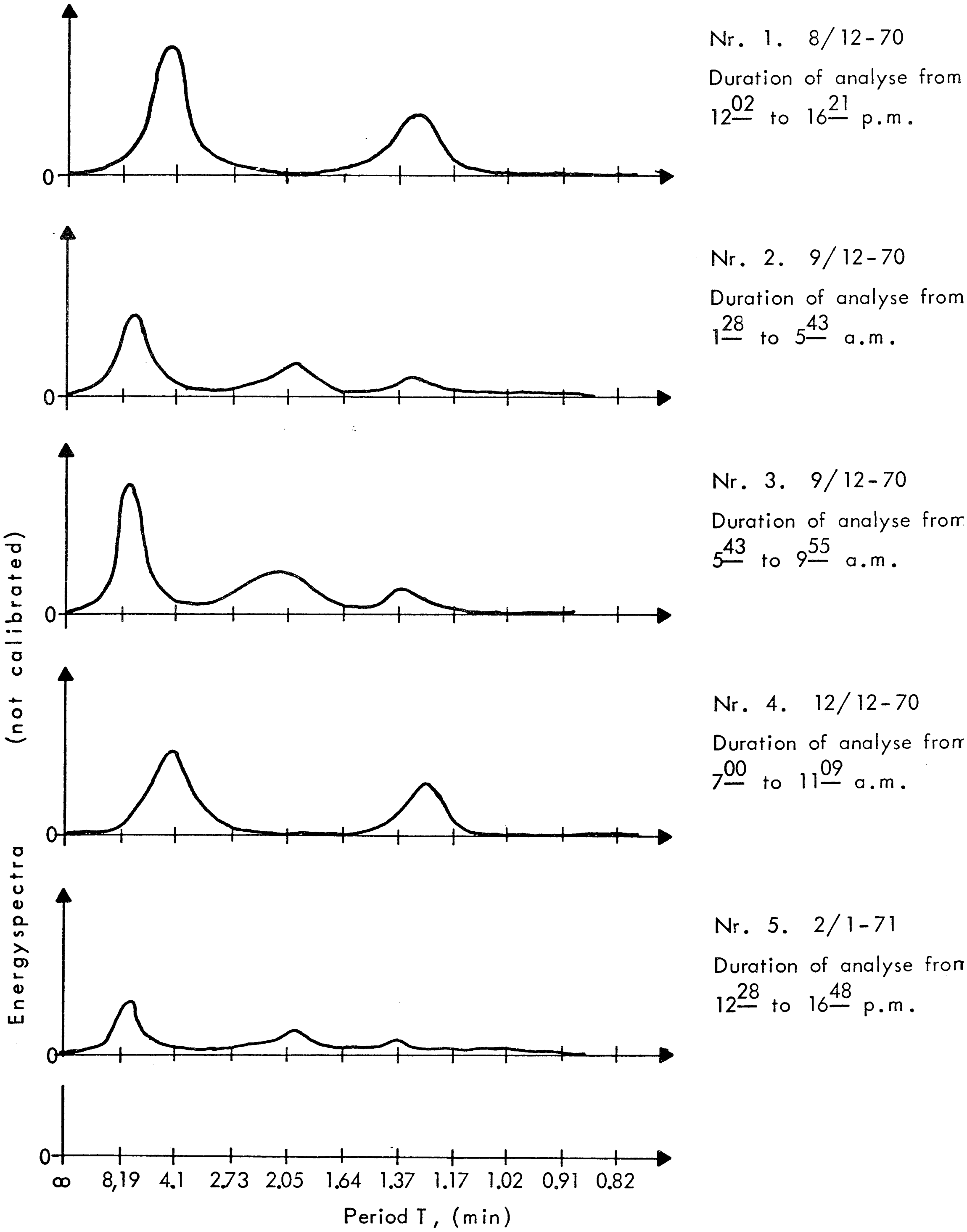
FIGURE 5

The records were Fourier analysed on an analog computer, and the spectra are shown on Fig. 6. These are rough calculations and the results have been smoothed. It is noted that the oscillations are due to resonance with the main peak to the left and the first and second harmonics to the right on the diagram.

Further on, we note that there may be some ambiguity in the determination of the peak frequency. It seems that we have to investigate two different cases of resonance action. Spectra no. 2 and 5 seem to correspond to each other, the main peak frequency being 4-5 minutes. The other 3 spectra seem to have a peak energy frequency of 7 minutes. Therefore there may be more than one possibility of resonance occuring. Different possibilities exist:

A. Resonance may occur in Markeila bay, see fig. 3.

Different possibilities for resonance may also occur inside the harbour. The harbour may be divided into two parts; the outer part which is rather deep, - approximately 18 meters, and the inner part which is rather shallow, - approximately 6 meters.



ENERGYSPECTRA FOR LIMNIGRAM. SØRVÆR HARBOR.

FIGURE 6

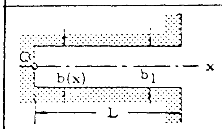
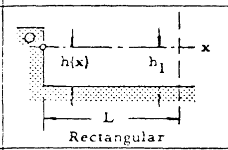
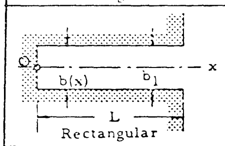
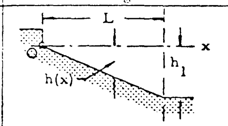
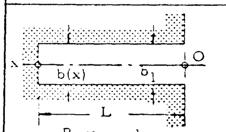
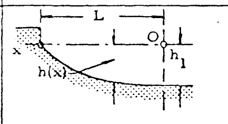
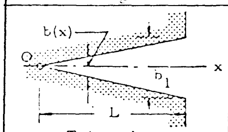
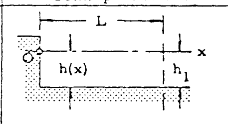
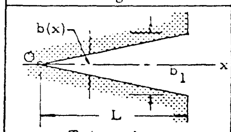
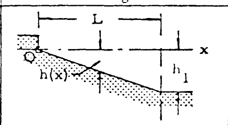
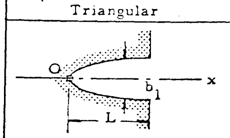
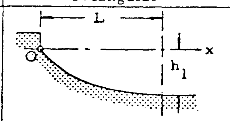
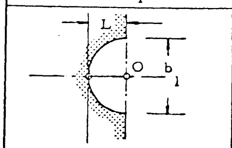
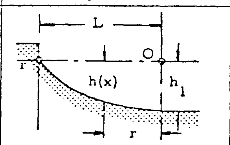
B. Resonance may therefore occur either in the inner basin,

C. or in the outer basin,

D. or in the harbour as a whole.

Some rough estimates of the resonance peak frequencies of the different possibilities were made, using the formulas shown on fig. 7.

MODES OF FREE OSCILLATION
IN SEMI-ENCLOSED BASINS OF SIMPLE GEOMETRICAL SHAPE
[BASED ON LAMB, (1932) & GOLDSBROUGH, (1930)]

BASIN TYPE		PROFILE EQUATION	PERIODS OF FREE OSCILLATION				
Plan Form	Depth Profile		Fundamental T_1	Mode Ratios T_s/T_1 $\left(n = \frac{s+1}{2}\right)$			
				n = 1	2	3	4
 Rectangular	 Rectangular	$h(x) = h_1$	$2.000 \frac{2L}{\sqrt{gh_1}}$	1.000	0.333	0.200	0.143
 Rectangular	 Triangular	$h(x) = \frac{h_1 x}{L}$	$2.618 \frac{2L}{\sqrt{gh_1}}$	1.000	0.435	0.278	0.203
 Rectangular	 Semi-parabolic	$h(x) = h_1\left(1 - \frac{x^2}{L^2}\right)$	$2.220 \frac{2L}{\sqrt{gh_1}}$	1.000	0.409	0.259	0.189
 Triangular	 Rectangular	$b(x) = \frac{b_1 x}{L}$ $h(x) = h_1$	$1.308 \frac{2L}{\sqrt{gh_1}}$	1.000	0.435	0.278	0.203
 Triangular	 Triangular	$b(x) = \frac{b_1 x}{L}$ $h(x) = \frac{h_1 x}{L}$	$1.653 \frac{2L}{\sqrt{gh_1}}$	1.000	0.541	0.374	0.283
 Semi-elliptic	 Semi-paraboloidal	$b_1/L = 2$ $b_1/L = 4/3$ $b_1/L = 1$ $b_1/L = 2/3$	$2.220 \frac{2L}{\sqrt{gh_1}}$	1.000	0.707 0.554 0.447 0.317	0.578 0.493 0.468 0.455	0.378 0.323 0.264 0.185
 Semi-circular	 Semi-paraboloidal	$h(x) = h_1\left(1 - \frac{r^2}{L^2}\right)$	$2.220 \frac{2L}{\sqrt{gh_1}}$	1.000	0.707	0.578	0.500

FEASIBILITY STUDY FOR A SURGE-ACTION MODEL OF MONTEREY HARBOR, CALIFORNIA by Wilson, Henderickson and Kilmer, 1965

FIGURE 7

The results of the estimates were:

A. Of order 7 minutes
B. Of order 5 minutes
C. Of order 2 minutes
D. Of order 7 minutes

From these estimates, the bay as well as the harbour could be causing the oscillating activity.

ORIGIN OF OSCILLATIONS

An attempt is made to give a meteorological background for one of these cases. One particular situation resulting in severe harbour oscillations was chosen for analysis; - 8th of December 1970. In the other cases, the oscillations were weaker and no features of interest were found.

Figure 8 shows the weather map from 8-12-1970 and the corresponding gage recording: A low pressure center is approaching from south-west, while the weather at Sørvær is rather calm. The harbour oscillations recorded are relatively weak.

Figure 9 probably describes the most interesting case. The weather map shown is the situation 6 hours later, with the corresponding gage recording. Note the approaching storm from south-west. The high pressure ridge over Sørvær causes the weather in the harbour area to be rather calm. The remarkable thing is that the oscillations are definitely intensified in spite of the moderate wind.

Another 6 hours later, fig. 10, the storm comes even closer to Sørvær. The wind starts blowing in the harbour area, the oscillations become severe. Fig. 11, 6 hours later, shows a front passing the harbour area, and the oscillating activity reaches maximum. From now on, the records show that oscillations attenuate.

The presentation of this single event cannot be regarded sufficient to draw any general conclusions. However, until additional observational material is available, this can be used as an indication of what the origin of the recorded oscillations may be. The fact that the oscillations activate earlier than the wind at Sørvær, indicates the suggestion that long periodic waves are generated within the

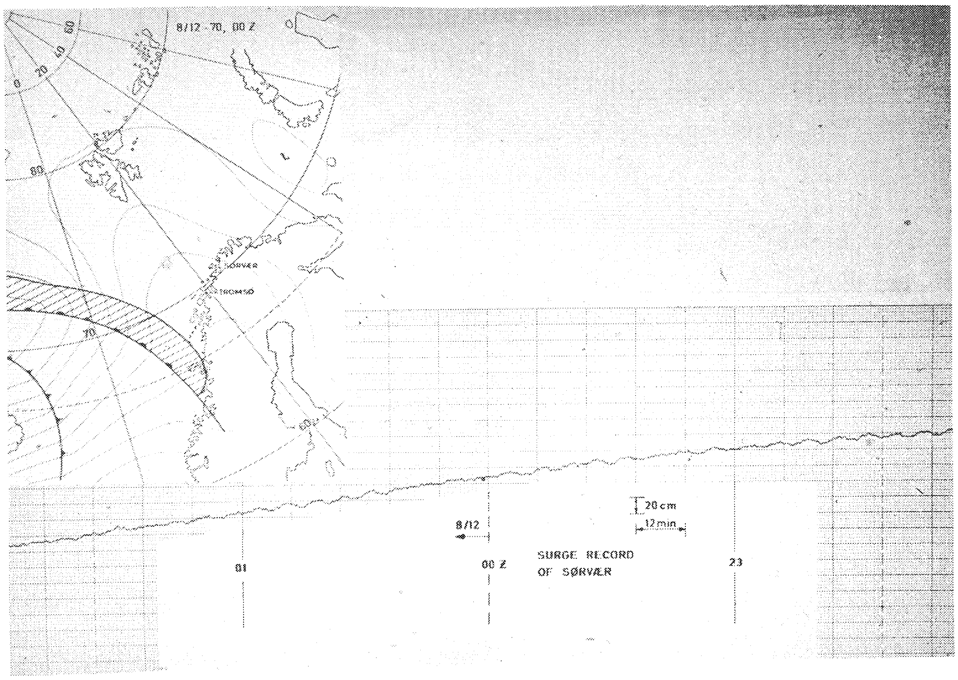


FIGURE 8

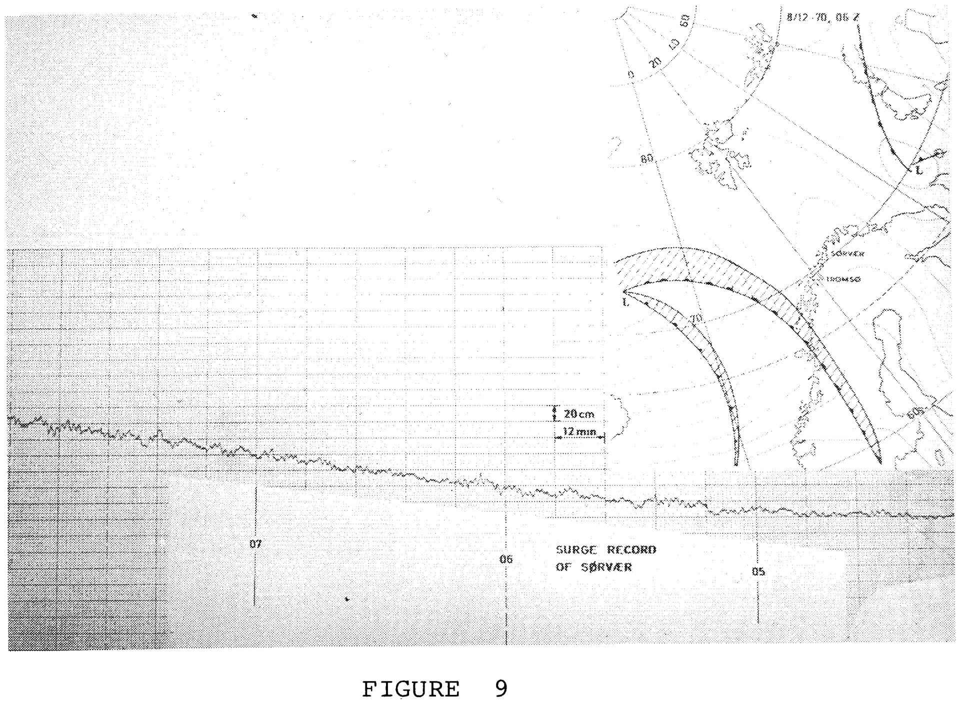


FIGURE 9

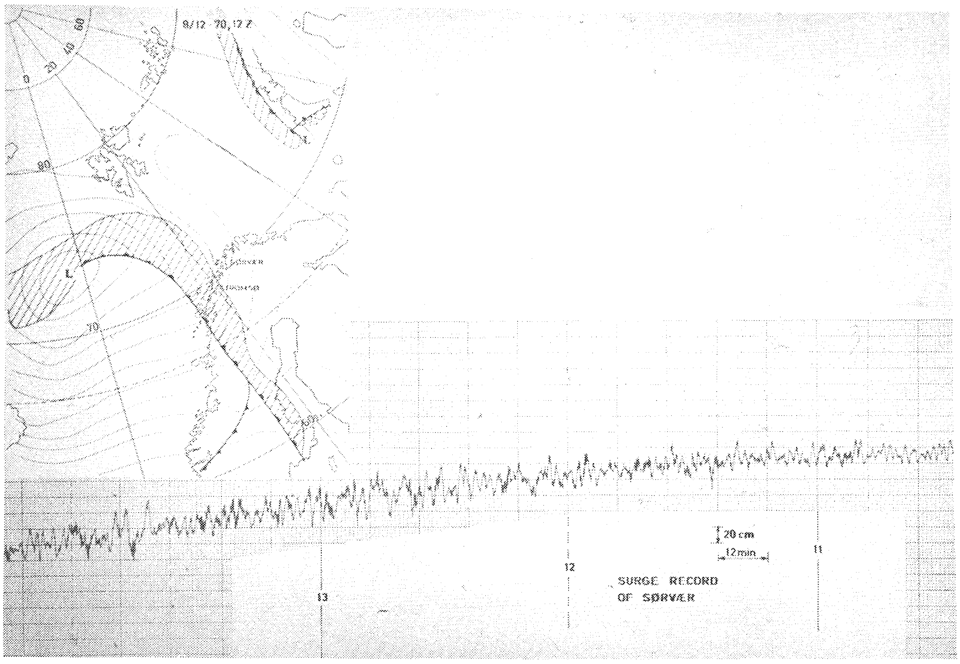


FIGURE 10

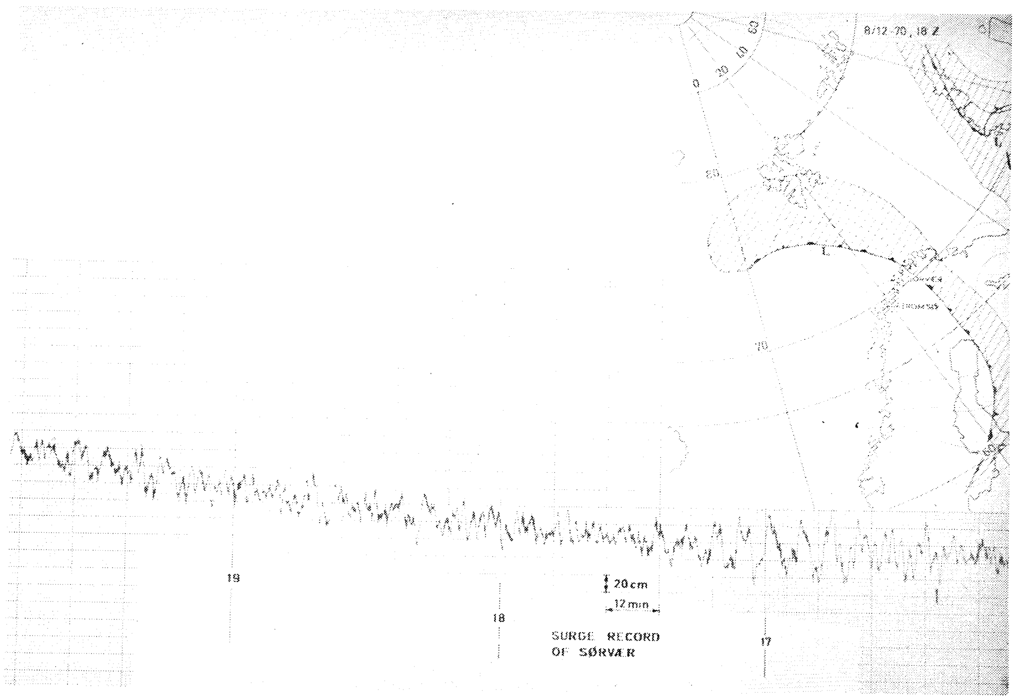
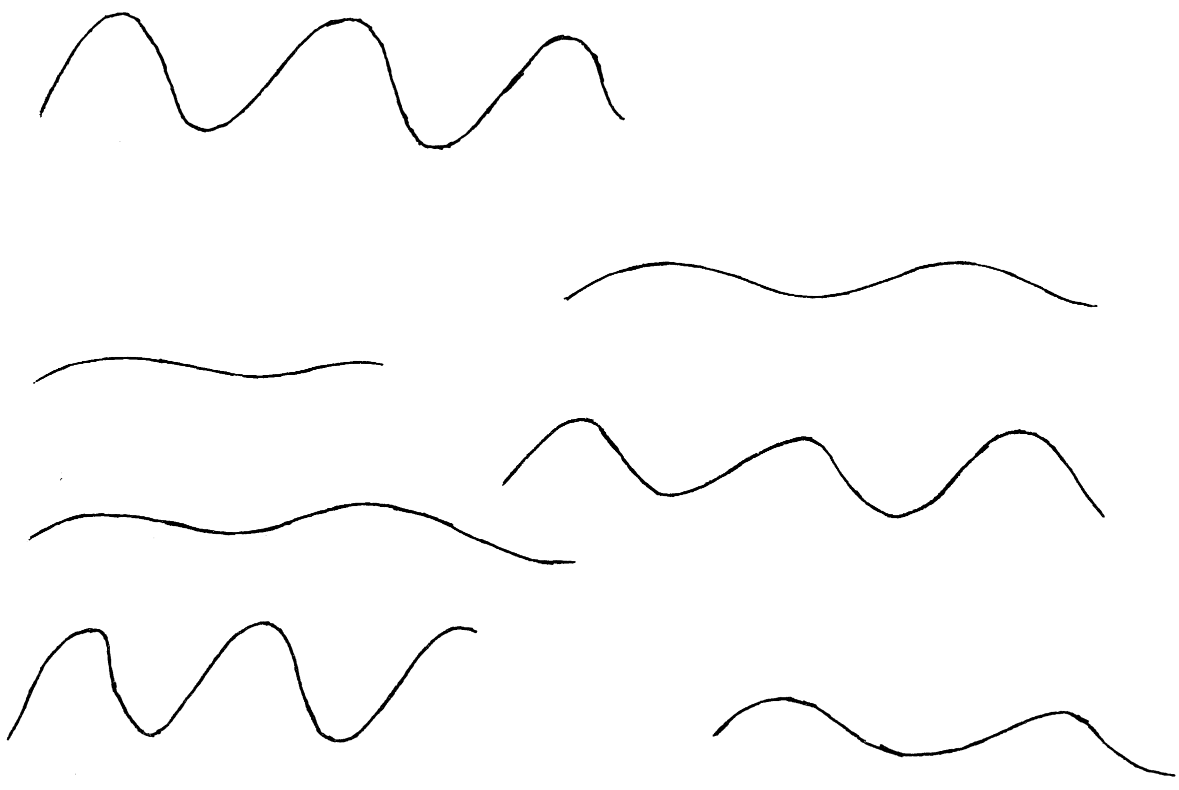


FIGURE 11

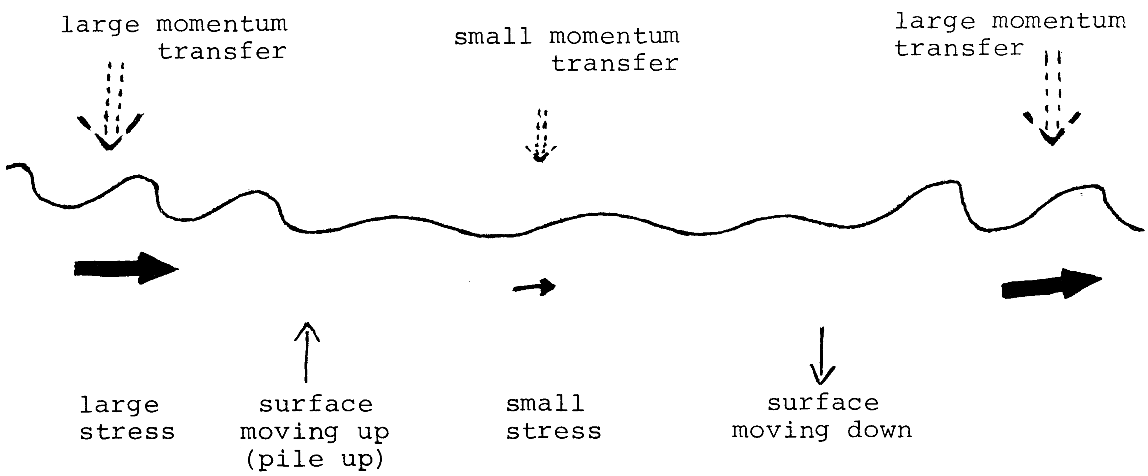
storm area in the open ocean. If this is so, these waves will travel in front of the storm; out of storm area, because of their very high propagation velocity. Consequently, they will reach the harbour area before the storm does, and may initiate the resonance activity. If this is the case, the next question is: What mechanism generates long periodic waves within a storm area? One possible mechanism is may be caused by the wind gustiness, and such a mechanism is explained in more detail in the section below.

WIND GUSTINESS AS A GENERATING MECHANISM FOR LONG PERIODIC WAVES

This mechanism is supposed to be valid within a storm area with growing waves. The wave energy spectrum for a growing wave area is very sharply peaked, causing a tendency for the waves to appear into groups, as outlined below:



As a consequence of this grouping, we obtain a distribution of areas having more wave "activity" than other areas. These "active" wave areas manifest themselves with a tendency to appear with steeper waves, higher waves and more white-caps than the surrounding areas. What is most important, these areas will have larger surface roughness than the surrounding sea, thus causing the momentum transfer from wind to sea to be distributed over the sea surface with local maxima within the "active" wave-areas. It is a well known fact that the wind within a storm area is not steady, it "gusts" with a periodicity of order minutes. (Of course, almost all components are present in a wind energy spectrum of a storm, but experience indicates the wind velocities to be maximum at intervals of order minutes rather frequently). This wind-gustiness will cause the stress distribution on the sea surface to be distributed not only in space, but also in time. The space distribution of the stress will cause the elevation of the sea surface to be modified:



The time distribution of the stress (caused by the gustiness of the wind) will make the sea surface move in the vertical direction with the same frequency as the wind variation. Thus the storm generates forced surface oscillations with periodicity of the same order of magnitude as the wind gustiness period.

An additional aspect of the mechanism should be mentioned. Because of the statistical properties of the wind, different wave-active areas will experience different magnitudes of momentum transfer and also have developed through different pre-stages. This will cause some wave-active areas to grow faster than other wave-active areas. In addition, the most wave-active areas will be favourized in further growth, because of their larger surface roughness a priori. Such selective mechanism might give rise to a number of wave-active areas with some kind of "maximum activity". These areas of "maximum activity", which could be relatively few, would be a most effective source to form surface oscillations.

From these areas, the largest long-periodic surface waves will emerge with a frequency of order minutes.

A mathematical formulation of the process described might be possible to work out. As far as I can see, such a formulation would involve a 4-dimensional stress distribution (3 in space, 1 in time) and the actual distribution would depend on wave spectra as well as wind spectra. It is beyond my capacity to make such a formulation, but any attempt would be welcome.

ACKNOWLEDGEMENTS

Thanks to Prof. Per M. Bruun for critisism and valuable suggestions regarding the formulation of the generating wind gustiness mechanism.

REFERENCES

B.W. Wilson et al.: "Feasibility study for a surge action model of Monterey Harbour, California", October 1965.