Chapter 21

EFFECTS OF HYDROGRAPHIC CHANGES DUE TO NEARSHORE DREDGER DUMPING ON WAVE REFRACTION AND LITTORAL SAND BALANCE

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This paper presents a case where, in the development of a harbour, dredged material was dumped in a location where a large accumulation eventually formed. This changed the offshore topography sufficiently to affect the predominant-wave refraction conditions. The wave environment along the principal bathing beaches was changed as a result, and a degree of beach erosion ensued which can be ascribed as partly due to the effects of continued dredger dumping in one area.

In the normal development of any port it must be accepted that some change of the wave environment has to take place due to the change in boundaries. This paper attempts to show that not only visible structural features, such as breakwaters, but also less evident submarine topographical changes can create some change in wave action. This can best be analysed and understood by making wave refraction studies of the conditions at various times.

Considerable hydrographic changes occurred within the port limits of Durban (situated on the southeast coast of Africa) over the period 1850 to the present. This resulted from the development of the harbour through dredging and then dumping the sand a few miles offshore. Figs 1(a) to (e), drawn from hydrographic maps available for five different surveys, show the remarkable build-up of two lens-shaped shoal areas close to the harbour entrance. Fig 2(a) and (b) show that the accretion during the period 1887-1926 occurred ENE of the entrance and in 1926-1961 mostly to the south east. This is due to a change in dumping grounds after 1938 when the larger accretion to the ENE began to assume alarming proportions. This dump contained 19 mill cu yd of dredged sand by 1926 corresponding to the dredging taking place in and around the entrance channel to maintain adequate draft. By 1938 the volume had reached 27 mill cu yd which is approximatel the present volume. Since 1938 accretion of a further 20 mill cu yd occurred due to dumping in the SE area.

The maintenance dredging of sand traveling northwards along the Bluff coast to the south of the harbour entrance has risen to a figure of 800,000 to 1 million cu yd/annum, and over the years a gradual depletion of sand along certain of the northern bathing beaches occurred that was countered by

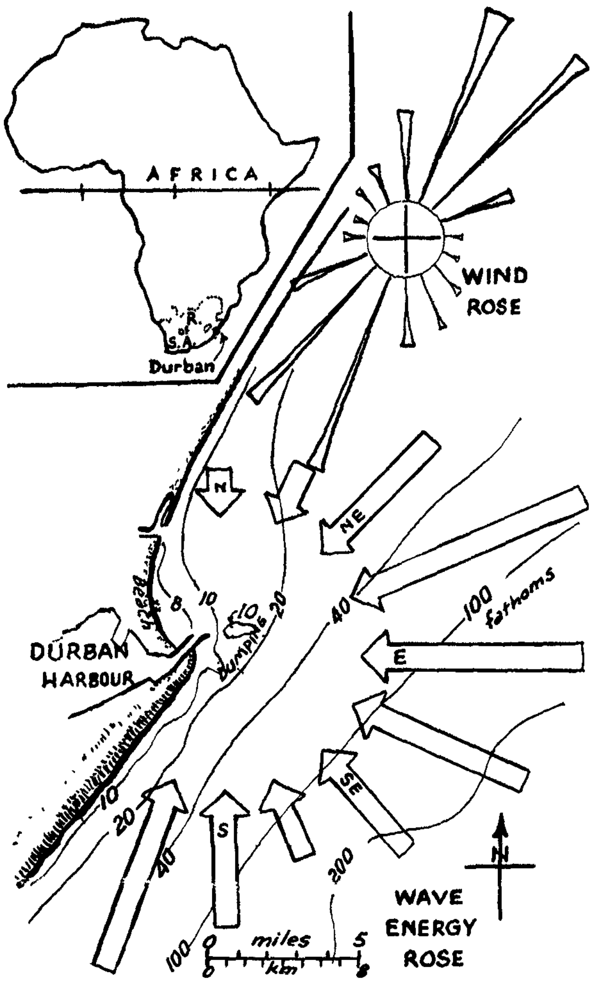
AFRICA
R. of S.A.
Durban
WIND ROSE
N
NE
E
SE
S
DURBAN HARBOUR
Beach
Dumping
100 fathoms
200
miles
km
WAVE ENERGY ROSE
N

Fig. a

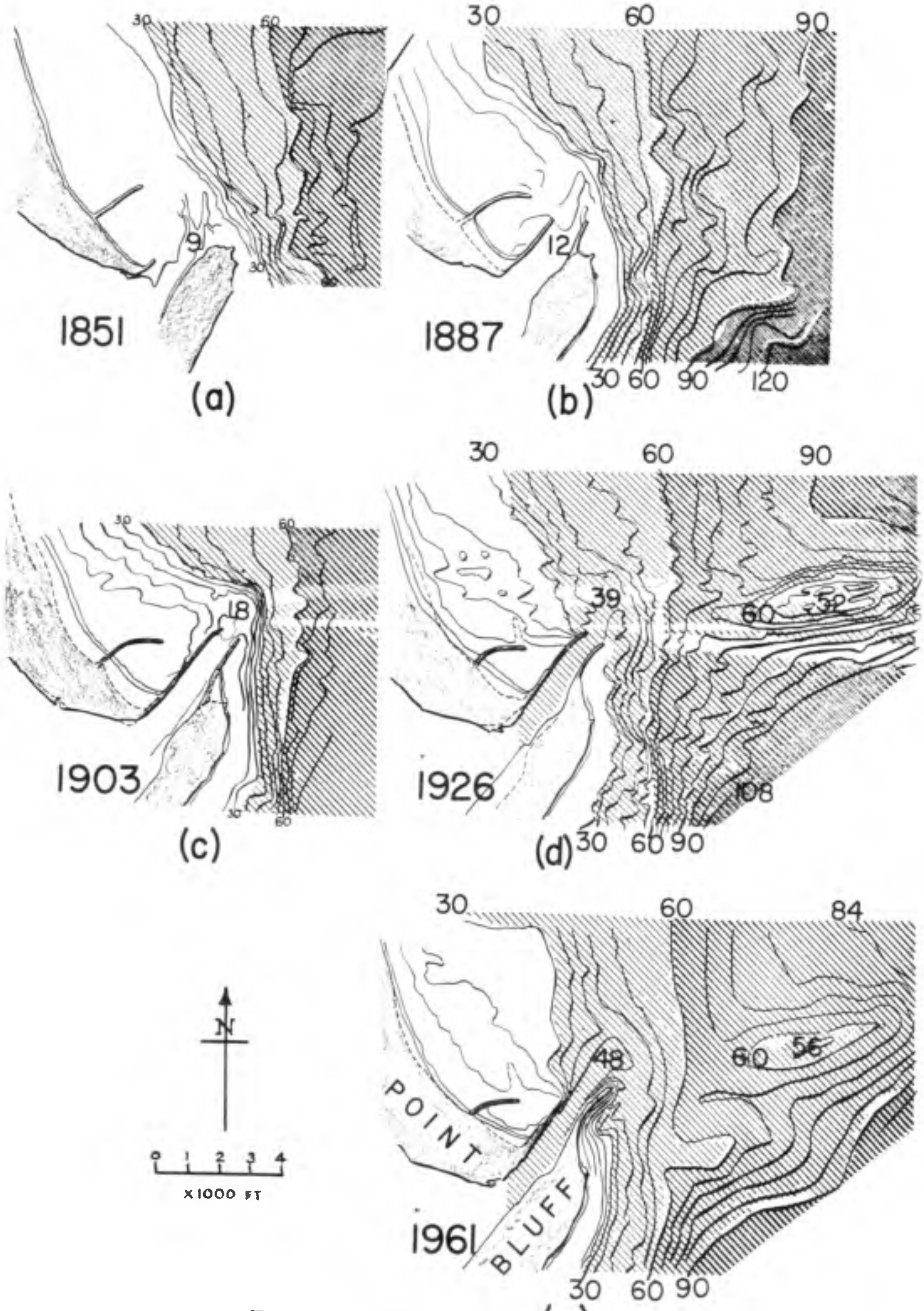
30
60
9
30
1851
(a)
30
60
90
12
1887
30 60 90 120
(b)
30
60
18
1903
30
60
(c)
30
60
90
39
60
52
1926
108
(d) 30 60 90
30
60
84
48
60
56
POINT
BLUFF
1961
30 60 90
(e)
N
0 1 2 3 4
X1000 FT

FIGURE 1

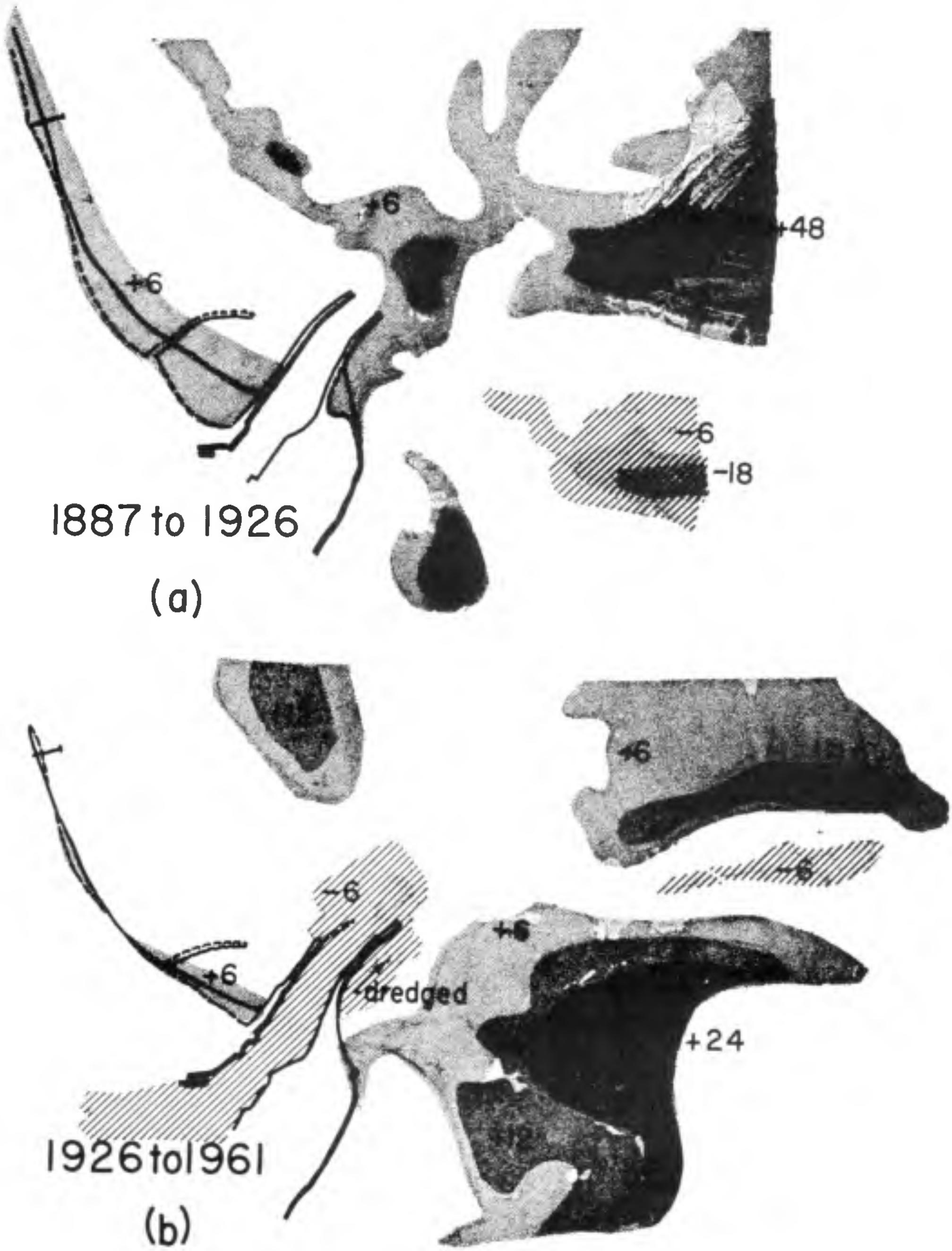

FIGURE 2

partial sand byoassing across the harbour entrance. A scheme whereby dredging could be reduced and better beaches be maintained was constantly sought leading to a comprehensive scale model investigation of the problem. This study was supported by analytical methods and field observations over a period of three years.

WAVE REFRACTION

It was found from model observations and later confirmed by field data taken during storms that the predominant swell waves are markedly higher along a particular stretch of the beach where the greater erosive tendencies were observed. Three sets of wave refraction diagrams were accordingly prepared for each of the three predominant wave approach directions and for the hydrographic conditions both before and after the offshore accretions took place, i.e. ESE, NE and SE wave approach for 1887 and for 1961 conditions. The results are shown in Figs. 3 to 5.

The shallow areas in the underwater topography present in 1961 but nonexistent in 1887 had the effect of changing the wave approach direction and consequently refocusing wave energy on certain parts of the coastline, which formerly was a zone of wave diffraction and gradual beach building. This explains why higher waves and greater erosive capacity were observed in the affected zone in both model and nature. It can be assumed that this region downdrift of the harbour entrance had been in relatively stable state before 1851 although, geologically speaking, slowly accreting. The beaches to the south (updrift) had a practically unlimited supply of sand from a long straight coastline southwards which was fed by many littoral-drift producing rivers. The rocky headland bounding the southern stretch of coastline confined the littoral drift to a narrow breaker zone and originally fed sand to the northern beaches across the shallow tidal inlet to the several square miles of Bay (which later became the harbour). When in recent years the tidal inlet was dredged to 42 ft plus to develop the harbour, all natural bypassing of sand to the north ceased, and it became necessary to maintain the approach depths by continuously dredging a "sand trap" immediately updrift (southeast) of the main breakwater defining the entrance channel.

The wave refraction diagrams for ESE and SSE swell show that a greater degree of sheltering occurred due to the south breakwater construction which, combined with the sand supply being cut off, reduced the northward drift along the northern beaches. Storm waves from NE were focused by the mound caused by dumping offshore onto the updrift coast region (Bluff) causing a likely return of part of the littoral drift southwards at times. The offshore accretions and the entrance dredging together have the net effect therefore of

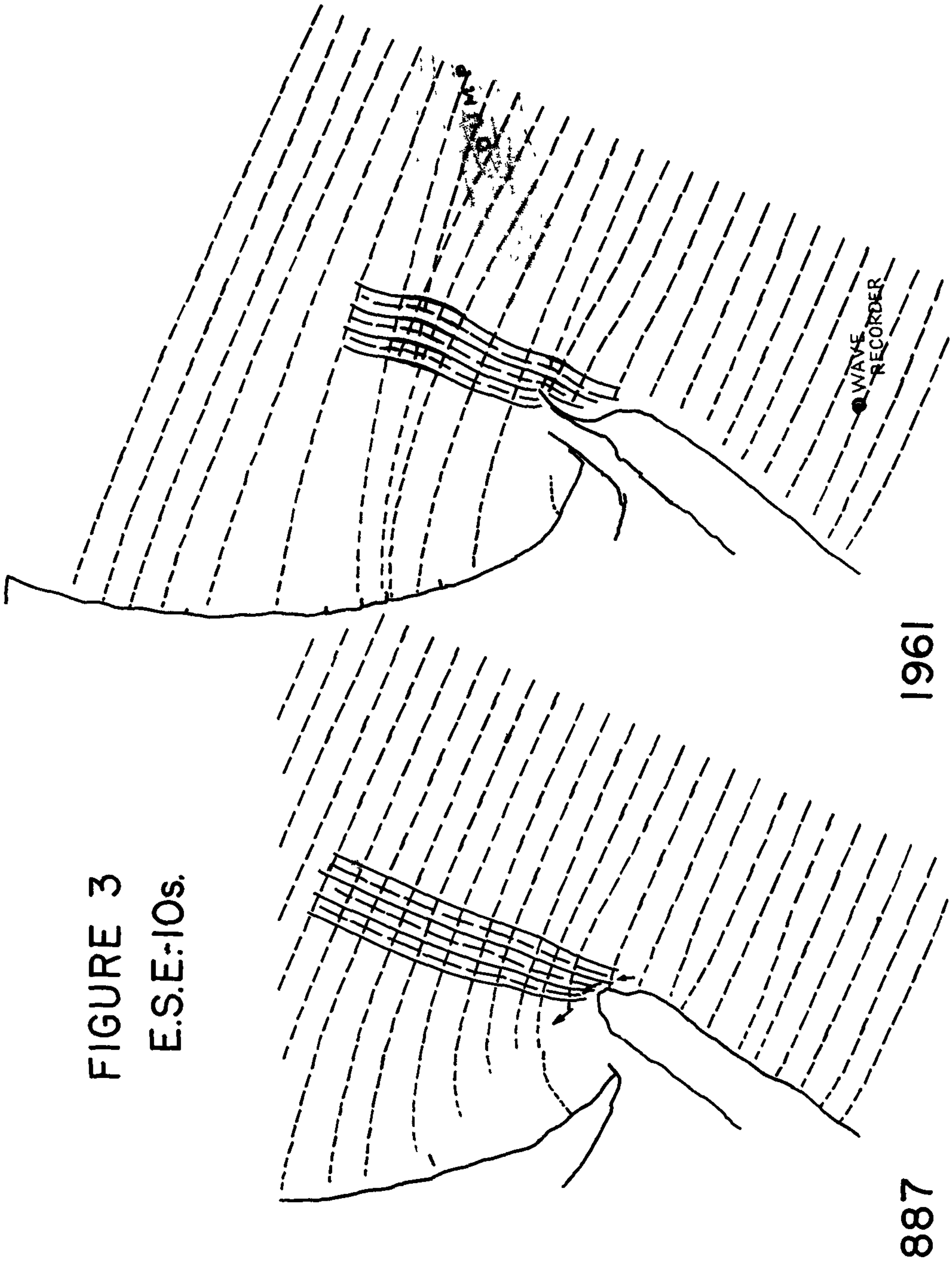

FIGURE 3
E.S.E.-10s.

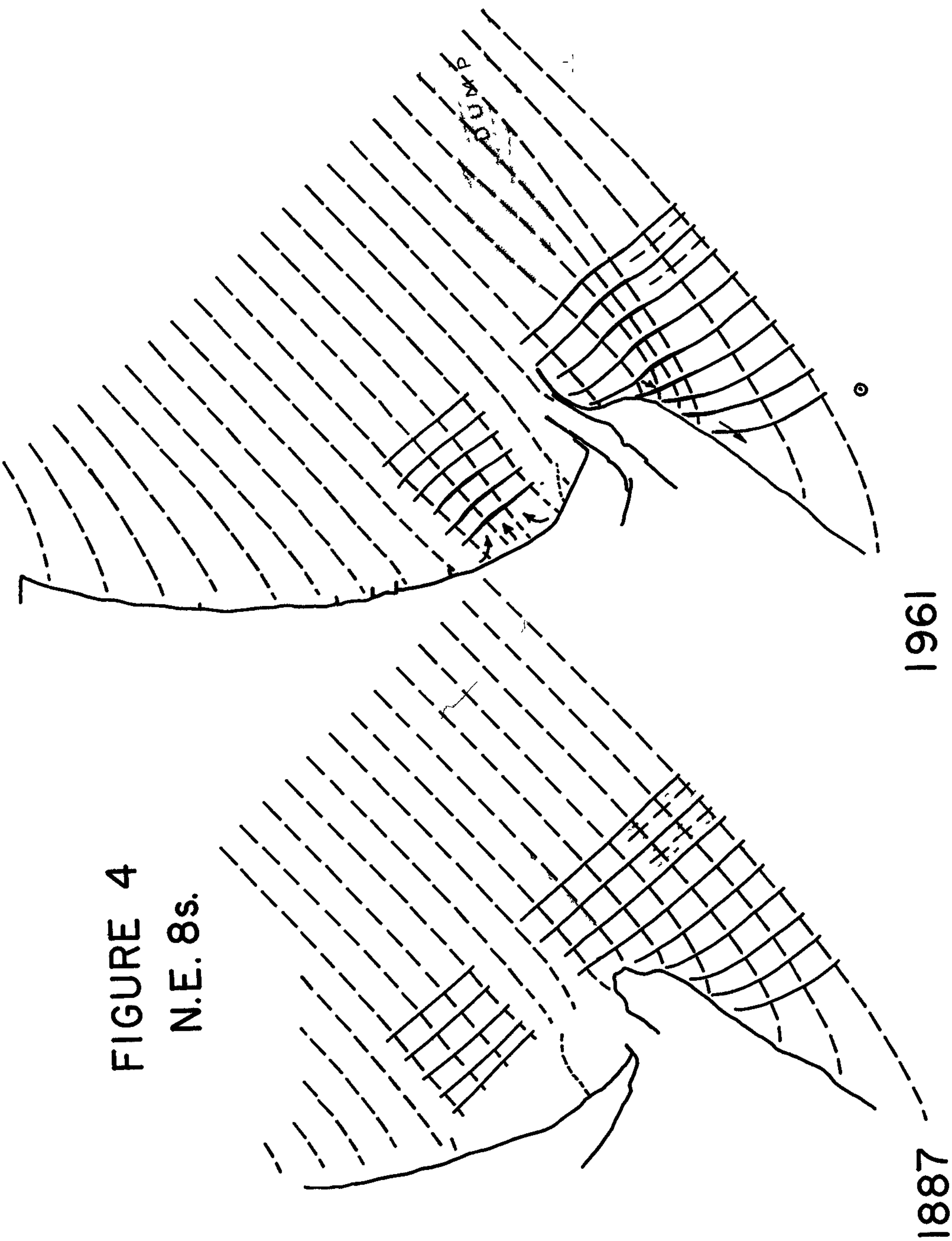

FIGURE 4
N.E. 8s.

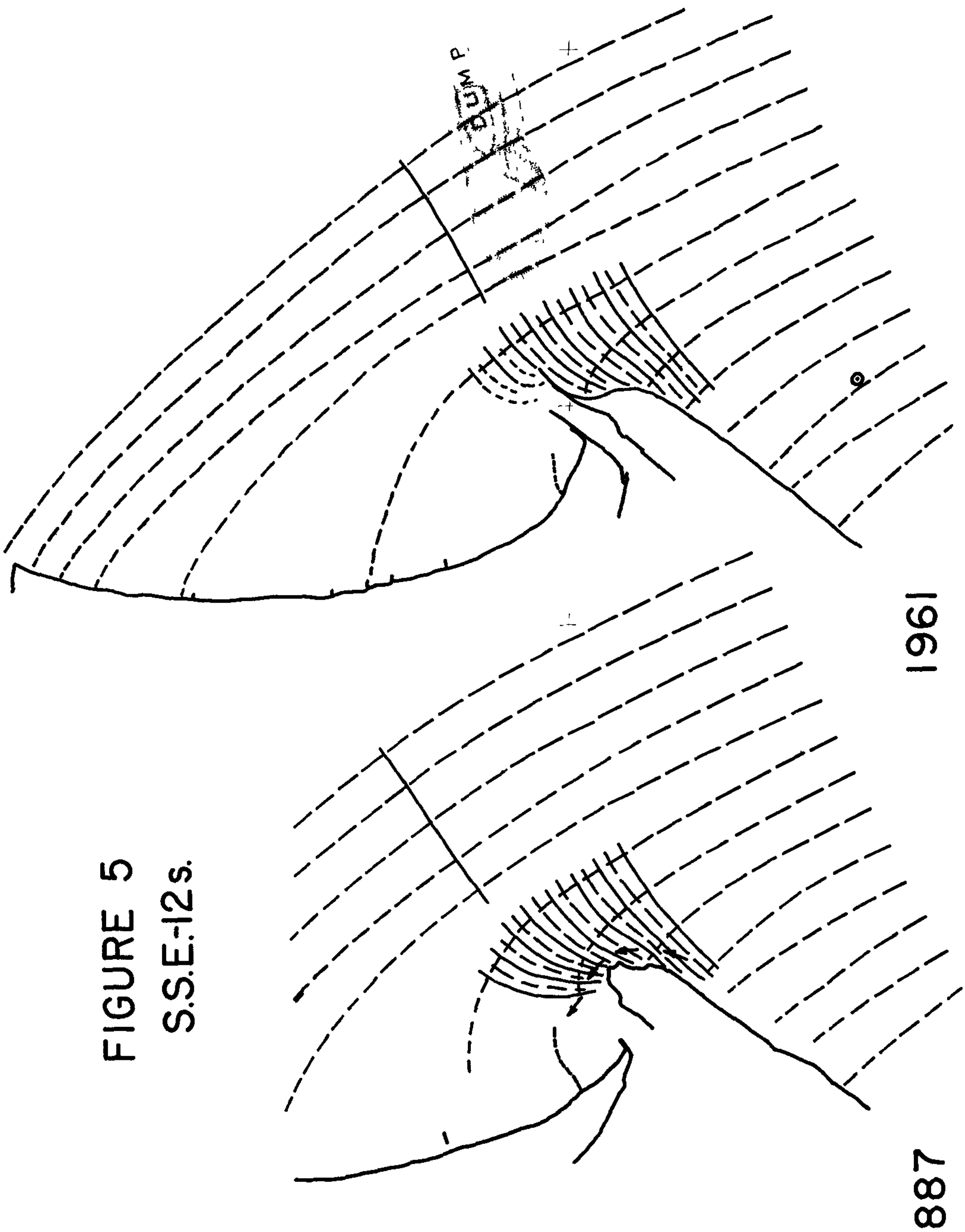

FIGURE 5
S.S.E.-12s.

changing the wave environmental conditions along the coastline. The northern stretch of beach, in response to the changed environment, tends to establish a new equilibrium shore line which is more concave seaward, by virtue of the sheltering of the lower Point area and the increased wave attack on the central area of this crescent-shaped stretch of beach. The two groynes that were built there in 1953 apparently are effective in maintaining present conditions there at a reasonably stable level, but this is inferior to requirements.

This hypothesis was subsequently tested by drawing the wave energy vectors for upcoast and downcoast littoral drift, Fig.6, which were obtained by collecting wave data over a period of over three years, combined from records and observations kept regularly at Stations 2, 3 and 4 and developing a "wave rose" diagram for offshore conditions. By means of the wave refraction studies here presented (and four others for different directions in 1961) the refracted (nearshore) wave roses for points 4 to 12 along the coastline were derived. The funicular diagrams for wave energy were drawn and the net longshore energy component, a relative measure of the net drift, obtained all along the coastline under consideration. Because of currents and wave interaction, the nearshore littoral drift combines with an offshore sand drift to a natural accretion area north of the harbour entrance (shown dot shaded in Fig 7). Along the southern (Bluff) coastline littoral drift is caused principally by an interaction of waves and currents and not by one or the other alone. A yearly influx of about 1 million cu yds sand occurs into the dredged sand trap area adjacent and seaward of the south breakwater, as shown schematically in Fig.7. From this trap sand is continuously dredged and dumped offshore, at present about 3 miles SE of harbour entrance.

CONCLUSIONS

With the aid of wave refraction studies and confirmed by model and field observational data, it was determined that man-made offshore shoal areas had the effect of increasing wave action down-weather thereof. As a result, wave- and wind-induced off-shore circulation in this locale was found to favor a condition of beach erosion. This result was confirmed by a study of the sorting and granulometric distribution of sand samped extensively in the offshore environment and by the diagnosis of the situation. This diagnosis was subsequently used as a basis for testing remedial measures on the model. It was apparent that redredging of the dump or attempts to flatten and spread it would be prohibitive, and possibly not fully effective. Schemes to reduce the wave energy over localized area were investigated, such as parallel-to-shore breakwaters or wave-screens of a semi-permeable nature. These were found hydraulically effective in the model but because

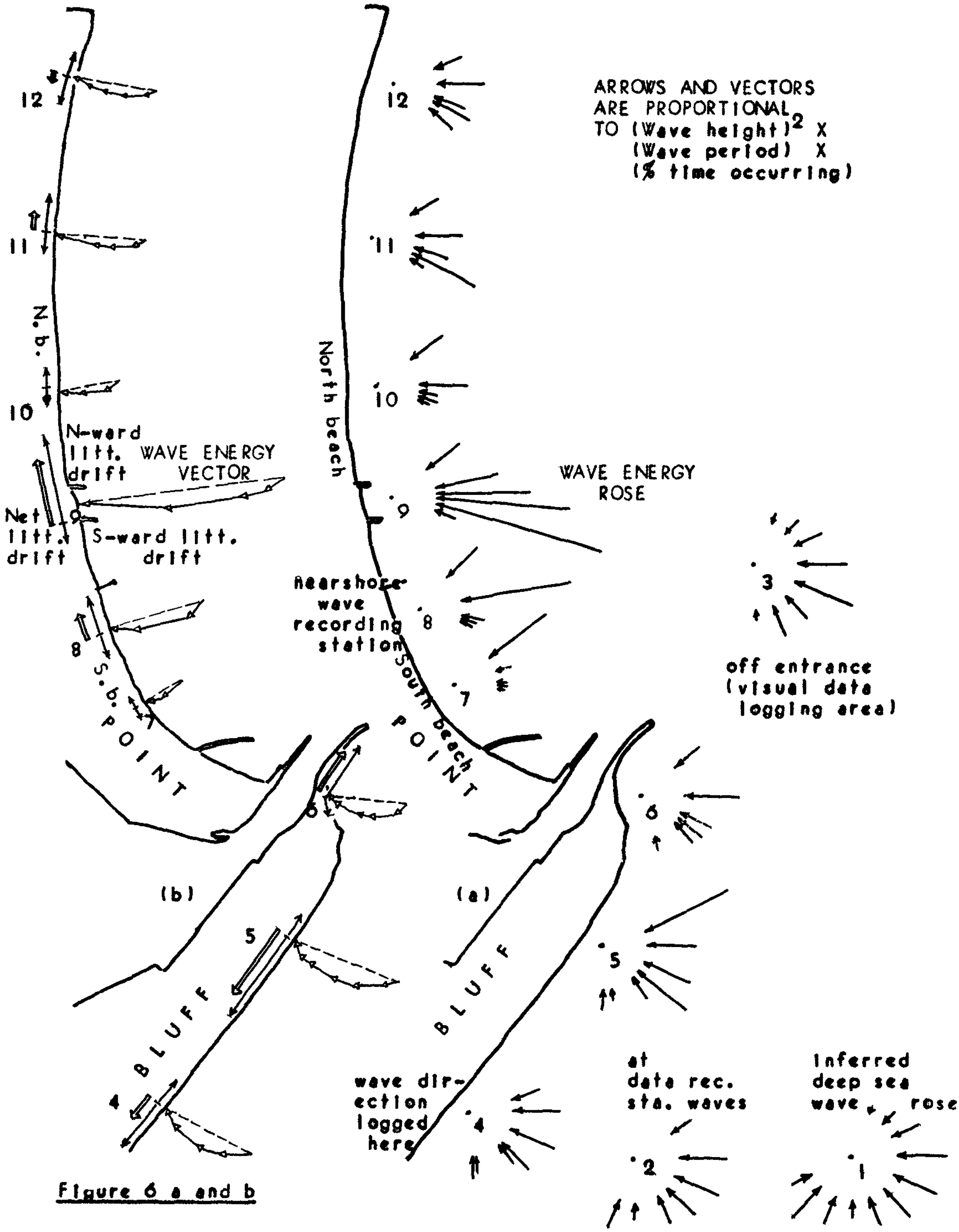

Figure 6 a and b

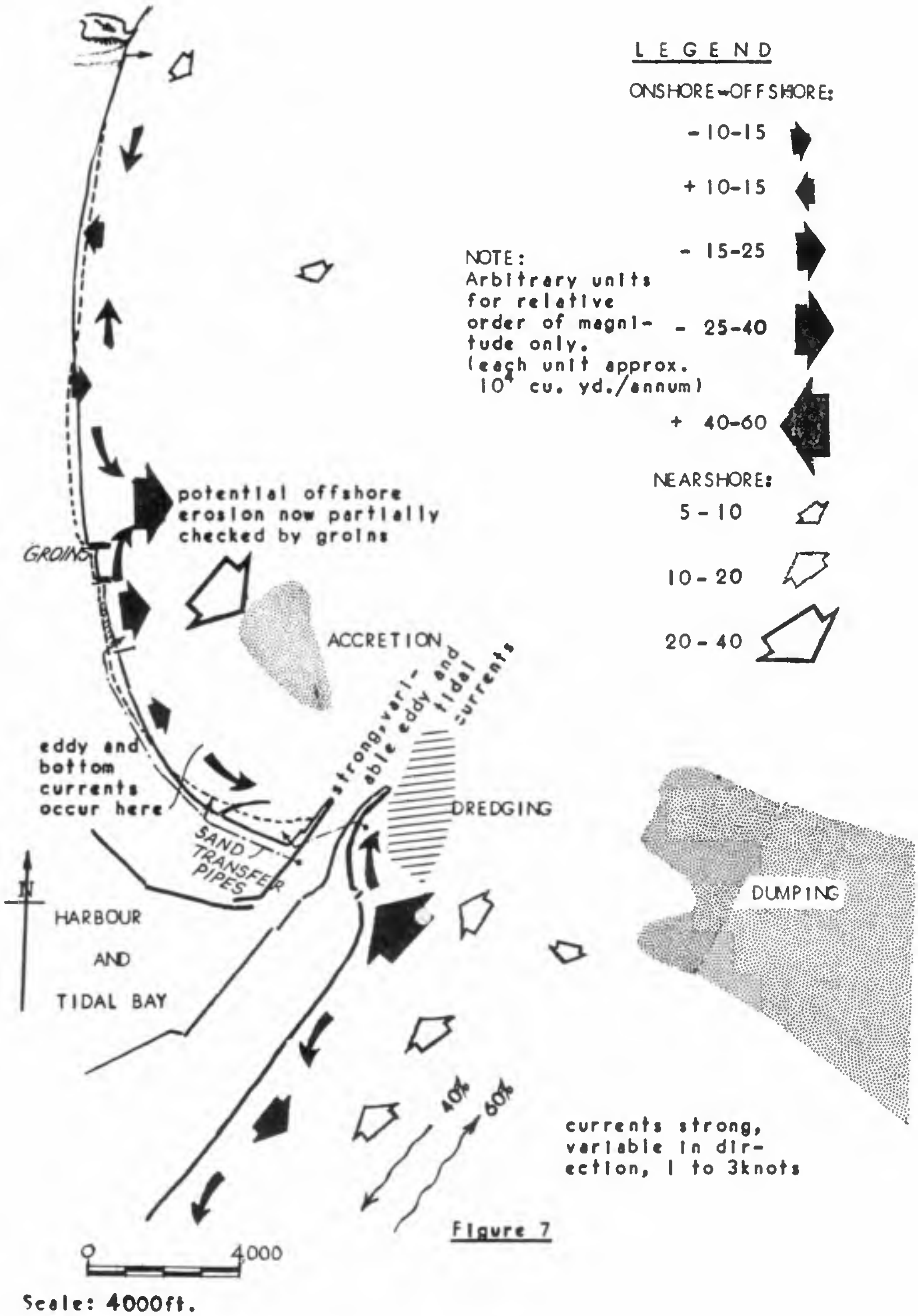
LEGEND
ONSHORE-OFFSHORE:
- 10-15
+ 10-15
- 15-25
- 25-40
+ 40-60
NEARSHORE:
5 - 10
10 - 20
20 - 40
NOTE:
Arbitrary units for relative order of magnitude only.
(each unit approx. 10^4 cu. yd./annum)
potential offshore erosion now partially checked by groins
GROINS
ACCRETION
strong, variable eddy and tidal currents
eddy and bottom currents occur here
DREDGING
SAND TRANSFER PIPES
N
HARBOUR AND TIDAL BAY
DUMPING
40%
60%
currents strong, variable in direction, 1 to 3knots
0
4000
Scale: 4000ft.

Figure 7

of their large size, of the order of several thousand feet long, would be very expensive to carry out in practice. Floating wave absorbers could not be guaranteed to outlast some of the storms witnessed while the study was conducted. Schemes to reduce the wave energy over the localized affected areas or alternatively, stabilize the beach with shore works and continued sand-bypassing and beach renourishment have been investigated.

ACKNOWLEDGEMENT

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List of Figure Captions