CHAPTER 2

OCEAN WAVE RESEARCH IN SOUTHERN AFRICA

by

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ABSTRACT

Wave recording on a national basis in South Africa commenced in 1967, when an "Ocean Wave Research" project was initiated, aimed at obtaining reliable data on sea conditions around the shorelines of the Republic and South West Africa and to improve on wave prediction techniques

Various instruments are being used in this programme Some of the problems encountered in practice with these instruments and the agreement between the results obtained using various wave recorders simultaneously at the same station are discussed An indication of the volume of wave data so far obtained and the methods of analysing them are included

INTRODUCTION

The realisation that accurate data on the wave conditions along the country's entire coastline and also over the continental shelf were indispensable for further coastal development and nearshore operations, has become evident in South Africa several years ago Although wave records had been collected on an ad hoc basis in certain localities for many years, it was not until February, 1967 that the "Ocean Wave Research" project was initiated This project was instigated by the South African National Committee for Oceanographic Research and is supported by various authorities and private bodies and aims at collecting wave data on a national and systematic basis The work is being carried out by a research team from the Hydraulics Research Unit of the CSIR's National Mechanical Engineering Research Institute

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OBJECTIVES AND PROGRAMME OF THE OCEAN WAVE RESEARCH PROJECT

The main objectives of the Ocean Wave Research project are to record and analyse wave conditions along the 4 000 km of coastline of South Africa and South West Africa, to correlate wave and wind data and to assist the South African Weather Bureau with wave forecasting

Wave recording stations are being operated or are being installed about 300 km apart, along the entire coastline Moreover, records are supplemented by deep sea data obtained from five research vessels operating in the country's coastal waters (see Figure 1)

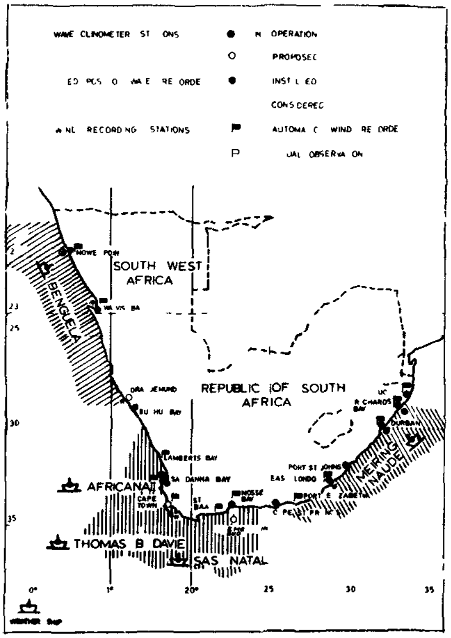

FIGURE 1 LOCATION OF WAVE RECORDING STATIONS

Most of the nearshore recording stations are in relatively shallow water of 10 to 30 m depth and the records obtained are only of local application Using well-known refraction techniques, however, all the individual records are converted into deep sea values which not only apply to the recording area itself but they apply to much longer stretches of coastlines initially estimated to be as long as 300 km Available data have confirmed the reliability of this estimate but extensive correlation studies between the data from adjoining stations are being continued to establish the optimum spacing of recording stations

The full programme will run until 1975 at the earliest It is possible that recordings at only a few key stations will continue on a permanent basis after this data

MEASURING INSTRUMENTS

When data from instruments are not available, visual wave records collected either from merchant ships or from lighthouses have to be used The Ocean Wave Research project, however, aims at using only data obtained from wave recording instruments and relying as little as possible on visual observations Instruments using optical, accelerometer, acoustic and pressure measuring systems are being used to obtain the wave recordings

Wave clinometer

The *wave clinometer* is an optical instrument developed in South Africa by the CSIR primarily for measuring wave direction As can be seen in the photograph in Figure 2, it consists of a specially adapted telescope which is mounted on a stand and in such a way that its axis can be inclined at one of three fixed angles, namely 3°, 5° or $7\frac{1}{2}^{\circ}$ to the horizontal The instrument is installed on shore at a fixed compass direction and the angle of inclination of the telescope fixed at one of these angles so that it can be focussed on the observation point at sea To measure wave direction, a horizontal cross hair in the telescope is aligned with the wave crests by turning the telescope about its axis and the angle is recorded on a graduated disc mounted on the telescope

Wave heights and wave periods are measured by observing the movements of an anchored floating buoy using the graduations provided in the telescope between which the image of the buoy moves The wave heights obtained agree closely with the so-called significant wave height, Hs By measuring the time for 20 waves to pass the buoy, the average wave period can be determined This is found to represent both the significant wave period T_s and the zero crossing wave period

T_z closely. The buoys used are usually inflatable polyform spheres 0.5 m in diameter. Unfortunately, they are easily lost, due to such reasons as theft, running over by ships and interference by fish. Moreover, they do not usually last longer than about six months due to wear and tear. Since they are not costly, they are normally replaced at four monthly intervals.

FIGURE 2: WAVE OBSERVATION WITH WAVE CLINOMETER

Greater accuracy is achieved when the telescope is inclined in the 5° or $7\frac{1}{2}^{\circ}$ positions, thus the instrument should preferably be sited on a high vantage point. The water depth at the observation point should not be less than about 12 m, which means that the slope of the sea bottom should preferably be steep.

At present a total of eleven clinometers are installed around the coast, most of them in lighthouses (see Figure 1). The recordings are hand-punched on computer cards to facilitate subsequent analyses. Recordings can only be made during the hours of daylight and are normally made at 5.00, 10.00 and 15.00 hours G.M.T.

Shipborne recorder

The well-known *NIO shipborne wave recorder* is an accelerometer type instrument and consists of two identical units fitted under the waterline on each side of the ship's hull. Each unit contains an accelerometer and a static water pressure transducer, connected to a recorder unit normally installed in the ship's wheelhouse[1]. The total vertical displacements of the ship are obtained by a double integration (electronically) of the output of the accelerometers and averaging the two results True wave height record is obtained after a correction is made for the ship's movements relative to the water surface by using the outputs of the pressure transducers Wave directions are estimated by the crew using the ship's compass

NIO recorders are installed on all five research vessels which operate in the areas shown hatched in Figure 1 Records of 15 min duration are made every six hours at 6 00, 12 00, 18 00 and 24 00 hours G M T daily The records are in graphical form and adjustments have to be made to the wave periods to eliminate the influence of the ship's speed In the past the graphic records were converted into digital form and punched on tape with a D-Mac pencil follower but arrangements have been made to install paper tape punch units in line with the graphical recorders to facilitate computer analyses of the data

The NIO recorders give reliable results but should be calibrated at regular intervals and should be operated preferably by the ship's officers, or the scientist on board the research vessels

<u>Boersma recorder</u>

The *Boersma wave height meter* is also an accelerometer type instrument It is normally installed on a float and connected to an integrating and recording unit on board ship In the early stages of the project the float, which is 1 m square, was launched from the weather ship (see Figure 1) but due to frequent cable breakage and instability of the float in heavy seas, it was later decided to install the accelerometer in the cabin of the 51 m long weather ship Records are obtained daily for 15 min durations at 6 00, 12 00, 18 00 and 24 00 hours G M T The records are in graphical form but a paper tape punch unit will be installed shortly

<u>Wave rider system</u>

The *Datawell wave rider system* is an accelerometer type instrument and consists of a telemetering buoy of spherical shape, anchored at sea and connected to a shore based receiving and punching unit The buoy contains an accelerometer and transmitting unit, whereas the shore units contain the receiver, programmer, pen-recorder and punch-unit Three buoys can be used with one receiver unit and they can be anchored up to 50 km from the shore station

A Datawell wave rider system is installed at Mossel Bay (see Figure 1) where wave height records of 30 min duration are obtained automatically at 6 00, 12 00, 18 00 and 24 00 hours G M T daily The records can be obtained either in graphical and/or punched form

The shore unit of the wave rider system must be installed at a "civilised" place, since regular attendance is required for proper functioning The Mossel Bay unit is installed at the radio station and has generally worked satisfactorily The buoy is anchored some 35 km from the shore in 100 m deep water, which is close to the shipping lanes The buoys have proved to be the weakest link in the system, since over a period of nine months, one buoy was lost and a second buoy was salvaged twice after it was presumed to have gone adrift It is difficult to decide whether a reward should be offered for the retrieval of a lost buoy, since this may encourage the removal of the buoy on purpose'

Normal echo sounder

Normal echo sounders, which are acoustic type instruments installed on small boats, e g skiboats, are often used to obtain synoptic wave records to measure the effects of wave refraction and diffraction Provided the boat is small and wave periods are relatively long, e g as in the case with swell, accurate wave records can be obtained with these instruments

INES wave recorder

The *INverted Echo Sounder* or *INES wave recorder* is an acoustic type instrument developed by the Hydraulics Research Unit of the CSIR It is a self-contained wave recorder which consists of a normal echo sounder housed in a waterproof canister placed in a supporting frame on the sea bottom The transducer is fitted in the lid of the canister and the acoustic waves are reflected from the water surface, thus giving a continuous wave record (see Figure 3)

INES recorders are operating at three stations at present and another four stations will be operative shortly (see Figure 1) The instrument is left unattended on the sea bottom for up to five weeks, giving 15 min duration records at 6 00, 12 00, 18 00 and 24 00 hours

G.M.T. daily. These records are in graphical form and are converted into digital form by a D-Mac pencil follower.

FIGURE 3: INES WAVE RECORDER

The INES recorders can be placed in any depth of water up to 36 m deep. Marker buoys indicate the position of the instrument, which are normally placed by divers to ensure that the tripod stand, which support the instrument, is in an upright position. They are serviced at monthly intervals normally by divers (see Figure 4) when the canister containing the instrument is released from the stand and brought to the surface. After servicing, it is taken down again. When operating in deep water, a spare serviced instrument is usually taken down by the diver on his first dive to replace the instrument which requires servicing. With this procedure, only one dive per instrument is required.

Good results have been obtained with these recorders but many problems have had to be overcome, e.g. leakage of the canister, breaking of the stylus and failure of the marker buoy mooring system.

FIGURE 4: PLACING OF INES WAVE RECORDER BY DIVERS

Ospos recorder

Ospos recorders are also being used. They are of the pressure type and are self-contained and can be left unattended for about four weeks. They are placed either on the sea bottom or suspended from an anchor on the sea bottom to "float" at a known distance, preferably 1 m below the lowest expected wave trough below the water surface. In deep water, therefore, there is considerable movement of the suspended instrument with wave action and this affects the results adversely. Moreover, since the depth of the transducer must be accurately known, the conversion from pressure changes to wave heights is dependent on the depth of submergence.

The instrument records pressure variations for durations of 15 min four times per day, usually at 6.00, 12.00, 18.00 and 24.00 hours G.M.T. The conversion from pressures to wave heights is very laborious and inaccurate and this recorder is used only if no other instruments are available.

CORRELATIONS BETWEEN VARIOUS INSTRUMENTS

Since the statistical analyses are based upon records obtained from different instruments, it is essential to check that their outputs are in good agreement[2].

Comparison of the wave directions read from a wave clinometer (inclined at 5°) with those obtained from aerial photographs specially made for this purpose showed a maximum deviation of 10° and an average deviation of 5°

A special correlation test was arranged at a point due west of Robben Island (Cape Town) in a water depth of 27 4 m on 2nd October, 1969 from 15 00 to 16 00 hours S A S T Simultaneous recordings were made using the following instruments

(a) Boersma wave height meter (using the float)

(b) INES wave recorder

(c) Ospos wave recorder

(d) NIO wave recorder on research vessel Africana II (NIO A)

(e) NIO wave recorder on research vessel Benguela (NIO B)

A comparison of wave height and wave period distributions using a 30 min period of the records, are given in Figures 5 and 6

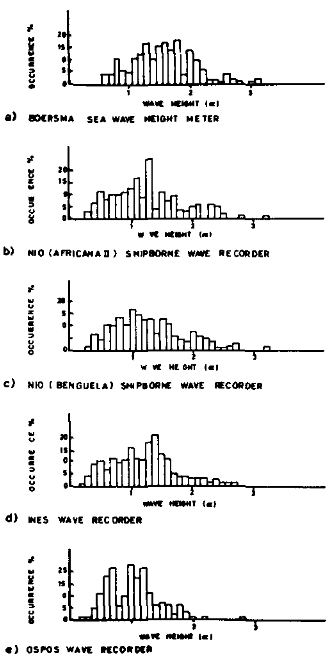

FIGURE 5 WAVE HEIGHT DISTRIBUTIONS

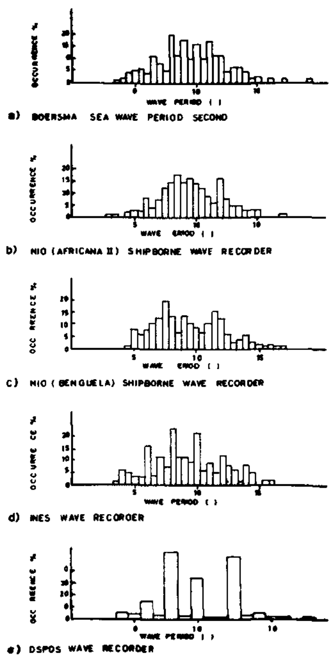

FIGURE 6 WAVE PERIOD DISTRIBUTIONS

The results show that the records of NIO recorders, installed on two different ships, are almost identical The Boersma wave buoy seems to over-estimate the wave heights, especially for the lower wave group, whereas the Ospos generally gives wave heights which are too low The INES records generally agree well with the NIO records, except for the maximum wave height Wave periods agree well with each other except for the Ospos records

In Figure 7 the smoothed energy density for a constant time interval of 1 8 seconds is plotted versus the frequency as obtained from the results of recordings with the INES wave recorder and NIO wave recorders on two different ships It will be noted from this plot that the frequencies for maximum spectral density lie close to each other, although there are noticeable differences in the values for maximum spectral density, with the INES wave recorder giving the lowest values

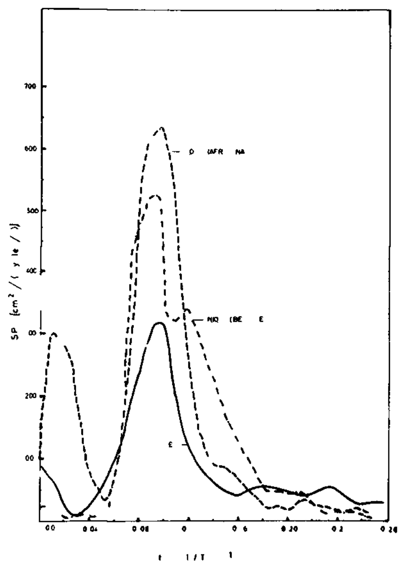

FIGURE 7 WAVE ENERGY SPECTRUM

AVAILABLE DATA

Data on ocean wave characteristics for the Ocean Wave Research project have been collected using the above-mentioned wave recording instruments since February, 1967 although wave data for certain areas have been collected since 1961 The number of recording stations has increased with the passage of time and the present situation is as shown in Figure 1 The following instruments are in use

11 Wave clinometers
5 NIO shipborne wave recorders
2 INES wave recorders
1 Wave rider system
1 Boersma wave height meter
1 Ospos wave recorder

The amount of data available from each instrument in its particular area or position is shown in Table 1 and Figure 8[4,5,6,7]

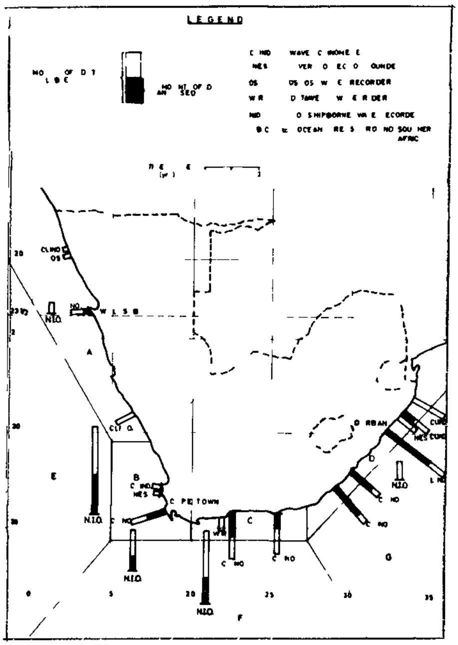

FIGURE 8 AVAILABLE WAVE DATA, MAY, 1970

WAVE ANALYSIS

The distance of approximately 300 km between wave recording stations, was assumed to be adequate to give a good overall coverage of the actual sea conditions along the coast of Southern Africa Since, however, wave data are obtained from both shallow and deep water, they have to be converted to deep sea values to obtain a basis for comparison This conversion is made using conventional refraction theories The method used for the construction of the wave refraction diagrams by computer, is that described by Wilson of the U S Army Coastal Engineering Research Center[8,9] The correction of all wave directions to deep sea values is made by use of graphs on which deep sea wave direction versus nearshore direction at the recording point (found from the above refraction diagrams) are plotted

The method used for the conversion of nearshore wave heights to deep sea values, is that developed by Dorrestein[10] whereby the wave direction graphs referred to above are used to obtain the height correction factors This method was found to be reliable and much quicker than the conventional method using pairs of orthogonals In certain cases a correction for shoaling water also has to be made[11]

Wave clinometer records

Wave parameters obtained from the clinometer records are as follows

(a) significant wave height (H_s)
(b) significant wave period (T_s) or
zero crossing wave period (T_z)
(c) wave direction

The clinometer records are converted to data applicable to deep sea by using the above-mentioned methods for the correction of the wave heights and directions This entails the production by computer of refraction diagrams for each recording station using the most recent bathymetric chart The wave clinometer records are obtained directly on hand-punched computer cards to facilitate the analysis procedure The actual deep sea corrections, statistical analyses and tabulation of the data are now all done by computer

Continuous wave records

The wave records obtained from the INES, wave rider, NIO and Ospos instruments all lend themselves to the same type of analysis, although the records of the Ospos, which gives pressure fluctuations, first have to be converted to water level fluctuations A computer programme is available to obtain the following wave characteristics from these records

(a) cumulative wave height (H)* distribution
(b) cumulative zero crossing wave period (T_z)* distribution
(c) cumulative crest period (T_c) distribution
(d) characteristic wave heights H_{50}, $H_{13\ 5}$, or H_s, H_1 and H_{max}
(e) characteristic zero crossing wave periods $(T_z)_{50}$, $(T_z)_{13\ 5}$ or T_s and $(T_z)_1$
(f) characteristic crest period $(T_c)_{50}$
(g) the period of the maximum wave in the sample (T_{Hmax})

To reduce the cost of analysis by computer a simplified programme will be prepared to give the following information

(a) wave heights H_{90}, H_{50}, $H_{13\ 5}$, H_{10}, H_1 and H_{max}
(b) zero crossing wave periods $(T_z)_{50}$, $(T_z)_{13\ 5}$, $(T_z)_{10}$ and $(T_z)_1$
(c) wave period of the maximum wave height viz T_{Hmax}
(d) wave crest period $(T_c)_{50}$

The wave rider system already produces a punch tape output, but the records from the other instruments are in graphical form and must be converted to punch tape on the D-Mac pencil follower before computer analysis is possible

Statistical analysis and presentation of data

The deep sea wave characteristics are analysed to yield seasonal and yearly directional distributions An example of the distribution of significant wave heights is shown in Figure 9 Standard forms of presentation are also used for cumulative distributions and exceedance curves The standards used and methods of presentation are shown in Figure 10

COMPARISON OF WAVE DATA

Cumulative distributions of wave direction, height and period for the various recording stations are plotted in Figures 11, 12 and 13

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* For definition of terms, see Appendix

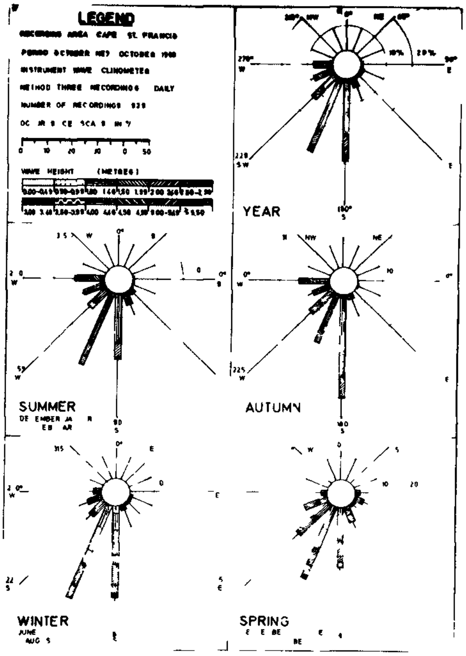

FIGURE 9 DEEP SEA WAVE HEIGHT ROSES FOR CAPE ST FRANCIS

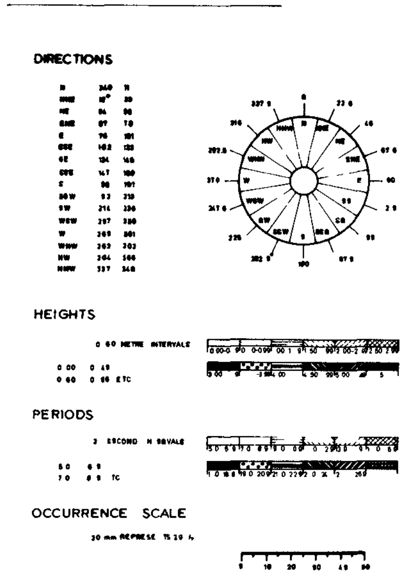

FIGURE 10 STANDARDS TO WHICH WAVE RECORDS ARE ANALYSED

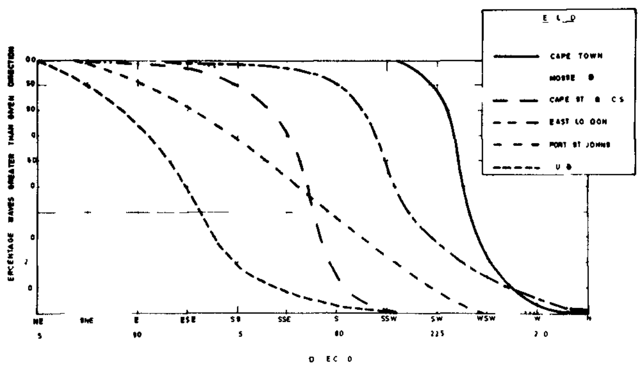

FIGURE 11 COMPARISONS OF WAVE DIRECTIONS CAPE TOWN TO DURBAN

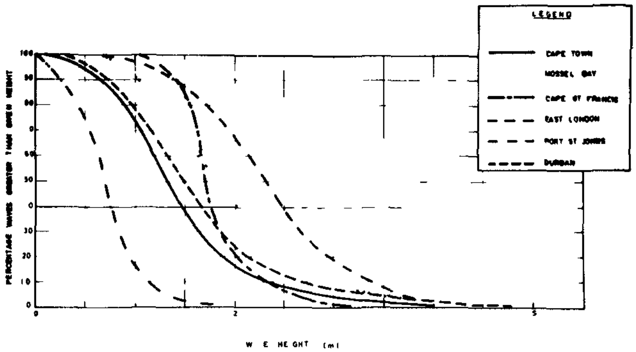

FIGURE 12 COMPARISONS OF WAVE HEIGHTS CAPE TOWN TO DURBAN

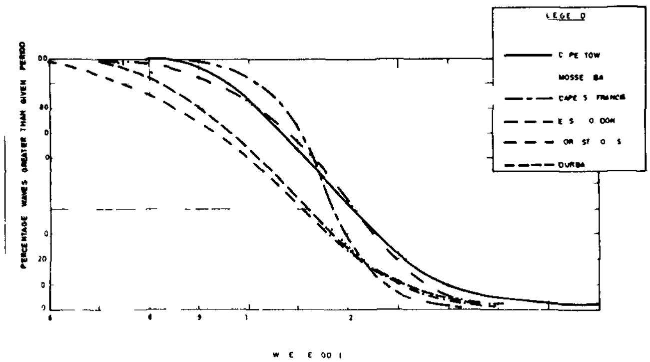

FIGURE 13 COMPARISONS OF WAVE PERIODS CAPE TOWN TO DURBAN

These figures show that there is an overall swing in the directions of wave approach from SW towards SE around the coast from Cape Town to Durban There is no obvious trend in the variation of wave height along the coast, except that at East London and Port St Johns the waves are significantly higher and lower respectively than at the other stations The wave period distributions indicate that there are two distinct areas, namely East London, Mossel Bay and Durban with an average median wave period of 10 7 s and Port St Johns, Cape St Francis and Cape Town with an average median wave period of 11 6 s

From these data the distance between stations of 300 km so far appears to be satisfactory More data will have to be obtained from some of the stations, however, before final conclusions on the suitability of this distance can be drawn

CONCLUSIONS

Since the commencement of the Ocean Wave Research project in 1967, data on wave conditions along the east and south coasts of Southern Africa have been systematically compiled The first data on wave conditions along the west coast will become available early in 1971 Already the project has provided the basic design data for various harbour and other coastal works, as well as for the present oil prospecting operations on the continental shelf

ACKNOWLEDGEMENTS

The energy spectra included in this paper were determined by J Forrer and L Langenegger Their assistance is acknowledged with thanks

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APPENDIX

GLOSSARY OF TERMS

H - wave height the vertical distance between a wave crest and the preceding wave trough

T_z - the average wave period obtained by dividing the duration of the entire wave record (in secs) by half the number of times the actual water profile crosses the mean water level

T_c - the mean crest period obtained by dividing the duration of the entire record (in secs) by the number of crests in the record

H_s - the average height of the highest one third of the waves occurring in a specified recording period

T_s - the average period of the highest one third of the waves occurring in a specified recording period

H_{max} - the greatest vertical height from crest to preceding trough in the record

T_{Hmax} - the period of H_{max}

H_{50} - 50 per cent of the waves occurring in a specific recording period are higher than H_{50}

$H_{13\ 5}$ - 13 5 per cent of the waves are higher than $H_{13\ 5}$ ($H_{13\ 5}$ = H_s when distribution is Raleigh)

H_1 - 1 per cent of the waves are higher than H_1

T_{c50} - 50 per cent of the waves occurring in a specific recording period are longer than T_{c50}

T_{z50} - 50 per cent of the waves occurring in a specific recording period are long than T_{z50}

$T_{z13\ 5}$ - 13 5 per cent of the waves occurring in a specific recording period are longer than $T_{z13\ 5}$

T_{z1} - 1 per cent of the waves occurring in a specific recording period are longer than T_{z1}

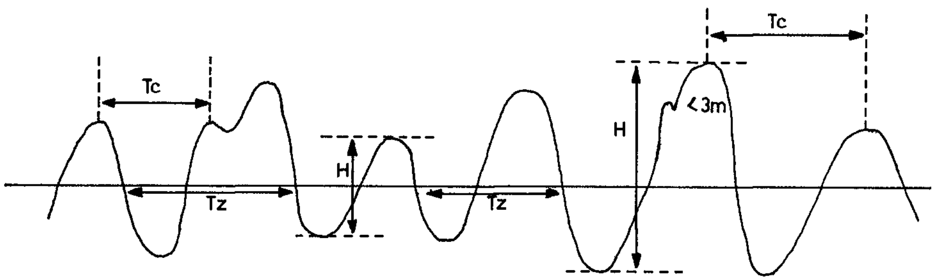

TABLE I AVAILABLE WAVE RECORDS MAY, 1970

PLACE/SHIP	POSITION	METHOD OF RECORDING	PERIOD	DEPRESSION OR DEPTH
St Lucia	Lighthouse	Visual	Apr '61–Mar '62	
		Wave clinometer	Feb '68 –	5^{o}
Richards Bay	North of bay mouth	Wave clinometer	May '68 –	3^{o}
	Opposite bay mouth	INES	Jan '69 –	18 m
Durban	West Street Jetty	Visual	Mar '61–Dec '61	
	Pilot boats	Visual	Jan '68 –	
	S A S Bluff	Wave clinometer	Apr '61–Nov '62	
	Radar station, Bluff	Wave clinometer	July '65–Sept '69	7.5^{o}
	500 yds SW of Cooper Lighthouse	Wave clinometer	Jan '70 –	5^{o}
Port St Johns	Cape Hermes Lighthouse	Wave clinometer	Feb '68 –	7.5^{o}
East London	Hood Point Lighthouse	Wave clinometer	June '67 –	3^{o}
Cape St Francis	Lighthouse	Wave clinometer	Oct '67 –	3^{o}
Mossel Bay	Cape St Blaize Lighthouse	Wave clinometer	June '67 –	7.5^{o}
	Deep sea (Area "C")	Wave rider	July '69 –	100 m
Cape Town	Signal Hill	Wave clinometer	July '66–Dec '68	5^{o}
Saldanha Bay	South Head	Wave clinometer	Dec '69 –	7.5^{o}
	Off South Head	INES	Jan '70 –	30 m
Buchu Bay	Buchu Bay	Wave clinometer	Apr '69 –	5^{o}
Walvis Bay	Pelican Point	Wave clinometer	May '69 –	3^{o}
Mowe Point	Mowe Point	Wave clinometer	Apr '70 –	5^{o}
	Off Mowe Point	Ospos	Jan '70 –	16 m
Africana II	Area "B"	NIO recorder	June '64 –	
Thomas B Davie	Area "B"	NIO recorder	Aug '67 –	For areas
Meiring Naudé	Area "D"	NIO recorder	Apr '69 –	"A" to "D"
S A S Natal	Areas "B" and "C"	NIO recorder	June '65–May '70	refer to
Benguela	Area "A"	NIO recorder	Oct '69 –	Figure 8