CHAPTER NINETY FOUR

Sediment Dynamics Field Experiment: Sunday's River

D H Swart*

ABSTRACT

A field exercise was performed on a high-energy beach east of the Sunday's River in Algoa Bay on the east coast of the Republic of South Africa in the latter half of April 1983. Recorded data include nearly continuous wave data at 7 stations within the breaker zone with simultaneous waverider recordings in a water depth of 10 m, suspended sediment data gathered by means of 'bamboo' poles and instantaneous bottle samplers, daily topographical measurements of the beach and inshore area, data on rip current intensity and spacing for a 10 km coastal strip, more than 3 000 bottom sediment sample analyses and visual observations of wave height and longshore current velocity at hourly intervals through the recording period. Analysis of the data has been completed and interpretation and correlation of various measured phenomena are underway. A second exercise was performed in August 1984, when the emphasis was on nearshore circulation patterns.

1. INTRODUCTION

The Departments of Botany and Zoology of the University of Port Elizabeth (UPE), South Africa, are studying the surf zone energetics in the Sunday's River mouth area. Surf diatom blooms occur very frequently in this area. One of the aspects which specifically needs attention is the physical mechanism which maintains these surf diatom blooms. Clarification of this aspect will help in establishing an energy balance for this area. The Sediment Dynamics Division (SDD) of the National Research Institute for Oceanology (NRIO) was approached to co-operate in the study. As a result two intensive field experiments were undertaken, one in April 1983 and the other in August 1984.

The exercise described here were undertaken jointly by the NRIO and the UPE, with the NRIO concentrating on physical aspects and the UPE on biological aspects. McLachlan and Bate (1984) have reported on certain aspects of the UPE work. The co-operation and support of the UPE were essential for the success of these field exercises. Although only one author is mentioned for this paper, the whole Sediment Dynamics Division co-operated in all aspects of the study.

2. OBJECTIVES

The data gathered during these two field exercises serve a multiple purpose:

* Head, Sediment Dynamics Division, National Research Institute for Oceanology, CSIR, Republic of South Africa.

(1) It aids research on coastal sediment dynamics being undertaken by the SDD, in particular various aspects of breaking wave characteristics, nearshore wave dynamics and interaction between waves and currents on the one hand and nearshore suspended sediment motion on the other hand;

(2) it will provide a physical description of the area to serve as a basis for the biological research carried out by UPE; and

(3) it will allow the calibration of a 2D finite-element mathematical flow model for the nearshore region, which can then be used to generate a set of possible flow conditions for various wave conditions and nearshore topographies. These can then be used to compute energy budgets for the biota in the nearshore region.

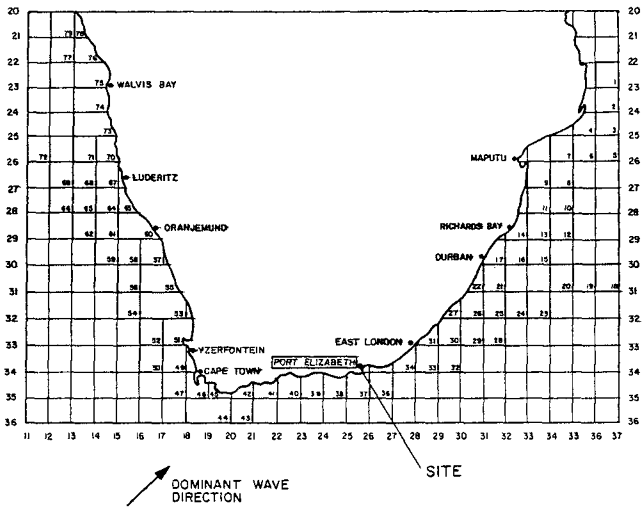
The collaboration with the UPE determined the site for the exercise, as the UPE has for the last ten years been studying various aspects of the biota at the Sunday's River site. Figure 1 shows the position of Port Elizabeth on the South African coastline, whereas Figure 2 shows that the site is situated in a south-facing crenulate-shaped bay with its control point at Cape Recife in the west. The surf zone is of an intermediate type between dissipative and reflective and is characterized by rapidly changing bars, channels and rip currents which are in sympathy with the incident wave climate. The breaker zone slope is relatively mild at 1 in 60 but the seaward face of the bars is frequently as steep as 1 in 10 (see, for example, Figure 3, which was measured by lead line from a helicopter in August 1984). The dominant wave direction according to VOS data is the sector 225° to 255°. The median incident deepsea wave height in the area is about 3 m.

The Sediment Dynamics Division of the NRIO intends to start instrumenting a measuring site closer to its base at Stellenbosch. It is intended to establish a permanent measuring site at Yzerfontein, 80 km north of Cape Town on the west coast of South Africa (see Figure 1). The field exercise performed at the Sunday's River therefore also have an important secondary aim, namely, to aid in the development of equipment which can withstand the hostile surf on a high-energy coastline. At all times the emphasis was on low-cost experiments.

3. EXPERIMENTAL DESIGN

A measuring grid with three onshore-offshore measuring lines 50 m apart was set out and measuring devices were attached to measuring stands.

Fig 1: LOCALITY MAP



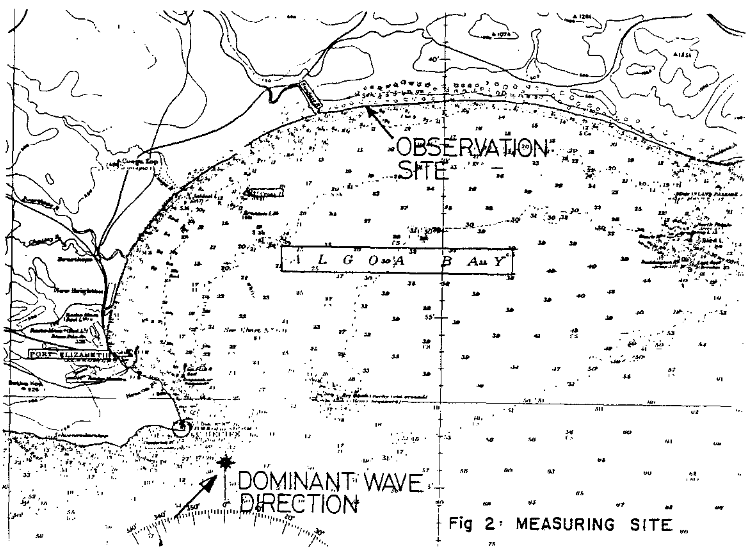
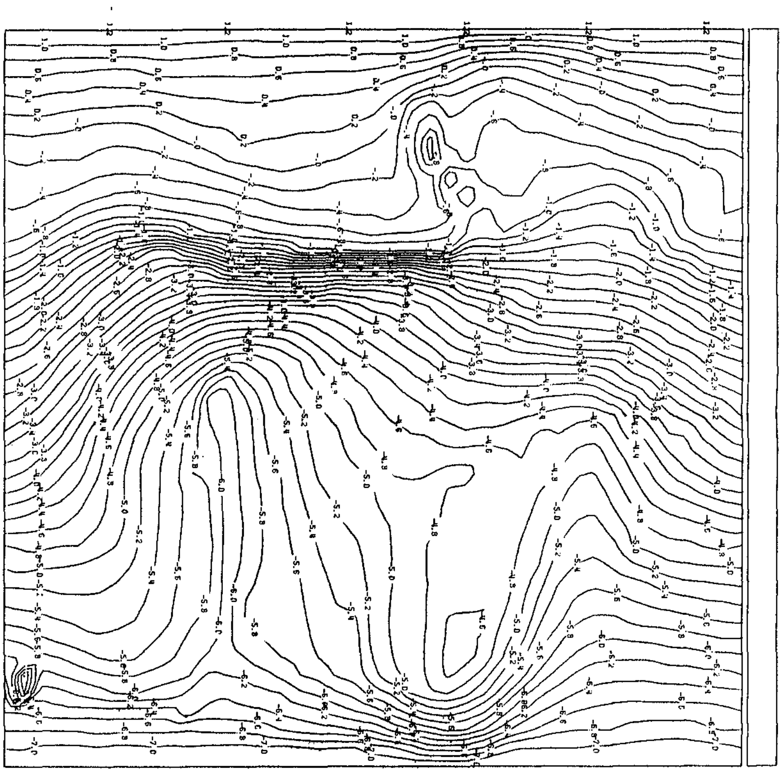
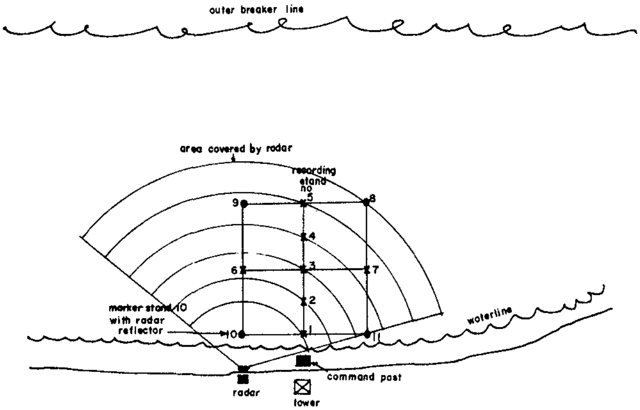


Fig 2: MEASURING SITE



SIZE OF GRID = 400m x 400m

Fig 3: SEA BED TOPOGRAPHY SUNDAY'S MEASURING SITE AUGUST 1984



The following aspects of the experimental set-up are particularly noteworthy:

- A measuring stand was designed after numerous trials. It has a base of 3 m x 3 m and a height of 4 m, and proved to be extremely stable in the surf zone (see Figures 4 and 5). It was placed loosely on the sandy bed and after settling some 5 to 10 cm did not move again, even though no formal anchoring was employed. It is thought that the open piped structure of the base was the reason for its stability. Various instruments were attached to the measuring stands.

- A 15 cm diameter segmented PVC "bamboo tube" with a length of 1,4 m (14 segments of 10 cm each) was designed as a sand trap in such a way that it could be easily attached to and removed from the measuring stand (Figure 6) and could be cleaned of its sand load as soon as possible (Figure 7). One half of the tube was continuous and the front half consisted of 10 cm wide semi-circular lids coinciding with the segments. The pairs of holes which allowed the sand to enter the segments were staggered by 90° at adjacent segments. Alternate pairs thus had the same orientation. Holes of 10 mm diameter were mostly used for 1 hour deployments. During longer deployments (up to 10 hours) holes of 5 mm diameter were used. To allow the transformation of the mass of sand caught in each segment to sediment concentrations, the bamboo tube was calibrated in the laboratory against known sediment concentrations.

Figure 4. Central line of measuring stand

Figure 5.
Measuring stand
in surf, note
wave staff

Figure 6. Replacing bamboo sampler at measuring stand

Figure 7. Cleaning of bamboo sampler

- A 3,5 m long resistance wave height probe was designed and built by the Electronics Systems Division of the NRIO for the determination of water level fluctuations. Results were relayed from each measuring stand to shore by cable where it was recorded at 0,5 s intervals on digital dataloggers. Synchronous data were obtained from 7 wave probes. Data capture was continuous but analysis of the data was performed in 1024s blocks.

4. PRELIMINARY RESULTS

The analysis of the raw data obtained in both experiments has just been completed and the interpretation of the analysed data has commenced. A brief summary of the methods employed and some preliminary results are given below.

During the 1983 Exercise (PE83) the following observations were made:

Incident waves: Waves were measured continuously for a week by waverider in 10 m water depth directly opposite the measuring site. The measuring interval was 0,5 s. The significant wave height varied between 0,7 m and 1,4 m during this period, while the peak wave period always exceeded 10 s. Observations were also made with a graded telescope mounted on a 15 m high tower which was placed on top of the 10 m high primary dune. In the past this instrument, the so-called clinometer, was used extensively in South African waters for the estimation of wave height, period and direction. It has practically fallen into disuse because the results are observer-dependent.

Surf zone waves: Continuous, synchronous wave recordings were made for 4 days at up to 7 locations. More than 700 usable records, each with a length of 1024s, were obtained at these surf zone stations in water depths between 0,7 m and 2 m. Visual estimates of wave height and period at each stand were also made hourly. Wave directions in the surf zone were determined hourly by radar. Extremely consistent results were obtained. The dominant wave direction during the exercise was consistently just west of the normal to the beach.

The surf zone water elevations were analysed in two ways: by normal Fourier techniques as well as by the higher-order Vocoidal Fourier analysis developed by Swart and Fleming (1980) and Swart (1982). In the higher-order analysis vocoidal component waves are extracted instead of sinusoidal waves as in a normal Founier analysis.

The results indicate that the representative height calculated from the higher-order analysis is always higher than for the customary first-order analysis (see Figure 8). This is in accordance with the earlier theoretical findings (Swart, 1982). Use of the first-order analysis leads to an underestimation of the representative wave height in shallow water. A similar conclusion is found to apply to the peak wave period, which again confirms an earlier theoretical conclusion (Swart, 1982). The wave records show the presence of energy of appreciably low frequency energy, with a peak period which is normally in the range 30 s to 100 s. The rms height in the low-frequency range ($f < 0{,}038\ s^{-1}$) is typically about 0,1 to 0,2 m, which can be as high as 25 per cent of the rms height in the gravity wave range ($f < 0{,}038\ s^{-1}$).

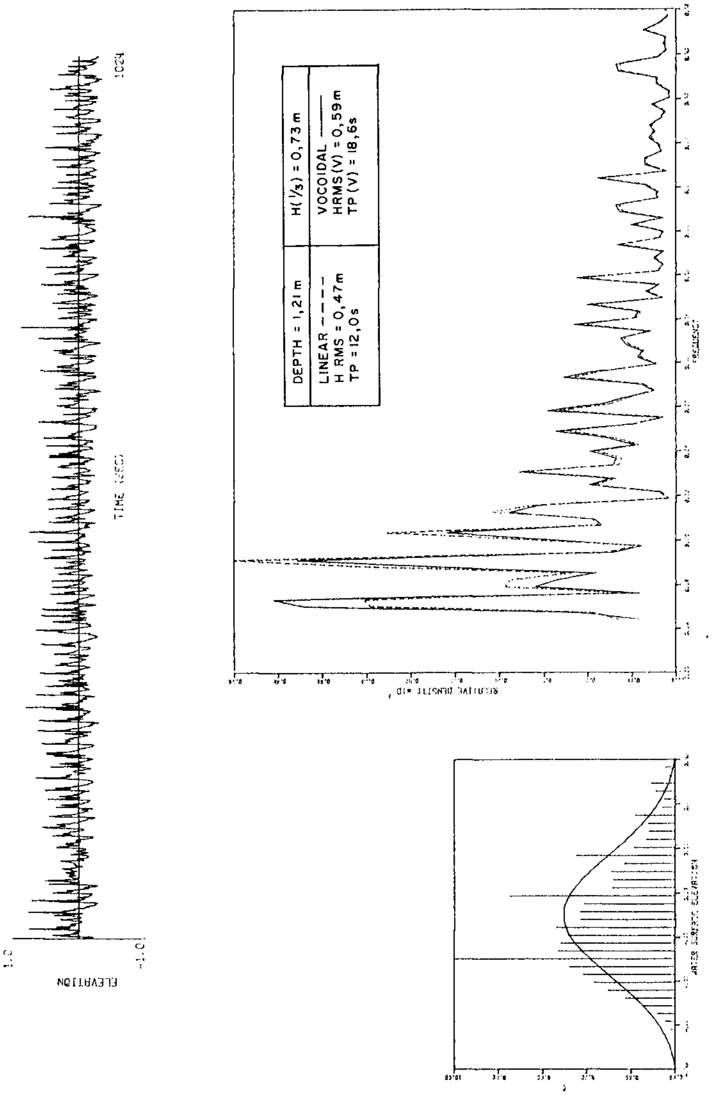


Fig. 8: TYPICAL LINEAR AND VOCOIDAL FOURIER ANALYSIS FOR SURF ZONE WAVES: 28 APRIL 1983; STAFF 4

Cross-sectional analyses are being done to differentiate between edge waves which essentially propogate alongshore and bound waves which essentially travel on-offshore. Figure 9 shows the coherency squared obtained by comparing the surface elevations at the outer (5) and central (3) wave staff in the central measuring line (staff 5 and 3 were 40 m apart) during both high and low tide. The coherency is more significant during high tide when the wave propagation is less affected by the irregularities in the topography. Figure 10 shows the accompanying phase diagram. The results indicate that bound waves in the low frequency band are more prevalent at high tide whereas edge waves are most prevalent at low tide. Analysis is still underway but this conclusion seems to be substantiated by the other analyses.

Topography: The nearshore topography from the upper beach to about 1 m below low tide level was determined daily over a distance of 500 m to each side of the central measuring line.

Current patterns: Longshore current velocities at the various measuring stands and nearshore current patterns were determined regularly by means of drogues and Rhodamine B dye. During the whole exercise an oblique rip current was situated across the central measuring line in a south-easterly direction. Mean current velocities of up to 5 m/s were measured in this reasonably confined (~ 20 m wide) rip current which pulsated with a period of 1 to 2 minutes and which was always stronger during low-tide.

In future exercises currents will be measured with ducted propellers and overall current patterns will again be determined by using dye.

Aerial photographs: A 10 km coastal strip to the east of the Sunday's River, with the measuring site situated about 2 km from the western end of the strip, was flown regularly during the week. Two overpasses were made each day during low tide and another two during high tide. On Friday, 29 April 1983 a total of 20 overpasses were made at roughly 15 minute intervals. The aerial photographs were combined into a mosaic for each overpass, which was then used to study the occurrence of rip currents. These currents were clearly visible on the photographs, while the extent of the surf circulation patterns could also be clearly discerned. The results show that the median surf cell width during the exercise varied between 250 m and 350 m, depending on the state of the tide and the incident wave conditions. The maximum width of the surf circulation cells, measured relative to the mean water line, was about 650 m.

Sediment in suspension: More than 100 sets of suspended sediment data were gathered during the week with the aid of bamboo poles and a further 20 sets of instantaneous suspended sediment data by means of sampling bottles. Figure 11 shows a typical correlation between the bottle sampler results and the bamboo sampler results. The 'bamboo' poles were usually removed after a deployment of one hour. Analysis of the sand weight caught in each 10 cm segment above the bed indicates that a sediment concentration based on any one of the following three assumptions would yield a goodness of fit to the data of nearly equal quality, namely a vertical diffusion coefficient which varies linearly or quadratically with distance above the bed or which is constant over the

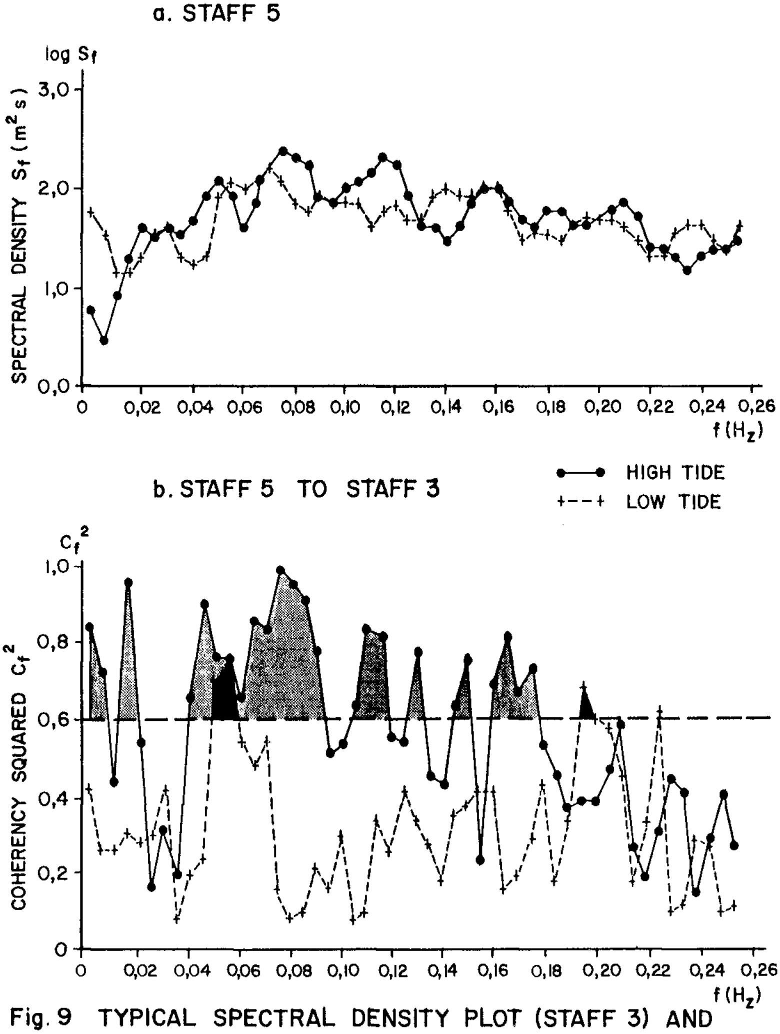


Fig. 9 TYPICAL SPECTRAL DENSITY PLOT (STAFF 3) AND COHERENCY (STAFF 5 TO STAFF 3)

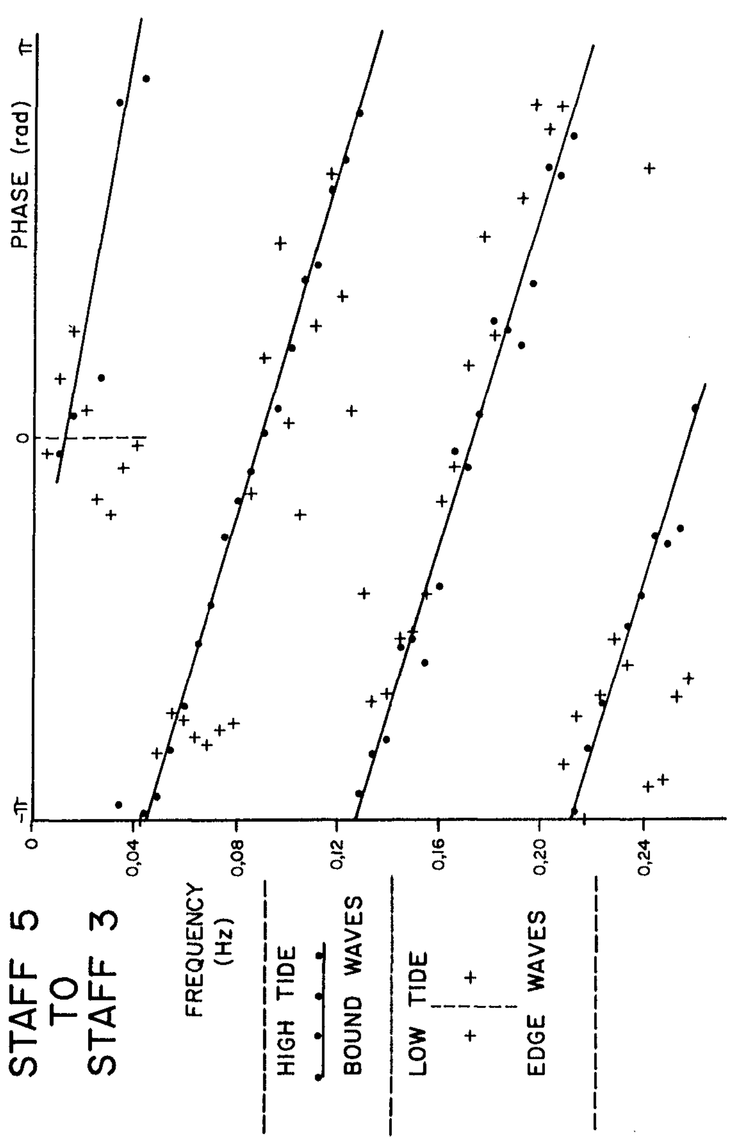


Fig. 10: RELATIONSHIP BETWEEN PHASE AND FREQUENCY: STAFF 5 TO STAFF 3

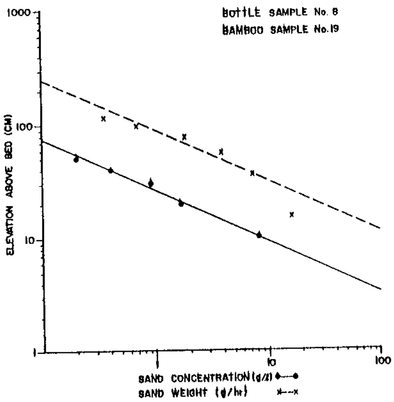


Fig. 11 TYPICAL CORRELATION BOTTLE SAMPLER / BAMBOO SAMPLER

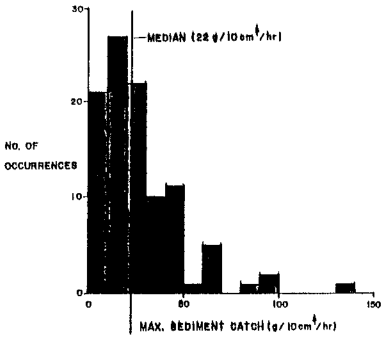


Fig. 12 VARIATION IN MAX. SEDIMENT CATCH

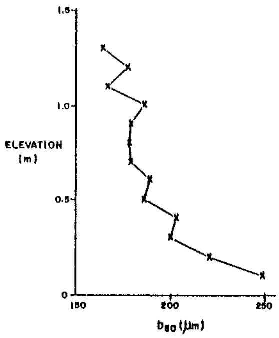


Fig. 13 TYPICAL VARIATION OF GRAIN SIZE WITH DISTANCE ABOVE BED

water column This is in accordance with earlier findings by Swart (1976) and others, for example, Das (1972). The highest average concentration measured over a one-hour period in the first 10 cm above the bed was 27,1 g/ℓ.

The variation in the maximum sediment load trapped in any segment (in all but a few cases this occurred in the bottom segment) is shown in Figure 12, which shows that the maximum load was 140 g/10 cm segment/hr, whereas the median load was 22 g/10 cm segment/hr. The data were also analysed for grain size variation with distance above the bed. Exponential decay of grain size was found (see Figure 13).

The magnitude of the total suspended load was found to be related strongly and uniquely to the relative position within the surf zone. A peak exists about halfway through the surf zone. It is intended to measure sediment concentration by optical or acoustical backscatter methods in future exercises, in parallel with the samplers employed to date.

Bottom samples: More than 3 000 bottom sediment samples were gathered on a regular grid in the measuring area as part of an investigation into the statistical distribution of bed material. The results indicate that longshore variations in grain size over a distance of 100 m are insignificant when compared to the onshore-offshore variations, which indicate a peak at the significant breaker line in both median grain size and the standard deviation of all measurements at a certain distance offshore. The standard deviation peaks at 10 per cent of the median grain size. The results give a preliminary indication about a representative sampling strategy to determine bed material characteristics.

In total 18 NRIO staff members and between 10 and 20 casual helpers participated in this exercise. The total running and capital expenditure was about US$30 000.

The 1984 Exercise (PE84) was geared to the simultaneous recording of nearshore topography and current patterns.

The following techniques were used:

Topography: Conventional survey techniques were employed for daily surveys of 1 km coastal strip in the same manner as discussed for PE83. In addition, two surveys were made by lead line from a helicopter in a 0,4 km x 0,4 km area (see Figure 3). The lead line had a marker attached to it which was triangulated in from shore stations. Survey accuracies are estimated at about 10 cm. The technique supplied topographical information in the central surf zone under relatively high wave conditions (incident significant wave height between 1,5 m and 3 m) when other techniques currently employed in South Africa such as echo-sounding from a skiboat could not be used.

Currents: Current patterns were determined on three occasions from the observation of dye distribution after surf zone releases. Extremely complex current patterns were observed, with strong rip currents being concentrated in the channels shown in Figure 3.

Aerial photographs: Aerial strips were again done four times daily as in PE83. Data analysis is still underway.

During this 1984 exercise, the staff involvement on the NRIO side was 5, with support from 1 to 2 casual helpers at times. The emphasis in this exercise was more on biological responses than was the case during PE83. The total running and capital expenditure for NRIO was about US$7 000.

5. SUMMARY

The following is a summary of the main conclusions from the two exercises and the results obtained to date.

(1) Extremely useful simultaneous, synchronous recordings at up to 7 wave staffs in the breaker zone and at a waverider in 10 m water depth were obtained. Interpretation of the data is shedding new light on the relative importance of edge waves and bound waves on high-energy intermediate beaches. In the barred beaches observed during the exercises edge waves predominated at low tide and bound waves at high tide.

(2) "Calibrated" data on sediment in suspension in the surf zone and good quantitative data on sediment sorting in the vertical under surf zone conditions were obtained.

(3) The bottom topography and flow patterns in a rough, wide surf zone were determined from a helicopter and by aerial photographs.

It is concluded that it is possible to run a prototype field exercise relatively inexpensively and still obtain very useful simultaneous wind, wave, current and sediment data.

The programme will be extended in the near future to include measured onshore-offshore and longshore current velocity components. A second site for future field exercises is being considered. It is situated in the centre of a 30 km long, flat crenulate bay about 80 km north of Cape Town.

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