EVALUATION OF ESTUARINE ENVIRONMENT OF MANDOVI RIVER MOUTH WITH REFERENCE TO BEACH EROSION

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A B S T R A C T

The hydrographic characteristics of the Mandovi estuary with particular reference to the formation of the so-called "Aguada sand bar" and their influence on the beach erosion have been discussed. The effects of tides, waves, currents, river runoff as well as meandering of the river on the littoral transport with particular reference to the stability of the adjoining shoreline have been evaluated. The result of the numerical wave refraction study carried out for this coastal region has also been presented. The problem associated with the protection of the shoreline at the Youth Hostel and the possible remedial measure have also been discussed in the paper.

INTRODUCTION

The beaches along the Goa coast have immense recreational value to both the local residents and the tourists. The Goan coastline is characterised by high degree of indentation with rocky cliffs and promontories alternating with rivers or estuaries. Engineering interest in the sand bar arises due to its importance in regard to safe navigation of vessels between various upstream locations along Mandovi river including Port of Panjim and the large commercial Port of Mormugao in the Zuari river. The coastal processes in the Mandovi estuary forms a complex pattern due to the formation of Aguada and Reis Magos bars at the river mouth, the meandering of the Mandovi river flow, tidal currents and fresh water discharge as well as the effect of varying waves attacking the shoreline. The various stretches of the shoreline extending from Campal to Caranzalem are being subjected to erosion particularly during the SW monsoon. During the 1980 SW monsoon, a sea wall constructed by the Public Works Department in an attempt to protect the Youth Hostel at Campal was exposed to severe wave attack and a major portion of the same got damaged beyond repairs. This illustrates how a solution based on inadequate data and studies could lead to functionally ineffective and structurally weak coastal protective measures. This paper aims at an evaluation of the coastal environment with an attempt to arriving at a solution to control the severe erosion prevailing at the Youth Hostel.

DESCRIPTION OF THE STUDY AREA

The estuarine system of Mandovi and Zuari rivers (Fig. 1) constitutes of two tidal estuaries linked by the Cambarjua canal. The Cambarjua canal is a 17 km long navigable canal following a meandering course. It is used by the barges carrying iron ore from the upstream region of the estuary to the Mormugao harbour during monsoon period when navigation through the mouth of the Mandovi river is not possible due to the formation of sand bar at its mouth.

In order to evaluate the coastal environment, an extensive study was undertaken along the shoreline from Campal to Cabo headland which includes Miramar and Caranzalem beaches (Fig. 2). The shoreline at Campal forms the left bank of the Mandovi estuary and is subjected to concentration of forces due to tidal currents, river floods and waves. At the Youth Hostel, however, the shoreline is subjected to severe wave attack during the monsoon season. As this stretch of the shoreline forms the outer bend of the meandering river channel, the river floods including the ebb and flood flows due to tides will have maximum eroding effect on the shoreline. Caranzalem beach as well as southern portion of the Miramar beach are protected to some extent by the Cabo and Aguada headlands.

The winds in this area are predominantly westerly during March to September and easterly during October to February. The monthly mean wind speed varies from 5 to 10 knots. The annual air temperature varies from 19°C to 33°C and the annual rainfall in this region is about 241 cm out of which, the rainfall of 219 cm occurs during the SW monsoon (June to September). Winds , waves and swells in this area are markedly different in characteristics during the SW monsoon as compared to those occurring in the fair weather season. Low swells approaching from west to northwest are predominant in the fair weather season, whereas high and steep wind waves approach from west to southwest during the southwest monsoon.

METHOD OF STUDY

The general information on wind pertaining to the problem area was extracted from West Coast of India Pilot, published by the Hydrographer of the Navy. The ship reported wave data were compiled from the Indian Daily Weather Report for the grid area between latitude 15-25°N and longitude 70-75°E. The visual observation on breaking waves were also made duding different months in 1981.

The monsoon waves were recorded by deploying a Datawell Wave Rider Buoy (Fig. 2) during June 1981 to August 1981. The waves were recorded for 20 minutes duration for every 3 hours. A tide level recorder developed by NIO was installed near the Verem jetty (Fig. 2) and the tide levels were recorded on 11_6-80 and 12-6-80. The recorded tide levels were compared with the predicted tide levels published by the Surveyor General of India, Dehra Dun.

One Aanderaa current meter was installed (Fig. 2) and the current speed and direction were recorded during the period 7_6-1981 to 22-7-1981. Surface floats and fluorescent tracers were used to determine the speed and direction of longshore currents in the surf zone during the premonsoon, monsoon and postmonsoon periods. Numerical refraction studies were carried out for different wave periods at different incoming wave directions in this area to determine the possible locations where concentrations of wave energy takes place along the shoreline.

RESULTS AND DISCUSSION

Mandovi River has a bay-like entrance referred as Aguada Bay (Fig. 2). The width of the connection between Cabo and Aguada headlands is 3,260 m with a depth of about 7 m below MSL. The bay was a surface area of approximately 1.15×10^7 m^2. Near Reis Magos, the river narrows significantly, taking a meandering shape with a width of 710 m, a maximum depth of 10 m and a mean depth of 4.5 m (Mehta, 1981). During the fair weather season, the flow is tide dominated and the estuary is mixed with comparatively low fresh water outflow during the months of December through May. With the onset of the southwest monsoon (June to September), the estuary becomes progressively stratified due to increasing fresh water outflow and a saline wedge is formed. It has been reported that the suspended sediments at the surface are of the order of 30 mg/litre in fair weather and 100 mg/litre during monsoon (Moorthy et al., 1976). Spring tidal prism, estimated from fair weather data is of the order of 9.76×10^7 m^3 (Mehta, 1981). Littoral sand exchange between the bar and the area outside Aguada Bay is probably very small as little material is likely to move into the bay past the protruding Aguada and Cabo headlands.

The results of the analysed wave data collected during June, July and August 1981 are presented in Figs. 3, 4 and 5. The significant wave height H_s varied from 1.9 m to 4.0 m and the maximum wave height H_{max} varied from 2.8 m to 6.5 m. The joint distribution of H_s and T_z (Fig. 4) indicates that the monsoon waves are high and steep with the wave steepness ranging from 1/50 to 1/20. The zero crossing wave period T_z ranged from 7 to 11 secs. The monthly breaking wave heights and periods based on the visual observations undertaken from the beach are given in Table 1. The average breaking wave heights ranged from 1.2 to 2.5 m during May to September with periods 8 to 10 secs. From October to April the breaking wave heights ranged from 0.8 to 1.5 m with periods 8 to 9 secs.

The tides in the Goan waters are predominantly semi-diurnal. The predicted tidal elevations as presented in the Indian Tide Tables for one spring tide to one neap tide in November 1982 at Mormugao Harbour is presented in Fig. 6. The percentage distribution of measured tidal current speed and direction is presented in Fig. 7. The current speed in general varied from 30 to 130 cm/sec with a short period of slack flow conditions. The current direction was towards south and south-west during the ebb tide and was predominantly towards north and northeast during the flood tide conditions. A time lag of about 2 to 3 hours was observed between maximum currents and high or low tide levels. The maximum current speed observed during the period of measurement was 175 cm/sec.

A typical variation of longshore currents observed in July 1982 is presented in Fig. 8. The longshore currents at Caranzelam and Miramar beaches had speeds ranging from 5 to 50 cm/sec. The longshore current generated as a result of breaking waves was comparatively stronger at Caranzelam beach than that observed at Miramar beach. The currents near youth hostel were predominantly governed by the tidal flows. Variations in longshore current directions were noticed at certain stretches of the Caranzelam and Miramar beaches during the monsoon. At a few locations, presence of weak rip currents causing the flow in the offshore direction were also observed on certain occasions. Wave refraction studies showed that the beach between Youth Hostel and Miramar is subjected to wave energy concentration for the waves approaching from west and southwest. This indicates that this particular stretch of the beach is highly vulnerable to monsoon waves. The typical refraction diagrams computed for 8 sec wave period for the wave directions West and West-Northwest are shown in Fig. 9 and 10 respectively.

The study indicates that the beach near Youth Hostel is situated along the outer bend of the meandering river channel and hence, subjected to erosion and scouring due to concentration of strong tidal and river currents. It is found from the wave refraction studies that during the southwest monsoon as well as during the fair weather period, concentration of wave energy takes place at this stretch of the shoreline. Relatively coarse beach material with 50% grain size (D_{50}) of about 0.205 mm present on the beach indicates that this beach segment is exposed to high energy waves, and currents. As some important buildings such as Kala Academy, Indoor Stadium and Youth Hostel are located close to the shoreline, suitable protective measures would be needed to control the erosion of the shoreline in this area.

Spurs of approximate length 30 m to 50 m spaced at about 60 m to 150 m apart may be constructed along the outer bend particularly in the vicinity of the Youth Hostel to divert the flow and thereby assisting the deposition of sediment between the spurs. These groins will also help in dissipating the wave energy reaching the shoreline and enhance the entrapment of littoral drift transported by wave action. In conjunction with this improvement, a sloping revetment with suitable filter and toe protection as indicated in Fig. 11 would be essential for the unprotected stretch in the vicinity of the Youth Hostel.

As this river channel is being used for navigation the spurs would have to be designed and constructed in conjunction with some dredging to improve the channel for safe navigation. It would be equally important to undertake a detailed hydraulic model study before adopting any major improvement scheme.

ACKNOWLEDGEMENT

The authors are grateful to Dr. H. N. Siddiquie, Director, NIO for his keen interest and encouragement.

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TABLE 1

Monthly Average Breaker Characteristics

Month	Breaker heights (M)	Period (sec)
January	0.8 - 1.2	7 - 8
February	0.8 - 1.2	7 - 8
March	0.8 - 1.2	8 - 9
April	0.8 - 1.5	8 - 10
May	1.2 - 2.0	7 - 10
June	1.8 - 2.5	7 - 10
July	2.0 - 2.2	7 - 10
August	1.8 - 2.2	8 - 10
September	1.2 - 1.8	7 - 8
October	1.0 - 1.5	7 - 8
November	0.8 - 1.5	8 - 9
December	0.8 - 1.5	8 - 9

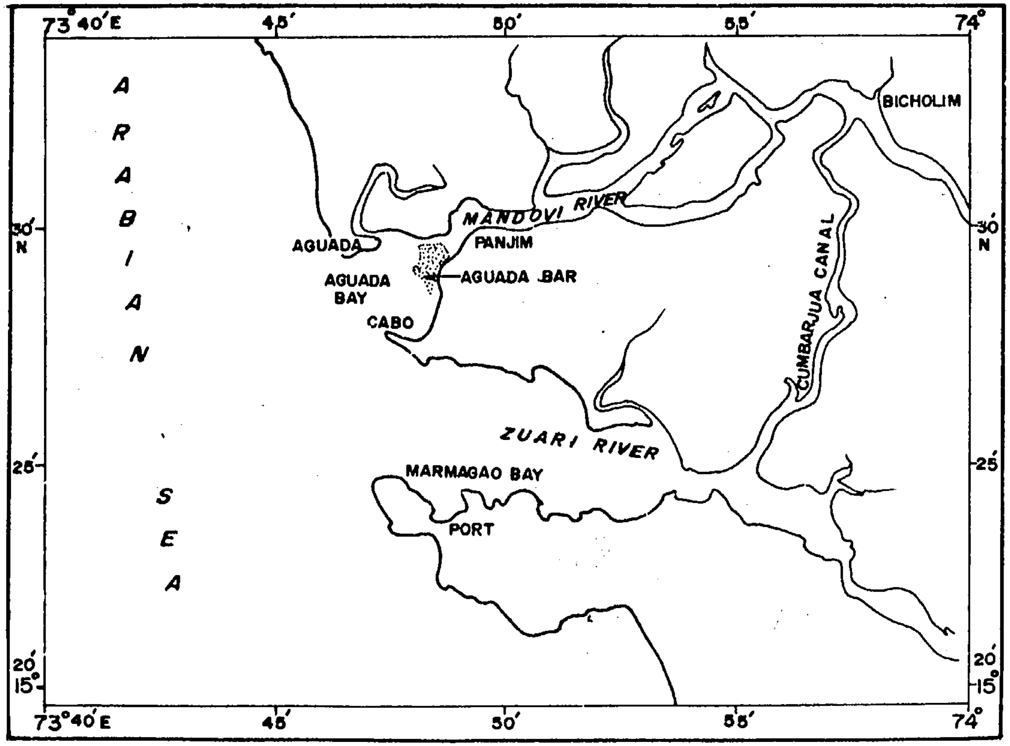


Fig.1. Mandovi and Zuari estuarine system.

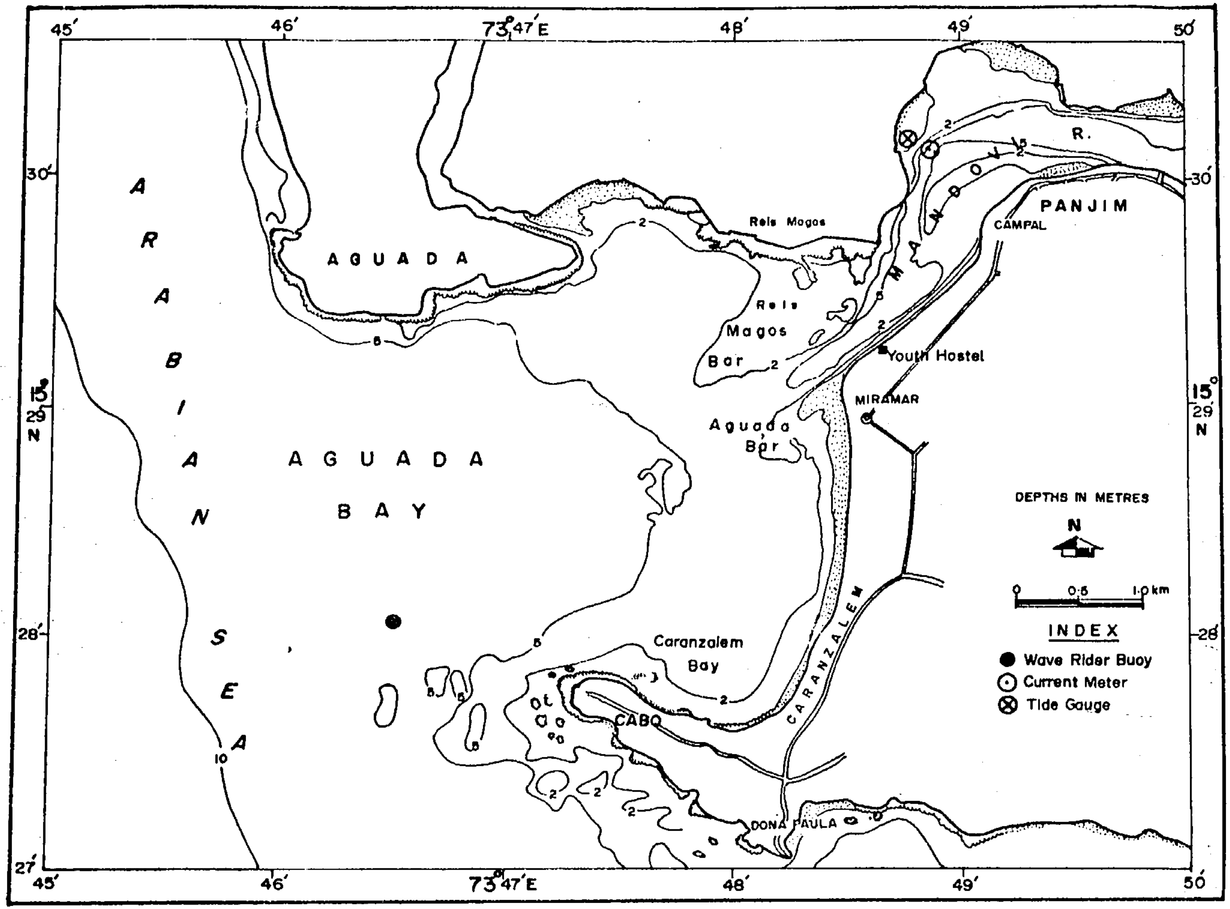
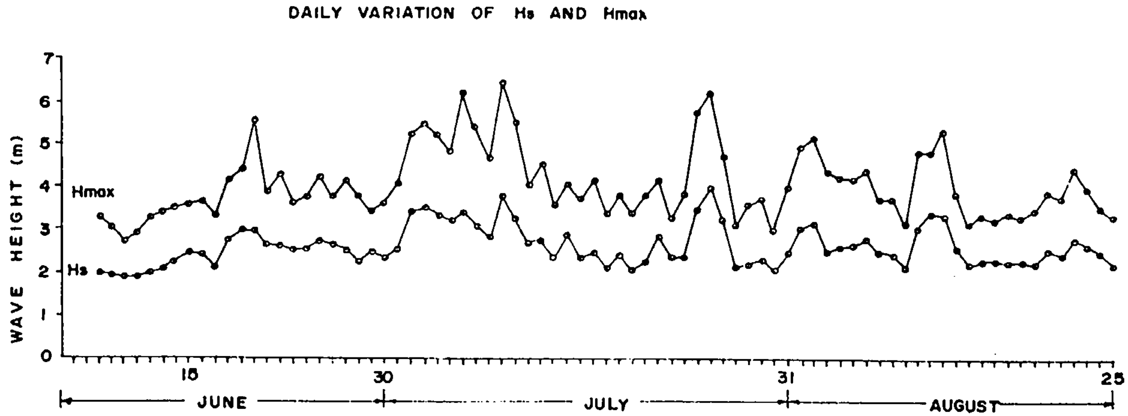


Fig.2. Location map



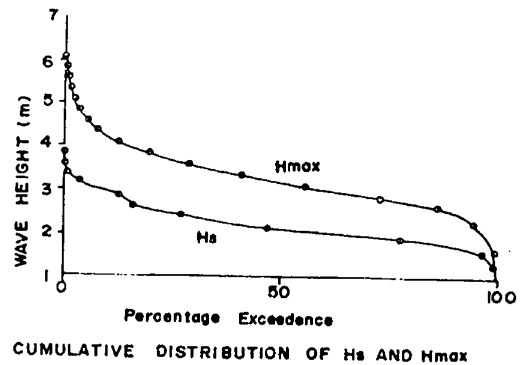


Fig. 3. Daily variation and cumulative distribution Hs and Hmax

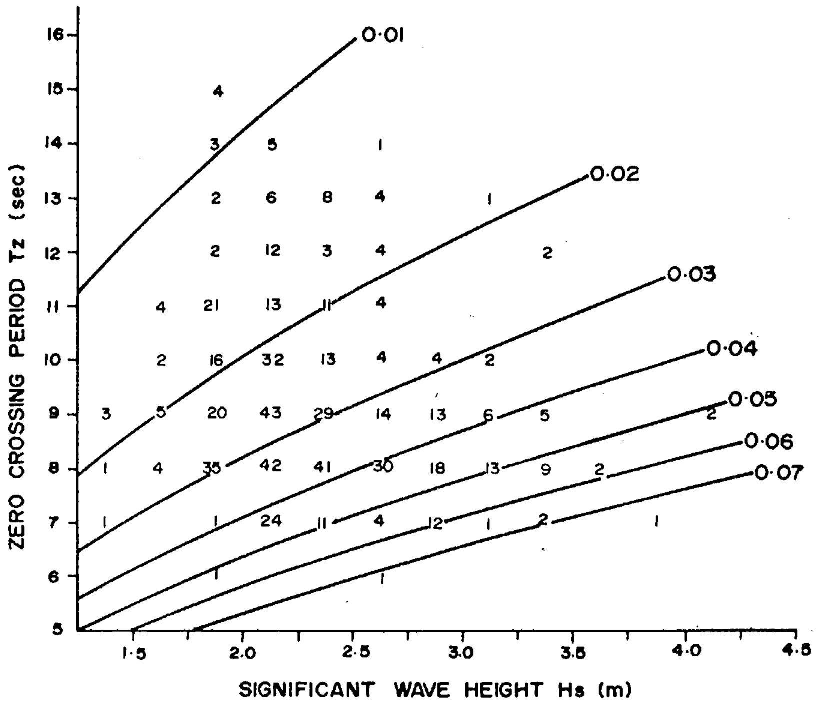


Fig. 4. Distribution of Hs and Tz.

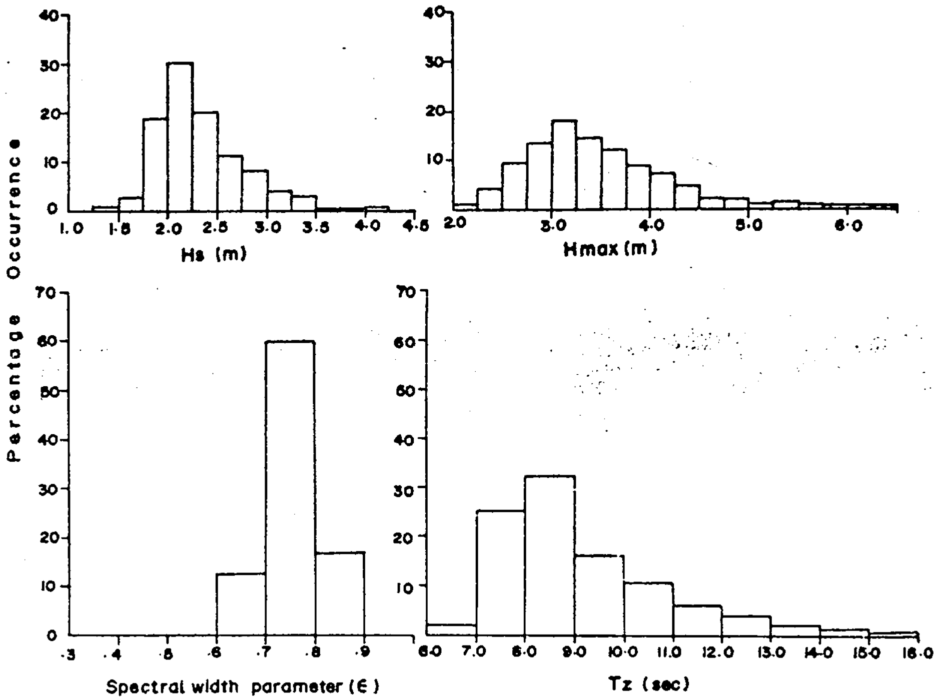


Fig.5· Frequency distribution of Hs, Hmax, ϵ and Tz.

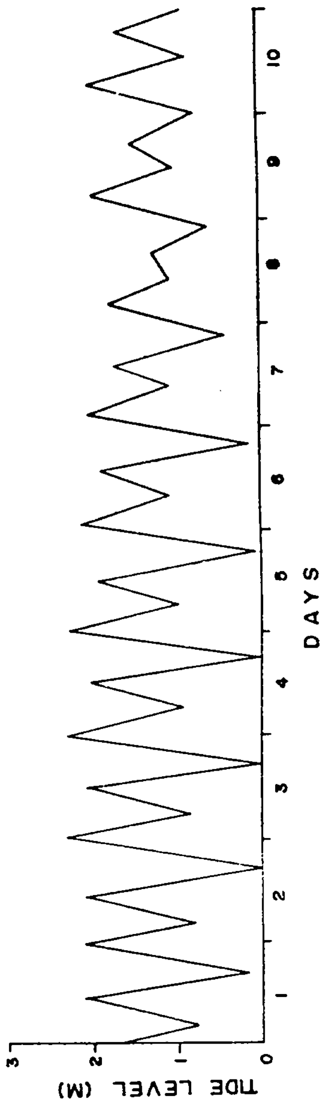


Fig.6. Predicted tide levels at Marmagao Harbour in November 1982.

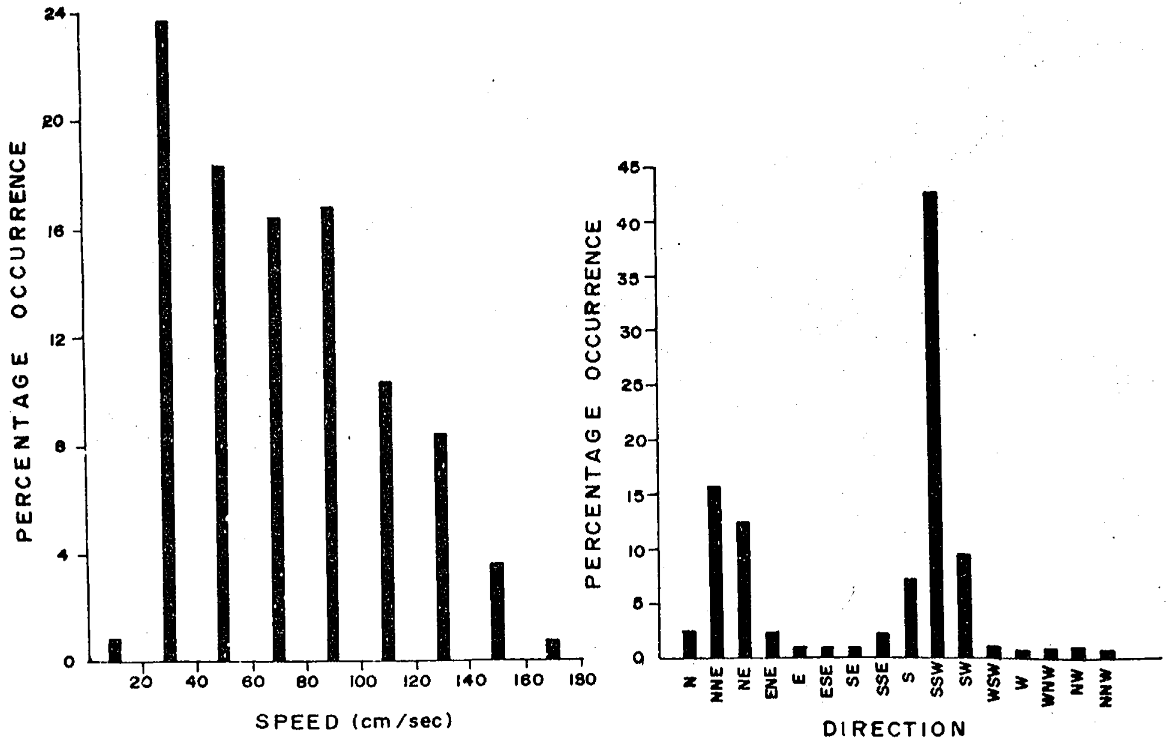


Fig.7. Percentage distribution of current speed and direction

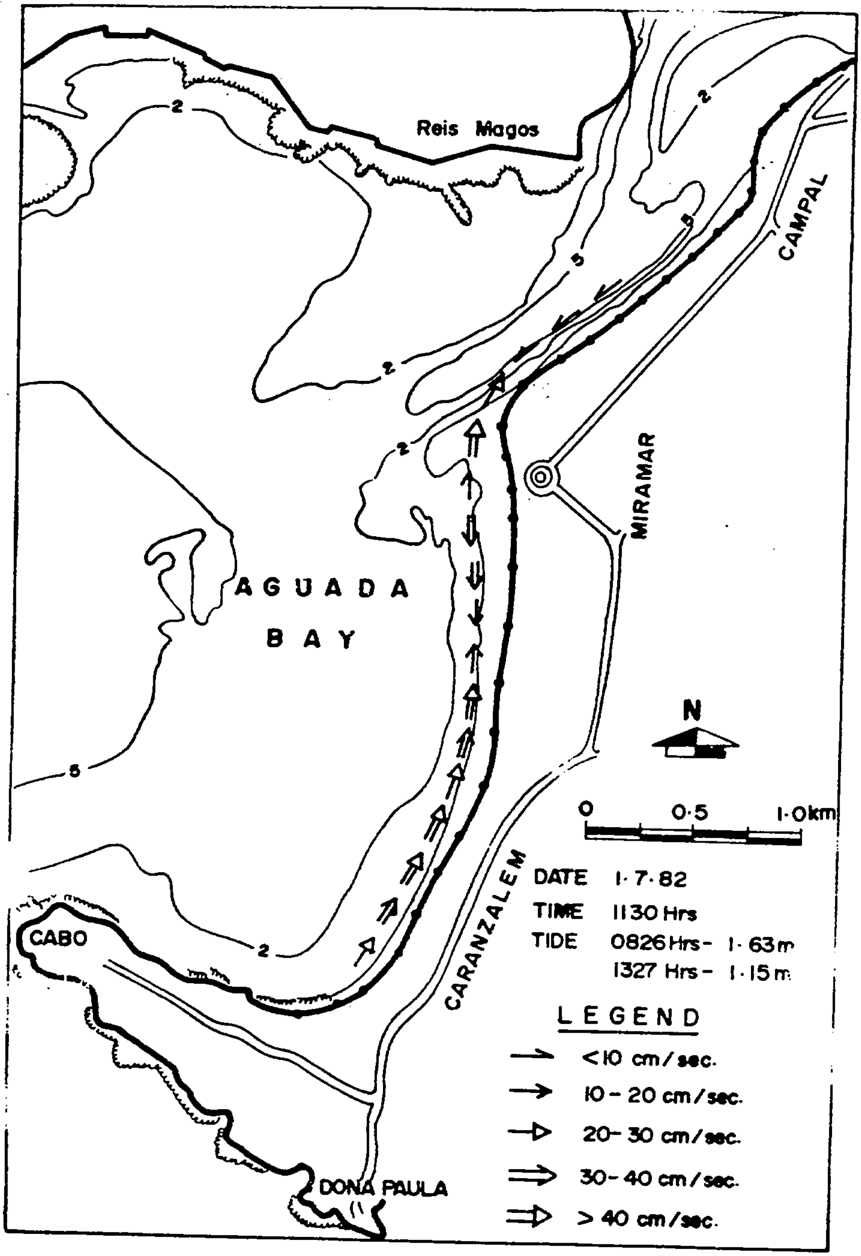


Fig.8. Observation on longshore currents.

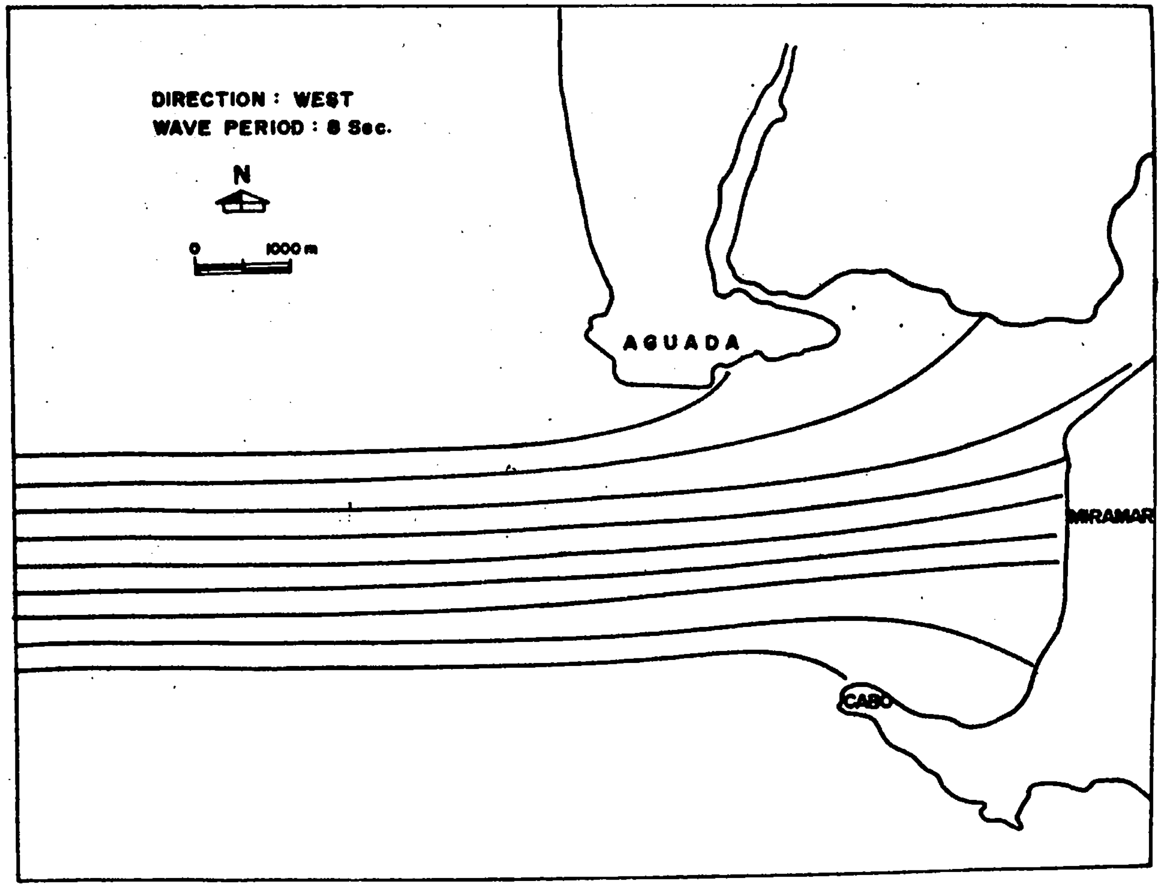


Fig. 9. Refraction diagram

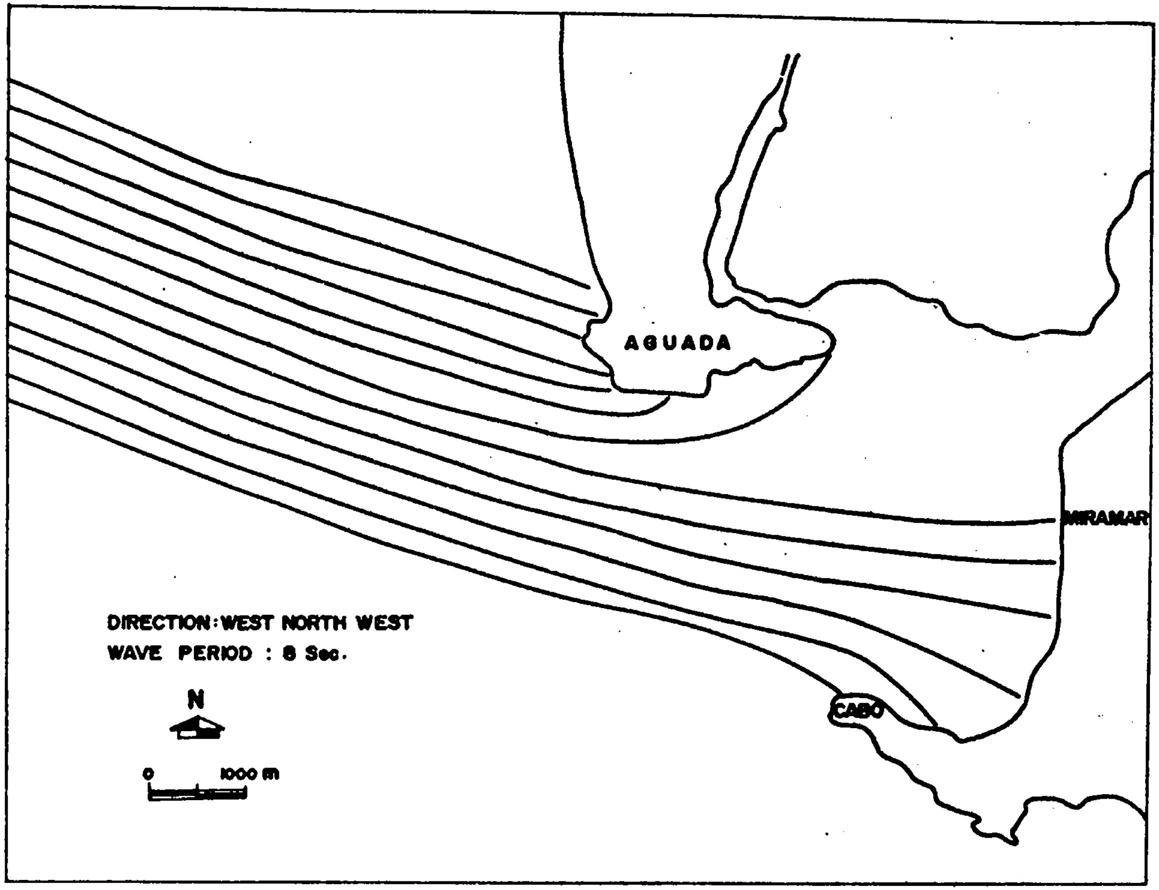


Fig.10 Refraction diagram

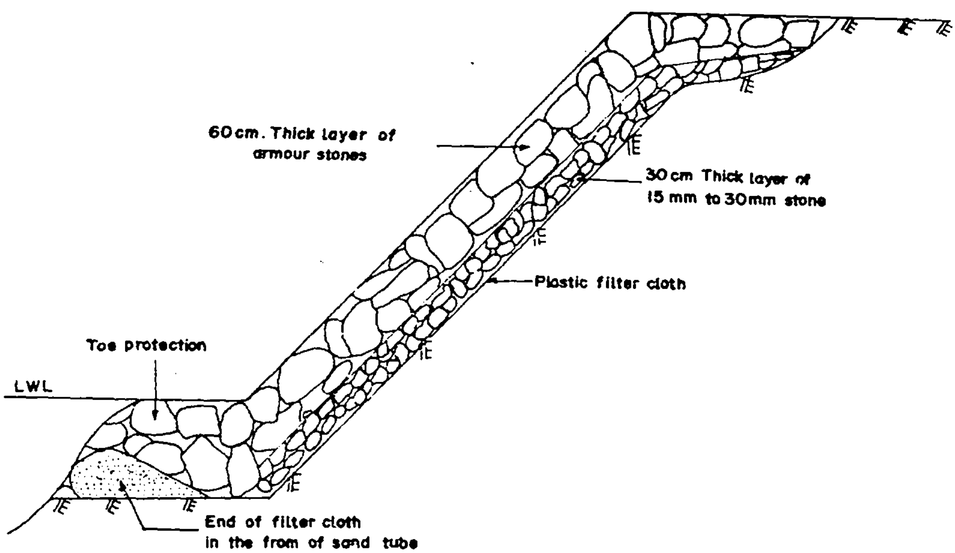


Fig. 11. Suggested cross section of a protective stone revetment