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Variation of longshore current and sediment transport along the south Maharashtra coast, west coast of India

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The longshore current velocity varied between 0.1 and 0.33 m.sec^{-1}. The longshore current direction was predominantly southward at Ratnagiri, Ambolgarh, whereas it was variable at Vengurla during the study period. Based on the field measurements, the estimated longshore sediment transport rates at Ratnagiri, Ambolgarh and Vengurla were 1.19×10^5, 1.9×10^5 and 0.53×10^5 m^3.y^{-1} respectively and the direction was southward. Significance of field measurement is emphasized here, in view of the large variation in the computed longshore sediment transport rates reported in earlier studies.

Longshore current is generated due to waves breaking at an angle to the shoreline, and is confined to the surfzone between the first wave breaker and the shoreline. Various studies carried out on longshore currents till recently have been reviewed[1,2]. Longshore current velocity varies across the surf zone, reaching maximum value close to the wave breaking point[3]. For practical purposes, the average longshore current measured in the surfzone would be sufficient in estimating sediment transport rate. In the present study, daily observations of longshore current velocity and direction have been made for a year (June 1989-May 1990) at 3 stations selected along the south Maharashtra coast. The measured longshore currents are used to estimate longshore sediment transport rates.

Study area

South Maharashtra coastline between Mulgund and Shiroda (Fig. 1) is hilly, narrow, highly dissected with transverse ridges of the western ghats, and at many places extending as promontories into Arabian Sea[4]. The shoreline is very irregular, associated with features like cliffs, notches, promontories, sea caves, embayments, submerged shoals and offshore islands. A number of west flowing rivers form estuaries, bays, mud flats, creeks, back waters and tidal marshes. The continental shelf of the study region is relatively wide. The seabed, up to the 100 m water depth, mostly consists of silty clay, and between 100 and 200 m, it is covered with sand[5]. The climate of this region is modified according to the southwest monsoon (June to September) and non monsoon period (October to May). The wave heights mostly vary[6] between 1.5-3 m, and the wave periods vary between 5-8 sec during June to September, and 0.5-1.5 m, 5-6 sec during October to May respectively. Tides in this region are

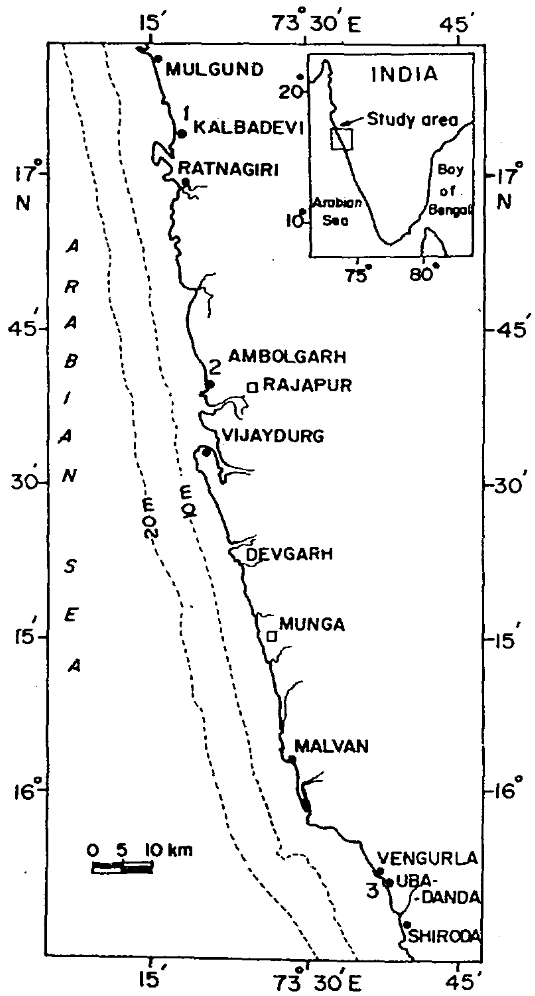

Fig. 1—Location map

predominantly semi-diurnal, with the range of 0.5-2 m.

Materials and Methods

Three base stations were established at Kalbadevi beach (north of Ratnagiri), Ambolgarh beach (near Rajapur) and at Uba danda beach (south of Vengurla) (Fig. 1). Longshore current velocity and direction were measured everyday, from June 1989 to May 1990, by releasing rhodamine B dye tracers in the surf zone and noting the distance covered in 2 min. Simultaneously, visual measurements on breaker height, period and surfzone width were also made. Heights of 10 consecutive wave breakers were visually measured and the average of them was taken as breaker height. The time required for 10 consecutive waves to break at a point was noted using a stop watch and the average was considered as breaking wave period.

The beaches along the south Maharashtra coast are intermittently intercepted by headlands and rocky outcrops. Hence, the application of commonly used longshore sediment transport equations[7], which are based on the assumption of long and open beaches with adequate sand supply, has certain limitations when applied to these regions. To make a realistic estimation of longshore sediment transport rate under this type of morphological condition, Walton's equation[8] can be suited well as it takes into consideration the measured values of longshore currents. Walton's equation is given by,

$$Q = \frac{1290\ \rho g H_b W v C_f}{0.78\ (5\ \pi/2)\ (v/v_0)}$$

where, Q = annual longshore sediment transport rate in $m^3.y^{-1}$; $\rho = 1025$ $kg.m^{-3}$; $g = 9.81$ $m.sec^{-2}$; $C_f = 0.01$; H_b = breaking wave height in m; W = surfzone width in m; v = longshore current velocity in $m.sec^{-1}$; (v/v_0) = theoretical dimensionless longshore current velocity[9].

Results and Discussion

The daily variation of longshore current velocity and direction at sts 1 to 3 are shown in Fig. 2.

Longshore current velocity—At st. 1 (Ratnagiri), the monthly mean longshore current velocity persisted between 0.17-0.2 $m.sec^{-1}$ from January to June, and between 0.2-0.3 $m.sec^{-1}$ from July to December. Relatively strong currents were observed during SW monsoon and NE monsoon as it appears that waves approach with more inclination to the coast during these periods. At st. 2 (Ambolgarh) the longshore current velocity persisted around 0.12 $m.sec^{-1}$ from January to May, and persisted around 0.15 $m.sec^{-1}$ from June to December. It persisted at st. 3 (Vengurla) between 0.15-0.2 $m.sec^{-1}$ from October to March, and between 0.2-0.3 $m.sec^{-1}$ from April to September. The field measurement indicates that the longshore current velocity varied with month and location along the study region. Relatively strong currents were observed in June and July (SW monsoon) at sts 2 and 3, and in November and December (NE monsoon) at st. 1. The high waves in SW monsoon and relatively strong currents in NE monsoon observed at st. 1 infers that, the waves approach the coast with more inclination during NE monsoon than rest of the year. The longshore current velocity was relatively low during January to March at all stations. In general, the longshore current velocity was observed to be relatively strong at sts 1 and 3, compared to st. 2.

Longshore current direction—At st. 1, the predominant longshore current direction was southward from January to April, August, September, November and December, and northward in June. At st. 2, the direction was southward from January to July, September and October, and was variable rest of the year. At st. 3, it was southward in February, April to June, and northward in March, September, November and December. In general, over the period of one year, the longshore current was predominantly southward at sts 1 and 2, and the direction changed frequently at st. 3.

Variation of breaker characteristics—The daily variation of measured breaking wave height, period and surfzone width are presented in Figs 3 to 5. At st. 1, the monthly mean breaking wave heights persisted around 0.5 m from November to June, and around 1 m from July to October. At st. 2, it persisted between 1 and 1.5 m from December to May, and exceeded 2 m from June to November. At st. 3, the monthly mean breaking wave height varied around 0.7 m from September to April, and exceeded 1 m from May to Aug-

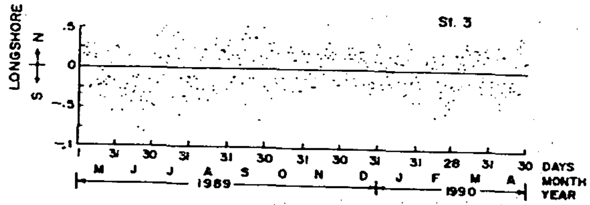

Fig. 2—Daily variation of longshore current velocity and direction

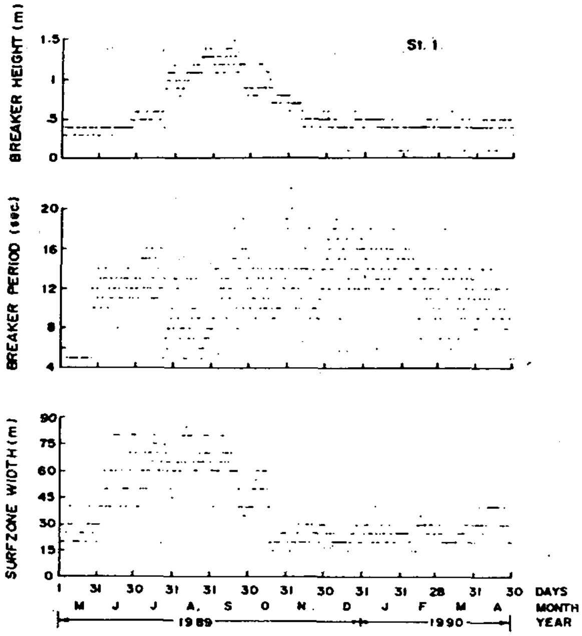

Fig. 3—Variation of breaker height, breaker period and surfzone width at st. 1

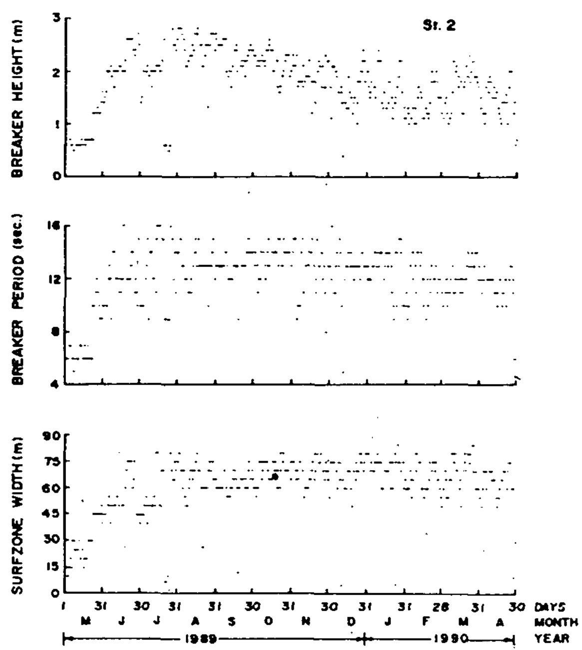

Fig. 4—Variation of breaker height, breaker period and surfzone width at st. 2

ust. It showed that the wave heights were high during SW monsoon, and st. 2 was exposed to relatively high waves compared to sts 1 and 3. There was no considerable variation in wave heights during NE monsoon and fair weather period along the study area. The wave period persisted between 6-14 sec at all stations

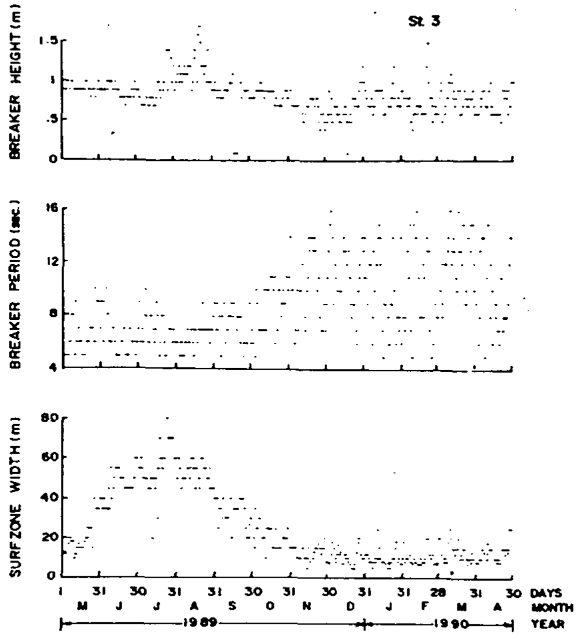

Fig. 5—Variation of breaker height, breaker period and surfzone width at st 3.

during the period of study. The surfzone width exceeded 60 m during June to Septmber, and was <30 m during rest of the year at all stations.

Longshore sediment transport—The estimated longshore sediment transport rates using Walton's equation are presented in Table 1. The monthly variation of longshore sediment transport rate and direction are shown in Fig. 6. At Ratnagiri (st. 1), the maximum sediment transport rate of 0.44×10^5 $m^3.month^{-1}$ was observed in August and a minimum of 0.01×10^5 $m^3.month^{-1}$ in May. The sediment transport was southward from August to May and northward during the rest of the year. The annual gross transport rate was 1.48×10^5 $m^3.y^{-1}$. The annual net transport rate was 1.19×10^5 $m^3.y^{-1}$ in the southerly direction. At Ambolgarh (st. 2), the maximum transport rate of 0.43×10^5 $m^3.month^{-1}$ was observed in September and minimum of 0.009×10^5 $m^3.month^{-1}$ in July. The sediment transport was southward from January to March, June, September and October and was northward during the rest of the year. The annual gross transport rate was 3×10^5 $m^3.y^{-1}$. The annual net transport was 1.9×10^5 $m^3.y^{-1}$ in southerly direction. At Vengurla (st. 3), the maximum transport rate of 0.63×10^5 $m^3.month^{-1}$ was observed in June and minimum of 0.003×10^5 $m^3.month^{-1}$ in January. The sediment transport was southward from April to July, January and February and northward during the rest of the year. The annual gross transport was 1.2×10^5 $m^3.y^{-1}$. The annual net transport was 0.53×10^5 $m^3.y^{-1}$ in the southerly direction.

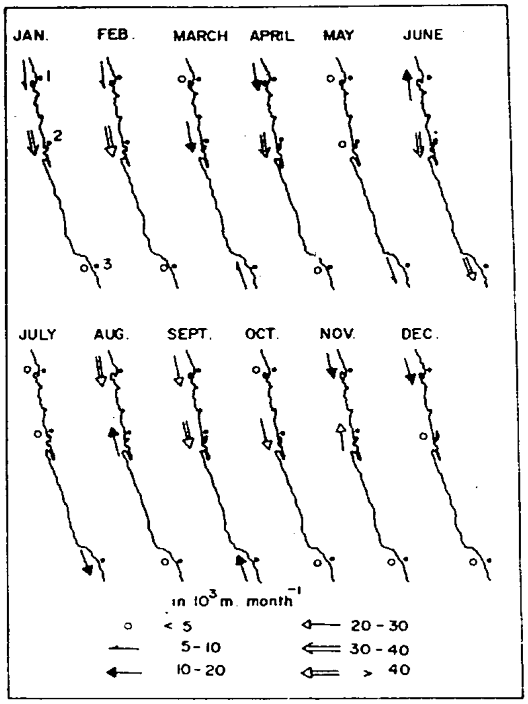

Fig. 6—Variation of longshore sediment transport rate and direction

The annual net longshore sediment direction, estimated by Walton's equation using daily littoral environmental observation data, and the direction reported by Chandramohan[10] is same at st. 3 but are opposite at sts 1 and 2. The gross sediment transport rate reported[10] is about 10 times higher than the present estimate. However, Chandramohan[10] has used deepwater ship data and also the longshore sediment transport equation, which is based on the assumption of long and open beaches. As the study region consists of headlands and rocky outcrops, there is a possibility of reduction in the incoming wave energy and later their directional distribution. Under such circumstances only the field data would be more reliable and the longshore sediment transport rate estimated based on Walton's equation could be considered more realistic. The study further proves that the field measurement is very important to assess the longshore current and longshore sediment transport rates particularly when the geomorphological conditions are varying as described in the present study.

Table 1—Longshore sediment transport rate ($m^3.month^{-1}$)

Month	Stations		
	1	2	3
May 1989	−1820	+3370	−7551
June	+10872	−36387	−63054
July	+3649	+854	−12165
Aug.	−44314	+19901	+3739
Sept.	−25848	−42581	+15612
Oct.	−3001	−26843	+2112
Nov.	−16457	+27501	+2442
Dec.	−11799	+3575	+2808
Jan. 1990	−5449	−32124	−296
Feb.	−6553	−56027	−2595
March	−4134	−18529	+6837
April	−13727	−32305	−929
Net ($m^3.y^{-1}$)	−118580	−189594	−53040
Gross ($m^3.y^{-1}$)	147621	299997	120141

(−)transport towards south; (+) transport towards north.

Acknowledgement

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