

Longshore sediment transport along the Indian coast

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An empirical sediment transport model has been developed based on longshore energy flux equation. Ship reported waves, published in Indian Daily Weather Reports, are compiled for 19 y and used for estimation of sediment transport. Annual gross sediment transport rate is high ($15-20 \times 10^5 \text{m}^3$) along the coasts of south Orissa, north Tamilnadu, south Kerala, north Karnataka and south Gujarat, whilst, it is comparatively less ($5-10 \times 10^5 \text{m}^3$) along the south Tamilnadu coast. Maharashtra coast and the part between Pondicherry and Point Calimere in Tamilnadu, show negligible order of annual net transport. Annual net transport along the east coast is in north and along the west coast in south but for south Gujarat coast.

The vast Indian coastal zone has been playing a major role in the economic development. Assessment of various nearshore dynamic parameters is a prerequisite in projects like ports and harbours, fisheries, coastal protection, marine recreation, pollution control, land reclamation, etc. Information available on such parameters in India is very limited. Serious erosion and siltation problems are faced today in harbours and in the vicinity of coastal structures. The important factor governing the beach erosion is the longshore sediment transport which is controlled predominantly by the waves and the nearshore topography. In the present study, an empirical sediment transport model is developed based on the longshore energy flux equation.

Methods

Wave data—Swell data reported in Indian Daily Weather Reports¹, for the period 1968 to 1986 are considered for the present study. Indian coastal region is divided into 8 grids, each of $5^\circ \times 5^\circ$ size and the swell data pertaining to each grid are accordingly grouped (Fig. 1). Ship reported wave heights are considered equivalent to the deep water significant wave heights (Hs) and the visually measured wave periods as the zero crossing wave periods² (Tz).

Longshore sediment transport equation—Longshore sediment transport rate is generally estimated based on empirical equation which relates the longshore energy flux in the breaker zone to the longshore transport rate^{3,4}. Based on the Shore Protection Manual⁵, the deep water version of the longshore transport equation is related to the longshore component of the wave energy flux as,

$$Q = 1288 \frac{\rho g^2}{64\pi} T (H_o \cdot Kr)^2 \sin 2\alpha_b \quad \dots(1)$$

where Q = volume rate of longshore transport in $\text{m}^3 \cdot \text{y}^{-1}$, ρ = seawater density in $\text{kg} \cdot \text{m}^{-3}$, g = acceleration due to gravity in $\text{m} \cdot \text{sec}^{-2}$, T = wave period in sec, α_b = breaker angle, H_o = deep water wave height and Kr = refraction coefficient.

By incorporating the effect of wave shoaling and the bottom friction, Eq. 1 can be rewritten as,

$$Q = 1288 \frac{\rho g^2}{64\pi} T (H_o \cdot Kr \cdot K_s \cdot K_f)^2 \sin 2\alpha_b \quad \dots(2)$$

where, K_s and K_f are the shoaling and bottom friction coefficients respectively.

As the data compiled in the present study correspond to deep water condition, Eq. 2 is used for estimating the longshore sediment transport rate. The procedure of Skovgaard *et al.*⁶ is followed to compute the shoaling, refraction and bottom friction coefficients and the details of its application to Indian coast is referred earlier⁷.

Empirical sediment transport model—For the coast assumed as long and open sandy beach with adequate supply of sand, the monthly longshore transport rate is obtained by,

$$Q = \frac{1}{12} \sum_{H=0}^{H=\infty} \sum_{T=0}^{T=\infty} \sum_{\beta=0}^{\beta=\pi} Q \cdot f(H, T, \beta) \quad \dots(3)$$

where Q = annual volume rate of longshore transport from EQ. 2, Q = monthly volume rate of longshore

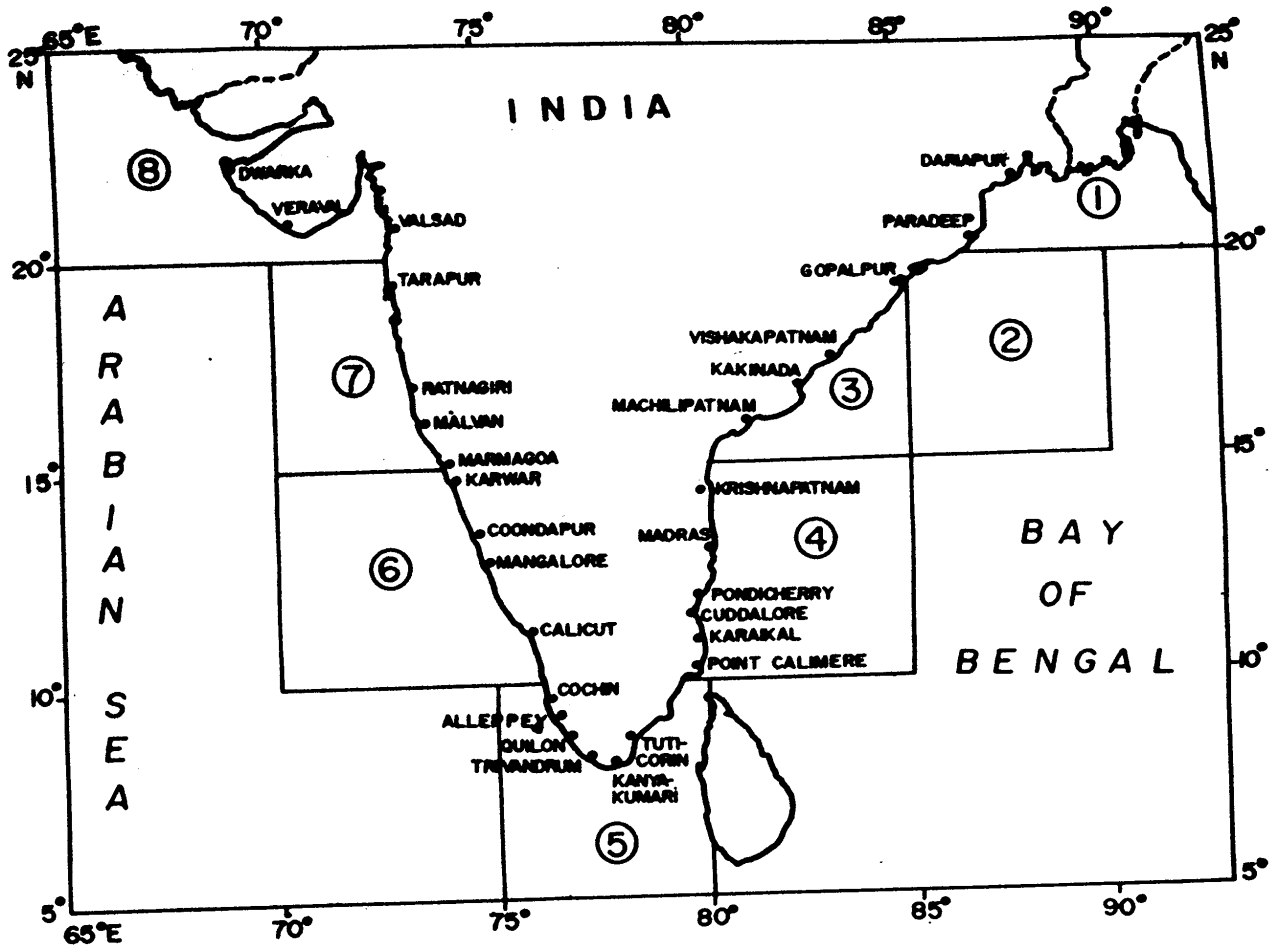


Fig. 1—Map showing the grids and station locations

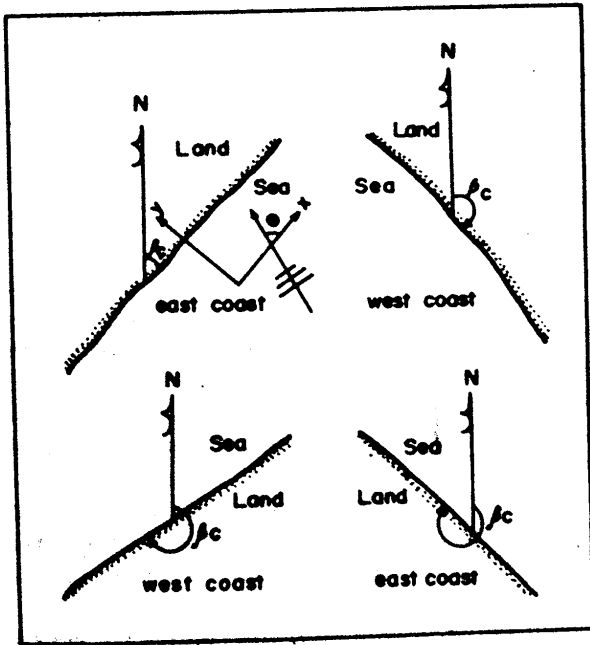


Fig. 2—Definition sketch for orientation of coastline

transport, $f(H, T, \beta)$ = frequency of occurrence of particular set of (H, T, β) in a month, α = azimuth of the coastline, and β = azimuth of the wave direction.

Rose diagrams—The method for measuring the orientation of the coastline with reference to the north for the place of interest is shown in Fig. 2. Using Eq. 3, the annual gross and net longshore sediment transport rates for every 10° variation of the coastline orientation in each grid are estimated and presented as rose diagrams (Fig. 3). The methods to read the rose are: (i) estimate inclination of the coast with respect to north (β) from the map or in field; (ii) identify the grid in which the coastal segment of interest falls (Fig 1); (iii) referring to the rose diagram of the corresponding grid, the transport rates for the known orientation of the coast can be read; and (iv) linear interpolation is made for the coast oriented with intermediate angle. Similar procedures are adopted and explained earlier².

Results and Discussion

Along the east coast, between Dariapur and Tutic-

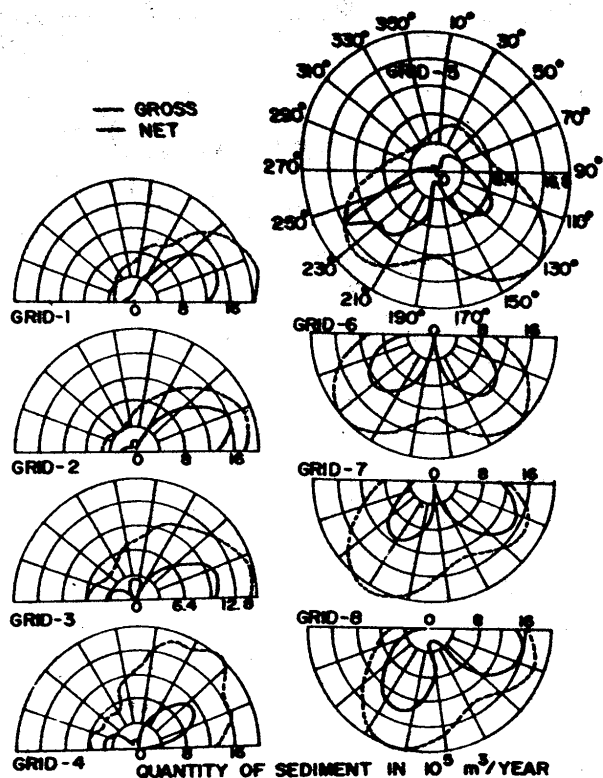


Fig. 3—Rose diagrams of annual sediment transport rates ($10^5 m^3 y^{-1}$)

orin (grids 1-4), the direction of longshore transport is northerly from March to October and southerly from November to February (Fig. 3). In general, the direction of annual net sediment transport is towards north from Dariapur to Pondicherry. In grid 4, north of Pondicherry, the annual gross and net transport rates are about $17.9 \times 10^5 m^3$ and $4.4 \times 10^5 m^3$ respectively, and south of Pondicherry till Point Calimere, $12.5 \times 10^5 m^3$ and $0.6 \times 10^5 m^3$ respectively.

Coastline of grid 5, is exposed to relatively higher waves than the rest of the Indian coast due to its direct exposure to the Indian Ocean. Between Manalmelgudi and Kanyakumari, the direction of transport is northerly from March to December and southerly in January and February. The transport between Kanyakumari and Trivandrum is southerly from May to December and northerly from January to April. Between Trivandrum and Cochin, the transport is southerly from January to February and June to September, and northerly from March to May and October to December.

Between Ponnani and Karwar (grid 6), the transport is southerly from February to September and is nearly equal on either direction from October to January. Between Goa and Tarapur (grid 7), the direc-

Table 1—Longshore transport at important locations along the Indian coast

Locations	Drift ($\times 10^5 m^3 y^{-1}$)	
	Southerly	Northerly
<i>East coast</i>		
Dariapur	2.73	15.28
Paradeep	2.84	16.25
Gopalpur	2.60	9.62
Visakhapatnam	3.18	8.45
Kakinada	2.62	9.60
Machilipatnam	5.02	4.40
Krishnapatnam	6.98	8.95
Madras	6.83	10.27
Pondicherry	6.92	9.39
Cuddalore	6.98	8.95
Karaikal	6.60	6.56
Tuticorin	3.30	3.30
Kanyakumari (east)	3.12	3.98
Kanyakumari (tip)	3.36	10.86
<i>West coast</i>		
Trivandrum	16.30	6.15
Quilon	15.73	6.23
Alleppey	10.62	6.77
Cochin	9.77	6.93
Calicut	10.89	3.49
Mangalore	10.69	3.62
Coondapur	8.73	5.08
Karwar	15.11	1.99
Marmagoa	8.20	5.30
Malwan	7.34	6.86
Ratnagiri	6.25	9.25
Tarapur	7.20	7.12
Valsad	5.94	9.80
Veraval	16.51	1.63
Dwarka	10.18	3.91

tion of longshore transport during southwest monsoon is northerly, and it is southerly during the rest of the year. In grid 8, the sediment transport between Umbergaon and Surat is southerly from November to April, and northerly during the rest of the year. In between Mahuva and Jakhau, transport is easterly throughout the year except in November.

To give more insight into the rose diagrams, the longshore sediment transport rates for important places along the Indian coast are presented in Table 1.

Distribution around the Indian coast—The general distribution of monthly longshore sediment transport rate along the Indian coast is shown in Fig. 4. It

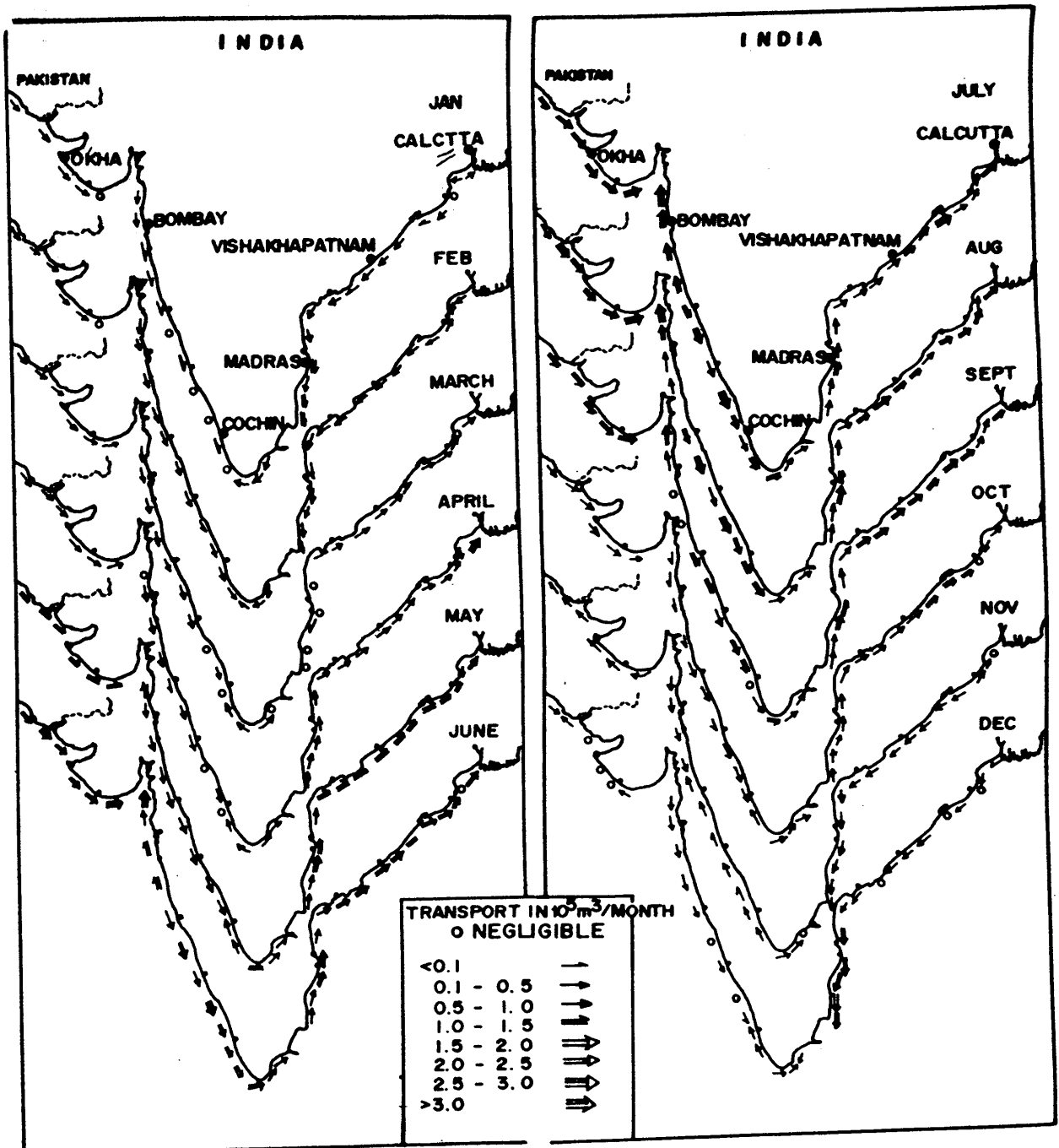


Fig. 4—Monthly sediment transport rates along the Indian coast

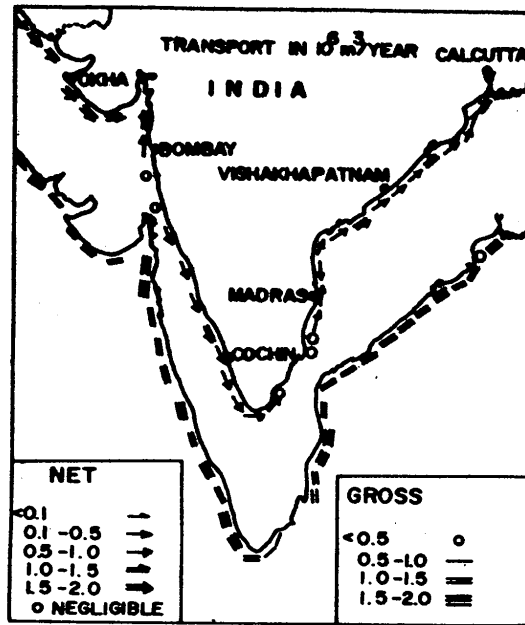


Fig. 5—Gross and net transport rates along the Indian coast

shows that, along the east coast, the longshore transport is southerly from November to February, northerly from April to September and variable in March and October. Along the west coast, the longshore transport is generally towards the south from January to May and in October. It is variable during other months showing northerly drift along the Maharashtra and south Gujarat coasts and southerly along the Karnataka and Kerala coasts from June to September. This phenomenon gets reversed in November and December.

Annual gross sediment transport rate is high ($15-20 \times 10^5 m^3$) along the coasts of south Orissa, north

Tamilnadu, south Kerala, north Karnataka and south Gujarat, whereas it is comparatively less ($5 \times 10^5 m^3$) along the southern Tamilnadu and Maharashtra coasts (Fig. 5). The annual net transport is northerly on the east coast and southerly on the west coast except along south Gujarat coast.

The estimation of longshore sediment transport rate in the present study is based on longshore energy flux equation with an assumption that the coast consists of a long, open beach with adequate supply of sand. Though the results are directly applicable for the east coast, it poses inherent limitation for certain segments of the west coast, where headlands and estuaries are intersecting the littoral zone. Hence, care should be exercised not to apply the present results to the pocket beaches, estuarine regions, etc. along the east and west coasts.

Acknowledgement

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