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NEARSHORE CIRCULATION IN RELATION TO EFFLUENT DISPOSAL OFF THAL, MAHARASHTRA, WEST COAST OF INDIA

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ABSTRACT

Tides, currents and related field parameters at Thal, Maharashtra coast, were studied to assess the environmental conditions for proper disposal of effluents from a large fertilizer factory. The tidal ranges being 1.6 and 3.9 m during neap and spring respectively, the tidal currents attained a maximum value of 1 m/s during springs and about 60 cm/s during neaps. The spatial variations were considerable, due to the presence of rock outcrops, tidal creeks and two islands. A composite picture of the flow pattern has been prepared for the three prominent seasons. The waters beyond Khanderi island described a course roughly parallel to the shore, whereas shallower waters exhibited cross-shore tendencies and irregularities, rendering them unsuitable for systematic effluent disposal, as also the southern and middle regions due to limitations in dispersive processes.

Key-words: tides, currents, effluent, dispersion

This work was carried out to help plan and design the coastal marine outfall for the effluents from one of Asia's largest fertilizer factories at Thal-Vaishet near Alibag in Maharashtra. The fertilizer complex would generate 40 to 45 million litres of liquid waste per day. It was decided by the company to treat the effluents suitably and to release them at an appropriate site off Thal. As a part of the multidisciplinary environmental study to evaluate the coastal water characteristics, the tides, currents and related field parameters were measured. This was the first time this area interspersed with shoals and islands was studied for oceanographic characteristics. The details of the nearshore circulation in relation to the disposal of effluents from this factory are presented here.

Thal is situated in the coastal approaches to Bombay harbour from the south, at a distance of 10-15 km from the harbour entrance (Fig.1). Thal village has 1.5 km long coast. From Alibag the coast tends north-northwestward for about 6 km to the northern end of Thal. The entire coastline is fringed with sandbanks and reefs, extending upto about 2 km offshore. Khanderi island lies at a distance of about 4 km from the shore. Underi islet is situated 2.5 km eastward of Khanderi island. The channel between Khanderi and Underi is narrow and is used only by small crafts with precise local knowledge. Thal reefs, the northern end of which is situated about 5.5 km northward off Underi islet, extend almost 5 km in the north-northeasterly direction. Thal shoal is composed of sand and rock, with several detached heads. Anchorage between Khanderi island and Thal is prohibited (Anonymous, 1975), and is very difficult for navigation.

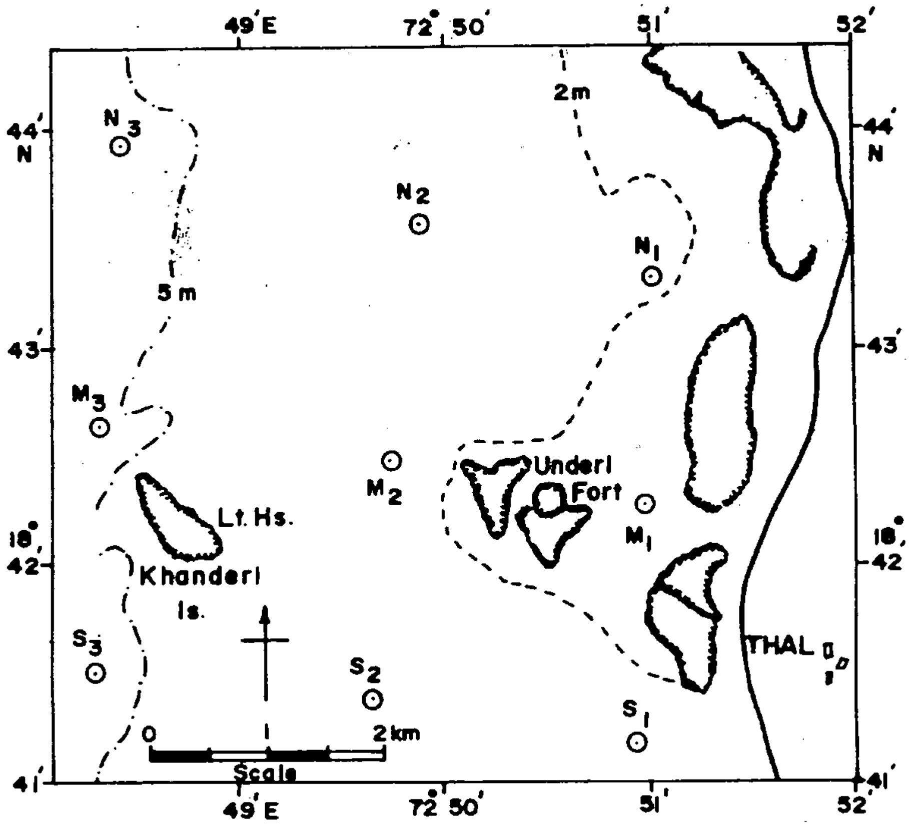

Fig. 1. Station location map.

The field observations were made along three transects (N, M and S) with three stations in each (Fig.1) during February-December, 1980. In addition, graduated tide poles were installed at M_1 (8.2.1980 - 11.3.1980) and at a sheltered point inside Thal creek (8.2.1980 - 27.2.1980). The reference points were levelled against the local Bench Mark. The readings were taken manually at 30 min interval during day-time, and at 1 hr interval during night hours continuously. The observations are shown in Figs. 2 & 3.

NIO rotor -induction current meter was used from an anchored boat to measure the current speed and direction at the surface (one metre below), mid-depth, and bottom (one metre above) levels. The observations covered spring and neap tidal conditions during pre- monsoon, monsoon and post-monsoon.

Drogues were also released at various locations in the vicinity of these stations during different stages of the tides, to track the trajectory of the surface water movement. The vane-float assembly was followed by mechanised craft and the positions were fixed periodically with the help of sextants and shore objects.

Tides - The tide at Thal is mixed semidiurnal (Fig.2). The time of occurrence of high and low water was approximately 30 min ahead of the corresponding time at Apollo Bunder,

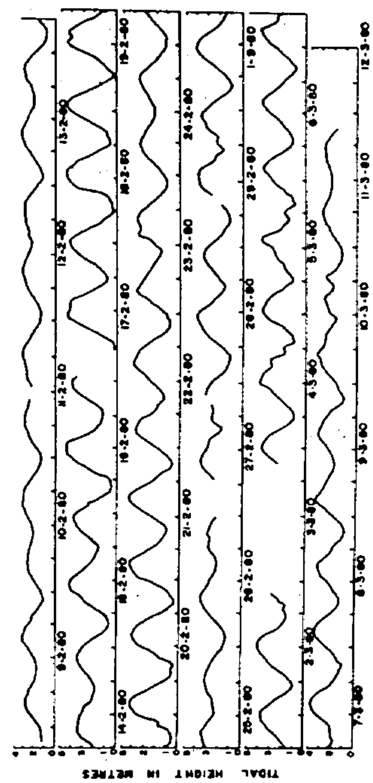

Fig. 2. Observed tides at Thal.

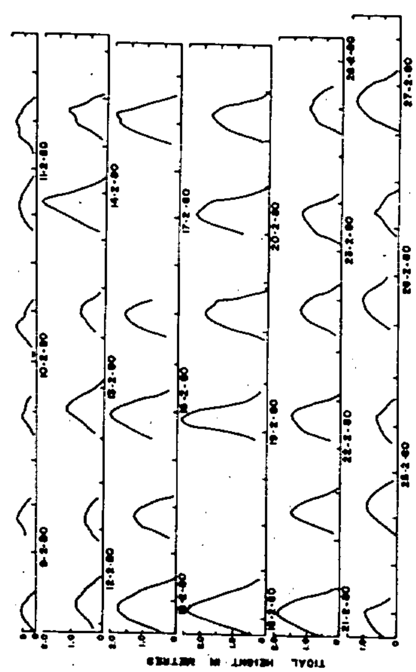

Fig. 3. Observed tides inside Thal Creek.

Table I. Predominant wave height and wave period for all directions during a year in 5° square grid off Thal (Source: Anonymous, 1989.

Month	Height (in metres)	Period (in sec)	Direction (in degrees)
Jan	0.5	5	030
Feb	0.5	5	330
Mar	1.0	5	330
Apr	0.5	5	300
May	1.5	5	270
Jun	2.5	8	240
Jul	3.5	8	240
Aug	3.0	6 - 7	240
Sep	1.5 - 1.0	5 - 7	270
Oct	1.0	5	270 - 330
Nov	1.0	5	0
Dec	1.0	5	030

Table II. Observed current speed (cm/s) off Thal (February to December 1980)

Stn	Depth	Spring		Neap		Medium	
		Max	Min	Max	Min	Max	Min
N_1	S	60	16	32	09		
	B	50	20	34	07		
N_2	S					85	11
	B					47	17
N_3	S			56	07		
	M			37	09		
	B			51	11		
M_1	S	87	02	46	04	62	7
	B	71	02	40	03	57	6
M_2	S	97	24				
	B	77	22				
M_3	S	74	10	59	12	(85)	08
	B	65	16	50	10	(77)	05
S_1	S					56	09
	B					47	06
S_2	S	102	18				
	B	95	07				
S_3	S						40
	B						42

Bombay Harbour (standard tide station). The amplitude is less than that at Apollo Bunder by a factor of 0.88 m. The tidal curve within Thal creek was distorted considerably (Fig.3) due to the presence of entrance bar and a basin.

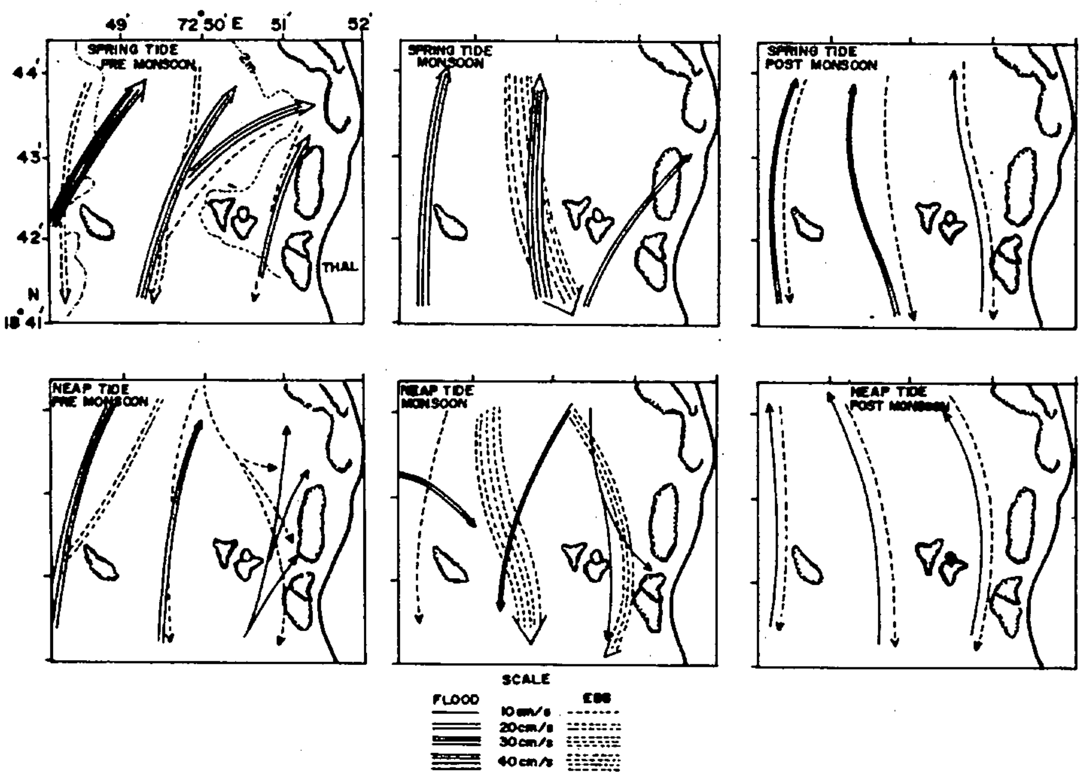

Fig. 4. Schematic representation of flow off Thal during different seasons.

Waves - The coastline is exposed to oceanic waves predominantly from the southwest and west (Table I) with a period ranging from 6 to 12 sec and with height occasionaly exceeding 8 m (Anonymous, 1982). Extensive refraction and diffraction of the waves would result in drastic changes in the distribution of wave energy along this shore with irregular bathymetry as seen from the beach profiles (NIO, 1980).

Currents - The currents in this area are predominantly tide-induced and hence vary considerably from spring to neap (Table II). Owing to the irregular geometry of the area, spatial variation in the current velocity has been noticed. Modifications are also effected by wind, land drainage and general (offshore) circulation characteristics. By the onset of the southwest monsoon, the tidal variations of currents are masked to a great extent; monsoon changes are characterised by fluctuations in the current velocity. While the surface to bottom variation in current direction was not appreciable, that in the current speed was substantial.

The observed currents showed that the flood currents were partially directed towards shore and the ebb currents were partially directed offshore, particularly during neap in the fair-weather (Fig. 4). The waters beyond Khanderi island described a course roughly parallel to the shore (in the general north-south direction). An overall shoreward drift of the waters could be noticed at shallow stations (e.g. M_1). The bathymetry in the vicinity of M_1 is irregular with shoals and rock outcrops. This station is in the lee of the island mass, and is, therefore, characterised by very low wave activity even during rough season.

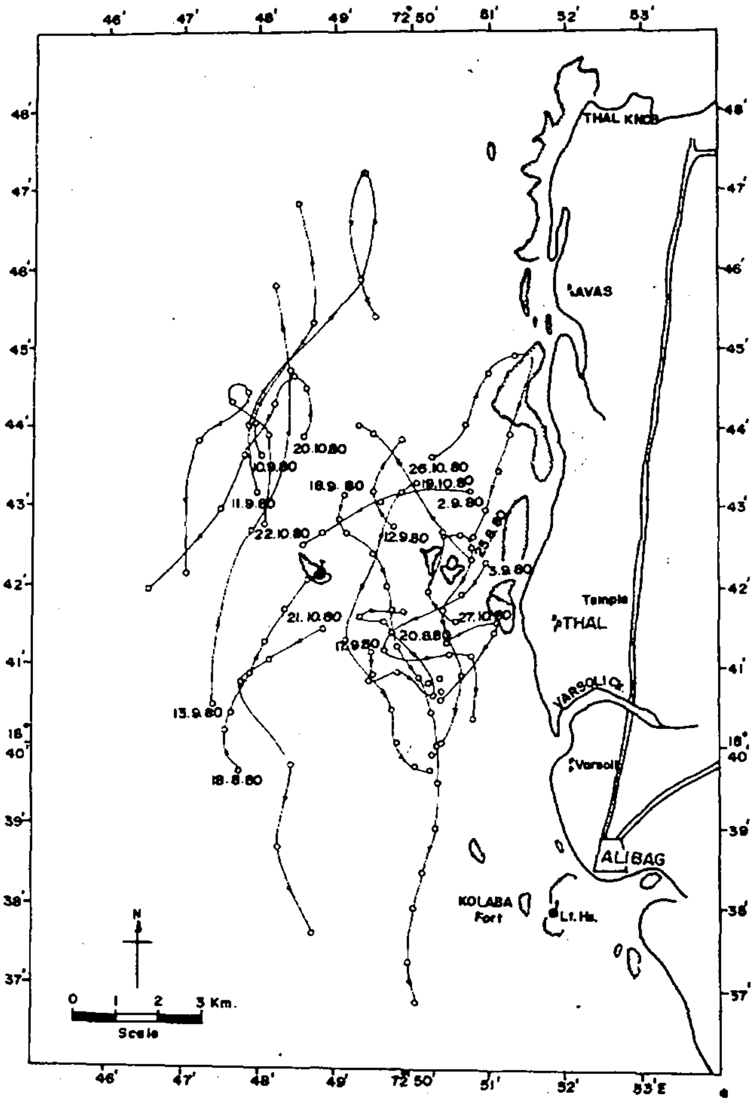

Fig. 5. Float trajectories off Thal.

Though the tidal current pattern was substantially modified during the southwest monsoon season, presumably due to wind and wave set up in the nearshore region, tidal currents at the offshore station M_3 were comparatively less affected by the monsoonal disturbances than those at the nearshore station M_1 (Fig. 4). Offshore component was remarkably absent at this station implying flow through the nearby creeks and channels. The currents at the northern and southern shallow stations had disturbed pattern.

The float trajectories (Fig. 5) confirmed that the waters near to the shore were driven towards the shore with flood tide. The drogues released at the offshore stations having depth more than 5 m described a course roughly parallel to the bottom contour. The drogues released nearshore, exhibited a tendency to form circulation cells with an onshore curvature. It was evident that the proximity of the two islands and the complexity of the sea bed profiles modified the circulation pattern of this region drastically. The circulation pattern in the middle transect (M_1, M_2 and M_3) was inconsistent due to rock outcrops and the irregular bed forms. There are possibilities of the currents funnelling through between the two islands as indicated by the intensification of the longitudinal current speed in this vicinity.

A typical one-day record of currents measured every 20 min with a direct reading current meter at N_3 during a fair day has been subjected spectral analysis by Suryanarayana and Swamy (1987). The spectra exhibited tidal effect more on the cross-shore components whereas the alongshore currents were prominently influenced by winds.

We note that the vertical shear in the current profile may dominate the diffusion pattern in this area. Substantial dispersion is expected from the horizontal diffusion alone. However, advective processes would set a limit to the effective dilution at a particular point in nearshore areas where closed circulation cells are present. Before attaining the desired dilution by shear diffusion processes, the effluent may be carried on to the nearest landmass, or get trapped in the circulation cell, particularly when the discharge is of continuous nature (Swamy, 1980). The dispersion in the southern portion of the islands appears to be limited by this factor. The islands also tend to restrict the flooding water in the southern section, whereas in the northern section, the flooding water would find a vaster expanse for the dispersion of the contaminants. The circulation in the middle transect is very inconsistent due to rock outcrops and proximity of the landmass, rendering the area comparatively difficult for systematic effluent discharge. The northern portion is, therefore, found more suitable for effluent disposal as viewed in terms of the advective current pattern.

From these considerations it was concluded that a location in the northern transect free from the coast and island effects, close enough to the shore for practical reasons, and deep enough to achieve effective dispersion was to be identified and confirmed through additional observations.

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