

CURRENTS AND SILTATION AT DHARAMTAR CREEK, BOMBAY

G. NARAYANA SWAMY, V. M. KOLHATKAR AND A. A. FERNANDES

*Regional Centre of National Institute of Oceanography, Seven Bungalows,
Versova, Bombay-400 061*

ABSTRACT

Hydrographic data collected in Dharamtar Creek during 1976-77 have been analysed. This showed that the waters in the Creek are well mixed and the salinity varied with the tide. The tidal currents are found to be generally strong. The distribution of suspended sediment load in relation to the tide showed that the rate of siltation in the Creek is not very high owing to the high rate of flushing. The areas south of Dharamtar Creek appeared to be prone to higher siltation.

INTRODUCTION

The hydrography of Bombay harbour has been well studied earlier. Pillai, Subbaratnam and Ganguly (1958) and Nair and Bhattathiri (1969) have carried out tidal current measurements in the harbour while the sediment transport in the harbour and the adjoining areas was studied by Sasry (1971). The radioecology of the Bombay harbour has been discussed by Patel, Mulay and Ganguly (1975). Maharashtra State Ports conducted some current observations along the Dharamtar Creek during the southwest monsoon of 1974. Various activities such as a scheme for sewage disposal by Bombay Municipal Corporation, the construction of water-intake jetty and the continuous utilisation of water from the Creek for cooling purposes by Oil and Natural Gas Commission and the construction of a bridge across the Creek connecting Karanja and Revas by Maharashtra Government have made this area quite well known in recent years.

In October, 1978 detailed current measurements were carried out by the National Institute of Oceanography (Bombay Regional Centre) in connection with the construction of water-intake jetty for the Uran Terminal for the Oil and Natural Gas Commission. The present paper describes briefly the tidal currents and the sedimentation pattern in the Dharamtar Creek.

The area of study adjoins the eastern limits of the Bombay harbour (Fig. 1). Dharamtar Creek, with Karanja in the north and Revas in the south, forms one of the tributaries joining the harbour on the south-eastern side. The river Amba empties at the head of the Creek. The tidal inlet is partially navigable. The tides in the area are semidiurnal. The currents are entirely governed by the tides during the non-monsoon seasons. During the rainy season (June to September), the ebb stream sets strongly (speed upto 4 kt) in a westerly direction out of Dharamtar Creek. Waves are generally low and the breakers cause negligible littoral transport along the Dharamtar shore which is mostly fringed with rocks. The bed is silty. About 0.84×10^6 m³ of silt flows into the harbour through all the creeks during the monsoon (CWPRS, 1963; Patel, Mulay and Ganguly, 1975). Average annual rainfall in this region is about 2000 mm.

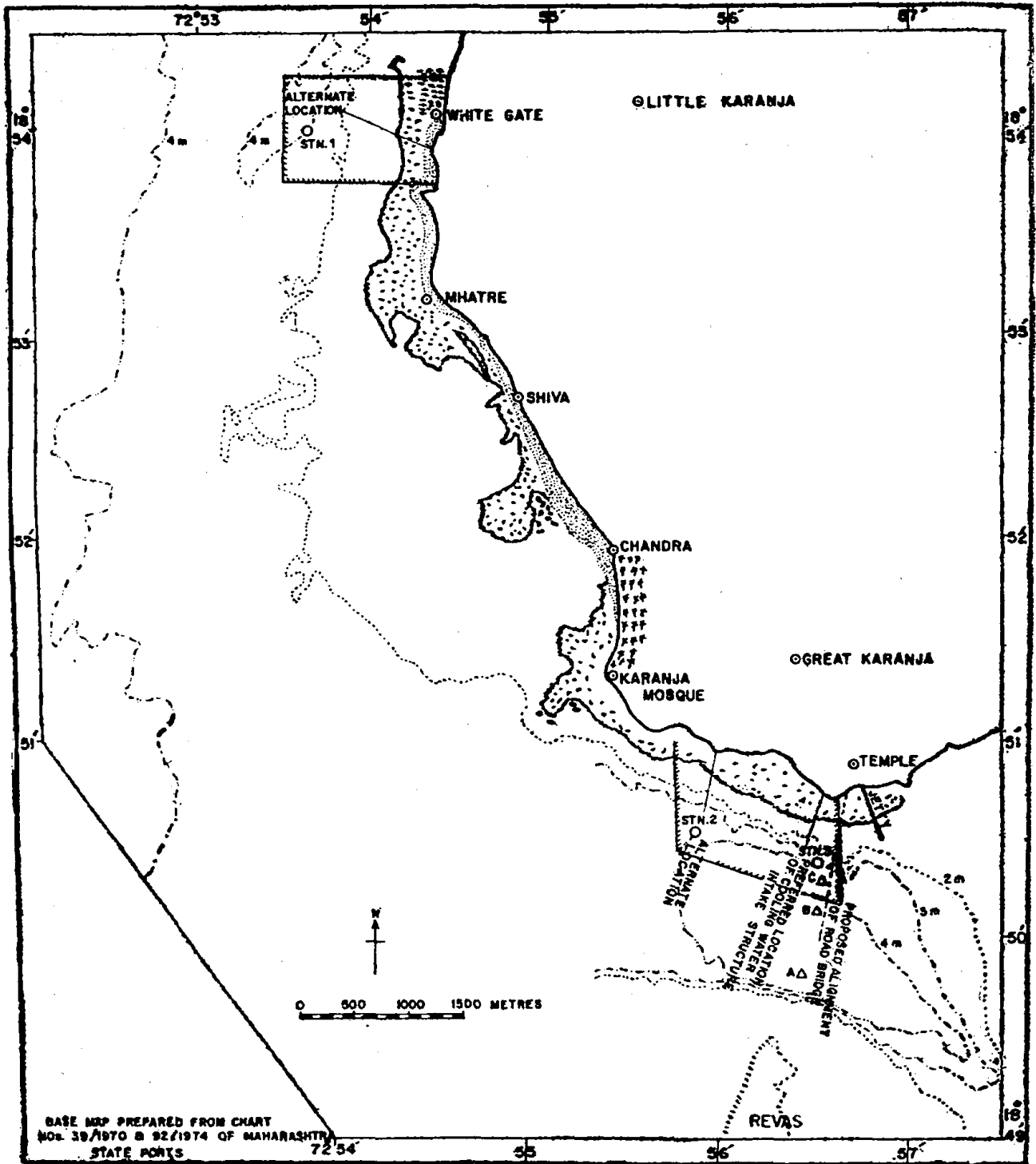


Fig. 1. Area of study and location of stations.

MATERIALS AND METHODS

Three stations (1, 2 and 3) were selected for observations and are shown in Fig. 1. These were preplotted and fixed with the help of a sextant. The vessel was anchored at each of the stations for a full tidal cycle (approx. 24 hrs) under spring and neap tidal conditions. Currents were measured using NIO made Rotor Induction Current Meter (DCM 100) and Lawrence and Mayo current meter (438 EE) at 1m below the surface and 1 m above the bottom. The observed currents at the three stations during spring and neap tides during October 1978 are presented in Fig. 2 (A-G) in the form of rose diagrams. The tide is also shown in Fig.2(A-G). The maxima and minimal values of these currents are given in Table I. Table II gives some summarised features of the monsoon currents at stations A, B and C based on the information available with the Maharashtra State Ports.

The water temperature was measured using ordinary thermometer (for surface water) and reversing thermometer (for sub-surface water). Water samples were obtained using Nansen reversing bottle and bucket sampler. Salinity was estimated following Knudsen method. Fig. 4 shows a typical diurnal variation of the temperature of the surface and the bottom waters. The monthly distribution of surface salinity and a typical diurnal variation of salinity (surface and bottom) based on earlier studies are given in Fig. 5.

For the estimation of suspended sediment load, water samples were filtered using Whatman No. 42 filter paper. Monthly average values of suspended sediment load at near surface and near bottom alongwith monthly mean values are presented in Fig. 6.

Fig. 7 represents the distribution of suspended sediments with the tides for different seasons. In this figure, the predicted tide at Apollo Bandar (Bombay) is also included. In Table III, the duration of the phases of the tide and the height at Apollo Bandar are given

Table I. Observed current speed (cm s⁻¹) at Dharamtar Karanja during October 1978.

Range	Tide	Station 1		Station 2		Station 3	
		S	B	S	B	S	B
Maximum	Spring	58	65	127	93	105	78
	Neap	39	24	70	48	49	34
Minimum	Spring	19	7	13	10	—	—
	Neap	0-5	0-5	0-5	0-5	0-5	0-5

Note : S=Surface (1 m below), B=Bottom (1 m above)

Table II. Observed surface current speed (cm s⁻¹) across Dharamtar Creek during July 1974.

Current	Station A	Station B	Station C
Maximum	139	139	154
Minimum	15	21	21
Flood average	61	78	75
Ebb average	89	94	91

Source : Maharashtra State Ports.

Table III. Tidal cycle periods and tidal heights at Apollo Bandar (Bombay).

Tidal cycle	Duration (Hours)		Height (Metres)	
	Monsoon		Non-monsoon	
	Spring	Neap	Spring	Neap
Low tide	5.85-6.95	5.20-6.95	5.91-6.60	5.45-7.38
High tide	6.20-6.92	6.32-6.92	5.93-6.38	5.30-7.40

Tidal cycle	Monsoon		Non-monsoon	
	Spring	Neap	Spring	Neap
	Low tide	-0.02-0.45	1.69-2.44	-0.11-0.55
High tide	4.67-4.82	3.18-3.46	4.41-4.95	3.13-3.70

The tidal changes at Dharamtar Creek with reference to the predicted tide at Apollo Bandar during 18-20th July, 1974 are given in Fig. 8. A general idea of the seasonal range (the maximum during the respective 3-months period) of the suspended sediment load, temperature and current speed (spring and neap) of the surface waters of Dharamtar may be obtained from Fig. 9.

RESULTS AND DISCUSSION

Temperature

The water temperature was found to vary in accordance with the air temperature. In this area, it is observed that the water temperature has seasonal extremes of about 23.5 and 32°C (Fig. 9). The temperature variation between surface and bottom was not very significant during the period of observation (Fig. 4). This indicates that the water is thoroughly mixed.

Salinity

The monthly average of the surface salinity (Fig. 5A) varies from about 25‰ (in August) to about 36‰ (in April). The water seems to be well-mixed; however, the variation of salinity during the passage of the tide was clearly noticeable (Fig. 5B).

Currents and tides

Based on the earlier studies conducted in the Dharamtar Creek, the maximum current speed was found to be about 2 m s⁻¹ (Fig. 9). The survey carried out by Maharashtra State Ports during monsoon (1974) indicated that the currents attained maximum value at C (Fig. 1) whereas, on an average, the currents were stronger at the mid-stream station B during the monsoon (Fig. 1 & Table II). The difference between the flood average and the ebb average was greater at A than at other stations. These variations might be due to the channelisation of the tidal currents.

During the observations made in October 1978, it was noted that both the surface (1 m below the surface) and the bottom (1 m above the bottom) currents were stronger at

the mouth of the Dharamtar Creek, whereas off Karanja the currents are relatively weak (Fig. 2, A-G). Surface to bottom variations in the speed were perceivable, although they were marginal at Station 1. Spring-to-neap variations in the current speeds were considerable at all the three stations (Table I). Station 1 experienced weaker currents presumably due to lesser funneling effect. The intensification of the currents at Station 2, as compared to the currents at Station 3, might be due to the boundary effects.

Earlier studies have shown that the flood-ebb direction of currents at Dharamtar is east-west, whereas towards north-west of Karanja, the currents take a north-south

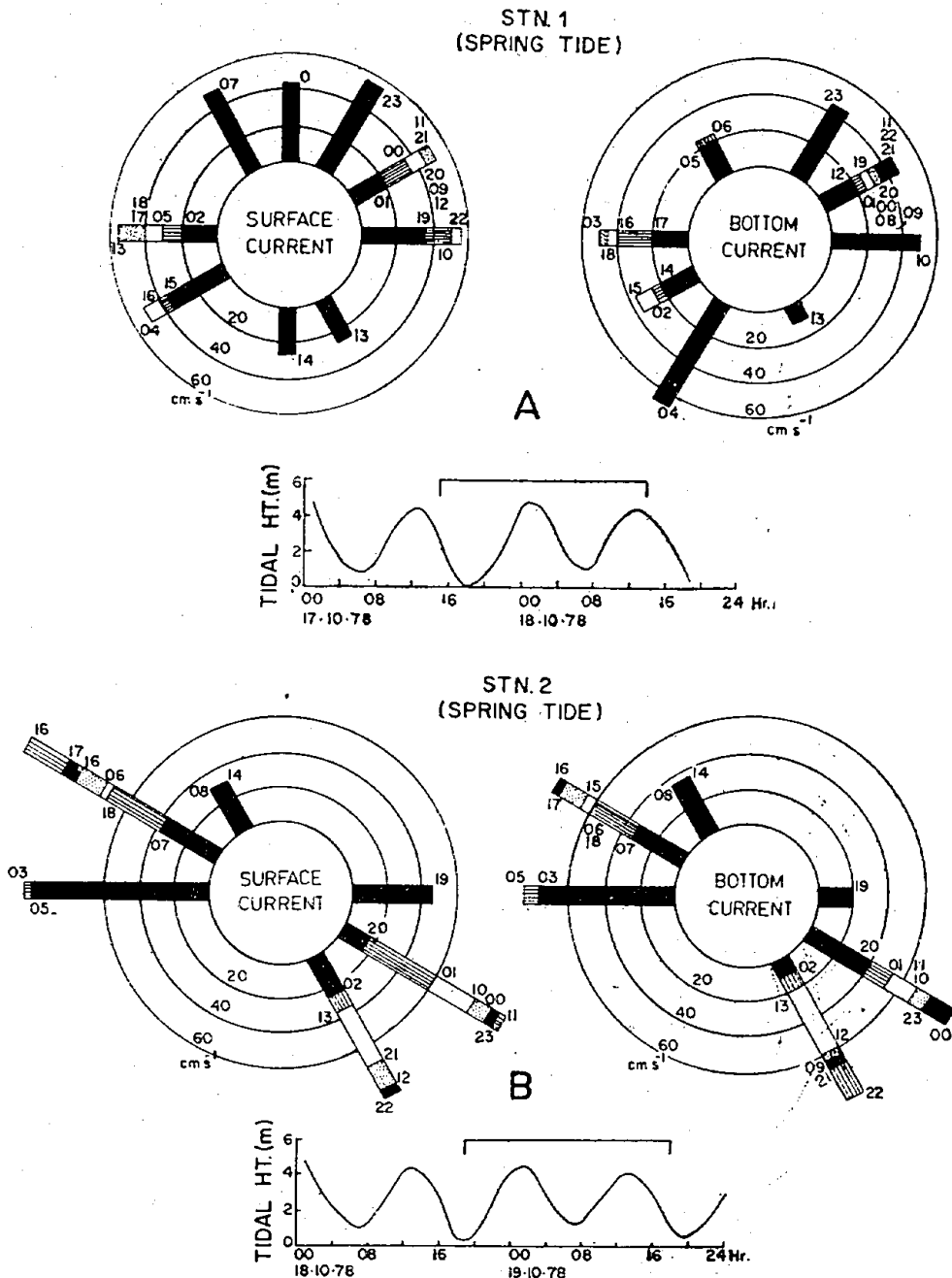


Fig. 2 (A-B). Current roses. (C-D continued).

direction. However, during the slack period, the directions are inconsistent. The ebb exceeds the flood velocity, and this is clearly so during the monsoon because of the velocity considerable influx of freshwater.

During the course of the present observations, the currents were found to be somewhat rotary at Station 1. The ebb and the flood currents at Stations 2 and 3 followed the orientation of the coastline during the spring tide. During the neap tide, however, this feature was not very prominent.

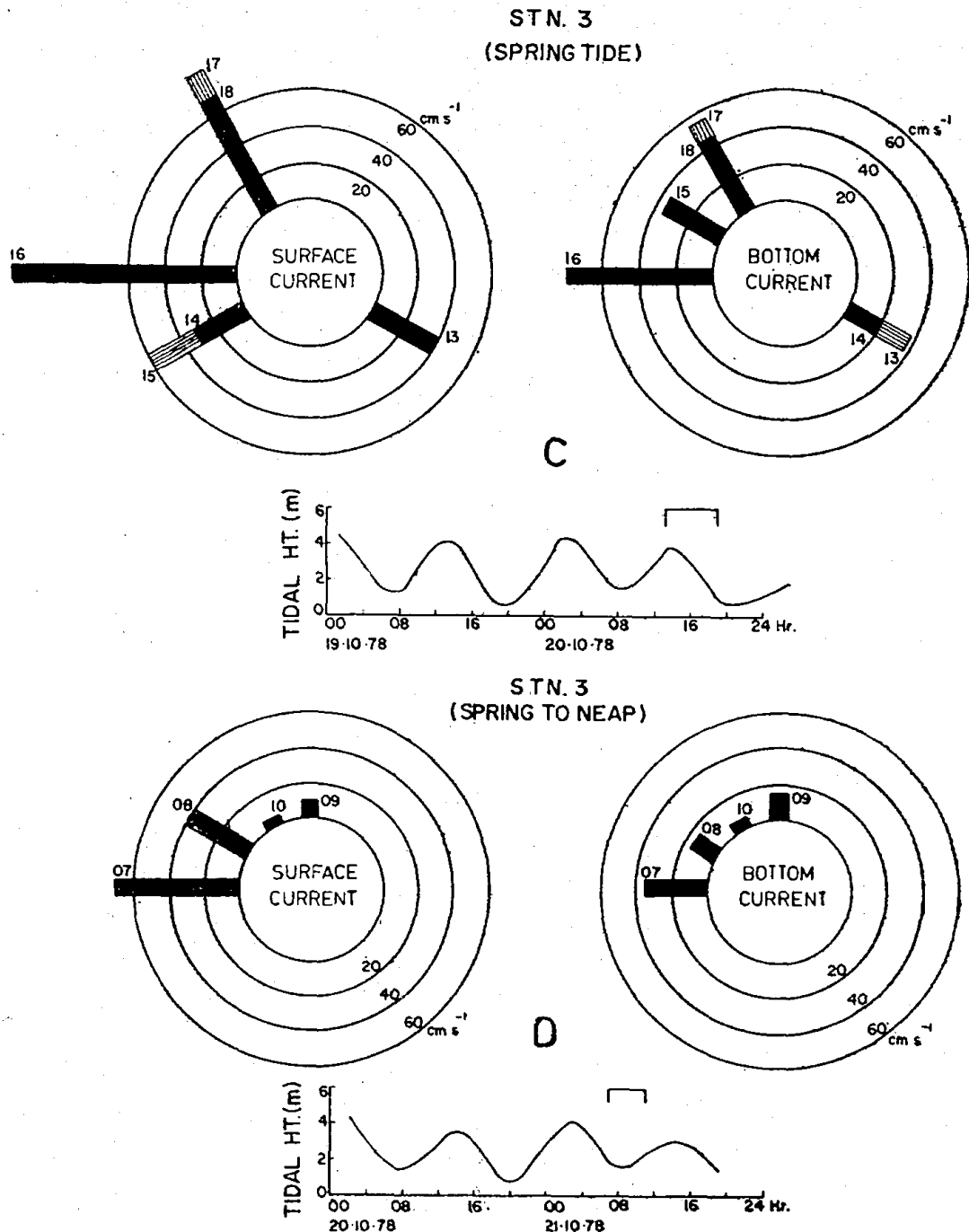
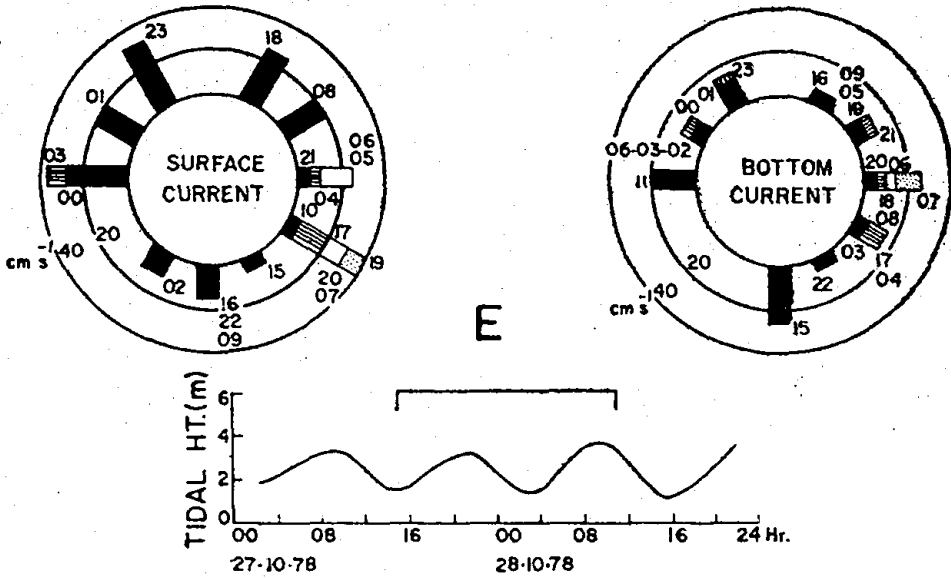
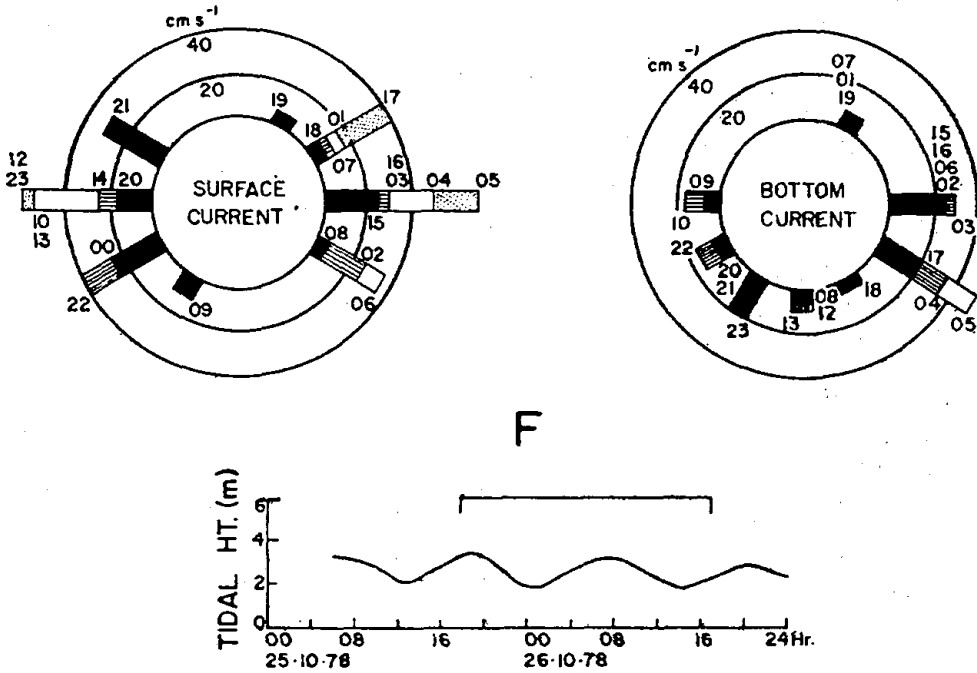


Fig. 2. Continued.

**STN. 1
(NEAP TIDE)**



**STN. 2
(NEAP TIDE)**



**STN. 3
(NEAP TIDE)**

Fig. 2. Continued.

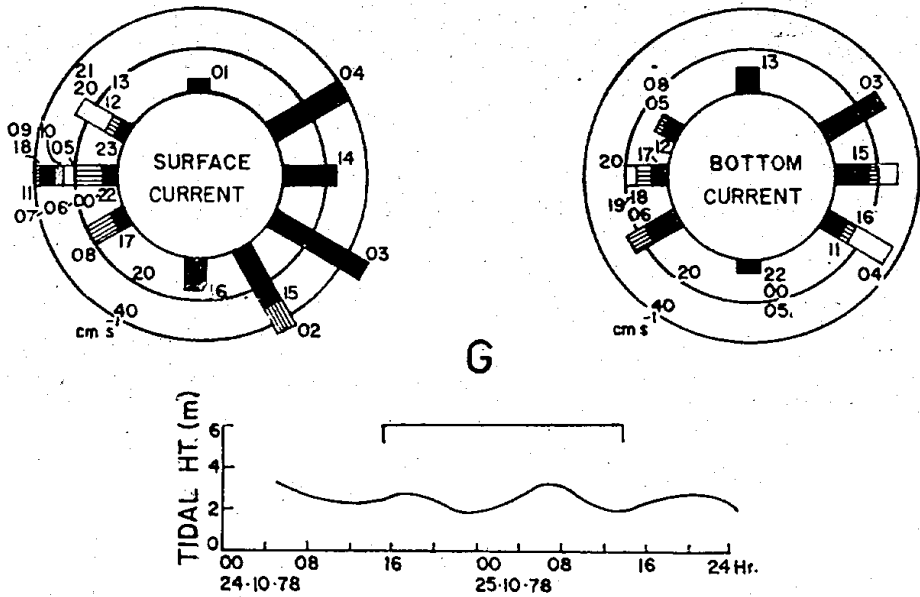


Fig. 2. Continued.

The currents are to be reviewed in the light of the existing tidal regime and the physical features of the site. It can be seen from Fig. 3, that the changes in the current speed follow the tidal rhythm. In this part of the coast, the tidal flow advances in a north-easterly direction and ebb towards southwest. Tidal front enters through the Bombay harbour and the Dharamtar Creek. The effects are felt first at the Dharamtar Creek which experiences high water ahead of the tide recording station at Apollo Bandar (Fig. 8). During the ebb, the Dharamtar Creek again leads. Monitoring during 1976-77 at the Dharamtar Creek

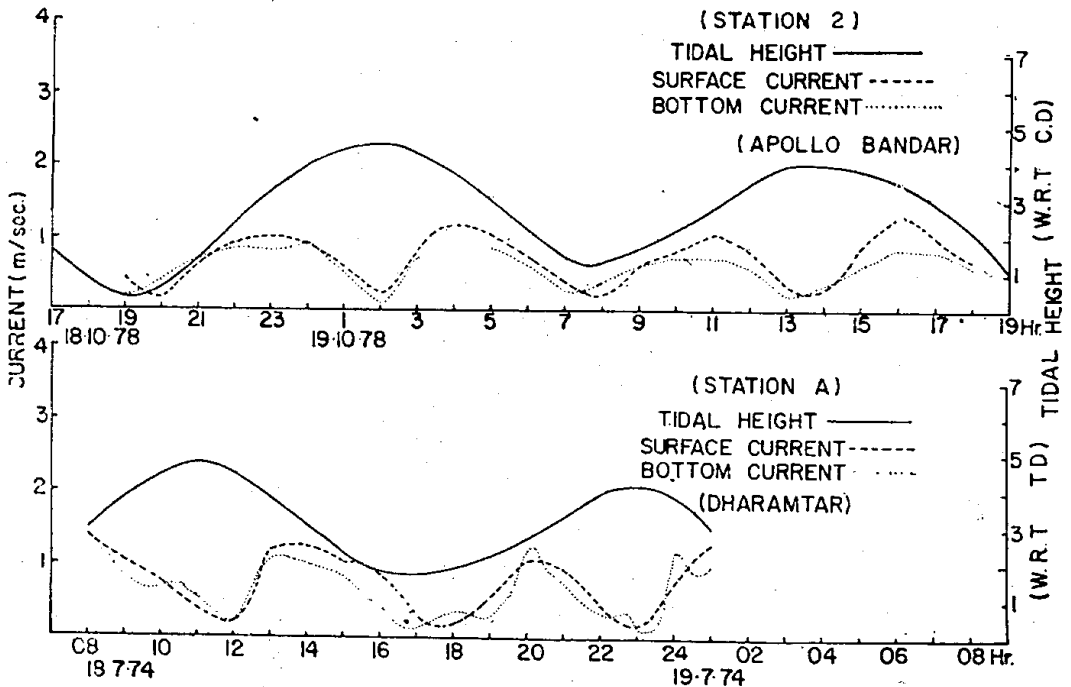


Fig. 3. Typical current distribution over a tidal cycle at two stations in the Dharamtar Creek.

indicated an average high tide lead of 30 min and an average low tide lead of one hour. The periods of occurrence of high and low tides at Dharamtar showed little variations from those recorded at Apollo Bandar (Table III). A critical examination of data showed that the low tides at Dharamtar area were slightly lower and the high tides usually higher than those at the Apollo Bandar (Fig. 8).

Suspended sediment load and siltation

Seasonal changes are well marked in the suspended sediment load of the Dharamtar Creek waters (Figs. 6, 7 and 9). During the monsoon season, the waters become highly turbid. As a result of the influx of silt-laden land drainage and the stirring up of the bottom mud-layer by strong currents, the suspended sediment load in the entire water is very high, exceeding 1000 mg/l. During this season, the amount of suspended material in the water column varies with the phase of the tide (Figs. 7 and 8). It is more during ebb flow than during the flood tide, since the silt-laden fresh water flow during ebb tide is more. The suspended sediment load is less during premonsoon season and the maximum sediment load during this period does not exceed 500 mg/l.

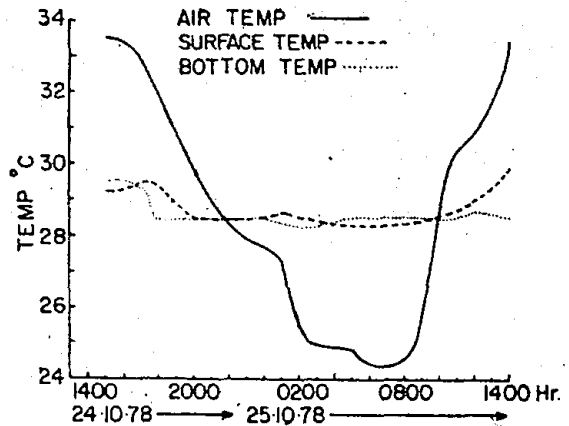


Fig. 4. Typical diurnal changes of air and water temperature at Dharamtar.

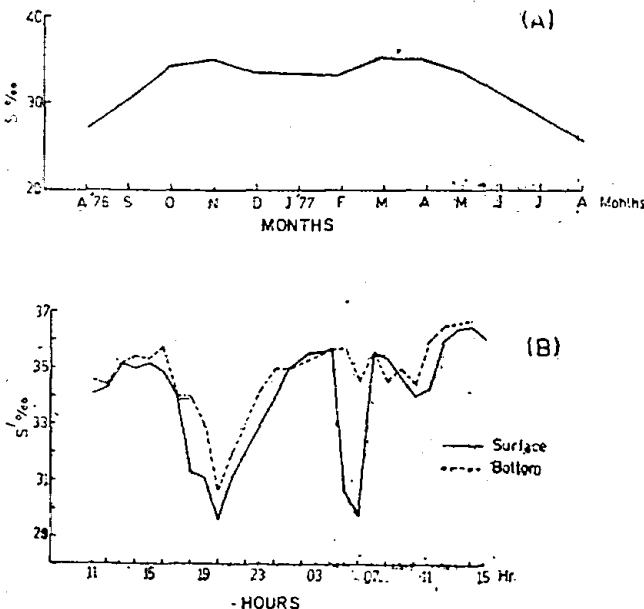


Fig. 5. Typical monthly (surface) (A) and diurnal (surface and bottom) (B) variations of salinity at Dharamtar.

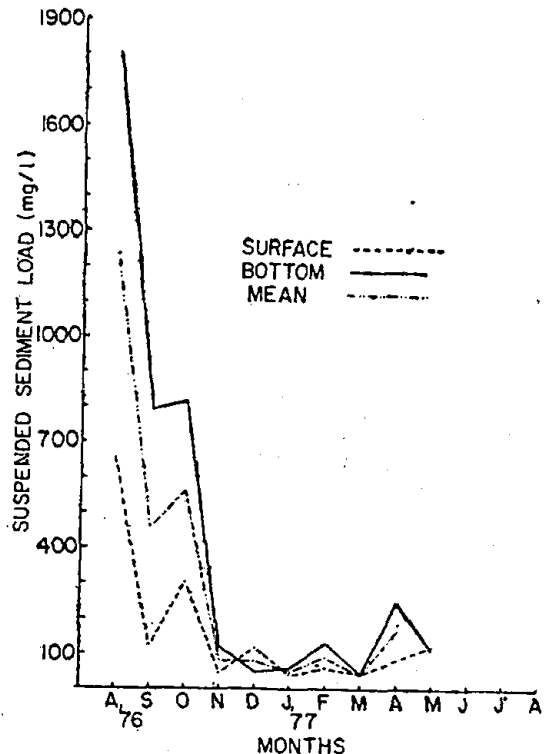


Fig. 6. Monthly average suspended sediment distribution (surface, bottom and mean).

— TIDAL HEIGHT
 ○ SURFACE SEDIMENT
 × BOTTOM SEDIMENT

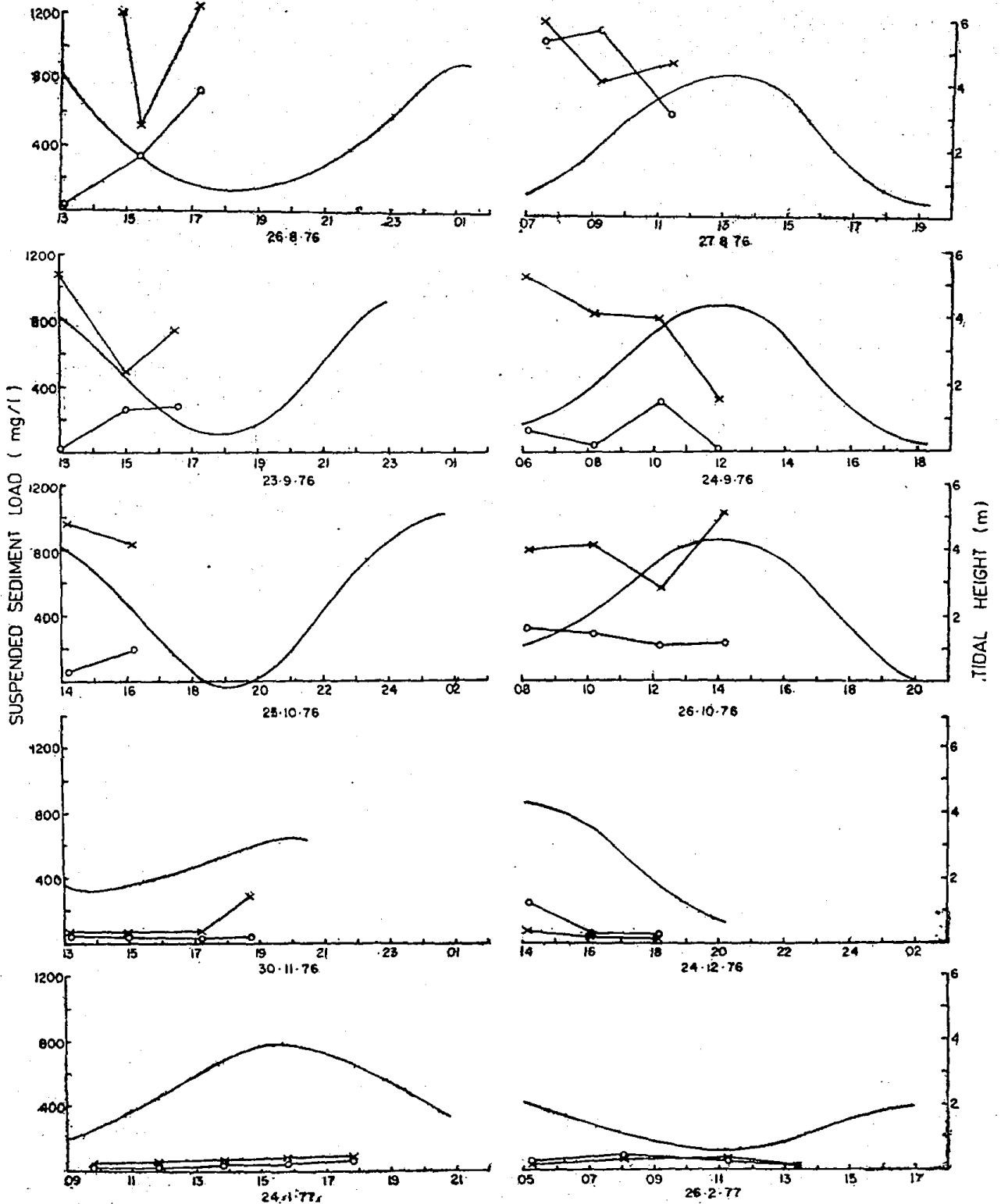


Fig. 7. Tidal distribution of suspended sediment load (surface and bottom) during different seasons.

The tidal influence on the sediment load was observed in all the seasons. The sediment load of the surface waters was found to be comparatively high when the currents were strong. This was remarkably so during the monsoon (Fig.7), when the terrigenous supply of sediment load was at its maximum. During the slack period, the sediment load of the surface water was low. However, the pattern of the suspended sediment load of the bottom water in relation to tide was reverse of that at the surface. This is presumably due to settling of the sediment from the surface to the bottom during the slack period. When the currents are stronger, sediment load in the surface water does not get enough time to settle down and hence the contribution from the surface to the bottom becomes minimal. During the post-monsoon months also the sediment load of the bottom water was found to go up during slack period (Fig. 6 & 7). For the rest of the tidal stages, the surface and the bottom values were almost same. The distribution of the monthly mean suspended sediment showed that the values near the bottom were higher than those at the surface in all the seasons (Fig. 6). Further, January onwards, no marked variation in the suspended sediment load with the tide was observed and the values for the surface and bottom were almost same.

The results of temperature and salinity observations suggested that the waters of Dharamtar were well mixed. Hence the contribution of stratification to the sedimentation process may be considered minimal in this area.

The probable movement of the silt near the mouth of the Dharamtar Creek has been discussed by Sastry (1971). McClure (1930-31) had suggested earlier that the siltation in the Bombay Harbour was mainly due to the movement of material from the sea into the harbour through its southern entrance. However, the amount of material present does not seem to cause significant silting in this part of the harbour. The material is likely to get accumulated in the region southward of the entrance of the Dharamtar Creek. The material cannot by-pass the Creek in the presence of strong currents. This was confirmed by later observations.

A note on the impact of dredging in the harbour area, on the siltation pattern of the environment is very relevant in this context. Patel, Mulay and Ganguly (1975) pointed out that to maintain the shipping channel, bottom material is dredged by port authorities and dumped towards the harbour mouth near Karanja side. Some of this material finds its way into the Dharamtar Creek. This is indicated by slightly higher radioactivity in the bottom sediment at the Dharamtar jetty than in the main channel south of Trombay.

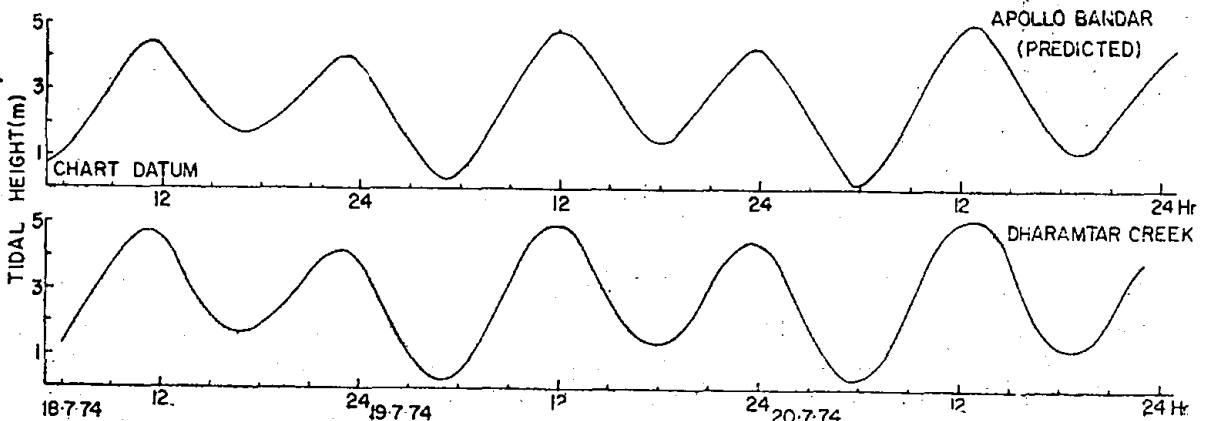


Fig. 8. Representative tides at Dharamtar and Apollo Bandar.

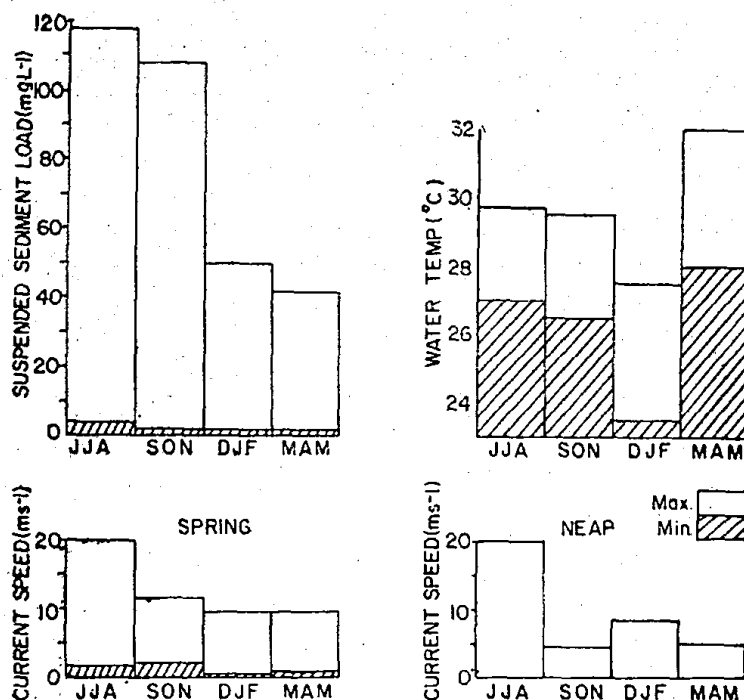


Fig. 9. Seasonal ranges (maximum and minimum) of suspended sediment load, water temperature and current speed of the surface water at Dharamtar Creek.

The large variation in the currents and their direct influence on the sediment transport complicate the siltation pattern of this region. The rotary currents if any, results in little net flow and hence lock up the suspended sediment in a particular area favouring siltation (Ippen, 1966). The tidal sweep and the duration of the slack periods, along with the quantum of suspended sediments govern the rate of siltation (Postma, 1967). At the same time, the location of shoaling is a function of the freshwater discharge from the upland direction and the tidal prism from the seaward (Neiheisel, 1966).

Dredging of the main shipping channel of the Harbour and the dumping of these sediments in the adjoining area must be carried out with caution so as not to upset the sedimentation balance of the Creek. Yet any man-made structure which may reduce the tidal flow and prism will have the impact of its own on the current regime and the subsequent siltation pattern. Since the needs of the construction of jetty-like structures and of the prevention of siltation in the neighbouring area are of somewhat contradictory nature, a compromise may have to be developed in such a way that the kinetics of the sea is not disturbed.

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