

## TIDAL MIXING IN DAHEJ CREEK WATERS

G. NARAYANA SWAMY\* AND R. VISWANATHA SARMA

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

### ABSTRACT

Mixing characteristics of a tidal inlet near Dahej at the mouth of Narmada River, Gujarat are examined in terms of tides, currents and bathymetry. The dilution potential of the Dahej Creek waters during a tidal march for a given rate of effluent discharge has been worked out. The allowable duration of discharge of the hypothetical effluent over a tidal cycle ensuring a specified minimum dilution has also been indicated to help optimise the degree of inplant treatment. The results suggested that the practical approach would be to carry out cost analysis based on the available discharge time and the possible inplant treatment for a given effluent output.

*Key words* : Tidal mixing, Narmada river, Dahej creek.

### INTRODUCTION

Increasing awareness of the dangers of pollution has necessitated the comprehensive study of the environment prior to the establishment of large industrial complexes. Since most of the chemical plants are located nearest to the freshwater sources, the waste water emanating from the factories is to be led to a disposal area far enough to avoid cross-contamination as well as environmental hazards. In certain cases the physical distance along the water body alone does not ensure the necessary dilution and the eventual dispersion of the toxic components. The effluents are to be dispersed by exposing them to a larger receptive medium and by physical stirring into it. By and large the marine environment offers such dispersing systems with a variety of choices and facilities, provided proper precautions are adhered to. Coastal creeks solely fed by tidal water form one such system with the effective flushing amounting to almost cent percent. The mechanics of stirring are strong enough to facilitate tremendous dispersion while the impact on the coastal community is fairly controllable.

Though such inlets are not abundant, their utility has always been sought for (Pearson, 1974). Dahej creek situated close to the mouth of Narmada River in Gujarat coast is one example (Fig. 1). During 1978-1979 the characteristics of this creek were investigated to examine its suitability as an alternate site where the effluents from an industrial complex in Bharuch could be discharged (NIO, 1980).

Dahej creek has direct access to the sea and a tidal prism having height of about 4 m sweeps the inlet twice daily. Contribution from the land drainage is

---

\*Present address : National Institute of Oceanography, Dona Paula, Goa - 403 004

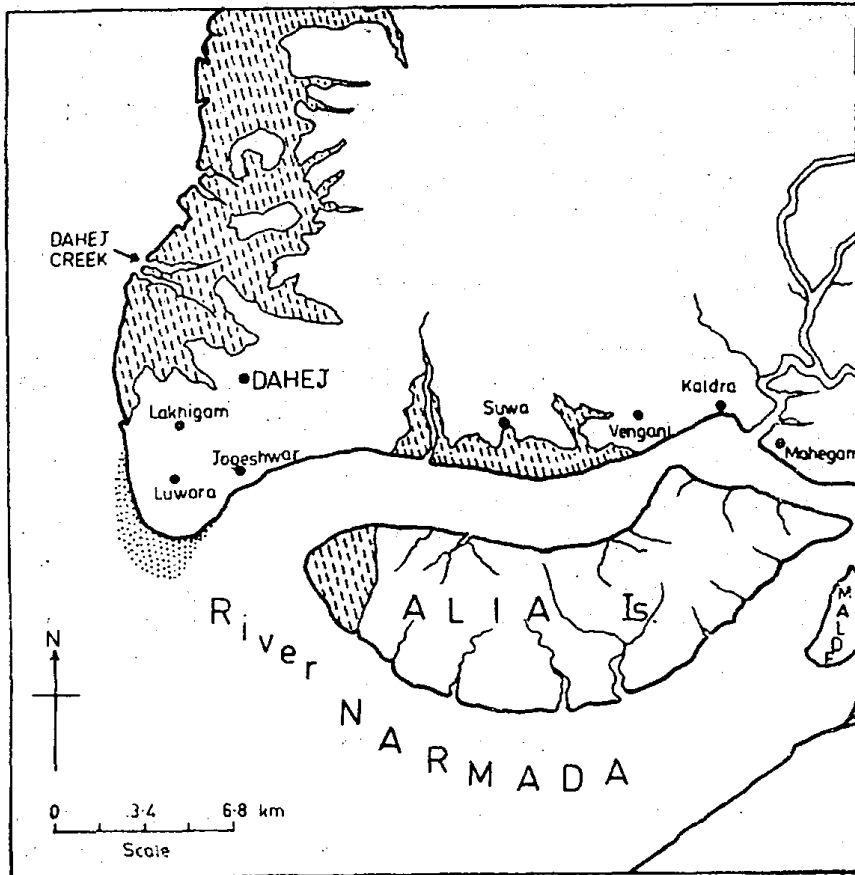


Fig. 1. Location map.

negligible and that too confined to a short spell of wet season during August-September. The creek runs with slight meandering over a stretch of about 2 km across the coastal mud flat. The landward portion is tapered and is connected to the Narmada delta.

#### METHOD OF STUDY

The creek as a whole was conceived of to be a single unit schematically. This assumption was all the more valid in the case of tidal flushing as each segment could be considered to behave in a uniform fashion as far as pollutant dispersion was concerned.

In order to establish the tidal regime, a tide gauge was installed at a point midway between the mouth and the head of the creek. The recordings were made at frequent intervals over complete tidal cycles. Typical tidal curves are shown in Fig. 2 and the results are summarised in Table II(a).

Currents were observed at the mid-channel of the creek (inner port) from a boat anchored fore and aft with 3-4 anchors to prevent drift by the tidal currents (Table I & II b). An element of error in the current observations was invariably in

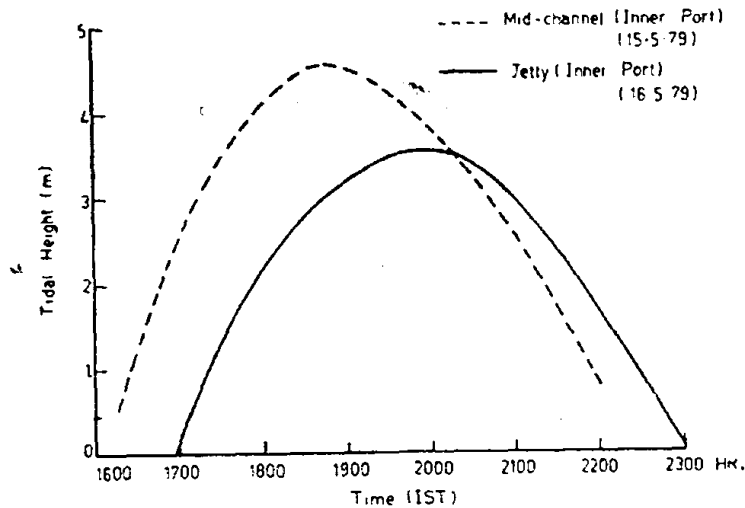


Fig. 2. Tide at Dahej Creek

produced as the water level changed very rapidly and lots of drift wood were encountered. Some observations were made off the mouth of Dahej creek in the open sea (Fig 3). These observations were made at an arbitrary station having a minimum depth of 10 m.

The cross-sections of the creek channel were mapped using a shallow-water echosounder mounted on a dinghy with outboard engine. The operation was carried out essentially during high water slack which was less than one hour. The currents were so dangerous that the dinghy could not be operated at other tidal stages. Bigger vessels were out of question owing to the navigational risks. The bathymetry at four sections situated at the upstream extremity, the inner port, between inner port and outer port, and the outer port (Sections I to IV respectively) are presented in Fig. 4.

The average flow across a particular transect, computed from the volume change within a given period of time and the area of cross-section is presented in Fig. 5.

All these data were utilised to compute the immediate volume of water a given volume of effluent, released continuously since the beginning of the tide, would come into contact with, and the potential dilution effected to it at a given instant. For this purpose the total volume of the tidal water available in the entire creek at a given time was calculated knowing the variation of tidal height, and the geometry of the creek. Different rates of effluent discharge (e.g. 5 MLD, 10 MLD etc.) were assumed and the ratio of the volume of tidal water to the volume of the effluent accumulated till that time was obtained. The apparent dilution factor ( $N_t$ ) was obtained thus:

$$N_t = \frac{x}{100} \frac{V_t}{v_t} \quad (1)$$

where  $V_t$  is the instantaneous total volume of tidal water in the creek,  $v_t$  the volume of effluent accumulated till that instant,  $x$  the percentage ambient mixing (assumed here

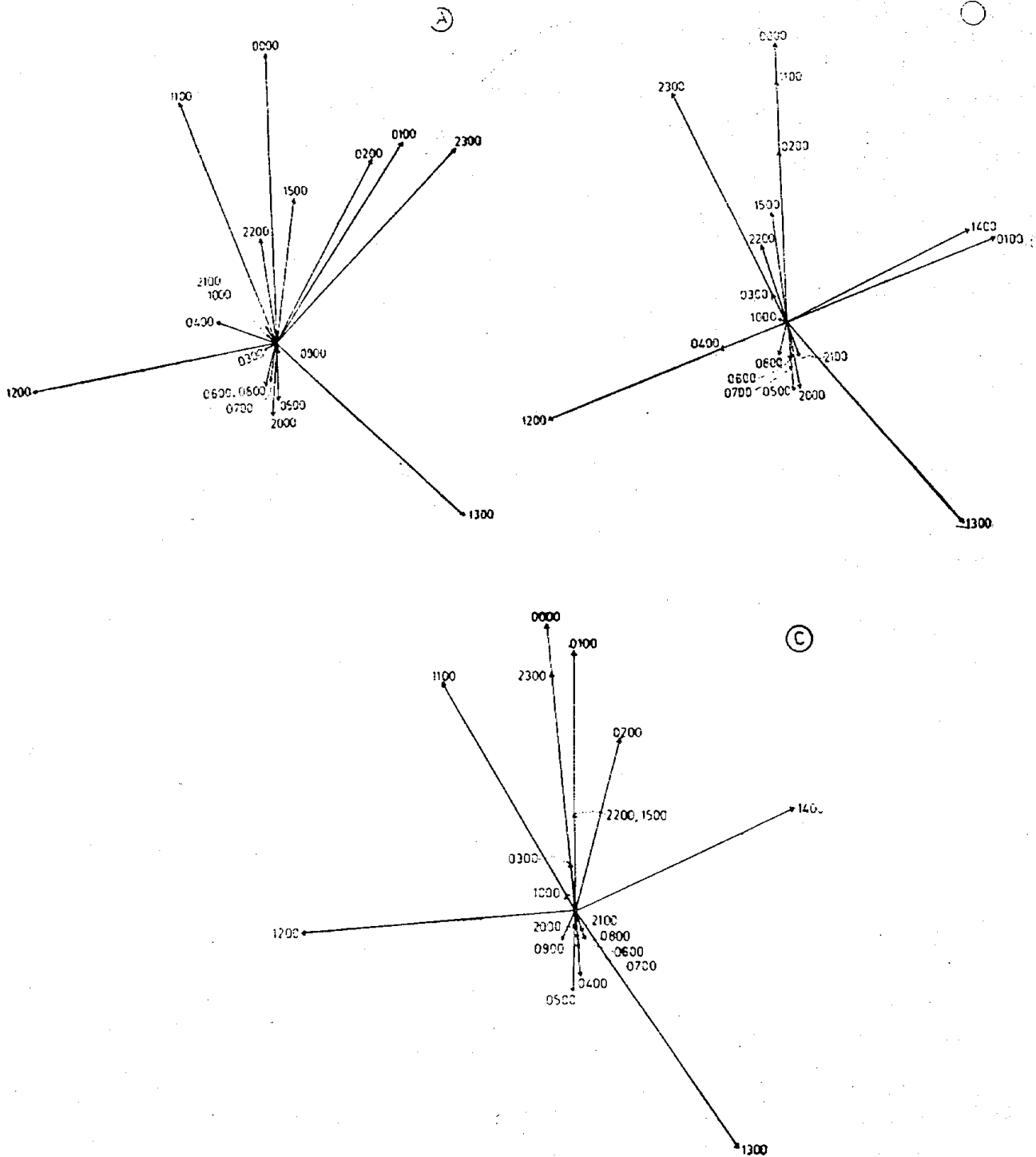


Fig. 3. Tidal current roses off the mouth of Lanej Creek. A — Surface; B — Mid-depth, C-Bottom.

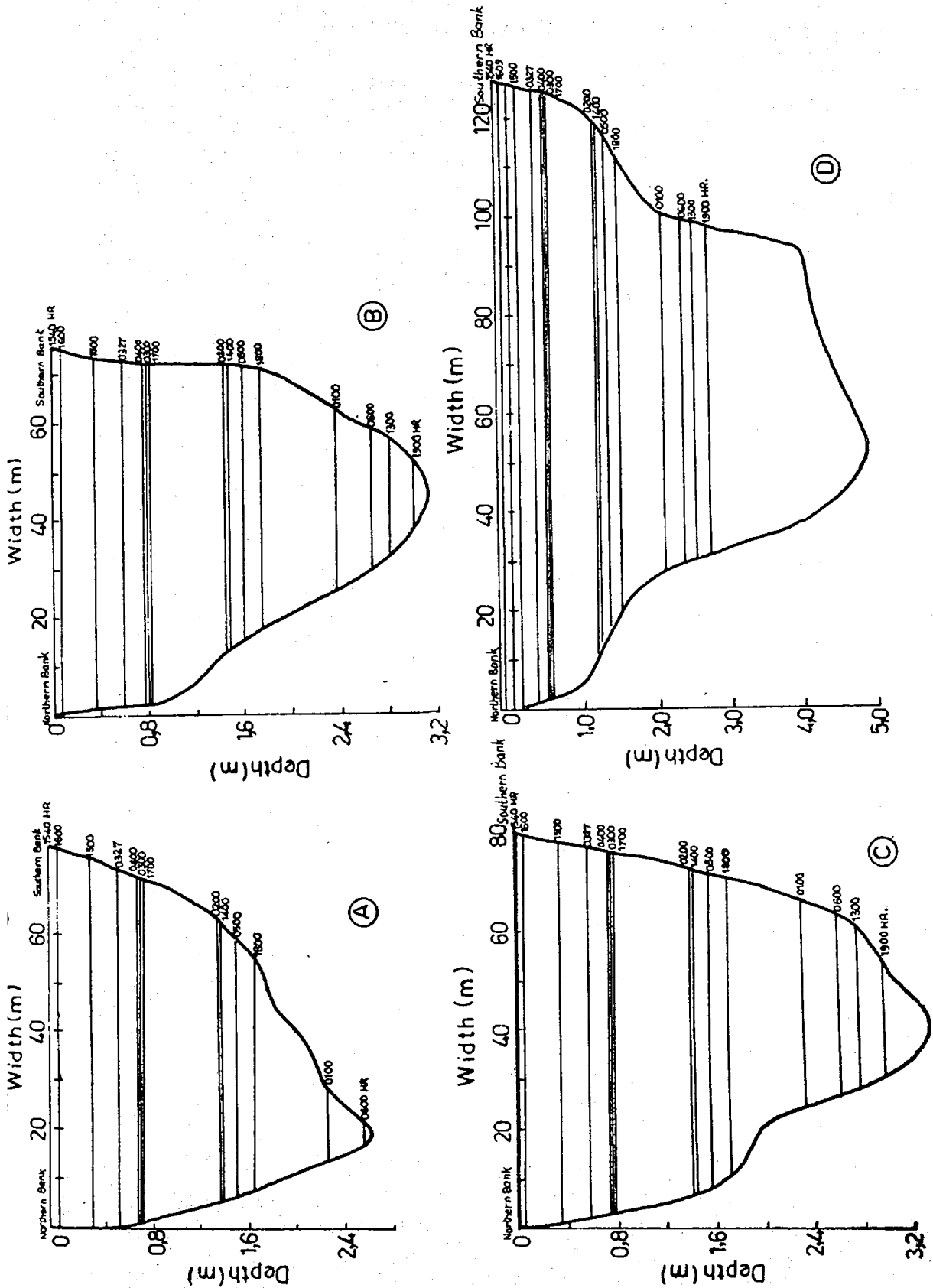


Fig. 4. Bottom topography across Dahej Creek (19.9.79). A - Upstream of Inner Port (Section I), B - Inner Port (Section II), C - Downstream of Inner Port (Section III), D - Outer Port (Section IV). Time in hours with corresponding water levels are also given.

Table I. Typical currents at Dahej Creek (19.9.79).

Time (hrs)	Tide	Depth (m)	Surface Current Speed (cm s <sup>-1</sup> )	Direction
0105	Fl	—	—	—
0125		0.5	45	US
0200		0.75	55	US
0300		1.5	13	US
0400	HW	2.0	(Nil)	—
0515	Eb	1.5	35	DS
0600		0.75	35	DS
0615		(Dry)	—	—
1310	Fl	—	—	—
1315		—	120	US
1400		1.5	80	US
1500		2.25	32	US
1630	Eb	2.5	15	DS

Note : US — Up Stream, DS — Down Stream, Fl — Flood Start, Eb — Ebb Start, HW — High Water.

to be 100 for convenience) and  $t$  the discharge time reckoned from the hypothetical low slack. Values of  $N_t$  plotted against  $t$  are given in Fig. 6. The time scale is apt to vary with the position of the point of discharge, marginally. For example, there is a difference of about 15 min between the time of start of tide at the mouth and at the Section II.

However,  $N_t$  would be an underestimate of the potential dilution of the effluent, during ebbing phase of the tide. During ebb a fraction of the effluent similar to the fraction of tidal water escaping from the creek also finds its way out of the creek. Thus, though the instantaneous volume of tidal water available for mixing in the entire creek during ebb is almost equal to the corresponding tidal stages during the flood, the dilution factor tend to increase in magnitude as the effective volume of the effluent present in the system is diminished. This is represented by the relationship,

$$N_t' = \frac{x}{100} \frac{V_t}{v_t - (V'/V_t) v_t} \quad (2)$$

where  $N_t'$  is the enhanced dilution factor and  $V'$  the amount of tidal water escaping from the system along with the ebb current. The mixing is assumed to be cent percent ( $x = 100$ ).

Based on this, the distribution curve  $N_t$  vs.  $t$  is modified into  $N_t'$  vs.  $t$  for the ebbing stage and is shown as dotted line in Fig. 6.

## RESULTS AND DISCUSSIONS

The relationship of the tide at Dahej to that of the nearest standard port (Bhavnagar) is given in Table II and may be made use of for the determination of tidal stages at Dahej at a required time. Since the channel dries up after a stage of the ebb tide the dotted portion in the tidal curve (Fig. 6) is virtual.

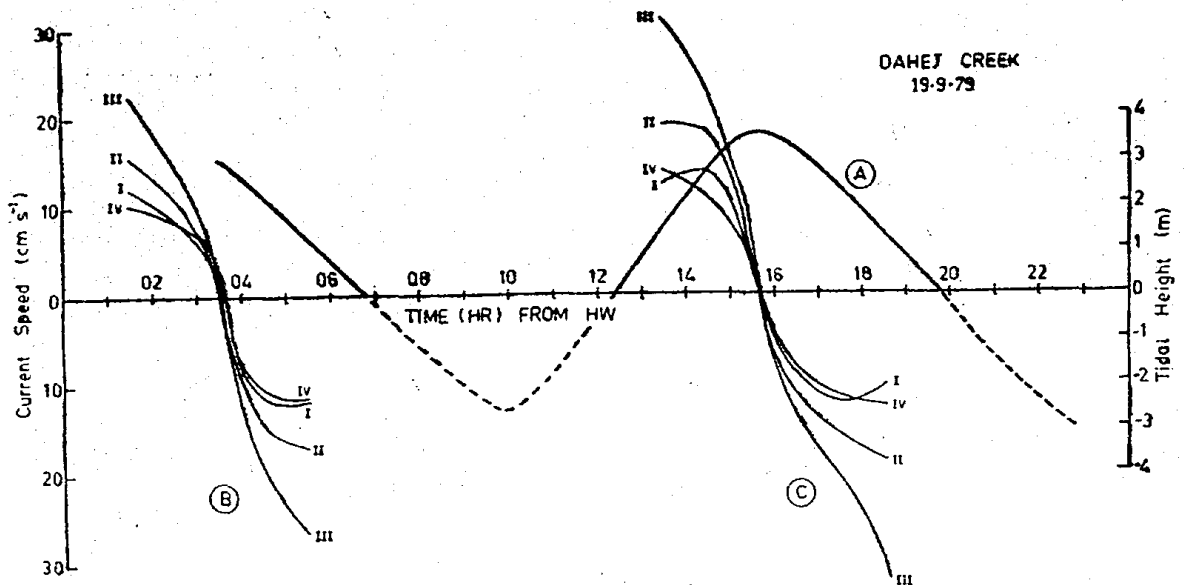


Fig. 5. Computed tide (Curve A), and average cross-sectional tidal currents (Curves B & C) across sections I-IV at Dahej.

The average flow across a particular cross-section seemed to agree with one-third of the value of the surface current recorded at the middle of the channel (Fig. 5). It may be noted in Fig. 5 that the cross-sectional mean current curves at Sections I and IV which are located at the upstream and downstream extremities of the creek respectively, are remarkably similar though the causative elements might be entirely different. The currents at the mouth are smaller owing to the increased sectional area while at the head the reduction in currents are presumably due to hydraulic factors.

Fig. 6 summarises the results regarding the potential dilution of the Dahej creek waters. The curves correspond to cent percent ambient mixing with the available volume of tidal water. It may be noted that the current profile has direct bearing on the ambient mixing rate among other factors. However, this paper does not purport to estimate the mixing rate other than indicating the functional relationship between discharge rate and discharge time. The pattern of the dilution curves remains essentially the same for different rates of ambient mixing. The period over which

Table II. Summary of tides and currents at Dahej.

(a) Tide :		(b) Current (cm s <sup>-1</sup> ) :		
Average range	: 2.6 m	Season	Surface (Max)	Bottom (Max)
Average flood period	: 3 hrs	Dry	105	75
Average ebb period	: 3 hrs	Wet	120	—
High water lead WRT Bhavnagar	: 0 hr 22 min			
Ratio of tidal range WRT Bhavnagar	: 0.3			
Maximum tidal range	: 4.0 m			
Spring average range	: 3.8 m			

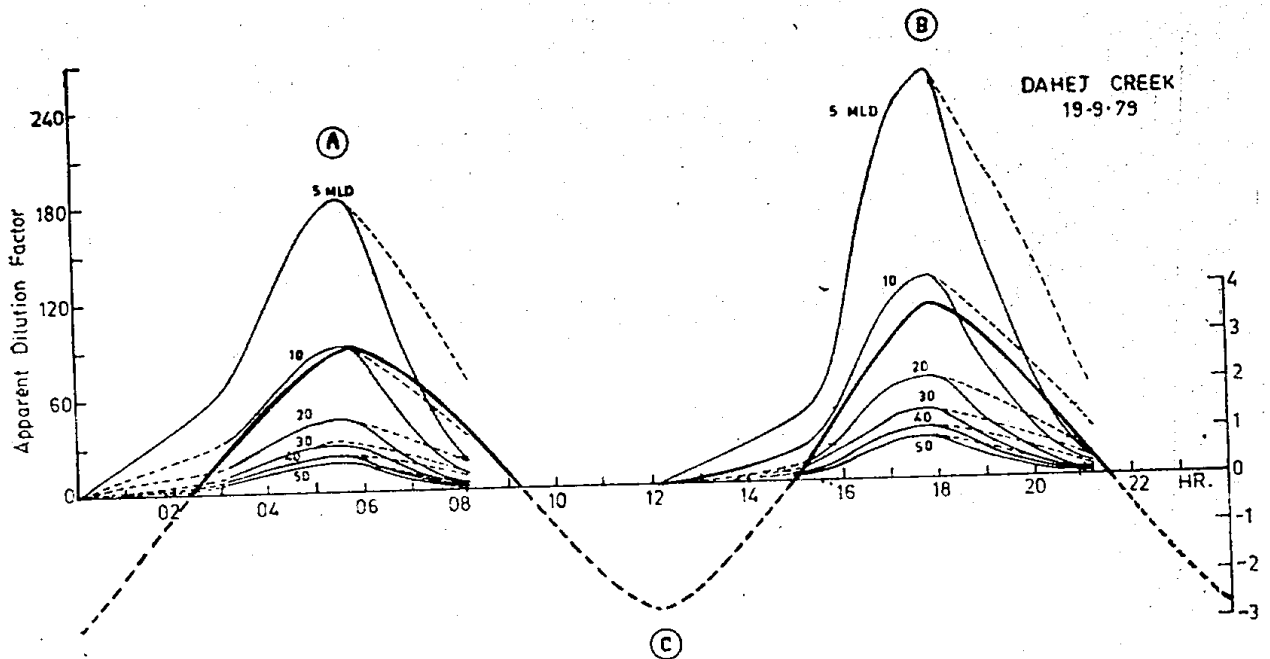


Fig. 6. Apparent dilution in Dahej Creek waters (Curves A & B) at different stages of the tide (Curve C) for various discharge rates.

the effluent can be released to ensure a threshold dilution, decreases with increasing rate of discharge of the effluent. It may also be noted that the period over which the effluent can be released is extended by an hour if we also consider the fractional removal of the effluent associated with ebbing currents.

The volume of the effluent that could be accumulated from the beginning of the tide till the tidal stage at which the threshold dilution is available need not necessarily be taken into account as the real discharge will commence only when the threshold dilution is assured. So the dilution curve would be more peaked than the one presented here depending on the minimal dilution requirement. The augmentation of  $N_c$  could be calculated once the threshold dilution requirement is known.

For a given discharge rate, the minimum dilution requirement can be lowered by inplant treatment and the duration of release can be further extended. For example, for a discharge rate of 10 MLD, minimum 50 times dilution is ensured for nearly 4 hours, while if the toxicity is reduced to half before discharge the minimum dilution requirement would be 25 times, and the effluent can be discharged for about  $6\frac{1}{2}$  hours. At the same time if it is feasible to dilute the effluent, say two times before discharge, the effluent emanating at a rate of 20 MLD could be disposed off safely for about 4 hours. Although it may appear that predilution before discharge does not alter the discharge time materially much, pre-dilution enables work with any ambient dilution (assumed till now 100%) of lower degree. In practice it will work out to be a matter of cost analysis based on the available discharge time, allowable toxicity and the possible inplant treatment for a given rate of effluent flow.



## ACKNOWLEDGEMENT

The authors are indebted to Dr. S. Z. Qasim, former Director, National Institute of Oceanography, for extending facilities for this study and for his constant encouragement. Sincere thanks are due to Dr B. N. Desai for his advice and guidance. The authors are grateful to their colleagues for helping them in the field data collection in extreme conditions. This study was sponsored by the Gujarat Narmada Valley Fertilizers Co. Ltd., Gujarat.

## REFERENCES

- NIO, 1980. Feasibility of Disposal of Effluents from the GNFC Plant into the Narmada River, *Technical Report, NIO Regional Centre, Bombay.*
- Pearson, Erman A., 1974. Conceptual design of marine waste disposal systems. In: *Discharge of Sewage from Sea Outfalls*, Proceedings of the Symposium, London, 27 Aug. — 2 Sept. 1974, edited by A.L.H. Gameson.