

# MODELLING OF COASTAL CURRENTS AND THERMAL PLUME DISPERSION -- A CASE STUDY OFF NAGAPATTINAM, EAST COAST OF INDIA

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## ABSTRACT

Thermal plume simulation has been carried out using a 2D model to understand the nature of spreading and rate of cooling of warm water discharge from a proposed outfall in the nearshore region off Nagapattinam. Four months representing the monsoons and the transition periods are selected to study the seasonal variability of simulated currents and thermal plumes. The plume showed northward spreading during March and July and southward during December. During October the spreading was mostly around the outfall with a weak southward component.

## 1. Introduction

The coastal currents off Nagapattinam undergo changes in their magnitude depending on the semidiurnal tide, but no reversal in the direction with the tide is noticed especially when the currents are of significantly large magnitude. However, reversal in the direction is noticed with respect to seasons when the wind direction reverses. Therefore, the predominant factor driving the currents is the seasonally reversing monsoon winds. Considering the annual cycle of observed and climatological winds, the following four periods can be identified for this region: the pre-monsoon, south-west monsoon, post monsoon and north-east monsoon. These four periods are

characterised by distinct coastal currents (Babu et al, 1998). Therefore, winds, currents and tides for March, July, October and December, representing the four periods, are selected along the open boundaries for simulation of currents in the area. Thermal plume mapping has been carried out to confirm the suitability of the intake and outfall locations. It is proposed to keep the intake and outfall facilities along a line normal to the coast at about 940m and 350 m respectively. Warm water is discharged at a rate of  $36,340\text{m}^3/\text{hr}$  through a diffuser at a depth of 4.1m. The results obtained are used to determine the extent of horizontal spreading, rate of

cooling and possible re-circulation of the warm water into the intake point, if any.

## 2. Model description

The 2D vertically integrated shallow water momentum equations for a Cartesian co-ordinate system with x-axis directed eastward, y-axis northward and the z-axis positive downward, are used in the model (ACRi 1994). The discretized form of the governing equations are obtained by integrating them over each element in the grid. Solutions for current components and tide at each node are obtained by solving the algebraic equations of each of the variables. In order to carry out simulation of currents and the thermal plume, the domain is divided into 80X43 square grids of 50m length; measured depths, speed and direction of winds and sea surface temperature are given as input to the model. The frictional stress at the bottom of the basin is computed using the near bottom current velocity and a constant friction coefficient (Simons, 1980). Water level variations at the open boundaries are given either from the measured values or from the Tide Tables (Anonymous). The initial and boundary values of currents are selected from the resolved components of observed currents. A time step of 6s is used as given by the CFL criterion (Ramming and Kowalik, 1980)

## 3. Simulation of currents

Simulation of currents have been carried out for the four periods represented by March, July, October and December. The simulated Currents for March and July

showed northward direction; currents intensified during July with the intensification of Southwest monsoon. In October the currents are very weak and directed southward. The reversal in current direction is due to the reversal in the wind system during October. December exhibited intensification of currents in the southward direction with a weak westward component. The currents simulated for different seasons are given in Table 1.

Month	U-comp	V-comp	Dir
	m/s		
March	-0.06 to 0.08	0.02 to 0.40	N
July	0.00 to -0.05	0.20 to 0.45	N
Oct	-0.03 to 0.05	-0.04 to 0.12	S
Dec	-0.15 to -0.01	-0.21 to -0.61	S

Table 1. Simulated currents off Nagapattinam

During March, the U components (east-west) of observed currents varied from -0.01 to 0.02m/s and the V components (north-south) from 0.10 to 0.25m/s. The water level changed from 0.20m to 0.58m between low tide and high tide. The simulated U-components varied from -0.06 to 0.08 m/s and the V-component from 0.017 and 0.40m/s. The currents are predominantly northward with a weak eastward component. Similar to March, flow pattern of July also indicated the dominance of a northward current. In October, the south-westerly winds reversed into north-easterly and the speeds are too low. As a result the currents are also very

weak. In December the simulated currents showed a southward current, flowing parallel to the coast. The model results agreed well with the measured currents and predicted tides in the region for the respective periods.

#### 4. Thermal plume

A continuous discharge of warm water (5°C above the ambient temperature) is introduced at the outfall after 5400 sec when the model stabilised. The results of the plume movement for the month of March with an ambient temperature of 30.0°C are analysed for 3 hrs, 6 hrs and 12 hrs of discharge. During a tidal cycle (12 hrs) the plume crossed a maximum distance of 1150m in the northerly direction and the core attained a temperature of 33.2°C (Fig.1).

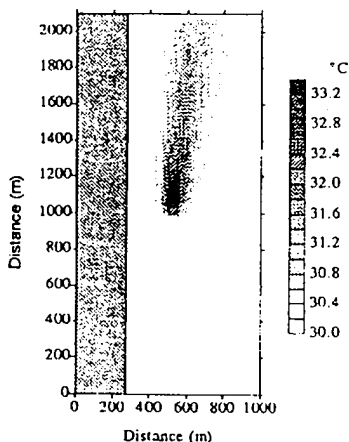


Fig.1 Thermal plume after 12 hrs in March

During July the temperature increase at the core is 1.6°C and the direction of spreading is similar to that of March. In October the plume appears to spread around the outfall with a weak southward southward movement. The net increase at the outfall during a tidal cycle is 3.6°C. The plume

showed strong southward spreading during December with an increase of 2.4°C at the core above the ambient temperature of 27°C (Fig.2).

As the purpose of the study is to determine the suitability of intake and outfall locations, an analysis has been carried out to study the lateral extent of the plume. We have confined the northern boundary to 1.15km from the discharge point. The results suggested that the lateral movement of the plume is very much restricted by the physical processes prevailing in the environment. It is evident from the movement of the plume that, if the outlet temperature is well within +5°C from the ambient, the possibility of warm water discharged at the outfall to move close to the intake point is very remote, even

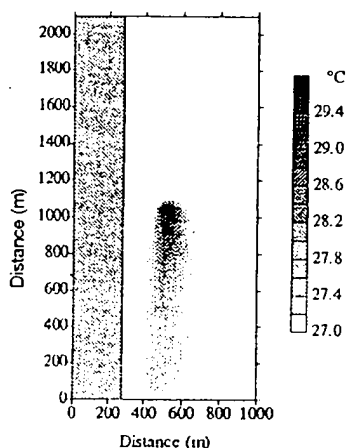


Fig. 2 Thermal plume after 12 hrs in December

during low wind and low current situations.

The study showed that after 12hrs of discharge about 68% cooling takes place at the discharge point for the months of July, October and December. However, during pre-monsoon period (March) the ambient temperature being maximum and the

currents minimum, the cooling is about 38% after 12hrs of discharge.

### 5. Conclusions

The circulation patterns for the pre-monsoon and southwest monsoon clearly indicate the northward coastal current. A similar coastal current, but in the opposite direction is seen during the post-monsoon and northeast monsoon seasons. Relatively higher cooling (68%) is achieved during July, October and December and cooling is very low during March (38%) mostly due to higher ambient temperature.

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