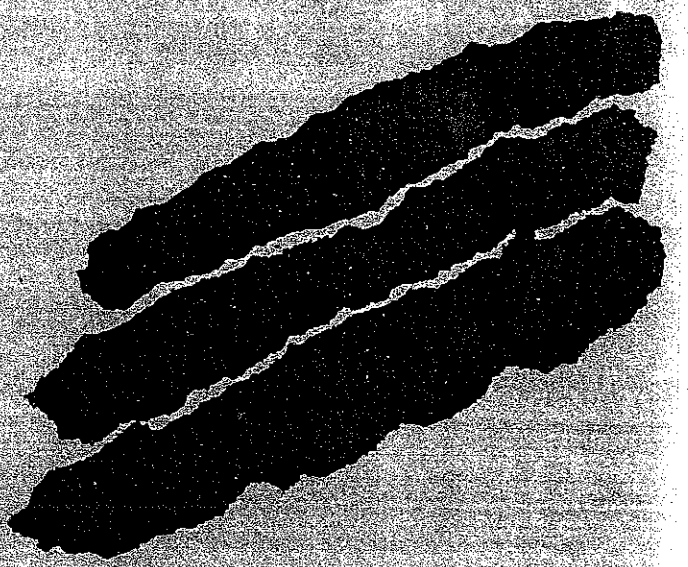
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Rapid Marine Environmental Impact Assessment for Ultra Mega Power Project Near Mundra

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JANUARY 2007



राष्ट्रीय समुद्र विज्ञान संस्थान

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Rapid Marine Environmental Impact Assessment for Ultra Mega Power Project Near Mundra

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1 INTRODUCTION

1.1 Background

Government of India is embarking on infrastructure development through private participation. Ministry of Power, Govt. of India alongwith Central Electricity Authority, Power Finance Corporation Ltd. (a Govt. of India Undertaking) has taken initiative for development of a number of coastal based and pit-head, coal-based Utra Mega Power Plants (UMPP) of about 4000 MW capacity each in the various locations in the country. Coastal Gujarat Power Limited (CGPL) a wholly owned subsidiary of M/s Power Finance Corporation, a body in the field of financing the power projects has embarked on developing the infrastructure for a 4000 MW thermal power project proposed to be set up at Mundra, Dist. Kachch in Gujarat State. CGPL had invited bids for the construction and operation of the same and based on the evaluation of these bids have awarded the Letter of Intent (LOI) to M/s. Tata Power Company Ltd on 28.12.06. M/s TCE Consulting Engineers Ltd., the technical consultants to CGPL, has examined the feasibility of setting up a 4000 Mw thermal power station. M/s CGPL has approached National Institute of Oceanography (NIO) for Rapid EIA and consultancy on the marine facilities.

The National Institute of Oceanography (NIO) has recently conducted studies for a similar but smaller power plant in the same location and the oceanographic data collected during that study as well as data available for the gulf of Kutchch collected over the last several years. This data is adequate to conduct marine environment related studies like identification of intake point, discharge point for release of wastewater and assess the impact of proposed development on the adjoining marine ecology. For this purpose the field investigations have been conducted during pre and postmonsoon season and subsequently the rapid and the comprehensive marine Environment Impact Assessment (EIA) report is to be submitted. Postmonsoon field investigation was conducted during January 2006, pre-monsoon observations conducted during April 2006 based on which this rapid marine EIA report is prepared.

1.2 Objectives

a) To evaluate the prevailing hydrodynamics and ecological status of the coastal water adjacent to the project site.

b) To suggest suitable mode and location for intake water and release of treated effluents in the Gulf of Kachchh.

c) To assess the impact of seawater intake, effluent release, ash disposal and other project operations on marine ecology.

d) To recommend suitable marine environmental management plan to minimize any adverse impact on marine area.

1.3 Scope of work

The location of seawater intake should be carefully decided in view of high ecological sensitivity of the Gulf. Likewise, the site of release of effluent meeting the norms of the Gujarat Pollution Control Board should be so identified that the contaminants are effectively dispersed within a reasonable distance from the release site and the effluent release system does not interfere with the operations of the nearby Mundra Port and intake facility of APPL.

In well-planned coastal developments, the probable adverse impacts are identified in advance so that the mitigation measures can be integrated within the design itself. Reliable prediction of impacts on marine ecology requires detailed information on water quality, sediment quality and biological characteristics of the area likely to be impacted and their tidal and seasonal variations. Ideally, the field data collection is required to be made in 3 seasons viz. postmonsoon, monsoon and premonsoon, since the coastal environment can change significantly from season to season. However, due to the dynamics of the Gulf it is not possible to undertake field investigations during monsoon. Moreover, due to high turbulence and wave action during monsoon, the contaminants entering the sea are dispersed at a much faster rate than during fair seasons. Hence, monsoon observations are not critical while conducting marine EIAs. The general area of the CGPL falls with in the area investigated for APPL power project for which data recently acquired during Pre and post monsoon periods is available. It is therefore proposed to conduct field investigations pertaining to intertidal area.

NIO has conducted several studies in the coastal waters of Mundra including the associated creeks in the past several years. The studies have generated an extensive database for the region, which can be usefully utilized to establish the baseline for the present studies. Based on the information available with NIO and the project information made available by CGPL, the following scope of work was finalized.

(a) Physical processes

A 2D numerical model would be used to define the hydrodynamics of the Gulf to enable quantifiable predictions. Bathymetry, tides and currents are the critical

inputs to such a model. To collate the predicted data, current measurements available with NIO will be made use of.

Apart from the circulation projected by the model, the tidal excursion would be estimated through drogue trajectories.

(b) Water quality

Water quality would be assessed at several locations to evolve a general background for the coastal sea off the project site including the creeks. The samples collected at the surface and bottom (wherever the depth exceeds 3 m) will be analyzed for salinity, suspended solids, pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), phosphate, nitrate, nitrite, ammonia, Petroleum Hydrocarbons (PHc) and phenols. Two critical locations will be sampled temporally to assess tidal variability of selected water quality parameters.

(c) Sediment quality

Subtidal and intertidal sediment off the project site would be studied for texture; selected metals (chromium, iron, cobalt, nickel, copper, zinc, lead, cadmium and mercury), organic carbon, phosphorus and PHc.

(d) Biological characteristics

The status of flora and fauna off the project area would be established based on phytoplankton pigments, population and generic diversity; zooplankton biomass, population and group diversity, macrobenthic biomass, population and group diversity, fisheries, mangroves and intertidal corals.

(e) Assessment

The data would be analysed to meet the objectives as stated above. Based on the environmental results and the probable perturbations due to the proposed project, the impact of various activities on marine ecology will be assessed during construction as well as operational phases of the project. Suitable mitigation measures in terms of marine environmental management plan will be suggested to minimize the adverse impact identified.

1.4 Approach strategy

Severity of negative impacts of developments in the coastal zone on associated marine ecology varies widely depending on many factors such as the extent, period and type of disturbance, anthropogenic perturbations, capacity of the

receiving water to assimilate contaminants and extent of its ecological sensitivity. Hence, the primary requirements for assessing such impacts are general baseline information for the Gulf as a whole and intensive site-specific data for the Tunda area.

NIO has been conducting general and site specific studies in the Gulf (Figure 1.4.1) since 1985 with more frequent investigations in recent years due to several proposed and ongoing developments bordering the Gulf, particularly along the southern coast. Thus, the site specific studies as detailed below conducted from time to time has resulted in a fairly extensive database for the Gulf.

Area	Period
Mithapur	1990-2004
Vadinar	1994-95, 1997, 1999, 2000, 2003, 2004
Sikka	1993-94, 1997, 1999, 2002, 2004
Bedi	1997, 2002-03
Navlakhi	1994
Kandla	1996-98, 2004
Luni	1997
Mundra	1998-99, 2000, 2002, 2003, 2005

These data were adequate to describe the general environmental setting of the Gulf and intensive field data acquisition off Tunda was considered sufficient to meet the objectives.

The published scientific literature and available technical reports indicated that apart from the studies conducted by NIO during 1998-2005 detailed information related to the ecology off Mundra was rather scanty This information was assessed to plan field data acquisition for the present study. Accordingly, subtidal stations covering an area of 200 km^2 off Tunda were considered for sampling. Intertidal area that would be used for intake water and effluent release pipeline was also considered for the study and the samples at several intertidal transects were investigated. To facilitate inter-comparison of results, the stations operated during 1998-2003 were sampled during the present study as far as possible. The sampling locations are illustrated in Figure 1.4.2.

Coastal waters often reveal significant seasonal changes in ecology. These variations should be clearly understood for assessing the prevailing status of a water body.

1.5 Studies undertaken

Subtidal sampling stations were selected based on the locations of the proposed developments including probable intake point and subsequent capital dredging for intake channel and effluent disposal point. Bathymetry for the area is given in the Chart No. 2055 of the Naval Hydrographic Office (NHO) and local close grid mapping supplied by TCE. The locations of previous investigations were also considered to obtain comparative information for offshore and onshore areas likely to be impacted by the proposed project as well as to create general ecological database for the wider region. These locations are illustrated in Figure 1.4.2. Stations 7, 12 and 13 represent the inshore environment of the Kotdi, Navinal and Bocha creeks. Considering the tidal excursion of more than 10 km of Mundra/ Wandh, changes in water quality over short distances are not expected. Nevertheless, near shore waters off Mundra was sampled at stations 1 & 2, 4 & 5 ,8, 11, 12. Stations 3, 6 and 9 are in the offshore segment of Gulf. Stations 4 & 5, 7 & 8 fall in the vicinity of the proposed development. Intertidal macrobenthos and sediment quality particularly in the areas likely to be disturbed due to dredging were studied at several transects between the High Tide Line (HTL) and the Low Tide Line (LTL). These are also shown in Figure 1.4.2.

1.5.1 Period of study

The field investigations as given below were planned in such a manner so as to get a detailed picture of the aquatic environmental characteristics during January 2006 (postmonsoon) and April 2006 (Premonsoon) and limited data pertaining to benthic fauna etc. were also collected during early November 2006.

1.5.2 Station locations

A total of 13 stations selected for marine environmental investigations are listed below and shown in Figure 1.4.2. Intertidal sediment was sampled along each transect in the area between the Low Water Line (LWL) and the High Water Line (HWL).

1.5.3 Sampling frequency

Water quality and biological characteristics were assessed at station 5 over a period of 12 h and at stations 4 and 6 for 6 h with 1 h sampling frequency for water quality and 2 h for biological characteristics. Other stations were spot sampled in duplicate at an interval of 30 min. Subtidal and intertidal sediments were collected once at each station/transect.

1.6.1 Physical processes

a) Tide

Available information on tides for Mundra and surrounding region was assessed. Tide data in the Kotdi creek was obtained by deploying a tide recorder. Tide data was also collected at the mouth of the Kotdi creek during premonsoon observations.

b) Currents

Currents were measured by deploying an Aanderaa (RCM 7) current meter at station 5 for about 7 d. The current meter was deployed at about 2 m from the bed level.

c) Circulation

Circulation was estimated by deploying a neutrally buoyant biplane drogue at prefixed location and tracking it over the desired time. The position of the drogue was periodically fixed with a GPS (Garmin hand held GPS 12). These positions were then plotted to obtain the trajectories.

1.6.2 Water quality

a) Sampling procedure

Surface water samples for general analyses were collected using a clean polyethylene bucket while an adequately weighted Niskin sampler with a closing mechanism at a desired depth was used for obtaining subsurface water samples. Sampling at the surface and bottom (I m above the bed) was done when the station depth exceeded 3 m. For shallow regions, only surface samples were collected. A glass bottle sampler (2.5 l) was used for obtaining samples at a depth of 1 m below the surface, for the estimation of PHc. For shallow areas only surface water was collected

b) Methods of analyses

Majority of the water quality parameters were analysed within 24 h of collection in the field laboratory. Colorimetric measurements were made on a Schimadzu (Model 1201) spectrophotometer. Perkin Elmer (Model LS 3B) fluorescence spectrophotometer was used for estimating PHc. The analytical methods of estimation were as follows:

i) pH :

pH was measured on a Eutech Cybernetics (Scan 2) pH Meter. The instrument was calibrated with standard buffers just before use.

ii) SS :

A known volume of water was filtered through a preweighed 0.45 pm Millipore membrane filter paper, dried and weighed again.

iii) Salinity :

A suitable volume of the sample was titrated against silver nitrate (20 g/l) with potassium chromate as an indicator. The salinity was calculated using Standard Tables.

iv) DO and BOD :

DO was determined by Winkler method. For the determination of BOD, direct unseeded method was employed. The sample was filled in a BOD bottle in the field and incubated in the laboratory for 5 d after which DO was again determined.

v) Phosphate:

Acidified molybdate reagent was added to the sample to yield a phosphomolybdate complex which was then reduced with ascorbic acid to a highly coloured blue compound which was measured at 882 nm.

vi) Nitrite:

Nitrite in the sample was allowed to react with sulphanilamide in acid solution. The resulting diazo compound was reacted with N-1-Naphthyl-ethylenediamine dihydrochloride to form a highly coloured azo-dye. The light absorbance was measured at 543 nm.

vii) Nitrate:

Nitrate was determined as nitrite as above after its reduction by passing the sample through a column packed with amalgamated cadmium.

viii) Ammonia:

Ammonium compounds (NH_4^+ + NH_3)-N in water were reacted with phenol in presence of hypochlorite to give a blue colour of indophenol. The absorbance was measured at 630 nm.

ix) N Total

Nitrogen compounds in the sample were oxidised to nitrate by autoclaving with alkaline persulphate. The solution was neutralized and nitrate was estimated as described under (vii).

x) PHc:

Water sample (2.5 l) was extracted with hexane and the organic layer was separated, dried over anhydrous sodium sulphate and reduced to 10 ml at 30°C under low pressure. Fluorescence of the extract was measured at 360 nm (excitation at 310 nm) with Saudi Arabian crude residue as a standard. The residue was obtained by evaporating lighter fractions of the crude oil at 120°C.

xi) Phenols:

Phenols in water (500 ml) were converted to an orange coloured antipyrine complex by adding 4-aminoantipyrine. The complex was extracted in chloroform (25 ml) and the absorbance was measured at 460 nm using phenol as a standard.

1.6.3 Sediment quality

a) Sampling procedure:

Subtidal surfacial bed sediment from all locations was obtained by a van Veen grab of 0.04 m^2 area. The sample after retrieval was transferred to a polyethylene bag and preserved for further analysis. Intertidal sediment was sampled using a hand shovel.

b) Methods of analyses:

i) Metals:

Sediment was brought into solution by treatment with conc HF-$HClO_4$-HNO_3-HCl and the metals were estimated on a Analyst-300 Atomic Absorption Spectrophotometer (AAS) by flame. Mercury was estimated by flameless AAS technique after digesting the sediment with aquaregia.

ii) C_{org} :

Percentage of C_{org} in the dry sediment was determined by oxidising organic matter in the sample by chromic acid and estimating excess chromic acid by titrating against ferrous ammonium sulphate with ferroin as an indicator.

iii) Phosphorus:

Digested samples [Section 1.6.3 (b)] were used for estimating total phosphorus in the sediment. The method used was similar to that described under Section 1.6.2 (b) (v).

iv) PHc:

Sediment after refluxing with KOH-methanol mixture was extracted with hexane. After removal of excess hexane, the residue was subjected to clean-up procedure by silica gel column chromatography. The hydrocarbon content was then estimated by measuring the fluorescence as described under Section 1.5.2 (b) (x).

1.6.4 Flora and fauna

a) Sampling procedure:

Polyethylene bucket and Niskin sampler respectively, were used for sampling surface and bottom waters for the estimation of phytoplankton pigments and population. Sample for phytoplankton cell count was fixed in Lugol's iodine and a few drops of 3% buffered formaldehyde.

Zooplankton were collected by oblique hauls using a Heron Tranter net (Mesh size 0.33 mm, mouth area 0.25 m^2) with an attached calibrated digital flow meter (General Oceanic). All collections were of 5 min duration. Samples were preserved in 5% buffered formaldehyde.

Sediment samples for subtidal macrobenthos were collected using a van-Veen grab of 0.04 m^2 area. Intertidal collections between the HTL and the LTL were done with a hand shovel for muddy and silty substratum while quadrants of different sizes were employed for sampling sandy and areas of compact sediment. Samples were preserved in 5% buffered formaldehyde - Rose Bengal.

Experimental bottom trawling and gill netting were undertaken wherever feasible using a high opening bottom net of 20.7 m (637 meshes of 50 mm) length and locally procured gill net.

b) Methods of analyses:

i) Phytoplankton pigments:

A known volume of water was filtered through a 0.45 gm Millipore membrane filter paper and the SS retained on the filter paper were extracted in 90% acetone.

For the estimation of chlorophyll *a* and phaeophytin, the extinction of the acetone extract was measured at 665 and 750 nm before and after treatment with dilute acid.

ii) Phytoplankton population:

The cells in the sample preserved with Lugol's solution were allowed to settle and transferred into a Sedgwick Rafter slide. Enumeration and identification of phytoplankton were done under a microscope.

iii) Algae, seaweeds and mangrove ecosystem:

Algal, seaweed and mangrove flora were assessed from the upper to the lower intertidal region along predecided transects.

iv) Zooplankton:

Volume (biomass) was obtained by displacement method. A portion of the sample (25-50%) was analysed under a microscope for faunal composition and population count.

v) Fish eggs, fish larvae and decapod larvae:

These groups were sorted out from zooplankton samples and counted. Frequency of occurrence and their percentage composition were then determined.

vi) Macrobenthos:

Sediment was sieved through a 0.5 mm mesh sieve and animals retained were preserved in 5% buffered Rose Bengal formaldehyde. Total population was estimated as number of animals in 1 m^2 area and biomass was determined on wet weight basis.

vii) Fishery:

After trawling, the fishes were sorted out into different groups and fish composition and catch rate were estimated. Fish landing data were obtained from the Department of Fisheries, Government of Gujarat (Jamnagar and Kachchh Districts) for assessing fishery potential.

viii) Corals:

The project domain area was carefully surveyed for corals on the intertidal segment during spring low tide.

2 PROJECT INFORMATION

The proposed project will be located at Tunda-Wandh villages in Mundra taluk, Kutch district of Gujarat coastal area. The site is located in the close vicinity of Mundra Special Economic Zone (MSEZ), which is located 25 km from the Mundra Port and Special Economic Zone Ltd. (MPSEZ) and 1.5 km from the coast of Gulf of Kutch. Tunda is accessible by road on NH-8A highway extension between Gandhidham and Mandavi towns and state highway SH-6 near Kandashera. The proposed project site is illustrated in Figure 2.0.1 while the satellite imagery of the region is given in Figure 2.0.2. An approach road to the project site will be required to be established from the highway for a distance of about 15 km bypassing two villages. The site is adjoining the first phase development of Mundra SEZ and adequate land for the project is being acquired by Mundra SEZ additional private land if required will be identified and aquired by CGPL. The proposed project consists of five power plant units totaling to 4000 MW gross capacity, utilising imported coal as fuel.

2.1 Need of the project

The demand for power is increasing steadily and the power shortage is felt everywhere. Mega power projects are the need of the day. With the Power grid in place it is possible to produce power at any location and feed it to the national grid. But the availability of fuel and water, the basic raw materials for power plant, are the important considerations. The site selected has both the attributes as coal can be imported through the nearest Mundra port and seawater can be used for cooling purposes. The area is under- developed and non-agricultural land availability is obvious.

2.1.1 Power demand scenario

Though the demand for power in the near areas are relatively smaller, demand on national scale exists for the power. The beneficiaries from the proposed project include Gujarat, Maharashtra, Punjab, Haryana and Rajasthan. The existing power for evacuation and transmission network will be strengthened to enable the transfer of the power to these identified beneficiaries.

2.1.2 Power evacuation

The feasibility study conducted by Power Grid Corporation of India Ltd. (PGCIL) revealed that the existing/planned inter state transmission network, which would be available by the year 2010 –11 may not be adequate for evacuation of

3500-3800 MW from the proposed power plant. Efforts are going on to strengthen the power evacuation and transmission network for feeding power to the various beneficiary states.

2.1.3 Configuration and selection of unit sizes

The selection of the configuration of the power plant/ unit size was left to the bidders with the requirement to adopt supercritical technology for boilers. The successful bidder, M/s. Tata Power Company Ltd., has offered to install 5X800 MW units to be commissioned in about 88 months period from effective date.

2.2 Land availability and site selection

The region around the proposed project sites is scarcely populated except in some clusters and a major part of the terrain is non-cultivated land.

The site at Tunda is considered suitable for the project based on the advantages that are enumerated herein below.

Tunda site is accessible by road NH-8A extension between Gandhidham and Mandvi towns. The nearest airlink is Bhuj Airport at a distance of about 60 kms from the project site. The site is adjoining the present phase of development of Mundra SEZ and adequate land for the project is already in acquisition of Mundra SEZ. Port facilities for handling imported coal to the tune of 12-14 million tones/ annum are available nearby.

The site is protected by sand banks and a shorter length of mud flat (Figures 2.2.1 and 2.2.2) around Kotdi creek. Also seawater could be drawn through an open channel that will be more economical than an offshore pumping system and pipeline, considering the volume of water required. The location of the selected site is indicated in Figure 2.0.1

2.3 Features of selected site

2.3.1 Water

The source of cooling water will be from the sea near Kotdi creek area. The cooling water requirement will be met from the seawater by adopting the recommendation by NIO for intake.

2.3.2 Fuel

Coal from International market could be procured from countries like Indonesia, South Africa, Australia, China and other possible sources. Imported coal received at MPSEZ port shall be transported to the project site by Merry Go Round (MGR) rail system, which is at a distance of about 25 km from the port.

2.3.3 Topographical and geological aspects

The area however is not prone to inundation. Pile foundation will be required for major equipment and structure foundations. The depth of piles and the related aspects will be decided appropriately based on soil investigations.

2.4 Plant layout configuration

In laying out the various facilities, consideration has been given to the following general principles.

- Power evacuation corridor for connection to grid.
- Raw water facilities
- Imported coal handling facilities at MPSEZ port
- Coal transportation from already operational MPSEZ port to project site.
- Approach road to the power plant from the highway, rail link to Adipur and airport facility at Bhuj 60 kms away.
- All facilities of the 4000 MW are laid out in close proximity to each other to the extent practicable so as to accommodate all facilities efficiently within the plant boundary.
- The layout also facilitates communication of men and materials between the various facilities both during initial construction and also during subsequent operation and maintenance.
- Availability of adequate space for fabrication / construction equipment beyond the power plant boundary which can be hired temporarily for the purpose.
- Site located in plain and barren area with minimal cultivation and habitation,
- Minimal eco-sensitive spots in vicinity of project site
- R&R issues not involved in absence of requirement for displacenment of any villages/ houses

2.5 Water requirement

The main requirement of water will be for power cycle condenser cooling and that of desalination plant. The cooling water requirement will be met from the seawater by adopting the recommendation by NIO for intake.

Fresh water for the plant, potable water, service water and feed water to the DM plant and other services will be met by the desalination plant.

2.5.1 Cooling water system

The cooling water systems considered are re-circulation type with 5 CTs for seawater or once through cooling system. A once through cooling system with seawater is preferred for the plant. The circulating system would be so designed to attain discharge temperature of less than +7°C above ambient seawater temperature.

2.6 Effluent disposal system

The effluents from the pre-treatment plant of the desalination plant, CT blowdown/once through cooling system and the Desalination plant reject water, being high TDS water, it is proposed to collect them in a common tank/ Guard Pond before discharging to sea (Figure 2.0.1) by a suitable mode at a location decided by scientific investigations.

3 GULF OF KACHCHH

The Kotdi Creek and surrounding region forms an integral part of the Gulf. Hence, the knowledge of general ecology of the Gulf is necessary for comparing the site-specific environmental conditions with that of the parent body.

The Gulf (Figure 1.4.1), which occupies an area of 7300 km^2, has maximum depth that varies from 20 m at the head (Kandla - Navlakhi) to 60 m in the outer regions. The actual fairway however is obstructed due to the presence of several shoals, needing periodic dredging in some areas, to facilitate navigation to the Kandla Port. The tidal scour that follows the axis of the Gulf has steep slopes and rugged surfaces. A number of scraps with relative elevation of 6 to 32 m occur on the sediment-free bed of the central Gulf.

3.1 Land environment

The coastal configuration of the Gulf is very irregular with numerous islands, creeks and bays. The coastal area of the Gulf (within 20 km from the shoreline) falls under the Kachchh (6749.77 km^2), Jamnagar (4863.53 km^2) and Rajkot (576.71 km^2) Districts. Cotton is the dominant crop in the Kachchh District while it is oil seeds in the Jamnagar and Rajkot Districts. Bajra, pulses, wheat, sugarcane etc are the other common crops in the region. The general vegetation in the area is sparse and scattered and of tropical dry mixed deciduous scrub and desert thorn type belonging to the xerophytic group.

Due to extreme unreliability of rainfall in the region, ground water is a more reliable source of water for domestic as well as agricultural needs. However, uncontrolled and indiscriminate withdrawal of ground water has resulted in a sharp decline in water table in the coastal belt causing ingress of salinity. The conditions are of considerable concern in Jodia and Okhamandal Talukas of the Jamnagar District and severe in Lakhpat and Anjar Talukas of the Kachchh District.

The coastal region of the Gulf is industrially less developed and the majority of large-scale industries including the RIL refinery is located in the Jamnagar District. Kachchh District is industrially backward and except for lignite mining, thermal power plant, fertilizer plant and Mundra and Kandla Ports, there are no major industries in the district. Okha and Bedi are the two important intermediate ports in the Jamnagar District.

3.2 Meteorological conditions

The Gulf is a semi-arid region with weak and erratic rainfall confined largely to the June-October period. With a few rainfall days, the climate is hot and humid from April till October and pleasant during brief winter from December to February. Rainfall alone forms the ultimate source of freshwater resource to the region. The average rainfall at Mundra is 414 mm/y on the northern coast and 490 mm/y at Mithapur on the southern coast.

The wind records at Okha indicate that (a) the speed varies between 0 and 30 km/h during November-February; the predominant direction being NW - NE, (b) the speed marginally increases during March-April with the change in direction to NW-SW, (c) maximum speeds (40-50 km/h) occur during May with predominant SW-W direction and (d) maximum speeds can reach upto 70 km/h with predominant SW-W direction during depressions in June - September.

Cyclonic disturbances strike North-Gujarat, particularly the Kachchh and Saurashtra regions, periodically. These disturbances generally originate over the Arabian Sea and sometimes the Bay of Bengal. The details of number of cyclonic storms, which struck the north Gujarat region during the last 100 y, are given in Table 3.2.1. Generally during June, the storms are confined to the area north of 15°N and east of 65°E. In August, in the initial stages, they move along the northwest course and show a large latitudinal scatter. West of 80°E, the tracks tend to curve towards north. During October the direction of movement of a storm is to the west in the Arabian Sea. However, east of 70°E some of the storms moves north-northwest and later recurve northeast to strike Gujarat-north Mekran coast.

The relative humidity is generally high during June-September (60-85 %) and marginally decreases during rest of the year (30-80 %). The sky is generally clear or lightly clouded excepting during monsoon period. Visibility is good throughout the year. However, average visibility of less than 1 km can be expected for a few days during the winter months.

3.3 Marine environment

Within the Gulf, though water depths of 25 m exist in the broad central portion upto the longitude 70°E, the actual fairway in the outer Gulf is obstructed by the presence of several shoals. The high tidal influx covers the lowlying areas of about 1500 km^2 comprising a network of creeks and alluvial marshy tidal flats in the interior

region. The creek system consists of 3 main creeks Nakti, Kandla and Hansthal, and the Little Gulf of Kachchh interconnecting through many other big and small creeks. All along the coast, very few rivers drain into the Gulf and they carry only a small quantity of freshwater, except during brief monsoon. They are broad-valleyed and their riverbed is mostly composed of coarse sand and gravel. The Gulf is characterised by numerous hydrographic irregularities like pinnacles, as much as 10 m high. The southern shore has numerous islands and inlets covered with mangroves and surrounded by coral reefs. The northern shore is predominantly sandy or muddy confronted by numerous shoals.

3.3.1 Physical processes

Tides in the Gulf are of mixed, predominantly semidiurnal type with a large diurnal inequality. The tidal front enters the Gulf from the west and due to shallow inner regions and narrowing cross-section, the tidal amplitude increases considerably, upstream of Vadinar. The tidal elevations (m) along the Gulf are as follows:

	MHWS	MHWN	MLWN	MLWS	MSL
Okha	3.47	2.96	1.20	0.41	2.0
Sikka	5.38	4.35	1.74	0.71	3.0
Rozi	5.87	5.40	1.89	1.0	3.6
Kandla	6.66	5.17	1.81	0.78	3.9
Navlakhi	7.21	6.16	2.14	0.78	4.2
Navinal Pt	6.09	5.65	1.81	0.37	3.4

The phase lag between Okha and Kandla is 2 h to 2 h 25 min while between Okha and Navlakhi it is 3 h to 3 h 20 min. Due to high tidal ranges in the inner regions, the vast mudflats and coastal lowlands that get submerged during high tide, are fully exposed during low tide.

Circulation in the Gulf is mainly controlled by tidal flows and bathymetry, though wind effect also prevails to some extent. The maximum surface currents are moderate (0.7-1.2 m/s) but increase considerably (2.0-2.5 m/s) in the central portion of the Gulf. The spring currents are 60 to 65 % stronger than the neap currents. The bottom currents are also periodic with a velocity normally 60-70 % of the surface currents.

With high tidal range, negligible land run-off and irregular topography, the waters are vertically homogeneous in terms of salinity and temperature.

3.3.2 Water quality

The general water quality of the Gulf is illustrated in Tables 3.3.1 and 3.3.2. The annual variation of water temperature is between 23 and 30° C though localised higher temperatures upto 35° C can result in isolated water pools formed in shallow intertidal depressions, during low tide.

SS is highly variable (5-700 mg/l), spatially as well as temporally, and largely result from the dispersion of fine sediment from the bed and the intertidal mudflats, by tidal movements. Evidently, nearshore shallow regions invariably sustain higher SS as compared to the central portions. The region between Okha and Sikka has low SS varying within a narrow range (10-50 mg/l) whereas the inner Gulf areas sustain markedly higher SS, sometimes in excess of 100 mg/l.

Average pH of the Gulf water is remarkably constant (8.0-8.3) and is within the range expected for the coastal tropical seas. The evaporation exceeds precipitation leading to salinities markedly higher than that of the typical seawater. This is particularly evident in the inner Gulf where salinities as high as 40 ppt commonly occur off Kandla and Navlakhi. Although the salinities decrease considerably for a brief period in some creeks of the Little Gulf of Kachchh under the influence of monsoonal runoff, the impact of this decrease in the Gulf proper is small and salinities exceed 36 ppt off Sikka and Mundra during normal monsoon periods.

The average DO is fairly high (3-5 ml/l) and the BOD is low (<0.1-4.0 mg/l) indicating good oxidising conditions. Hence, the organic load in the water column is considered to be effectively oxidised. The nutrients (PO_4^{3-}-P, NO_3^--N, NO_2^--N, NH_4^+-N) are more or less uniformly distributed in the Okha-Sikka-Mundra segment and their concentrations indicate healthy natural waters. Their levels however are marginally high in the Kandla-Navlakhi segment. The networks of creeks of the Little Gulf of Kachchh sustain high natural concentrations of nutrients perhaps due to high regeneration rates. As expected for an unpolluted coastal environment, the concentrations of PHc and phenols are low.

3.3.3 Sediment quality

Central portion of the Gulf extending from the mouth to upstream of Sikka is rocky with sediments confined only to the margins. The nearshore sediment that consists of light gray silt and clay and fine sand with patches of coarse sand in-

between, are poorly sorted with highly variable skewness. The major source of this sediment is considered to be the shore material and the load transported by the Indus River. The portion of sediment derived from the hinterland is considered to be small because of the low run-off. Moreover, the streams discharging in the Gulf (during brief monsoon season) are short with dams constructed on many of them.

The concentrations of heavy metals such as chromium, manganese, cobalt, nickel, copper, zinc, mercury and lead though variable (Tables 3.3.3 and 3.3.4), indicate natural background levels and there is no evidence of gross sediment contamination. The concentrations of PHc are also low though large quantities of petroleum crude and its products are off-loaded at Vadinar and Kandla respectively.

3.3.4 Flora and fauna

The Gulf abounds in marine wealth and is considered as one of the biologically richest marine habitat along the west coast of India. Quantitative information for selected biological characteristics of the Gulf is given in Tables 3.3.5 to 3.3.10

The marine flora is highly varied, which includes sand dune vegetation, mangroves, seagrasses, macrophytes and phytoplankton. The dominant species of sand dune flora are *Euphorbia caudicifolia, E.nerifolia, Aloevera* sp, *Ephedra foliata, Urochodra setulosa, Sporobolus maderaspatenus, Eragrostis unioloides, Calotropis procera, Fimbristylis* sp, *Indigofera* sp and *Ipomoea pescaprae*. The common seagrasses found growing on the mud flats are *Halophila ovata, H.beccarii* and *Zostrea marina.*

The most common marine algal species are *Ulva fasciata, U.reticulata, Enteromorpha intenstinalis, Dictyota* sp, *Hypnea musciformis, Sargassum tennerimum, S.ilicifolium, Gracilaria corticata, Cystocera* sp, *Padina tetrastomatica, Corallina* sp, *Laurencia* sp, *Caulerpa racemosa, C.peltata, Bryopsis* sp, *Turbinaria* sp, *Ectocarpus* sp, *Acanthophora* sp, *Chondria* sp, and *Codium* sp (Table 3.3.5).

The primary production of the water column as assessed from chlorophyll *a* concentrations is generally good in the outer Gulf but decreases in the inner regions (Tables 3.3.6 and 3.3.7). The major phytoplankton genera are *Rhizosolenia, Synedra, Chaetoceros, Navicula, Nitzschia, Pleurosigma, Thalassiothrix, Biddulphia, Stauroneis, Coscinodiscus* and *Skeletonema.*

The Gulf has a vast intertidal area with rich biota. Sheltered bays, creeks and mud flats provide ideal sites for mangrove vegetation over an estimated area of about 1036 km^2 (Table 3.3.8). The formations are of open scrubby type, with isolated and discontinuous distribution from Kandla- Navlakhi in the northeast to Jodia, Jamnagar, Sikka, Salaya and Okha in the southwest, as also at Pirotan, Positra, Dohlani and Dwarka. Vast stretches of mangroves also exist along the northern shore of the Gulf. The dominant species of mangroves are *Avicennia marina* var *acutissima, A officinalis, Bruguiera parviflora, B gymnorphiza, Rhizophora mucronata, R apiculata, Ageiceros corniculata* and *Sonneratia apetata* alongwith the associated species of *Salicornia brachiata, Sueda fruticosa, Artiplex stocksii* and a lichen, *Rosella montana*.

The marine fauna of the Gulf is rich, both in variety and abundance. Sponges having an array of colours are seen, both in the intertidal and subtidal biotopes. The common species of sponge is *Adocia* sp, associated with coral reef fauna. In sandy and silty mud shores, *Tetilla dactyloidea* (Carter) is common.

The most frequently encountered hydrozoans are *Sertularia* sp and *Plumularia* sp. The giant sea anemone (*Stoichactis gigantum*) is a common sight in the coral ecosystem. Sea anemones, belonging to *Anemonia, Bunodactis, Paracondylactis, Anthopleura* and *Metapeachia,* are wide spread. A zoantharian, *Gemmaria* sp, is found forming extensive hexagonal green mats in the coral pools. Another interesting actiniarian is the *Cerianthus* sp found in tubes in the soft mud.

One of the most interesting biotic features of the Gulf is the presence of living corals, thriving as patches, rather than reefs, either on the intertidal sand stones or on the surface of wave-cut, eroded shallow banks along the southern shore of the Gulf. The species diversity however is poor with identification of 44 species of Scleractinian and 12 species of soft corals (Table 3.3.9).

A number of polychaete worms, both sedentaria and errantia, with the dominant genera of *Eurythoe, Terebella, Polynoe, Iphione* and *Nereis* are rather common. Amongst a variety of sipunculid and echiuroid worms, the dominant species are *Dendrosromum* sp, *Asphidosiphon* sp and *Ikadella misakiensis* (Ikeda). The intertidal crustacean fauna is very rich and equally diverse with spider crab (*Hyas* sp) and furry crab (*Pillumnus* sp), as specialities.

Amongst the invertebrate component of the marine fauna of the Gulf, the molluscs have the highest representatives. As many as 92 species of bivalves, 55 species of gastropods, 3 species of cephalopods and 2 species each of scaphopods and amphineurans have been reported. The most notable members of the molluscan fauna are octopus, pearl oyster and a variety of chanks, including the sacred chank.

The echinoderm fauna represented by 4 classes and 14 genera, have the commonest genera of *Palmpsis, Astropecten, Asteria, Temnopleura* and *Holothuria*. The subtidal benthic fauna of the Gulf is dominated by polychaetes, crustaceans, echinoderms, gastropods and bivalves, with an average biomass of 25 g/m^2.

The Gulf has a variety of exploitable species of finfishes and shellfishes. The scienides, polynemids, perches, eels, cat-fishes, elasmobranchs and prawns are commercially important groups with an average catch of $1.4x10^5$ t/y. Fishing grounds for Ghol, Karkara, Khaga, Dhoma, Magra and Musi exist in the Gulf.

The Gulf region offers plenty of facilities for feeding, breeding and sheiter to a variety of birds (Table 3.3.10). In the mangrove forests lining the islands and along the coast, the birds find a near perfect environment. In addition, they are well placed to reach their food supply i.e. the shoals of fish, squids, mud-skippers and other animals, during low tide. All along the creeks and around islands, mangrove trees and mudflats are seen crowded with Grey Herons, Pond Herons, Painted Storks, Large and small Egrets, Reef Heron, Darters, Cormorants, Flamingos, Lesser Flamingos, etc during the periods of seasonal migration (November-March).

A large number of migratory birds pass through the Gulf and a small population of most species comprising mainly of juveniles and non-breeding adults take shelter in this area during summer. Salt works spread-out along the coast, are also important for feeding and breeding of birds. They act as alternate sites for them to roost during high tide.

Though a detailed systematic survey of biota is lacking, following number of species have been reported:

Flora/Fauna	Species (no)
Algae	130
Sponges	70
Corals	37
Fishes	200
Sharks	8
Prawns	27
Crabs	30
Molluscs	200
Sea turtles	3
Sea mammals	3
Birds	200

Because of its high biogeographical importance and rich flora and fauna, several areas along the southern Gulf are notified (Figure 1.4.1) under the Marine National Park (16289 ha) and the Marine Sanctuary (45798 ha).

4 SITE SPECIFIC MARINE ENVIRONMENT

4.1 Area description

The assessment domain of the present study involved the section of the Gulf between the Mudwah Point and Bocha creek. The development of Mundra Port is largely confined to the Navinal Island near the Mundra village on the northern shore of the Gulf about 70 km west of the Kandla Port. The coastal stretch of the Gulf has variegated topography with vast intertidal mudflats criss-crossed by numerous creeks, which transport seawater several kilometres inland due to high tidal ranges. In general, Bocha, Navinal, Baradi Mata and Kotdi creeks are the major tidal inlets in the vicinity of the Mundra Port area, which are broad but shallow and navigable only during flood tide. Occurrence of a large number of creeks has created a number of islets; the prominent being the Navinal and Bocha Islands. These two islands are separated by the Navinal Creek, which in the interior joins the Bocha as well as the Baradi Mata Creeks.

The intertidal mudflats and many of the creeks of the surrounding area harbour mangroves and associated biota though several areas have suffered damage due to anthropogenic pressures. Large stretches of mangroves also suffered destruction during the cyclone of June 1998.

The region is semi-arid with average annual rainfall of <400 mm. The precipitation being erratic, the agricultural produce, which is dependent on rains, fluctuates considerably. As a result, the farming which has been the major occupation of the local inhabitants is gradually declining with the people shifting over to other occupations such as services, construction work etc.

May and June are generally the hottest months with a mean maximum temperature of about 37°C. The coldest month is January with a mean minimum temperature of around 10°C. In the winter season, the lowest temperatures can be below 5°C under the influence of cold waves. The relative humidity is moderate (55%) most of the time though higher humidity (70-80%) occurs during monsoon months.

The wind records of Bhuj indicate that (a) during November-February the wind speed varies between 0 and 30 km/h; the predominant direction being NW-NE, (b) the wind direction changes to NW-SW during March-April with a marginal increase in wind speed, (c) during May the predominant direction is SW-W with

maximum speeds between 40 and 50 km/h, and (d) during monsoon (June-September) the wind direction is predominantly SW-W and maximum speeds can reach 60 - 70 km/h.

Nagmati, Bhukhi and Phat Rivers are the major drainage streams of Mundra Taluka, which originate from the slopes of the central highland. These rivers are however dry and carry land runoff to the Gulf in brief spells only during monsoon.

The ground water is the major source for domestic use. The quality and availability however is variable depending on the rainfall, topography and hydrological setting. The level of water suitable for drinking and irrigation ranges from 5 to 35 m below the ground. The water at greater depths tends to be saline. Increased rate of extraction and scanty rainfall in recent years has not only lead to groundwater depletion but seawater ingress has occurred in many areas along the coast.

The fertility of the coastal soil is affected by salinity. The vegetation mainly consists of trees, shrubs, under shrubs and climbers with stunted growth with an admixture of xerophytes and thorny species. The dominant floral species are of *Phoenix sylvestris, Achras zapota, Prosopis juliflora, Acacia senegal, Mytenus emarginatea* and *Acacia nilotica*. The shrub community is dominated by the species of *P.juliflora* and *Indigofera oblongifolia*.

The region between Mundra and Mandvi on the northern coast of the Gulf of Katchch is interspersed with numerous creeks and islets. Some of these islets exhibit mangrove vegetation in their lower fringes where as some are made up of sand and sand dune vegetation.

The area proposed for the development of power plant of CGPL is located between two ephemeral rivulets namely Khari Nadi in the west and Wae a contributory of Nagavati river in the east. There are two moderate size villages Tunda (in the east) and Wandh (in the west) in the vicinity of the project site. The intertidal area of this region is devoid of mangroves. The bottom is sandy and the inlets are partially sedimented. Tidal water enters the creek about 1-1.5 h after low water slack during spring and remains well connected, though not navigable, during neap and average low waters. Some of the sandy beaches are used by local fishing folk for beaching their shallow draft crafts and land above high water line for drying fish. The

prominent vegetation is mainly composed of Babool (*Presopsis Julifolia*). Mundra, the nearest major town is approximately 28 km in the E-NE direction.

4.2 Physical processes

4.2.1 Tides

Tide levels recorded at Mundra port are compared with the predicted tide at Kandla Port in the following table:

	Mundra	Kandla
Spring high water (m)	6.09	7.04
Neap high water (m)	5.65	6.84
Neap low water (m)	1.81	2.50
Spring low water (m)	0.37	0.17

A comparison between the data sets for the two ports indicates that the time of occurrence of flood and ebb tide at Mundra lead by 27 and 46 min respectively with respect to the Kandla tide. The tidal range ratio (Mundra : Kandla) is 0.83 and 0.88 for spring and neap tides respectively.

The mean sea level at the Mundra Port (Bocha Creek) is estimated at 3.31 m (above CD) which is comparable to that reported for Navinal Point (3.38 m) in the Admiralty Tide Tables. Tide was also measured at Kotdi Creek during January 2006 (Figure 4.2.1). The tidal ranges during this period vary from 1 to 3.5 m with the time lag of 5 to 10 min as compared to the phase of the tide at the Mundra Port. The tide recorded during April 2006 (Figure 4.2.2) at both the mouth of Kotdi creek and inside Kotdi creek indicates that the site of measurement inside the creek is about 1.8 m above CD. During this period the spring low water at Kotdi mouth is 1.0 above CD which indicates that the tidal flow is not available in the Kotdi creek for about 1.5 h during end of the spring ebb and a similar duration in the beginning of the following flood. This renders the creek partially dry and partially stagnant for about 3 h in a flood tide. The neap tide is of comparable magnitude in the creek as well as the mouth area of the creek.

4.2.2 Currents

The currents in the Gulf and associated creeks are largely tide induced and oscillations are mostly bimodal reversing in direction with the change in the tidal phase. Influence of wind on variations in current is minor. The current reversals are quite sharp occurring within 30 - 60 min. Currents were recorded at station 5 in the vicinity off the Kotdi Creek. The maximum current speed observed is 0.8 m/s. The U

component of the currents (Northward) is stronger than the V component indicating weak lateral transport, as expected. The maximum current speed varies from 0.5 to 1.2 m/s. The predominant direction of the current is 45° during ebb and 220° during ebb.

4.2.3 Circulation

The drogue studies conducted from stations 5(Figures 4.2.3&4.2.4) indicate that the circulation is generally elliptical with the major axis in the east-west direction. These trajectories suggest that the excursion lengths are in the range of 10 to 15 km depending on the tidal phase (neap or spring). The paths traced by the drogue were sufficiently away from Kotdi creek indicated cross contamination at intake is remote .

4.3 Water quality

The water quality around Mundra was assessed in Navinal, Bocha and Kotdi Creeks and the nearshore water off Mundra/Tunda during January and April 2006 (Tables 4.3.1 to 4.3.13). The long term data (1998-2005) of water quality of the Navinal, Bocha and Kotdi Creeks, and off Mundra (Gulf) is presented in Tables 4.3.14 to 4.3.18. Since the water quality can vary temporally in areas swept by strong tides, hourly measurements were conducted over a tidal cycle at stations 5, 4 and 6 to evaluate the tidal variability of selected water quality parameters. These variations are presented in Figure 4.3.1 and 4.3.2.

4.3.1 Temperature

The water temperature around Mundra varies in accordance with the air temperature though maximum in their temporal profiles is considerably smoothened as expected (Figure 4.3.1). The observed ranges in variations in temperature (°C) given below indicate that the changes are small, and within a narrow range (18.0 to 31.0°C).

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	29.5-30.8 (30.1)	28.5-29.8 (29.0)	-	-	28.0-28.98 (28.5)
March 1999	22.0-27.1 (24.4)	25.1-27.0 (26.7)	24.9-27.6 (26.6)	-	23.1-28.5 (24.7)
September 1999	-	-	-	29.0-31.6 (30.6)	-
March 2000	25.0-25.8 (25.6)	20.0-27.0 (24.0)	-	-	21.5-25.5 (24.0)
June 2003	28.9-29.2 (29.0)	28.5-31.5 (29.2)	-	-	28.4-30.0 (29.1)

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
October 2003	28.7-29.5 (29.0)	28.0-29.7 (29.1)	29.0-31.0 (30.0)	-	27.7-30.8 (29.7)
December 2004	23.8-23.9 (23.9)	23.0-23.7 (23.4)	19.0-22.8 (20.9)	-	27.0-30.1 (29.0)
May 2005	28.8-29.0 (28.9)	28.2-30.1 (28.8)	28.5-29.1 (28.8)	-	22.2-24.6 (23.4)
January 2006	21.8-22.1 (22.0)	21.8-22.6 (22.1)	-	18.0-18.5 (18.3)	19.0-23.2 (21.1)
April 2006	28.0-28.1	27.0-27.5	27.5	25.0-27.0	25.6-26.4

4.3.2 pH

Under the influence of buffering action of $CO_3^{2-}/HCO_3^-/CO_2$ system the pH of water was fairly constant during both the seasons with variation in a narrow range of 7.7 and 8.5 accompanied with minor spatial and temporal changes. The recorded variations in pH at different segments are given below.

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	8.2-8.3 (8.2)	8.0-8.2 (8.1)	-	-	8.2-8.2 (8.2)
March 1999	8.0-8.3 (8.2)	8.1-8.3 (8.2)	8.1-8.3 (8.3)	-	7.7-8.3 (8.2)
September 1999	-	-	-	7.9-8.4 (8.1)	-
March 2000	8.0-8.1 (8.1)	8.1	-	-	8.0-8.4 (8.2)
June 2003	8.0-8.0 (8.0)	7.9-8.0 (8.0)	-	-	7.9-8.0 (8.0)
October 2003	8.1-8.2 (8.2)	8.0-8.3 (8.2)	8.1-8.1 (8.1)	-	8.0-8.2 (8.2)
December 2004	8.3-8.4 (8.4)	8.4-8.4 (8.4)	0.2-8.4 (8.3)	-	8.1-8.4 (8.3)
May 2005	8.2-8.3 (8.3)	8.2-8.5 (8.3)	8.2-8.4 (8.4)	-	8.2-8.5 (8.3)
January 2006	8.2-8.2 (8.2)	8.2-8.2 (8.2)	-	8.1-8.1 (8.1)	8.0-8.3 (8.1)
April 2006	8.1	8.1	8.0	7.9-8.0	8.0

4.3.3 Suspended solids

The waters of Navinal, Bocha and Baradi Mata Creeks and off Mundra are muddy and turbid with high and variable SS (mg/l) as given below.

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	122-251 (1821)	236-614 (357)	-	-	189-387 (292)
March 1999	33-445 (115)	66-166 (94)	49-123 (69)	-	20-170 (69)
September 1999	-	-	-	49-160 (94.5)	20-282 (87)
March 2000	42-125 (84)	43-94 (65)	-	-	102-440 (145)
June 2003	108-176 (138)	80-288 (144)	-	-	102-440 (145)

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
October 2003	44-94 (72)	30-596 (89)	38-46 (42)	-	26-166 (89)
December 2004	24-26 (25)	18-24 (21)	34-42 (28)	-	44-168 (106)
May 2005	30-34 (32)	80-150 (115)	36-108 (72)	-	20-78 (49)
January 2006	32-32 (32)	24-62 (43)	-	32-34 (33)	30-139 (57)
April 2006	54	104-120	44	24-44	30-36

The particles are largely inorganic and their source is the fine grained bed sediment getting dispersed in the water column by tidal movement. Their levels are high in the bottom water. High SS in the open shore waters during June 1998 may be due to rough weather conditions. Concentration of SS during January 2006 is quite comparable with the earlier data.

4.3.4 Salinity

Gulf is an area of negative water balance with salinities commonly exceeding 36 ppt even during normal monsoon days. In the absence of freshwater inflow the salinity (ppt) in the creeks as well as the Gulf is markedly high as evident from the following table.

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	36.3-41.4 (39.9)	36.8-40.7 (39.9)	-	-	41.0-41.7 (41.3)
March 1999	36.2-38.4 (37.0)	36.9-40.0 (37.5)	36.5-37.2 (36.9)	-	35.9-38.2 (37.3)
September 1999	-	-	-	38.0-38.9 (38.6)	-
March 2000	38.4-38.7 (38.5)	37.2-38.0 (37.6)	-	-	37.4-39.3 (38.2)
June 2003	38.5-38.7 (38.5)	38.5-39.0 (38.8)	-	-	37.7-39.0 (38.6)
October 2003	36.5-38.1 (37.3)	35.3-37.1 (36.7)	36.5-37.0 (36.8)	-	36.1-37.7 (36.6)
December 2004	37.6-38.2 (38.0)	38.2-38.6 (38.4)	37.6-40.4 (39.0)	-	37.5-40.5 (39.1)
May 2005	39.2-39.5 (39.4)	37.7-38.5 (38.1)	38.4-40.6 (39.5)	-	37.1-38.6 (38.0)
January 2006	37.1-37.3 (37.2)	36.9-37.1 (37.0)	-	37.3-37.7 (37.5)	36.5-38.8 (37.2)
April 2006	37.0-37.2	36.8-37.4	37.2-38.1	37.1-40.1	36.0-37.3

The above results indicate, the average salinities between 1998 and 2006 are more or less comparable within the natural variability inherent to coastal waters. Temporal variations in salinity are minor though decrease during low tide is evident from Figure 4.3.1 which suggests some freshwater inflow the creeks from nearby domestic source. Average salinities during January 2006 vary between 36.9 and

37.7 and 36.5 and 38.8 respectively in creek and offshore waters. Surface to bottom variations are minor and the waters are well-mixed vertically.

4.3.5 DO and BOD

DO content of water is a vital water quality parameter influencing the health of aquatic biota and is intimately linked with its availability. Although there is considerable dispute on the minimum level of DO required for a healthy tropical marine environment, it is considered that the DO levels should not fall below 3 ml/l for prolonged periods in creeks, estuaries and coastal waters for health of the ecosystem. The source of DO in natural water are photosynthesis and dissolution from the atmosphere across the air-water interface; the former being more important. However, DO is consumed by respiration and decaying organic matter. Hence, the high content of organic load on an aquatic system can deplete DO to levels that can be detrimental to aquatic life.

DO (ml/l) in Gulf segment off Mundra recorded during the present study is compared with the earlier results in the following table.

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	4.0-5.5 (4.4)	3.5-4.6 (4.4)	-	-	2.0-4.6 (3.9)
March 1999	2.2-5.3 (3.5)	2.9-5.2 (4.0)	5.3-6.2 (5.6)	-	1.8-6.2 (4.7)
September 1999	3.2-4.4 (3.9)	-	-	1.5-5.3 (3.1)	-
March 2000	-	1.8-5.1 (4.2)	-	-	1.7-5.3 (3.9)
June 2003	2.7-4.3 (3.7)	2.5-4.5 (3.5)	-	-	1.9-4.6 (3.4)
October 2003	3.8-4.7 (4.4)	3.4-5.4 (4.4)	4.5-4.9 (4.8)	-	2.9-5.2 (4.4)
December 2004	5.3-5.5 (3.4)	5.3-5.5 (5.4)	2.4-5.5 (4.0)	-	1.0-4.8 (3.2)
May 2005	3.8-4.3 (4.0)	1.8-5.0 (3.4)	4.1-4.6 (4.4)	-	3.1-6.0 (4.6)
January 2006	4.6-5.4 (5.0)	5.0-5.0 (5.0)	-	5.3-5.5 (5.4)	1.8-5.7 (4.6)
April 2006	4.5-4.7	4.5-4.7	4.5-4.7	4.1-4.8	4.1-4.8

The DO off Mundra varies from 1.0 to 6.2 ml/l in the creek and openshore but the average is generally above 3 ml/l suggesting for good ecological conditions, low individual values sometimes recorded off Mundra however indicate some stress conditions. Considering that the DO in water is a function of several parameters including primary productivity, BOD, salinity, temperature and turbulence, only one data set in a season is insufficient to draw inferences and further investigation is necessary to establish the trends.

Temporal variation in DO at station 5 (Figure 4.3.1) indicates that though the DO remained between 3 and 5.4 ml/l most of the time on one occasion value of 2 ml/l was recorded. The possible reasons for the occurrences of occasional low DO can be (a) inflow of water from mangrove and marshy areas which are often depleted in DO (b) operations at the jetty and (c) release of oxidisable organic matter from nearby regions. Though the depletion of DO for short duration does not adversely influence majority of organisms, some sensitive animals may experience stress.

All natural waters contain oxidisable organic matter in low concentration leading to BOD which can be 2-5 mg/l when the productivity is high. The BOD (mg/l) between 1998 and 2006 is given in the following table.

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	1.8-5.6 (3.5)	2.9-5.2 (4.4)	-	-	1.3-3.1 (2.3)
March 1999	0.2-5.1 (3.1)	2.9-4.0 (2.4)	1.5-4.4 (2.8)	-	0.2-4.7 (2.2)
September 1999	-	-	-	0.2-4.1 (1.1)	-
March 2000	1.1-3.9 (2.4)	0.2-2.8 (1.8)	-	-	0.2-3.4 (1.3)
June 2003	0.1-2.0 (1.0)	0.3-4.4 (2.5)	-	-	0.5-4.6 (2.4)
October 2003	2.2-2.9 (2.6)	0.9-5.1 (3.4)	0.7-5.4 (3.1)	-	0.9-5.1 (3.3)
December 2004	2.3-3.1 (2.7)	5.4	0.2-1.3 (0.8)	-	1.2-6.4 (3.3)
May 2005	0.5-3.5 (2.0)	1.2-2.2 (1.7)	1.7-3.0 (2.4)	-	1.3-5.7 (3.5)
January 2006	-	-	-	1.1-1.1 (1.1)	0.5-5.4 (1.6)
April 2006	1.0-2.9	0.6-3.6	0.6-2.9	0.6-3.6	1.9-3.6

The BOD off Mundra varies in range of 0.2-6.4 mg/l which is comparable with that of the Gulf in general suggesting that the BOD has not significantly changed since 1998.

4.3.6 Phosphorus and nitrogen compounds

Dissolved inorganic phosphorus and nitrogen compounds though present in low concentrations in natural surface waters, they play and important role in controlling the production at the primary level and in turn the fishery potential of the area. However, their high concentrations such as those resulting from release of sewage and industrial effluents rich in their compounds in areas of restricted water exchange such as some estuaries and creeks, can result in an excessive growth of algae creating an unhealthy environment.

The major dissolved inorganic species of phosphorus is orthophosphate while nitrate, nitrite and ammonia are the major species of nitrogen of which nitrate is generally dominant. Nitrite is thermodynamically unstable and ammonia is biochemically oxidized to nitrate via nitrite apart from being directly assimilated by algae. Hence, concentrations of nitrite and ammonia are often very low in natural waters.

The range average (parenthesis) concentrations (µmol/l) of phosphate (PO_4^{3-}-P) off Mundra are as follows:

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	0.9-2.2 (1.5)	1.3-2.7 (1.8)	-	-	0.8-1.8 (1.5)
March 1999	0.9-1.7 (1.3)	0.6-1.8 (1.2)	0.5-1.5 (1.1)	-	0.4-4.4 (1.7)
September 1999	-	-	-	0.5-2.2 (1.3)	-
March 2000	1.1-1.7 (1.4)	1.5-2.4 (1.9)	-	-	0.2-11.7 (1.9)
June 2003	2.2-3.6 (2.6)	0.9-2.3 (1.8)	-	-	1.1-3.0 (1.7)
October 2003	0.3-1.3 (1.0)	0.4-2.1 (1.1)	0.4-1.4 (0.8)	-	0.5-2.7 (1.1)
December 2004	0.9-1.3 (1.2)	1.1-1.2 (1.1)	0.3-1.1 (0.7)	-	0.3-3.1 (1.7)
May 2005	0.3-0.8 (0.5)	0.9-2.8 (1.9)	0.8-1.8 (1.3)	-	0.6-1.9 (1.5)
January 2006	1.5-1.8 (1.7)	0.8-2.0 (1.4)	-	1.7-1.7 (1.7)	0.3-2.3 (1.6)
April 2006	0.9-1.8	0.8-1.8	0.5-1.6	1.0-3.1	0.8-2.7

The above results indicate no appreciable change in the concentration and distribution of phosphate off Mundra since June 1998 after the Mundra Port and other developments has become operationai.

In well-oxygenated coastal waters, nitrate is the dominant species of nitrogen. Hence, in line with the Gulf the range and average (parenthesis) concentrations (µmol/l) of nitrate off Mundra are relatively high as evident from the following results.

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	3.8-33.5 (6.3)	4.9-7.7 (6.9)	-	-	4.4-6.6 (5.8)
March 1999	0.1-5.7 (1.4)	0.1-1.4 (0.6)	0.6-2.0 (1.2)	-	ND-6.6 (1.9)
September 1999	-	-	-	0.4-10.0 (4.4)	-
March 2000	0.6-0.9 (0.8)	3.5-7.8 (5.4)	-	-	1.1-13.3 (3.4)
June 2003	2.3-3.5 (3.2)	04.-3.9 (3.0)	-	-	1.0-5.1 (3.0)
October 2003	1.9-3.2 (2.4)	ND-7.0 (1.6)	0.1-0.4 (0.3)	-	0.2-7.3 (3.1)

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
December 2004	1.6-5.5 (3.6)	2.0-3.4 (2.7)	0.4--2.7 (1.6)	-	0.1-14.4 (7.3)
May 2005	1.2-2.1 (1.6)	0.2-8.1 (2.8)	0.7-1.5 (1.1)	-	0.1-5.7 (2.9)
January 2006	8.8-10.6 (9.7)	8.1-10.8 (9.3)	-	6.5-7.6 (7.1)	4.7-12.6 (7.8)
April 2006	1.5-2.3	1.4-2.1	2.4-3.9	0.1-3.4	2.3-4.7

The concentrations vary considerably as commonly noted for shallow coastal waters under high tidal influence. The levels recorded during January 2006 are comparable with the June 1998 baseline within the natural variability inherent to coastal waters.

Unlike nitrate the average levels (µmol/l) of nitrite off Mundra are low as evident from the following results.

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	0.3-1.0 (0.6)	0.5-0.9 (0.7)	-	-	0.2-0.6 (0.4)
March 1999	0.5-0.7 (0.5)	0.4-0.7 (0.6)	0.1-0.4 (0.3)	-	0.1-1.9 (0.4)
September 1999	-	-	-	0.2-1.0 (0.6)	-
March 2000	0.3-0.4 (0.3)	0.3-0.7 (0.5)	-	-	0.2-1.3 (0.5)
June 2003	0.2-0.4 (0.3)	0.2-0.6 (0.5)	-	-	0.2-0.9 (0.5)
October 2003	0.2-0.4 (0.4)	0.2-0.8 (0.4)	0.1-0.2 (0.1)	-	ND-0.7 (0.3)
December 2004	0.3-0.4 (0.4)	0.2-0.3 (0.3)	0.2-0.4 (0.3)	-	0.2-1.0 (0.6)
May 2005	0.5-0.6 (0.6)	0.8-1.3 (1.1)	0.3-0.9 (0.6)	-	0.1-0.4 (0.3)
January 2006	0.4-0.5 (0.5)	0.4-0.6 (0.5)	-	0.4-0.6 (0.5)	0.2-0.5 (0.4)
April 2006	0.4-0.6	0.5-0.6	0.5-0.6	0.4-0.8	0.3-0.6

The above data indicate no appreciable change in the concentration of nitrite off Mundra during the post development phase of the Mundra region.

Like nitrite, the concentrations of ammonia are expected to be low in the Gulf. This is also true off Mundra, which is clear from the following averages (µmol/l):

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	0.2-4.9 (1.3)	0.6-1.4 (1.0)	-	-	0.2-0.6 (0.4)
March 1999	0.9-2.2 (1.3)	0.6-2.2 (1.1)	1.6-5.1 (2.9)	-	0.4-6.4 (1.4)
September 1999	-	-	-	ND-3.6 (1.2)	-
March 2000	0.1-0.3 (0.2)	0.1-1.9 (0.4)	-	-	ND-23.5 (1.3)
June 2003	ND-0.2 (0.1)	0.1-3.2 (0.5)	-	-	ND-4.4 (1.1)

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
October 2003	0.3-1.9 (0.9)	0.1-4.1 (0.7)	0.3-2.8 (1.6)	-	ND-14.5 (0.8)
December 2004	ND-0.3 (0.2)	0.2-0.4 (0.3)	0.3-0.8 (0.6)	-	0.5-3.4 (2.0)
May 2005	1.2-.2 (1.7)	0.7-3.0 (1.6)	0.7-1.2 (1.0)	-	0.1-1.8 (1.0)
January 2006	0.2-0.5 (0.4)	ND-1.0 (0.5)	-	0.3-0.8 (0.6)	ND-6.1 (0.4)
April 2006	0.6-0.7	0.5-0.8	0.4-0.6	0.5-1.1	0.2-1.0

Ammonia in natural marine waters is a product of oxidation of organic matter though most marine organisms excrete ammonia in small quantities. Under oxidizing conditions in shallow coastal areas this ammonia is oxidized to nitrate via nitrite. In waters under pollution stress, ammonia often occurs in high concentrations.

The results presented in the above table are indicative of no appreciable change in the concentration of ammonia off Mundra except for abnormal levels in the Gulf off Mundra during March 2000 and October 2003. This would be an isolated case since the average concentrations of ammonia throughout the study region were low during January 2006 and comparable to the results of June 1998. Occasional occurrence of relatively high levels of ammonia has also been recorded at other sites in the Gulf.

The overall assessment indicates that the water quality off Mundra with respect to nutrients has not measurably altered after the Mundra Port and other development have become operational.

4.3.7 PHc and phenols

Oil enters the marine environment by a number of different routes as a result of both human activities and natural processes. By far, the biggest contribution comes from terrestrial sources, mainly in the form of municipal and industrial wastes. The rate and extent to which oil dissolves, depends upon its composition, extent of spreading, water temperature, turbulences and degree of dispersion. The heavy components of crude oil are virtually insoluble in seawater whereas lighter compounds particularly aromatic hydrocarbons such as benzene and toluene, are slightly soluble. However, these components are also the most volatile and so are lost very rapidly by evaporation, typically 10-1000 times faster than by dissolution. Concentrations of dissolved hydrocarbons thus rarely exceed 1 mg/l even in areas receiving their fluxes.

Earlier and present concentrations of (A) PHc (µg/l) (B) Phenols (µg/l) off Mundra are as follows:

Year	PHc/ Phenols	Creek				Gulf
		Bocha	Navinal	Baradimata	Kotdi	
June 1998	A	0.9	1.2	-	-	0.8
	B	24	21	-	-	-
March 1999	A	1.8	1.3	0.8	-	1.3
	B	108	104	93	-	86
September 1999	A	-	-	-	0.3	-
	B	-	-	-	86	-
March 2000	A	2.7	11.9	-	-	2.5
	B	38	64	-	-	46
June 2003	A	1.3	0.9	-	-	4.6
	B	21	41	-	-	28
October 2003	A	7.0	5.0	2.2	-	4.6
	B	26	29	39	-	41
December 2004	A	9.6	26.0	15.0	-	12.6
	B	47	70	59	-	28
May 2005	A	1.5	12.0	19.9	-	12.2
	B	12	61	13	-	36
January 2006	A	16.7	17.2	-	26.1	15.8
	B	4.6	14.6	-	63.8	24.8
April 2006	A	17.4	19.0	13.8	14.9-17.7	10.6-24.9
	B	21.4	1.4	26.2	21.8-32.0	12.0-41.0

These results indicate that the concentration of PHc off Mundra is low in line with the levels recorded for the Gulf. Further, it appears that the levels of PHc have increased in the post developmental phase of the Mundra Port; the maximum value recorded being 26.1 µg/l in January 2006 (Table 4.3.7).

The average concentrations of phenols in water are low and indicate an environment free from contamination by phenols.

4.4 Sediment quality

Determination of trace pollutants such as heavy metals and organic compounds in water often reveals fluctuations as the concentrations depend on the location and time of sampling, nature of pollutant and chemical characteristics of water. Moreover, several pollutants get fixed rapidly to particulate suspended matter and are thus removed from the water column. In several instances, it is observed that even close to a location of effluent release, the metal content in receiving water often decreases to a normal value making assessment of contamination through analysis of water, a difficult task.

The pollutants adsorbed by the particulate matter are ultimately transferred to bed sediment on settling. Evidently, concentrations of pollutants in sediment increase over a period of time in regions receiving their fluxes. Hence, sediment can serve as a useful indicator of certain trace pollutants such as heavy metals and PHc.

4.4.1 Texture

The northern shore of the Gulf is predominantly sandy or muddy confronted by numerous shoals. The local sediment regime at Mundra is highly dynamic under the influence of strong tidal currents and wave action, particularly during monsoon. The littoral sediment transport is high, with the movement, induced by breaking waves being the dominant cause of sediment transport along the upper intertidal area. In the lower intertidal, the sediment is mobilised by wave action is transported by tidal currents. Computational modelling of sediment transport (H.R.Willingford) indicates a net drift rate of 3.2 x 10^5 m^3/y directed towards eastwards at Mundra. Under the influence of this transport the sediment of intertidal area is poorly sorted with highly variable skewness.

The sediment texture along openshore of the Navinal Island is generally sandy while the intertidal areas of the creek are largely sandy silt with occasional sand patches.

The shallow cores retrieved from the area of the Mundra Port indicate the occurrence of greyish brown, dense nonplastic sandy silt upto the termination depth of 30 m. The surface 1.5 m layer typically contains of 70 - 90% sand with silt and clay in minor proportions. The specific gravity of the sediment, which does not vary significantly in texture upto the termination depth, varies between 2.65 and 2.68.

4.4.2 Heavy metals

Natural sediments always contain heavy metals to a varying degree depending on the source rock from which they are derived as well as the environment of deposition. This lithogenic fraction should be known fairly accurately to estimate increase due to anthropogenic fluxes. The situation however is complicated due to significant variations in concentration of metals in different areas of the given region primarily because of the grain-size effect; the sediment with high clay content often exhibiting higher lithogenic metals. The grain size effect can be compensated to a certain extent by normalising the metal value with aluminium, which can be considered as a measure of clay content.

The results of analyses of subtidal and intertidal sediment around Mundra are presented in Tables 4.4.1 for January 2006 whereas long term (1998-2006) sediment quality of Bocha Creek, Navinal Creek, Bocha Creek and Gulf segment of Mundra is

presented in Tables 4.4.2 to 4.4.5 respectively. The results are summarised in the following table:

Metal	July 1998			
	Bocha Creek	Navinal Creek	Kotdi Creek	Gulf
Al (%)	6.6	6.2	-	2.9
Cr (µg/g)	71	52	-	47
Mn (µg/g)	792	738	-	477
Fe (µg/g)	4.5	4.3	-	2.1
Co (µg/g)	34	32	-	16
Ni (µg/g)	56	52	-	17
Cu (µg/g)	36	31	-	20
Zn (µg/g)	75	72	-	36
Hg (µg/g)	0.42	0.51	-	0.15
	March 1999		* Sept 1998	
Al (%)	9.3	7.8	-	4.1
Cr (µg/g)	172	138	-	79
Mn (µg/g)	893	835	-	602
Fe (µg/g)	4.9	4.4	-	2.9
Co (µg/g)	43	37	-	28
Ni (µg/g)	67	55	-	26
Cu (µg/g)	47	38	-	24.5
Zn (µg/g)	102	85	-	51
Hg (µg/g)	0.22	0.5	-	0.26
	March 2000			
Al (%)	8.5	5.7	-	3.5
Cr (µg/g)	139	136	-	62
Mn (µg/g)	837	660	-	610
Fe (µg/g)	4.6	4.3	-	2.6
Co (µg/g)	39	36	-	29
Ni (µg/g)	59	54	-	29
Cu (µg/g)	44	40	-	20
Zn (µg/g)	92	79	-	66
Hg (µg/g)	0.3	0.2	-	0.5
	June 2003			
Al (%)	7.8	7.3		3.3
Cr (µg/g)	250	167		45
Mn (µg/g)	1051	755		538
Fe (µg/g)	8.0	4.8		2.4
Co (µg/g)	34	20		7.4
Ni (µg/g)	81	55		21.5
Cu (µg/g)	101	40		15
Zn (µg/g)	148	98		56
Hg (µg/g)	0.34	0.22		0.31
	October 2003			
Al (%)	7.2	6.3		3.1
Cr (µg/g)	80	101		29.2
Mn (µg/g)	705	635		401
Fe (µg/g)	4.7	3.8		1.6
Co (µg/g)	21	18		5
Ni (µg/g)	59	51		13.5
Cu (µg/g)	49	39		13
Zn (µg/g)	95	80		34
Hg (µg/g)	-	-		-

Metal	July 1998			
	Bocha Creek	Navinal Creek	Kotdi Creek	Gulf
December 2004				
Al (%)	8.2	6.9		3.3
Cr (µg/g)	50	123		75
Mn (µg/g)	714	1162		716
Fe (µg/g)	5.0	5.1		3.2
Co (µg/g)	ND	20		9.7
Ni (µg/g)	57	59		26
Cu (µg/g)	-	44		19
Zn (µg/g)	151	84		71
Hg (µg/g)	ND	0.05		0.1
May 2005				
Al (%)	7.1	7.2		4.6
Cr (µg/g)	92	90		47
Mn (µg/g)	807	820		554
Fe (µg/g)	4.9	4.4		2.9
Co (µg/g)	22	22		12
Ni (µg/g)	80	87		45
Cu (µg/g)	40	42		22
Zn (µg/g)	77	85		55
Hg (µg/g)	-	-		-
January 2006				
Al (%)	-	-	4.2	2.7
Cr (µg/g)	-	-	49	45
Mn (µg/g)	-	-	602	778
Fe (µg/g)	-	-	6.8	5.4
Co (µg/g)	-	-	28	19.8

Metal	July 1998			
	Bocha Creek	Navinal Creek	Kotdi Creek	Gulf
Ni (µg/g)	-	-	53	31.6
Cu (µg/g)	-	-	23	23
Zn (µg/g)	-	-	258	173
Hg (µg/g)	-	-	-	-

Wide variations in the concentration of metal not only from pre to post development phase of the Mundra but also at a given location during the two sampling events. Such differences can occur if the texture and the composition of the sediment changes due to the movement of the bed material under continuous tidal movements which are significant in the Gulf, accretion and erosion, changes in sediment littoral transport etc. From the Tables 4.4.1 to 4.4.5 it appears that the differences in the trace metal concentrations in the sediment are intimately associated with the variation in the sediment character rather than due to anthropogenic influences. It is also evident that the concentrations of most metals are relatively high in the creek region as compared to open Gulf.

4.4.3 C_{org} and phosphorus

The levels of these constituents in the subtidal sediments vary in the following range.

Year	Bocha Creek		Navinal Creek		Gulf	
	C_{org} (%)	P (µg/g)	C_{org} (%)	P (µg/g)	C_{org} (%)	P (µg/g)
June 1998	0.8	1341	0.8	1059	0.2	542
March 1999	0.9	845	-	808	0.4	572
March 2000	-	693	-	755	-	588
June 2003	1.5	846	0.8	610	0.05	464
October 2003	0.9	540	0.9	278	0.12	189
December 2004	0.7	1822	0.8	790	0.3	674
May 2005	0.8	906	0.9	956	0.3	731

These levels are low and indicate sediment free from organic pollution and do not indicate accumulation of these constituents in the sediments of this highly bio-produce environment. Also, the present results are comparable with the 1998 results.

4.4.4 PHc

The PHc content (µ/g; wet wt) of the subtidal and intertidal sediment off Mundra vary in the following regions.

Zonation	PHc (µg/g, wet wt)						
	June 1998	March 1999	June 2003	December 2004	May 2005	January 2006	April 2006
Subtidal	-	1.5	0.8	0.3	0.2	4.0	
Intertidal	-	-	-	-	-	5.0	

The concentration (µg/g, wet wt) of PHc presented above suggests that the PHc accumulation in the sediment is insignificant. Hence, the traffic of crude oil and petroleum products, which is substantial in the Gulf, has not caused sediment enrichment with PHc, off Mundra.

4.5 Flora and fauna

Whenever probable implications of a coastal development on marine environment are assessed, it must be remembered that despite many changes the development may cause in the physico-chemical properties of the coastal marine ecosystem including the bed sediments, the ultimate concern is inevitability the biological resource. Hence, the assessment of status of flora and fauna at the development site is very important. Floral and faunal components in the coastal zone are highly diverse inhabiting a variety of ecosystems. However, it is not practical to include all components in a monitoring programme and EIA studies because of shear complexity of ecosystem. However, areas of high ecological importance such as zones of rich biological productivity and feeding, breeding,

spawning and fishing grounds of economically important organisms which can be degraded due to a coastal activity should be studied in more detail and should be included in the investigations of this nature.

The living community of an ecosystem comprises of consumers, producers and decomposers and related non-living constituents interacting together and interchanging materials as a whole system. The basic process in an aquatic ecosystem is the primary productivity. The transfer of energy from the primary source through a series of organisms is defined as the food chains, which are of two basic types; the grazing food chain and the detritus food chain. The stress may cause the communities to exhibit low biomass and high metabolism. In addition, due to depressed functions of less tolerant predators, there may be also a significant increase of dead organic matter deposited in sediments of ecosystems modified under stress. Depending upon the type, strength and extent of a stress factor, the ecosystem will react to either re-establish the previous equilibrium or establish a new one, or it may remain under prolonged disequilibrium.

The biological parameters considered for the present monitoring study are phytoplankton pigments and cell count, zooplankton standing stock and population, macrobenthic biomass and population and fishery status. The first two reflect the productivity of water column at the primary and the secondary levels. Benthic organisms being sedentary animals associated with the seabed, provide information regarding the integrated effects of stress, if any, and hence are good indicators of early warming of potential damage. Assessment of mangroves and corals are considered as a part of overall ecological evaluation. The aggregate data presented in Tables 4.5.1 to 4.5.36 and Figures 4.5.1 to 4.5.4 are used to evaluate the status of flora and fauna in the coastal system off Mundra.

4.5.1 Seaweeds, seagrasses and mangrove ecosystem

Marine flora like algae and mangrove play a significant role in enriching nearshore sea, by adding dissolved organic matter, nutrients and detritus besides serving as nursery areas for the larvae and juveniles of several marine animals.

Coastal vegetation such as seaweeds, seagrasses and mangroves were studied from the subtidal to the HTL in the Navinal - Bocha - Baradi Mata - Kotdi Creeks complex and within the proposed development site where the intertidal region is largely sandy - silt. The marine alga *Enteromorpha* sp commonly occurs in the

intertidal area while seagrasses are dominated by *Halophila ovata* and *Halodule uninervis*.

Mangrove ecosystem

Mangroves are salt tolerant forest ecosystem of tropical and subtropical intertidal regions of the world. Where conditions are sheltered and suitable, the mangroves may form extensive and productive forests like around Mundra, which are the reservoirs of a large number of species of plants and animals. The role of mangrove forests in stabilizing the shoreline or coastal zone by preventing soil erosion and arresting encroachment on land by sea, is well recognised thus minimising water logging and formation of saline banks.

Vegetation of mangrove ecosystem can be divided into the following broad categories.

(a) Mangroves
(b) Salt marshes
(c) Sand stands

a) Mangroves

Mangrove forests are extensive along the coastal belt of Kachchh District occupying an area of 1067 km^2 as a dense forest; dominant species being *Avicennia* with almost pure stands at place. In some localities these are associated with *Avicennia officinalis, Rhizophora mucronata, Bruguiera gymonorrhiza, Ceriops tagal, Aegiceras corniculatune* and *Sonneratia apetala*. Other associated mangrove flora includes species such as *Salicornia brachiata, Sucieda fruticoa* and *Atriplex stocksii*.

The areas around Kandla-Nakti, Hansthal, Navinal-Bocha, Baradi Mata-Kotdi Creek complex, Khori Creek etc represent the best mangrove formations along the northern shore of the Gulf. These mangrove areas are seen as red patches bordering the creeks in satellite imagery shown in Figure 2.0.2. The study area is represented by a few species of mangroves and 3 obligate halophytes (Table 4.5.1). Mangroves are dominated by *Avicennia marina* and are of fringing type in regularly inundated zones along the water ways. Mangrove belts bordering short segments of Kotdi Creek/Baradimata Creek-2, are degraded and under pressure of camel grazing and cutting for firewood. The stray plants of *Rhizophora mucronata* also occur among *Avicennia* stands. *Salvodora persica* commonly occur in the supralittoral regions towards the HWL.

Avicennia thickets are generally dwarf (0.5 - 1.5 m height) and sparse in regions away from the water ways, however, the height (> 3 m) exist along the water ways in about 20 - 50 m belt about 11 Kms away from the project area. (Figure 4.5.2). A small patch of dwarf and sparse plants of mangroves exist at about 4 Kms from the project site with density (1 - 2 nos./100 m^2).

Sesuvium portulacastrum is common at the HTL along the creeks. Beds of *Salicornia brachiata* commonly habit the areas inland of regularly inundated zones or above the mean high tide line. The *Salicornia* stands are more dense towards waterways and become sparse in saline banks. *Sueda maritima* is sparsely distributed in the saline bank regions.

The major land portion proposed for the developments falls under saline bank, which is devoid of mangrove vegetation except for a few stray plants. Very poor leaching of salts due to low frequency of inundation and poor rainfall result in salt encrustation of saline banks rendering them unsuitable for vegetation to grow except for stray halophytes like *Sueda maritima*. It may be mentioned here that it is a common practice to utilize such saline banks or supralittoral regions of low biological productivity and diversity for salt works in the Gulf.

Overall assessment indicates that the site proposed for the development largely falls under the category of supralittoral and saline banks devoid of mangroves. However, the area proposed for intake and discharge channels sustain sparse (plant density 0-4 /100m^2 average 1plant/100 m^2 stunted(<0.6m) mangroves of monospecies (Avicennia marina).

b) Salt marshes

The vegetation of this zone consists predominantly of *Aeluropes lagopoides*, supported by *Sporoblus* sp. *Cressa cretica* also occur in dried salt marshes and salt pans. Presence of species such as *Cyperus pangorei*, *Bergia adorata* and *Oldenlandia umbellata* is probably an indication of retrogression due to the detrimental effect of salt works.

c) Sandy stands

In the sandy patches between the rocks, a few species such as *Cyperus conglomerates* and *Asparagus demosus* are identified.

4.5.2 Phytoplankton

Phytoplankton forms the vast array of minute and microscopic plants passively drifting in natural waters and mostly confined to the illuminated zone. In an ecosystem these organisms constitute primary producers forming the first link in the food chain. Phytoplankton long have been used as indicators of water quality. Some species flourish in highly eutrophic waters while others are very sensitive to organic and/or chemical wastes. Some species develop noxious blooms, sometimes creating offensive tastes and odours or anoxic or toxic conditions resulting in animal death or human illness. Because of their short life cycles, plankton respond quickly to environmental changes. Hence their standing crop in terms of biomass, cell counts and species composition are more likely to indicate the quality of the water mass in which they are found. Generally, phytoplankton standing crop is studied in terms of biomass by estimating chlorophyll *a* and primary productivity and in terms of population by counting total number of cells and their generic composition. When under stress or at the end of their life cycle, chlorophyll *a* in phytoplankton decomposes with phaeophytin as one of the major products.

Phytoplankton biomass is estimated in terms of concentration of phytopigments. The levels of chlorophyll *a* (0.2 - 14.1 mg/m^3) and phaeophytin (0.1 - 10.2 mg/m^3) vary in wide range in the coastal ecosystem off Mundra (Tables 4.5.2 and 4.5.3). The variations from the surface to bottom are negligible indicating their uniform distribution throughout the water column. This homogenous nature of the water mass perhaps provides stability for the biological processes. The comparison of their distribution in the area during 1998 to 2005 with present study (Table 4.5.4) is given in the table below.

Year	Chlorophyll a (mg/m^3)				
	Creek				
	Bocha	Navinal	Baradimata	Kotdi	Gulf
June 1998	1.1 - 2.7 (1.7)	2.1-5.3 (3.8)	2.1-3.2 (2.8)	-	1.1-4.3 (2.2)
March 1999	0.5-2.7 (1.4)	0.6-2.7 (1.6)	0.5-2.7 (2.2)	-	0.5-4.8 (1.2)
September 1999	-	-	-	12.8-16.0 (14.4)	-
March 2000	1.6-3.2 (2.3)	1.1-2.1 (1.6)	-	-	0.5-3.2 (1.3)
June 2003	1.1-2.4 (1.8)	0.4-4.3 (2.1)	2.4-4.3 (3.7)	-	0.2-4.1 (1.0)

Year	Chlorophyll *a* (mg/m^3)				
	Creek				
	Bocha	Navinal	Baradimata	Kotdi	Gulf
October 2003	1.5-1.7 (1.6)	0.2-2.4 (1.4)	1.5-2.9 (2.0)	-	0.2-3.4 (1.0)
December 2004	1.1-3.8 (2.5)	2.8-7.5 (5.2)	2.4-38.5 (14.0)	-	0.2-12.8 (10.0)
May 2005	1.1-1.5 (1.3)	0.2-2.1 (1.2)	0.2-3.2 (1.4)	-	0.2-2.1 (0.8)
January 2006	0.9-1.1 (1.0)	0.2-0.4 (0.3)	0.4-0.9 (0.8)	0.2-1.7 (0.9)	0.2-14.1 (1.6)
	Phaeophytin (mg/m^3)				
June 1998	0.1-2.2 (1.2)	0.8-2.9 (2.0)	1.3-2.7 (2.0)	-	0.9-2.1 (1.3)
March 1999	0.2-3.5 (0.7)	0.3-3.7 (1.0)	0.3-1.1 (0.7)	-	0.1-2.7 (0.6)
September 1999	-	-	-	3.3-3.4 (3.4)	-
March 2000	0.2-1.0 (0.8)	0.1-1.0 (0.5)	-	-	0.1-1.2 (0.5)
June 2003	0.2-1.3 (0.7)	0.1-1.9 (0.8)	0.3-0.8 (0.6)	-	0.1-1.6 (0.5)
	Phaeophytin (mg/m^3)				
October 2003	0.2-1.0 (0.5)	0.1-1.0 (0.5)	0.3-1.0 (0.6)	-	0.1-1.5 (0.4)
December 2004	0.1-1.1 (0.6)	0.4-1.5 (1.0)	0.4-4.0 (2.2)	-	0.1-26.7 (2.8)
May 2005	2.5-3.7 (3.0)	2.2-6.4 (4.4)	3.1-10.4 (5.7)	-	0.4-7.2 (2.6)
January 2006	0.9-1.1 (1.0)	1.4-2.3 (2.1)	0.6-2.4 (1.2)	1.2-2.4 (1.8)	0.1-10.2 (2.3)

It is evident from the above table that average concentrations of chlorophyll *a* and phaeophytin have not changed significantly off Mundra and the sea around, though high values are occasionally observed.

The average concentration of phaeophytin is often lower or comparable with the concentration of chlorophyll *a* as commonly observed for coastal waters of the Gulf. The temporal variation in phytoplankton pigment concentrations does not show any marked variation (Figure 4.5.2).

In line with the high variability of pigments, the average cell count (no x 10^3/l) of phytoplankton also varies (Tables 4.5.5 - 4.5.7) dramatically as evident from the following results.

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	14.7	10.1	-	-	5.0
March 1999	69.5	58.3	60.8	-	65.1
September 1999	-	-	-	1465	-
March 2000	18.5	9.9	-	-	10.0
June 2003	164.1	117.6	164.0	-	90.9
October 2003	170.3	104.1	169.0	-	114.4
December 2004	260.4	524.1	1414.5	-	1878.5
May 2005	115.1	330.4	69.1	-	197.2
January 2006	14.4	22.0	12.8	55.6	415.6

These results reveal variable phytoplankton cell counts in the region with marked increase during recent years. These results indicate no regular trend in the distribution pattern of phytoplankton. This can be due to high patchiness and uneven distribution of phytoplankton cells in the coastal waters. The following table also indicates marked variations in the average (no) genera of phytoplankton in the Gulf off Mundra.

Year	Creek				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	5	5	-	-	3
March 1999	10	10	10	-	11
September 1999	-	-	-	14	-
March 2000	15	12	-	-	11
June 2003	14	12	13	-	11
October 2003	19	20	20	-	16
December 2004	19	15	15	-	17
May 2005	10	10	13	-	13
January 2006	13	13	12	13	13

The results indicates an increase in generic number since June 1998. Enhanced generic diversity in association with higher cell counts indicates good conditions of phytoplankton growth. The generic diversity varies from 7 to 17 (av 13) in the area (Table 4.5.8). Overall, about 40 genera of phytoplankton are recorded from Mundra region during January 2006. The populations are dominated by *Thalassiosira, Thalassionema, Pleurosigma, Amphiprora, Biddulphia, Coscinodiscus Diploneis, Ditylum, Fragilaria, Gyrosigma, Melosira, Navicula, Nitzschia* and *Rhizosolenia*.

Overall, the results reveal a fluctuating primary productivity in both the creek and Gulf area. The generic diversity is comparable in both regions. The generic distribution and the dominance of phytoplankton between the pre and post-developmental phases are broadly comparable within the general variability inherent to coastal waters.

4.5.3 Zooplankton

By virtue of sheer abundance and intermediate role between phytoplankton and fish, zooplankton is considered as the chief index of utilization of aquatic biotope at the secondary trophic level. Zooplankton includes arrays of organisms, varying in size from the microscopic protozoans of a few microns to some jelly organisms with tentacles of several metres long.

Zooplankton standing stock in terms of biomass (av1.5 - 123.0 ml/100m^3) and population (av 2.4 - 163.7 x 10^3/100m^3) reveals good secondary production in the coastal waters off Mundra (Tables 4.5.9) though the distribution indicates considerable spatial and tidal fluctuations. The temporal variations in distribution of zooplankton standing stock revealed no particular trend (Table 4.5.10). The zooplankton standing stock in different segments of the study area recorded during the present study is comparable with the results of 1998-2005 (Table 4.5.11) in the following table.

Year	Biomass (ml/100m^3)				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
June 1998	0.4-14.2 (4.9)	7.7-17.1 (13.3)	-	-	7.4-38.4 (16.7)
March 1999	0.9-262.7 (92)	2.7-343.5 (93.0)	8.4-18.8 (13.6)	-	1.2-124..2 (13.5)
September 1999	-	-	-	2.0-2.2 (2.1)	-
March 2000	0.4-25.1 (15.6)	0.4-10.2 (4.3)	-	-	0.4-80.0 (9.3)
June 2003	2.0-6.1 (4.3)	2.5-4.7 (3.3)	2.9-3.2 (3.1)	-	0.9-9.6 (2.7)
October 2003	0.5-2.6 (1.5)	2.2-6.0 (3.9)	0.5-2.9 (1.7)	-	1.1-21.8 (5.2)
December 2004	1.5-12.2 (11.9)	8.4-9.0 (8.7)	1.9-27.3 (9.5)	-	3.0-23.2 (7.2)
May 2005	1.2-10.9 (5.5)	13.0-17.1 (15.1)	19.2-31.0 (24.5)	-	0.8-409.9 (123)
January 2006	2.3-6.7 (4.5)	3.3-4.5 (3.9)	1.9-3.0 (2.5)	2.1-2.9 (2.5)	2.2-13.1 (5.2)
Population (nox10^3/100 m^3)					
June 1998	5.2-45.2 (27.7)	38.3-156.1 (98.4)	-	-	19.9-28.5 (24.7)
March 1999	3.7-280.3 (116.6)	7.0-571.9 (163.5)	43.9-151.5 (97.7)	-	2.5-152.2 (34.0)
September 1999	-	-	-	6.4-25.4 (15.9)	-
March 2000	5.2-141.5 (74.4)	4.1-62.8 (21.7)	-	-	5.3-234.6 (42.0)
June 2003	35.7-95.8 (64.4)	12.0-87.2 (61.7)	40.9-49.7 (45.3)	-	7.7-58.1 (18.7)
October 2003	2.7-42.9 (22.9)	4.7-48.1 (28.1)	3.6-6.8 (5.2)	-	11.7-315 (38.1)
December 2004	26.2-34.7 (30.4)	17.2-17.5 (17.3)	6.5-261.3 (74.0)	-	5.1-58 (20.7)
May 2005	4.3-50.2 (19.8)	35.3-105.1 (70.2)	07.8-136.4 (94.7)	-	3.2-232.3 (37.4)
January 2006	3.7-10.4 (7.0)	4.9-5.8 (5.3)	1.7-3.2 (2.4)	14.4-18.8 (16.6)	5.1-141 (30.2)
Total groups (no)					
June 1998	6-13 (11)	10-13 (11)	-	-	11-13 (12)
March 1999	6-17 (12)	4-15 (11)	10-13 (12)	-	9-13 (10)

Year	Biomass (ml/100m^3)				Gulf
	Bocha	Navinal	Baradimata	Kotdi	
September 1999	-	-	-	14-16 (15)	-
March 2000	6-9 (8)	8-13 (10)	-	-	6-18 (11)
June 2003	15-19 (18)	15-18 (17)	15-17 (16)	-	12-18 (15)
October 2003	11-20 (16)	12-20 (17)	13-19 (16)	-	12-17 (15)
December 2004	18-21 (20)	16-17 (17)	16-19 (17)	-	13-19 (16)
May 2005	11-17 (15)	14-15 (15)	11-12 (12)	-	12-18 (15)
January 2006	14-18 (16)	13-16 (15)	11-15 (13)	16-18 (17)	13-21 (17)

Wide spatial variation in zooplankton biomass and population off Mundra is evident from the above results. These variations in zooplankton standing stock are invariably associated with factors like tide, patchiness in their distribution, seasonal changes and grazing pressure within the food chain. Such variations are common to dynamic coastal waters.

A comparison of average zooplankton standing stock of the Mundra area is given below:

Parameter	June 1998	March 1999	Sept 1999	Mar 2000	Jun 2003	Oct 2003	Dec 2004	May 2005	Jan 2006
Biomass (ml/100 m^3)	11.3	53.0	2.1	9.7	3.4	3.1	9.3	42.0	3.7
Population (nox10^3/100 m^3)	50.3	103.2	15.9	46.0	47.5	66.0	35.6	55.5	12.3
Faunal groups (no)	11	11	15	10	17	16	18	14	16

The above table reveals noticeable seasonal fluctuations in zooplankton standing stock but suggests relatively better standing stock during premonsoon period as compared to other season. A marginal decreased in average standing stock of zooplankton from 1998 to 2006 is also evident. However, the faunal group diversity is comparable between the these periods. The variation in zooplankton standing stock is probably responsible for variation in phyto population and (Section 4.5.2) due to grazing pressure.

The zooplankton community structure reveals (Table 4.5.12) the dominance of copepods and decapod larvae in the study area as given Table 4.5.12. The other common groups are foraminiferans, siphonophores, medusae, ctenophores, chaetognaths, polychaetes, ostracods, mysids, *Lucifer*, gastropods, lamellibranches and appendicularian. Also the community structure of major groups between the pre- and post development phases of the Mundra Port is also comparable and noticeable changes in ecology of zooplankton off Mundra is absent. A total of 26 faunal groups

are encountered (Table 4.5.12) though all of them do not occur at any given location. The group diversity of zooplankton varies from 13 to 21 (av 16 groups). It is also evident from the above that the faunal group diversity of zooplankton at different segments is closely comparable.

In general, the coastal waters off Mundra reveal good production of zooplankton associated with significant spatial, temporal and seasonal changes.

Breeding and spawning

To identify breeding grounds of fishes and crustaceans, extensive field observations over a long duration are required. This approach was not possible during the present short term investigations. Hence, alternatively, decapod larvae, fish eggs and fish larvae were studied from zooplankton collections and taken as indices of probable existence of spawning grounds. The adults, caught during trawling, were considered for comparison. The available information on the breeding habits of the species found in the area are also included as a supportive literature.

i) Decapods

This group forms the major constituent of zooplankton and includes the larval stages of commercially important shrimps. During January 2006, the population density varied from 53 to 1.9 x 10^4 no/100 m^3 (av 3.1 x 10^3 no/100 m^3) constituting 0.3 to 63.7% (av 22.7%) to the total zooplankton population (Table 4.5.13). The population of larvae is markedly high in the creeks, the most common constituents being crab zoea, stages of *Acetes* and *Lucifer* sp, Alpheids, megalopa and porcellenid larvae.

The distribution of decapod larvae, *Acetes* and *Lucifer* sp are given in Table 4.5.14 and average (nox10^3./100m^3) off the Mundra are summarized here which varies in accordance with the season in line with zooplankton distribution.

Year	Creek				Gulf	Average
	Bocha	Navinal	Baradimata	Kotdi		
June 1998	16.6	17.7	-	-	2.4	12.0
March 1999	18.9	25.9	29.1	-	5.1	19.8
September 1999	-	-	-	-	-	-
March 2000	13.5	4.0	-	-	6.6	8.0
June 2003	45.5	48.0	35.0	-	3.2	32.9
October 2003	22.2	18.6	-	-	7.4	16.1
December 2004	9.1	9.7	44.8	-	4.1	16.9
May 2005	10.5	25.7	91.5	-	-	42.6
January 2006	2.9	1.1	<0.1	4.3	6.7	3.1

All commercial penaeid prawns of the Indian waters breed in the sea in relatively deeper waters in relation to the area of normal habitat of adult prawns. Penaeid prawns have high fecundity and the number of eggs produced varies from species to species and size of the prawn. *M.affinis*, *M.dobsoni*, *M.monoceros* and *P.stylifera* breed throughout the year with individually delineated peak breeding period. The eggs are released while swimming in the columnar waters or near the bottom. The early development takes place in the open sea and post larvae enter the creeks/estuaries/backwaters and attain all the adult characters including secondary sexual characters. They return to the sea where maturation of the ovary and subsequent spawning takes place.

Generally, the spawning grounds of penaeid prawns are away from the coast. The spawning ground of *M.dobsoni* is reported to be at 20 - 30 m while that of *M.affinis* is at still deeper waters. Spawning ground of *M.monoceros* is reported to be at 50 - 65 m and that of *P.stylifera* at 18 - 25 m. *M.affinis* and *P.stylifera* prefer areas of soft mud and zones of rich plankton for mating and spawning.

Acetes indicus are another common economically important species of shrimps. During January-April they form conspicuous aggregations near the shore and are fished on a large scale. Fishing grounds of these shrimps are mostly located in calm muddy intertidal zones or waters shallower than 5 m. The life span of *Acetes* is 3 - 10 months and the adults die soon after spawning. Breeding is continuous and surface water currents stimulate *Acetes* to swarm in shallow inshore waters when the wind blows moderately towards the coast.

The Gulf has a varied representation of prawns and so far 27 species belonging to Penaeidea and Caridea are recorded. Out of these, species like *P.penicillatus*, *M.brevicornis*, *M.kutchensis* and *Parapenaeopsis sculptilis* are commercially important. *M.brevicornis* occur in high number along the northern shore of the Gulf between Mandvi and Luni where the substratum is sandy. Higher percentage of *M.kutchensis* are generally confined to the inner Gulf area because the substratum predominantly contains clayey silt. The Gulf segment off Mundra is generally composed of sandy silt (Section 4.4) which can influence the distribution of *M.kutchensis* a very hardy, euryhaline prawn with a probable preference for clayey silt substratum. Beside the substrate preference, another possible factor, which may control the distribution of prawns along the northern coast of the Gulf can be tidal

currents which during the course of their movement (prawns) into and out of the Gulf, may act as a hydraulic barrier.

ii) Fish eggs and larvae

Fish eggs and larvae though less in number (0 - 240 no/100 m^3; av 22/100 m^3) are fairly common among zooplankton (Table 4.5.15). Fish eggs occur in 67.3% samples in January 2006 with an increase in the open Gulf.

The relative occurrence and abundance of fish larvae are more than fish eggs. During January, the variation in fish larvae is from 0 to 65 no/100 m^3 (av 15 no/100 m^3) and occurred in 75% of zooplankton samples.

The relative abundance and frequency of occurrence of the fish eggs and fish larvae are given in Table 4.5.16 and their averages are summarized here.

Year	Creek				Gulf	Average
	Bocha	Navinal	Baradimata	Kotdi		
Fish eggs (no/100 m^3)						
June 1998	2	1	-	-	13	5
March 1999	43	3	-	-	12	19
September 1999	-	-	-	-	-	-
March 2000	6	1	-	-	5	4
June 2003	25	1	-	-	4	10
October 2003	1	1	-	-	5	2
December 2004	57	80	9	-	19	41
May 2005	1	153	-	-	9	54
January 2006	182	42	-	6	6	59
Fish larvae (no/100 m^3)						
June 1998	40	119	110	-	52	80
March 1999	339	8	-	-	7	118

Year	Creek				Gulf	Average
	Bocha	Navinal	Baradimata	Kotdi		
Fish eggs (no/100 m^3)						
September 1999	-	-	-	-	-	-
March 2000	6	5	-	-	7	6
June 2003	3621	838	-	-	52	1470
October 2003	5	21	-	-	10	12
December 2004	6	1	15	-	5	7
May 2005	102	44	120	-	181	112
January 2006	8	-	-	13	19	13

As expected, it is evident from the above table that occurrence and abundance of fish eggs and fish larvae are more in creek region than the open Gulf. A wide variation when compared to the data between 1998 and 2006 is clearly evident.

In general, the species of Gobiidae like *Gobius planifrons*, a non economically important group is dominant among fish larvae. Larvae of economically important species like *Thryssa purava, Scomber microlepidatus,* Clupeidae, *Colia dussumieri, Stolephorus indicus, Hilsa kelee*, Sciaenids, Percoidei and Belonidae occur in very low numbers. From the overall distribution pattern of fish larvae it is evident that none of the economically important species are common in the area except for isolated relatively higher records of *Thryssa purva* and *Scomber microlepidatus.*

Trawl catch from the coastal water off Mundra is dominated by *Harpadon nehereus*. However, the abundance of fish eggs and early stages of the species was poor in the zooplankton samples. *H.nehereus* is a continuous breeder with intense activity from October to April and slack from May to September. Breeding of the species is reported in deeper waters (> 75 m) and the number of ova produced vary from 1.5×10^4 to 1.5×10^5 no.

The mud skippers or gobids are not economically important and larvae of this group dominate the area. Early preflextion stages of the groups are common suggesting that they are local breeders..

The economically important group like *Thryssa purava* is fished commercially in small quantities in Mundra region. The fish grows upto a length of 30 cm and is reported to breed in estuaries and tidal reaches of rivers.

The larvae of other economically important species like *Scomber microlepidatus* is a pelagic shoaling fish synonyms to Rastrelliger or Mackerel. The spawning and breeding season on the west coast corresponds with the south-west monsoon. In July-August intensive spawning is reported in the inshore regions.

The other economically important groups namely *Stolephorus indicus*, Clupeidae, Engraulidae, *Hilsa kelee* and Sciaenids though present, their numerical abundance is not sufficient to suggest a spawning ground in the area. These fishes are normally associated with regions of high plankton production.

4.5.4 Macrobenthos

Depending upon their size, benthic animals are divided into three categories, microfauna, meiofauna and macrofauna. Benthic community responses to environmental perturbations are useful in assessing the impact of anthropogenic perturbations on environmental quality. Macrobenthic organisms which are considered for the present study are animal species with body size larger than 0.5 mm. The presence of species in a given assemblage and its population depends on numerous factors, both biotic and abiotic.

Samples for macrobenthos were collected from intertidal segments as well as subtidal stations for the estimation of macrobenthic density, biomass and composition.

a) Intertidal fauna

The intertidal macrobenthic standing stock in terms of population (0-24464/m^2, av 3218/m^2) and biomass (0.0- 963.2 g/m^2, av 26.0g/m^2 wet wt) varies widely (Tables 4.5.17 and 4.5.18) as evident from the results which are compared with the earlier (Table 4.5.19) studies and summarised here.

Period	Population (no/m^2)		Biomass (g/m^2; wet wt)		Faunal groups (no)	
	Range	Av	Range	Av	Range	Av
June 1998	10-1800	800	0.01-13.2	3.7	2-8	6
March 1999	0-48400	6600	0-135.8	25.3	2-10	6
September 1999	-	-	-	-	-	-
March 2000	100-133100	26033	3.3-76.9	32.0	1-8	5
June 2003	200-6500	1566	1.5-109.8	20.2	2-7	5
October 2003	20-3100	900	0.1-47.7	6.1	1-6	3
December 2004	100-18800	3125	0.1-84.8	6.9	1-7	4
May 2005	100-8800	2225	0.1-55.4	8.7	1-7	4
January 2006	0-24464	3219	0-963.2	28.3	0-7	3

These results do not indicate any significant changes in the macrobenthic standing stock both in terms of biomass and population. Total faunal groups are also comparable both in creeks and Gulf segment. Comparatively January 2006 period recorded higher biomass population than October 2003, December 2004 and May 2005.

The region wise distribution of intertidal macrobenthos during January 2006 is compared and presented in the table given below with average in parenthesis.

Region	Population (no/m^2)	Biomass (g/m^2; wet wt)	Total groups (no)
Off Tunda (I, II, III)	0-17952 (1691)	0.0-963.2 (44.1)	0-7 (3)
Kotdi Creek (IV & V)	0-6336 (1804)	0.0-78.3 (13.9)	0-5 (2)
GAPL Jetty (VI)	1056-14960 (6409)	0.1-36.1 (13.7)	2-7 (4)
Navinal/ Bocha (VII)	2288-24464 (7201)	5.8-30.27 (24.3)	3-6 (3)

Though, the region in general, sustains rich intertidal benthos, significant variation in the macrobenthic standing stock as well as group diversity is clearly evident. Overall Gulf region around GAPL jetty harbours relatively higher population counts and faunal diversity whereas, Gulf region off Tunda area sustained more benthic biomass.

The faunal composition of intertidal macrobenthos of the area is given in Table 4.5.20 while the distribution of major groups is given below.

Groups	Transect						
	I	II	III	IV	V	VI	VII
Gastropods	+	+	+	+	-	+	+
Pelecypods	+	+	+	+	+	+	+
Polychaetes	+	+	+	+	+	+	+
Cumaceans	+	+	+	-	-	+	+
Isopods	+	+	+	+	+	+	+
Amphipods	+	+	+	+	+	+	+
Brachyurans	+	+	+	+	+	+	+
Nematodes	-	-	-	-	+	-	-
Copepods	-	-	-	-	+	-	+
Anthozoans	+	-	-	-	-	-	-
Oligochaetes	-	-	-	-	-	+	-
Miscellaneous	+	+	+	-	-	-	-

Thus, the distribution of major faunal groups between different regions as well as different transects is closely comparable. The intertidal macrofauna is mainly constituted by polychaetes, crustaceans and molluscs. As evident from Tables 4.5.19 and 4.5.20 the total number of faunal groups in the intertidal transects vary from 0 to 17 (av 3). Overall about 10 groups of intertidal macrobenthos are recorded off Mundra during the present investigation. Their community structure is closely comparable with the earlier data (1998-2005) indicating the absence of gross changes in intertidal ecology during the post port development of Mundra.

b) Subtidal macrobenthos

The faunal standing stock in terms of population and biomass varies from 0-2900/m^2 and from 0-15.03 g/m^2 (wet wt) respectively (Table 4.5.21). The long term distribution of subtidal macrobenthos is given in Table 4.5.22 and summary of distribution of subtidal macrobenthos at different segments is given below with average in parenthesis.

Period	Creeks				Gulf	Average
	Bocha	Navinal	Baradimata	Kotdi		
Biomass (g/m^2; wet wt)						
July 1998	0.5-0.7 (0.6)	0.1-5.1 (2.6)	-	-	0.5	1.2
March 1999	0.5-1.2 (0.9)	29.2-63.1 (46.2)	-	-	0.2-46.3 (13.3)	20.7
September 1999	-	-	-	1.2	-	1.2
March 2000	0.1-1.8 (0.9)	0-0.18 (0.1)	-	-	0.5-11.5 (4.3)	1.8
June 2003	0.5-7.1 (3.1)	0.0-16.13 (4.0)	-	-	0.0-4.5 (0.4)	2.5
October 2003	0.02-4.0 (1.1)	0.0-5.0 (0.6)	-	-	0.0-6.01 (1.4)	1.0
December 2004	1.1-3.2 (2.0)	0.2-1.8 (1.0)	0.4-42.8 (9.9)	-	0.1-13.1 (1.6)	3.6
May 2005	0.1-1.9 (0.7)	0.9-28.4 (16.4)	0.4-3.8 (2.2)	-	0.0-9.2 (1.0)	6.7
January 2006	0-3.10 (1.6)	<0.1-15.03 (3.81)	<0.1-4.1 (1.8)	0.3-0.8 (0.6)	0-3.4 (0.5)	1.7
Population (no x 10^3/m^2)						
July 1998	0.2-0.7 (0.5)	0.14-1.9 (1.03)	-	-	0.5	0.68
March 1999	1.1-1.2 (1.2)	8.0-17.7 (12.8)	-	-	0.12-78.6 (20.0)	11.33
Sept 1999	-	-	-	17.2	-	17.2
March 2000	0.1-0.3 (0.21)	0-1.5 (0.8)	-	-	0.3-173.3 (44.92)	15.3
June 2003	0.43-1.4 (0.80)	0.0-0.58 (0.16)	-	-	0.0-1.3 (0.24)	0.40
October 2003	0.03-0.95 (0.44)	0.0-0.5 (0.11)	-	-	0.0-1.2 (0.3)	0.28
December 2004	1.5-4.3 (2.3)	0.4-1.2 (0.7)	0.2-1.7 (0.8)	-	0.1-1.8 (0.5)	1.08
May 2005	0.2-0.9 (0.5)	1.0-3.2 (2.4)	0.2-1.7 (0.7)	-	0.0-0.6 (0.2)	0.95
January 2006	0-2.1 (1.0)	0.1-2.1 (0.7)	0.1-0.6 (0.3)	0.4-0.7 (0.5)	0-2.9 (0.4)	0.58

The above table indicates wide variations in the faunal standing stock in the region and no clear seasonal trend in the distribution is discernible, suggesting high patchiness and seasonal variability in the distribution of subtidal macrobenthos.

During January 2006, the standing stock of subtidal macrobenthos at the study area both in terms of biomass (av 1.7 g/m^2; wet wt) and population (580/m^2) was low and varied widely.

The faunal distribution (Table 4.5.23) reveals low diversity (av 3 groups) with a low variability (0-7 groups). The faunal abundance of subtidal macrobenthos off Mundra is presented in Table 4.5.22 and the results are summarized below.

Period	Creeks				Gulf	Av
	Bocha	Navinal	Baradimata	Kotdi		
Faunal groups (no).						
June 1998	1-2 (2)	1-6 (4)	-	-	3	3
March 1999	3-6 (5)	7-7 (7)	-	-	4-7 (6)	6
September 1999	-	-	-	4	-	4
March 2000	2-3 (3)	3-3 (3)	-	-	4-7 (6)	4
June 2003	1-4 (2)	0-4 (2)	-	-	0-4 (2)	2
October 2003	1-4 (2)	0-4 (2)	-	-	0-4 (2)	2
December 2004	3-4 (3)	3-5 (4)	2-6 (4)	-	1-4 (3)	4
May 2005	2-3 (3)	1-2 (2)	1-3 (2)	-	0-4 (2)	2
January 2006	0-7 (3)	1-6 (3)	2-3 (3)	4-6 (5)	0-10 (3)	3

In general, about 16 groups of subtidal macrobenthos are recorded off Mundra during the present investigation (Table 4.5.23). Their community structure is closely comparable with the earlier result indicating the absence of gross changes on subtidal ecology during the post development phase of the Mundra Port. The faunal composition indicates the dominance of polychaetes, crustaceans and molluscans.

Comparison of intertidal and subtidal macrobenthos during January 2006 is given in the following table with the average in parenthesis.

Zone	Population (no x 10^3/m^2)	Biomass (g/m^2; wet wt)	Total groups (no)	Major groups
Intertidal	0-24.5 (3.2)	0-963.2 (28.3)	0-7 (3)	Polychaetes Amphipods Pelecypods
Subtidal	0-29.0 (0.6)	0-15.0 (1.1)	0-10 (3)	Polychaetes Amphipods

Overall, the intertidal region sustains better standing stock of macrobenthos both in terms of population and biomass as compared to subtidal zone. However,

faunal diversity is well comparable with the dominance of polychaetes and amphipods at both the region.

4.5.5 Fishery

The prevailing fishery status of the region off Mundra is evaluated on the basis of data from the Department of Fisheries, Government of Gujarat and experimental fishing undertaken in creeks and Gulf segments during the present and earlier studies. High tidal movements, uneven topography and unusually strong currents make trawling or gill-netting for fish difficult and risky in the creeks. Evidently, no large scale commercial fishing operations prevail in these shallow creeks except for minor shore based hand-net and gill-net operations (Figures 4.5.3 and 4.5.4). However, along the northern coast of the Gulf, fishing by trawlers is common particularly off Mandvi, Modhwa, Mundra, Bhadreshwar and Tuna. Depending on the topography of the coast and type of fishing, necessary modifications are made to economise fishing operations by local operators. Small, plank built canoes and traditional crafts like the sail boat locally known as "Machuwa" are also deployed for fishing. The gear commonly used by these traditional crafts are drift nets, gill nets and large bag nets.

Gujarat is a leading state in marine fish landings and during 2004-05 the total landings were 5.9×10^5 t (Table 4.5.24). Landings at various centres of Kachchh District contribute about 10% to the total landings of the state. The landing of the district which was around 8.1×10^4 t during 2002-03 is the highest for the previous 30 y, followed by a decrease during 2003-04 and 2004-05 (Tables 4.5.24 and 4.5.25). Recent 6 y composition of fish catch indicates the incidence of 27 different groups (Table 4.5.25); the common groups being small scienides, Bombay duck, *Coilia*, prawns, ribbon fishes, sharks and shrimps. Monthwise composition of fish landings of the district indicates that October-December period is peak season followed by January and September with March-July period as the lean season (Table 4.5.26). The landings at Mundra contribute about 0.6 to 3.9% to the total landings of the district (Table 4.5.27). The composition of fish catch at Mundra indicates incidence of 20 different groups (Table 4.5.28) with October to January as the peak landing period (Table 4.5.29).

Navinal, Jarpara, Mundra, Chenkhedia, Luni, Bhadreshwar and Kukadasar are the seven major fish landing centres in the Mundra region. However, their contribution to the district landing is meagre (Table 4.5.30). The composition of fish

landings at these centres reveals the incidence of 26 different groups (Table 4.5.30); the common groups being Bombay duck, *Coilia*, mullet, cat fish, ribbon fish, white pomfret, small scienides, shrimps and prawns. During 2002-03, the total catch for Navinal, Jarpara, Mundra, Chenkhedia, Luni, Bhadreshwar and Kukadasar was 849.9, 532, 1645.3, 239.5, 1489.4, 1618.7 and 1220t respectively and contributed less than 10% to the landings of the Kachchh District. Higher landings occur at Mundra during October and May followed by November and January (Table 4.5.31). This is due to heavy landings of Bombay duck and *Coilia* which formed 38.4% and 15.5% respectively of the landings for 2002-03 (Tables 4.5.30 and 4.5.31). The other landing centres also follow more or less similar pattern (Tables 4.5.30 and 4.5.31). District-wise details of fishing activities, total number of fishermen and fishing gears are given in Table 4.5.32 whereas total number of fishermen and fishing boats of Navinal, Jarpara, Dhrab, Mundra, Chenkhedia, Luni and Bhadreshwar are given in Table 4.5.33.

During experimental fishing in January 2006 (Table 4.5.34) the fish catch rate varied between 8.0 and 18.5 kg/h (av 7.4 kg/h). This catch consists of 22 species of fishes, 7 species of prawn and 5 species of crab and Loligol squilla. *Harpadon nehereus, Coilia dussmieri, Johnius glaucus, Lepturacanthus savala, Mugil sephalus* and *Thryssa* sp. recorded as the most dominant species. The other common species are *Otolithes* sp, *Polynemus heptadactylus, Arius caelatus, Scaliodon laticaudus, Pampus argenteus,* and *Ilisha megaloptera* (Table 4.5.34). Prawns are mostly represented by species *Parapenaeopsis sculptilis, Exopalaemon styliferus, Exopalaemon ensirosatris* and *Penaeous indicus*, whereas *crabs are presented mostly by Neptune pelagica* and *Charybdis annulata.* Available long term data at Mundra is given in Table 4.5.35 and summarised here.

Period	Total catch (kg/h)			Total species (no)		
	Min	Max	Av	Min	Max	Av
July 1998	-	-	15.5	-	-	10
August 1998	1.7	20.2	11.0	10	12	11
March 1999	8.5	17.0	12.8	8	9	9
March 2000	8.5	23.5	15.8	8	19	16
June 2003	4.7	9.2	7.4	8	12	9
October 2003	3.5	24.0	11.9	5	21	12
December 2004	2.4	10.2	5.2	13	21	16
May 2005	3.5	16.9	8.1	15	24	18
January 2006	8.0	18.5	13.7	18	20	19

The above data reveals wide fluctuation in fish catch around Mundra with marked decrease in June 2003 which may be due to prevailing natural variation in the coastal waters of Gulf.

4.5.6 Corals and associated biota

The southern coast of the Gulf sustains coral reefs with reef dependant flora and fauna. Many of the islands in the southern Gulf also support fringing reefs and coral patches are found in between the islands. However, due to extreme conditions of temperature and salinity and high turbidity, coral growth is patchy with poor diversity of living corals.

The Mundra region however does not sustain reef building corals as the intertidal area is largely sandy or muddy. Coral growth in the subtidal region is also unlikely in view of the high suspended load in the water column, the conditions under which corals do not thrive. Recently NIO has conducted coral survey in the subtidal waters and found that geo-chemical and physico-chemical conditions off Mundra are not conducive for the growth of reef building corals. Reef building corals are also not sighted at the subtidal area off Mundra.

4.5.7 Birds

The saltpans, islands and intertidal coastal system with mangroves off Mundra offer plenty of facilities for feeding, breeding and shelter to a variety of birds. The mangroves are often seen crowded with Grey herons, Pond herons, Painted storks, Large and small egrets, Darters, Cormorants etc. During receding tide, hectic activity of various Gulls, Avocets, Whimbrel, Curlew, Terns, Egrets, Grebes, Plovers etc is common.

A study carried out during November 1999 reveals high avifaunal diversity in the Mundra region. On the whole, 140 species are documented; 85 terrestrial and 55 aquatic. Out of these, 71 are resident species, 44 migrants and another 25 resident migrant. Based on sightings, 21 species are reported to be abundant, 42 common, 51 rare and 26 very rare. The scientific name, common name, abundance status etc of the aquatic birds are given in Table 4.5.36. Exotic species like Greater Flamingo (*Phoenica pterus ruber*), Lesser Flamingo (*P.minor*) and Dalmatian Pelecan (*Pelecanus cripus*) and Eurasian Spoon Bill (*Platalea leucorodia*) were commonly recorded, thus emphasising the importance of the study site. Dalmation Pelecan, Greater Flamingo, Lesser Flamingo and Spoon Bills commonly occur in salt pans.

4.5.8 Reptiles

In the Gulf, the reptiles are mainly represented by marine turtles *Chelonia mydas* and *Lepidochelys olivacea* which have their breeding and spawning ground on the sandy beaches along the coast as well as on the islands particularly along the southern Gulf. No turtle however was sighted in the creek system off Mundra during the study period.

4.5.9 Mammals

The mammals are chiefly represented by dolphin (*Dolphinus delphis*), whale (*Balanoptera* spp) and Dugong (*Dugong dugon*) in the Gulf especially along the Jamnagar coast but not sighted during the study period.

5 SEAWATER INTAKE

The power station will have to depend upon seawater to meet both consumptive and cooling water requirement due to non-availability of sweet water either from surface water sources or underground sources on a sustained basis. The proposed plant is located at about 0.55 km from the nearest shore of the Kotdi Creek (HTL) and the interspersed land is basically salt encrusted waste land.

In the planning of the arrangement of the intake system it is necessary to consider plant operation and the future developments of the power plant and desalination plant. The following criteria should be considered while selecting the intake system.

i) Existing marine conditions such as water levels, wave heights, sea currents, bathymetry, salinity, temperature, suspended material, littoral sand drift and marine ecology.

ii) Seawater drawl alternatives such as submerged intake pipe, intake well and open intake channel.

iii) Future expansion needs.

iv) Increase in temperature and salinity of the seawater discharged back to the sea.

5.1 Location of intake

a) Re-Circulation system

The re-circulation system requires about 35000 m^3/h of sea water for make up loss and desalination requirements. The following alternatives have been considered:-

i) Open Channel

This water can be drawn through an open channel of 10m width dug to a depth of 2 m below CD to a length so as to meet the 2 m depth contour in the open coast.

ii) Caisson well and pipeline system

Sea water can be drawn from an intake well situated at a depth of 10m through submarine pipelines of diameter of 2.8 m connected to a sump in the project site.

b) Once through cooling system

The following *alternatives* have been considered:-

i) Caisson and pipeline system

As discussed above for the re-circulation system , each caisson well situated at 10m depth and 2.8 m diameter pipeline can deliver about 35000 m3/h of sea water. Going by simple multiplication it requires about more than 13 well and pipeline systems to deliver such quantity of water . It also will involve sump of proportionate size. Such pipelines are difficult to maintain. Hence this type of intake arrangement for a once through cooling is not viable on practical grounds.

ii)Open channel

As the sea water requirement for the project is large about (470000 m^3/h), drawal of by conventional well and pipe systems is unviable due to reasons indicated above. The only alternative being drawl through a channel whose size would depend on the availability of sufficient height of water column above the entrance to the sump. The basic governing principle is Bernouli's equation. The amount of water entering the sump depends on the level difference between that of sea (tidally varying reservoir of infinitely large area) and that of the sump(kept at a low level by constant and continuous with drawl by pumping out) . The channel bottom , which is level with the mouth of the sump , should be decided with respect to the minimum water level of the reservoir (CD). The channel should extend to the sea till it meets the natural local depth contour equal to the channel depth. The width and depth can then be decided to suit the requirement of with drawl. The following tables illustrate the quantity of water available with different configurations (the current speeds for the drawl of 470000 m^3/h);

A 50m wide channel Dug to and extended to the natural contour in adjacent sea									
3m below cd				2m below cd			1m below cd		
tide (cd)	Depth (m)	Availability ($10^5 m^3/h$)	Current speed (m/s)	Depth	Availability ($10^5 m^3/h$)	Current speed (m/s)	Depth	Availability ($10^5 m^3/h$)	Current speed(m/s)
0	3	31.5	0.87	2	17.1	1.31	1	6.0	2.63
1	4	48.5	0.66	3	31.5	0.87	2	17.1	1.31
2	5	67.8	0.52	4	48.5	0.66	3	31.5	0.87
3	6	89.1	0.44	5	67.8	0.52	4	48.5	0.66
4	7	112.3	0.37	6	89.1	0.44	5	67.8	0.52
5	8	137.2	0.33	7	112.3	0.37	6	89.1	0.44
6	9	163.7	0.29	8	137.2	0.33	7	112.39	0.37

A 80m wide channel dug to and extended to the natural contour in the adjacent sea									
3m below cd				2m below cd			1m below cd		
tide (cd)	Depth (m)	Availability ($10^5 m^3/h$)	Current speed (m/s)	Depth	Availability ($10^5 m^3/h$)	Current speed (m/s)	Depth	Availability ($10^5 m^3/h$)	Current Speed (m/s)
0	3	50.4	0.54	2	33.6	0.81	1	9.7	1.63
1	4	77.6	0.41	3	51.7	0.54	2	27.4	0.81
2	5	108.5	0.33	4	72.3	0.41	3	50.4	0.54
3	6	142.6	0.27	5	95.1	0.33	4	77.6	0.41
4	7	179.7	0.23	6	119.8	0.27	5	108.5	0.33
5	8	219.6	0.20	7	146.4	0.23	6	142.6	0.27
6	9	262.0	0.18	8	174.7	0.20	7	146.4	0.23

From the above tables it can be visualized that all the configurations considered are capable of delivering the requisite quantity of water irrespective of the tidal phase. However, the current speeds generated in the channel exceed 0.8 m/s during lowest low tides are not conducive for the channel stability considering the loose sandy terrain of the channel, which may transport sand into the channel and sump there by silting both. Any larger organisms entering the stream can swim back from the screens if the forcing velocities are low. The option suitable is a 80 m wide channel upto 3m contour.

It is also pertinent to note that the channel width mentioned is at the bottom. Considering the sandy terrain it becomes imperative that the sides should slope gently to avoid sand transport in to the channel by the cross currents at the mouth region. A 15° slope would require about 20-25m for providing sloping on each side. Thus the width of the channel would be 80 m at the bottom and about 130 m at surface during high water. Hence a channel with 3m below CD with a side slope of 15° is a plausible option which can take care of certain amount of sedimentation also.

The channel deepened to 3m below CD can deliver almost ten times the requirement even at low water and can take care to mitigate long term sedimentation. The main aim is to keep the channel currents low even at the low waters of spring when the cross sectional area of the flow in the channel is expected to be minimum. In such case the sediment movement in the channel would be less

and finer soil only can move in to the channel. This also produces suitable habitat for the benthic fauna.

Though channel intake is often preferred, acretion particularly during monsoon months due to wave action can be high in the Mundra area requiring periodic maintenance. However, considering the facilities available at the Mundra Port maintenance dredging of the channel may be an overall economic option.

The coordinates of the point to which the channel should be extended to meet the 3m below CD contour are 22^0 45' 00" N, 69^0 32' 34" E about 2.2 km from the low water line. The total length of the channel in subtidal and intertidal stretch would be about 5.5km.

The performance will be tested by use of 2D model to study erosion and deposition in the channel and its surroundings.

6 EFFLUENT RELEASE

a) Re-circulation cooling effluent.

The total 4000 MW project envisages water drawl of about 35000 m^3/h of which about 25000 m^3/h would have to be discharged back to the sea as cooling tower blow down and its cooling process involves substantial evaporation losses and the salt content in the effluent will increase to 53 ppt. The effluent would be denser than the sea water around. The disposal would be difficult in the open channel as the high saline water is not conducive to the health of the normal marine life. Discharging at a deeper location would not permit the water to mix well as the effluent tends to settle on the bottom due to higher density. The only way the temperature can come down in such case would be advective diffusion, which will be slow at bottom as the currents near bottom are relatively weak as compared to that at the surface. A sophiscated diffuser would be required to attend high jet velocities to achieve mixing of high density of water with the ambient seawater. Such diffusers ~~are diffusers~~ are difficult to maintain.

b) Once through cooling effluent

The total 4000 MW project (5X800 MW) envisages water drawl of about 470000 m^3/h of which about 467000 m^3/h will have to be discharged back to the sea at a suitable location in the Mudhwa Creek as return coolant. This effluent will have a temperature of less than 7°C rise over the ambient sea water temperature. The salinity also will be marginally higher by 0.8ppt (about 37.8-38.9 ppt against the ambient of 37-38 ppt). The water would be lighter than the ambient water due to the higher temperatures of the effluent with a marginal increase in salinity As the water spreads on the surface there would be exchange of heat with the atmosphere thereby decreasing the temperature during the flow to the gulf. Hence wherever is feasible open channels are preferred to piped discharges if the temperature is the main concern.

6.1 Effluent Disposal alternatives

i) Release in the Gulf for re-circulation system

a) Through pipe

The effluents being high saline (about 53-55 ppt) will be denser even with temperature raise of 7°C above ambient. The high salinities are not conducive to the intertidal ecosystem. The effluent being denser would sink to the bottom. Hence it is imperative that they should be provided with certain initial dilution by adopting pipeline and diffuser system. Such a pipe line would be of a diameter of

2.1m for a velocity of 2m/s and 1.7 m for a velocity of 3m/s. The effluent will rise only 2-3 m even when directed vertically and would sink and spread along the bottom and mixing would be delayed process exposing the local biota to increase temperature and salinity.

b) Through open channel

The high saline and high temperature water is not suitable to be discharged in open channel as the temperature may decrease with atmospheric heat exchange will become denser and will not mix with ambient waters effectively. This option cannot be used as it is detrimental to the intertidal ecology.

ii) Release for once through cooling system

a) Through pipe

As discussed earlier the once through cooling system will have a raise in temperature of less than 7° C above ambient and salinities almost near ambient (about 37.8-38.9 ppt against the ambient of 37-38 ppt) . The densities would be marginally higher than the ambient . However to transport the large quantity of water would require a pipe line of 7.5 m diameter with 3m/s velocity and 9m diameter for a velocity of 2m/s. It is difficult to maintain such velocities in large pipes. Such a pipeline can not be laid on the sea floor with out obstructing and altering the flow regime. Alternatively it has to be buried and trenching to 8m to lay the pipeline will cause wide spread disturbance due to regular and strong tidal currents destabilizing the trench and carrying the trench material to the area around.

Another option is to provide a number of pipelines and diffusers. Going by a simple proportion this would require about 13 pipelines of the dimensions proposed for a re-circulation cooling system (para 6.1 (i) (a)).

b) Through open channel

(i) The return coolant in case of once through cooling is not expected to contain any harmful chemicals and the only addition would be thermal and marginally saline. The segment of the creek in the project site is devoid of mangroves and the Mudhwa creek which has only sparse and stunted monospecies stands is well separated from the Kotadi Creek so that the impact of the effluent is expected to be minimal.

(ii) The salinity difference is only marginal and temperature unlike other pollutants can have exchange to atmosphere above and attain near ambient conditions quickly. The thermal effluents are permitted to be released in to the creeks if the impacts are minimal.

(iii) However, Mudhwa creek is shallow and has of a vast intertidal area and exchange of water to open gulf is limited. With the channel dredged to below CD the exchange would improve considerably.

The impacts if any on the temperature and salinities of the region are studied using a 2D model. Based on which the final recommendations are made.

6.2 Location of release

The location of release should be so selected that the effluent attains adequate dilution and background levels of contaminants are attained close to the release site. Also, it should be ensured that the effluent released does not enter the area of seawater intake causing cross-contamination. The high tidal influence and swift currents results in tidal excursion of several kilometers. Hence, ideally the intake and release areas should be at least a few kilometers apart.

The flow field of an effluent, released into an aquatic system, is controlled by the momentum and buoyancy forces. The effluent though more saline than the ambient the higher temperature would make it lighter than the ambient though marginally. As the surface cools due to exchange with the atmosphere the density would gradually increase attaining density of ambient sea water. This process is more effective in reducing the temperature difference between the effluent and the ambient seawater. The configuration considered for the discharge channel is 60 m bottom width with side slopes of 1:4, depths dug to 1m below CD and extending the channel to a location defined by the coordinates 22^0 46' 30" N, 69^0 30' 38" E on the 1m below CD contour. The length of the channel from the creek mouth would be about 3.0 km.

A 2D model incorporating the mixing and transport with the temperature decay and source components is used to find the impacts and the requisite deepening of the Mudhwa creek is studied.

The model description and the results are discussed in the following section.

6.3 Modelling physical processes

6.3.1 Introduction

Modelling the hydrodynamic processes is an integral part of a water quality or a carrying capacity study. For this purpose, the tides, tidal currents and salinity distribution in the coastal waters of Tunda-Wandh and creek waters of Kotdi-Mudhwa were modelled. The information that emerges was used to track the

trajectories of effluent release and to predict the impact of release on water quality parameters such as salinity and temperature. If the impact is unacceptable, the release site was shifted in a manner that acceptable impact was predicted.

The basic water quality model POLSOFT was modified and improved for use in the present work to estimate the capacity of the coastal waters of Tunda-Wandh to assimilate return cooling water. As a first step, the hydrodynamic part of the model (flow) is described and its use in evolving temperature and salinity structure in the estuary is discussed. The Mudhwa Creek is relatively narrow in the upper reaches, while, the mouth segment is broad where the tidal forcing interacts with the open ocean waters of the Gulf of Kutchch across its southern boundary. These features make the task of numerical modelling of the creek easier, as a 2-D hydrodynamic model is sufficient to accurately reproduce the tides and currents in the system. The intake of sea water through Kotdi creek along with the discharge in Mudhwa creek constitutes the intake discharge system. Hence it is pertinent to study the combined effect so as to delineate the spread of the effluent and ensure no rise in the temperature and salinity of the intake water.

6.4 Model description

6.4.1 Basic governing equations

Simulation of tides and currents in the coastal waters of Tunda-Wandh and creek waters of Kotdi-Mudhwa has been carried out by solving the two dimensional shallow water equations of continuity and momentum. These equations that describe the flow field are based on incompressible flow and vertically integrated hydrostatic distribution. Hence, the vertical acceleration of the flow is assumed to be much smaller than the pressure gradient. After applying these conditions, the governing equations of mass and momentum can be written in the conservation form as follows:

Continuity equation:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0$$

Momentum equations:

$$\frac{\partial u}{\partial t}+\frac{\partial uu}{\partial x}+\frac{\partial uv}{\partial y} = fv - gH\frac{\partial e}{\partial x}+\frac{\partial}{\partial x}\left(K_x\frac{\partial u}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y\frac{\partial u}{\partial y}\right)$$

$$\frac{\partial v}{\partial t}+\frac{\partial vu}{\partial x}+\frac{\partial vv}{\partial y} = -fu - gH\frac{\partial e}{\partial y}+\frac{\partial}{\partial x}\left(K_x\frac{\partial v}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y\frac{\partial v}{\partial y}\right)$$

where, t is time; x, y are cartesian co-ordinates; u, v are depth averaged velocity components in x, y directions, respectively; f = Coriolis parameter; g = acceleration due to gravity; K_X, K_Y = diffusion coefficients in x, y directions, respectively; H = total water depth; e = water elevation with respect to mean water level.

6.4.2 Boundary Fitted Coordinate (BFC) system

In the Cartesian or rectilinear co-ordinate system it is difficult to represent the complex coastline accurately as grid size remains the same at any given location. On the other hand, BFC is a curvilinear co-ordinate system in which the complex coastline can be represented more accurately with varying grid sizes in the entire model domain. In order to achieve this, it is necessary to convert the governing conservation equations of flow from Cartesian to BFC system. Hence, the momentum equations in 2D and the other conservation equation of flow in the y direction are written in the BFC coordinate system.

The chain rule transformation is resulted in a relatively complex set of equations. Boundary conditions are also quite complicated because the cartesian velocity components are generally not parallel to the local grid lines.

6.4.3 Diffusion coefficients

The horizontal diffusion coefficients K_x and K_y are calculated as follows:

$$K_x = \alpha_x g\sqrt{(u^2+v^2)}/C^2$$

$$K_y = \alpha_y g\sqrt{(u^2+v^2)}/C^2$$

where α_x and α_y are the diffusion factors in x and y directions and C is the Chezy coefficient.

6.4.4 Numerical solution strategy

The transformed governing equations of flow have been discretized on a staggered grid and solved using Leapfrog trapezoidal scheme through a predictor and corrector step method. The scheme is fully centered in space and time and can obtain second order accuracy. The scheme consists of two level computations predictor and corrector steps within the time step Δt.

$$F(K^n)=(K^* - K^{n-1})/(2\Delta t)$$

$$F(K^n)+F(K^*)=2(K^{n+1} - K^n)/(\Delta t)$$

where, K^* = predicted variable level. The grid transformation derivatives ($\eta_x, \zeta_x, \eta_y, \zeta_y$) can be specified at the cell centers and cell mid-faces

Since the range of the co-ordinates in the computational plane is arbitrary, the mesh increments are specified as unity for convenience. Consequently, the geometric variables are defined on a finite difference mesh with cell increments of 0.5. The computations were carried out for the next time-step through predictor and corrector schemes using the above finite difference quotients.

6.5 Model domain and calibration

6.5.1 Model setup and boundary specifications

The larger domain of study is shown in Figure 6.5.1. The computational domain of the model was selected from Okha to Kandla. The model domain was divided into suitable grids . The interpolated bathymetric depth contours are reproduced in Figure 6.5.2.

The bottom roughness in the model domain is expected to vary because of changes in the bed topography and variation in sediment grain size. The bed material consists of various sizes of clay, silt and sand and even rocks in places. According to the type of bed configuration, the Manning's roughness coefficient 3 is selected for computational purposes. The interpolated Chezy's coefficient was calculated based on Manning's roughness and water depth (Figure 6.5.3).

The comparison of computed and observed water levels and currents at several places in the Gulf are compared to validate the model.

A series of simulation runs were made to obtain an insight into the basic hydrodynamic behaviour of the coastal waters of Tunda-Wandh and creek waters of Kotdi-Mudhwa system due to tidal forces.

6.5.2 Initial conditions

The initial conditions for the model were selected based on steady water flow conditions. The vertical density gradients due to the variation in salinity were neglected since the water column in the creek system and shallow coastal water off Tunda-Wandh is well mixed and there is no freshwater influx. The BFC grid

technique was adopted to take care of coastal shape and make fine mesh near the coastline, as described in Section 6.5.1. The grid is highly non-uniform both in x and y directions and it is a skewed mesh.

6.5.3 Model simulation and validation

Initially, several runs of the model were carried out with the available measured data to test its efficiency in reproducing the tides and currents in the computational domain. The model was calibrated using the simulated currents and tides at the diagnostic (monitoring) points with the measured current /tide data wherever available. The results were stored at every 1 h interval. The Manning's roughness coefficient was adjusted such that the predicted tides at diagnostic points match with the computed tides. The comparison of computed and measured tidal variation is shown in Figure 6.5.4 and 6.5.5, which shows a good agreement between the measured and the computed tides both in phase and amplitude.

The sensitivity analysis was carried out with variable bed roughness, which was the combined effect of d_{50} sediment size and bed configuration, to validate the model with respect to the tide data of January 2006 at diagnostic points. The results of the analysis indicated that the bed roughness coefficients selected for tidal computation are the most suitable for the computations of tide in the area of interest.

6.6 Modeling of tides and currents

The model clearly reproduces the tidal variations at various locations all along the Gulf of Kutchch.

6.7 Modeling of salinity and temperature

6.7.1 Salinity

The basic governing equation of salinity transport in a well – mixed system can be written as

$$\frac{\partial}{\partial t}(HS) + \frac{\partial}{\partial x}(UHS) + \frac{\partial}{\partial y}(VHS) = \frac{\partial}{\partial x}\left(D_x H \frac{\partial S}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_y H \frac{\partial S}{\partial y}\right)$$

Where S is salinity in ppt , D_x and D_y are the dispersion coefficients which are the function of local currents and water depth.

The above equation is transformed into BFC coordinates system and can be written as

$$\frac{\partial}{\partial t}(HS)+\varsigma_x\frac{\partial}{\partial \varsigma}(UHS)+\eta_x\frac{\partial}{\partial \eta}(UHS)+\varsigma_y\frac{\partial}{\partial \varsigma}(VHS)+\eta_y\frac{\partial}{\partial \eta}(VHS)-\varsigma_x\frac{\partial}{\partial x}(D_xT_{xx})-\eta_x\frac{\partial}{\partial \eta}(D_xT_{xx})$$
$$-\varsigma_y\frac{\partial}{\partial \varsigma}(D_yT_{yy})-\eta_y\frac{\partial}{\partial \eta}(D_yT_{yy})=0$$

Where ζ_y, η_x, ζ_x, η_y are grid transformation parameters and U, V are the depth, averaged velocities, H is total depth.

$$T_{xx} = \varsigma_x\frac{\partial}{\partial \varsigma}(SH) + \eta_x\frac{\partial}{\partial \eta}(SH)$$
$$T_{yy} = \varsigma_y\frac{\partial}{\partial \varsigma}(SH) + \eta_y\frac{\partial}{\partial \eta}(SH)$$

The above transformed equation has been described into finite difference formulation. Using ADI scheme in ζ and η direction result in, the following algebraic equation, which can be solved using the diagonal algorithm.

$$\alpha S_{ij-1}^{n+1/2} + \beta S_{ij}^{n+1/2} + \gamma S_{ij+1}^{n+1/2} = \gamma_{ij}$$

$$\alpha S_{i-1j}^{n+1} + \beta S_{ij}^{n+1/2} + \gamma S_{i+1j}^{n+1} = \gamma_{ij}$$

The above algebraic equation has been solved for salinity at all the given points.

6.7.2 Temperature

The generic two-dimensional transpose and transformation equation for temperature representation by the temperature variable T is

$$\frac{\partial}{\partial t}(TH)+\frac{\partial}{\partial x}(UTH)+\frac{\partial}{\partial y}(VTH)=\frac{\partial}{\partial x}\left(K_{Hx}H\frac{\partial}{\partial x}T\right)+\frac{\partial}{\partial y}\left(K_{Hy}H\frac{\partial}{\partial y}T\right)\pm SH$$

The water surface boundary condition for the transpose equation is

$$\frac{1}{\rho_w C_{pw}}\left(J_h + J_c + J_e\right)$$

Where C_{pw} is the specific heat of water (4182 J/Kg deg K). The heat fluxes, J are due to net long wave back radiation defined as the long wave radiation from the water surface less the atmospheric long wave radiation (b), convection or sensible heat transfer (c) and evaporation or latent heat transfer (e). The source term in the above equation is given by

$$R_T = \frac{I}{\rho_w C_{pw}} \frac{\partial I}{H \partial Z}$$

Where I is the down ward short wave solar irradiance. The model uses heat flux formulation bound on the NOAA geophysics fluid dynamic laboratory, atmospheric heat exchange formulation. The net long wave back radiation is given by

$$\frac{J_b}{\rho_w C_{pw}} = \frac{\varepsilon \sigma T_S^4}{\rho_w C_{pw}}\left(0.39 - 0.05 e_a^{1/2}\right)\left(1 - B_c C_c\right) + \frac{4\varepsilon\sigma T_S^3}{\rho_w C_{pw}}\left(T_s - T_a\right)$$

Where T_s and T_a are the water surface and atmospheric temperatures, ε is the emissive (0.95), σ = Stefan – Boltzman constant (5.6713 – 8J/(sq m – second deg K^{-4})), e_a is the atmospheric vapour pressure in millibars, C_c is the fraction cloud cover and B_c is an empirical constant equal to 0.8. The convictive or sensible heat flux is given by

$$\frac{J_c}{\rho_w C_{pw}} = C_h \frac{\rho_a C_{pa}}{\rho_w C_{pw}} \sqrt{U_w^2 + V_w^2 (T_s - T_a)}$$

where C_h is a dimensionless transfer coefficient of the order of $1E^{-3}$ in magnitude, ρ_a is the atmospheric density ($1.2E^{-3}$ Kg/m^3) and C_{pa} is the specific heat of air (1010 J/Kg deg K).

The evaporation or latent heat flux is given by

$$\frac{J_e}{\rho_w C_{pw}} = C_e \frac{\rho_a L}{\rho_w C_{pw}} \sqrt{U_w^2 + V_w^2 \left(e_{sa} - R_w e_{sa}\right)} \frac{0.622}{pa}$$

Where C_e is dimensionless transfer coefficient on the order of $1E^{-3}$ in magnitude, L is the latent heat and evaporation($2.5E^6$ J/Kg), e_{ss} and e_{ss} are the saturation vapour pressure in millibars corresponding to the water surface and atmospheric temperature value representing R_h is the fractional relative humidity and ρ_a is the atmospheric pressure in millibars. The corresponding evaporation rate is in velocity units is given by

$$W_e = C_e \frac{\rho_a}{\rho_w} \sqrt{U_w^2 + V_w^2} (e_{sa} - R_h e_{sa}) \frac{0.6x}{\rho_a}$$

The saturation vapour pressure in millibars used in the above equation is given by

$$\log_x e = \frac{0.7859 + 0.034777}{1.0 + 0.004127}$$

The irradiance attenuation ratio is given by

$$\frac{I}{I_s} = \gamma \exp(-\beta_t H(1-2)) + (1-r)\exp(-\beta_s H(1-2))$$

Where I_s is the irradiant short wave solar radiation at the water surface (W/m^2), β_t, β_s are fast and slow scale alternative coefficient (1/m) and r is a distribution fraction between 0 and 1. For shallow water environment, β_t generally falls within the range of 0.2 and 4 per meter.

For simulation of water temperature of the Mudhwa creek meteorological parameters like the wind speed and direction, dry bulb and wet bulb temperature, atmospheric pressure, solar radiation, evaporation rainfall have been used from the averages available for Bhuj for the season. The simulated temperature values show a good agreement with the general temperature pattern observed at the test locations. The temperature shows semidiurnal oscillations associated with the air temperature. Overall average water temperature at these locations is 28°C for the season.

6.8 Sediment transport model

Basic governing equations

The basic governing equations of suspended sediment transport and bed load are solved numerically in prediction the morphological changes of bottom bed due dredging processes in the coastal environments. These equations are coupled

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LIST OF CLOSED HOLIDAYS FOR THE YEAR 2007

In accordance with the recommendations of CGEWCC, Mumbai, it has been decided to observed the following days as closed holidays for this Regional Centre, for the year 2007.

This list is prepared in line with the list of holidays published by CGWECC vide their circular No. CGEWCC/Holidays 2006 dt. 29th August 2006.

Sr.No.	Holiday	Date	Day
1.	Idu'l Zuha (Bakrid)	01.01.2007	Monday
2.	Republic Day	26.01.2007	Thursday
3.	Moharram	30.01.2007	Tuesday
4.	Maha Shivaratri	16.02.2007	Friday
5.	Sri Ram Navmi	27.03.2007	Tuesday
6.	Mahavir Jayanti	31.03.2007	Saturday
7.	Milad-Un-Nabi (B'day of Prophet Mohammed)	01.04.2007	Sunday
8.	Good Friday	06.04.2007	Friday
9.	Buddha Purnima	02.05.2007	Wednesday
10.	Independence Day	15.08.2007	Wednesday
11.	Janmasthmi	04.09.2007	Tuesday
12.	Mahatma Gandhi's Birthday	02.10.2007	Tuesday
13.	Idu'l Fitr	14.10.2007	Sunday
14.	Dussehra	21.10.2007	Sunday
15.	Diwali (Deepavali)	09.11.2007	Friday
16.	Guru Nanak's Birthday	24.11.2007	Saturday
*	Idu'l Zuha (Bakrid)	21.12.2007	Friday
17.	Christmas Day	25.12.2007	Tuesday

with flow equations and solved them numerically. The basic governing equations of suspended sediment transport can be written as follows:

$$\frac{\partial C}{\partial t}+u.\frac{\partial C}{\partial x}+v.\frac{\partial C}{\partial y}-\frac{\partial}{\partial x}.\left(k_x.\frac{\partial C}{\partial x}\right)-\frac{\partial C}{\partial y}\left(k_y.\frac{\partial C}{\partial y}\right)-q_c=0$$

where, t = time; C = suspended sediment concentration(mg/l), x, y are Cartesian co-ordinates; u and v are depth averaged velocity components in the x and y directions, respectively; Kx, Ky diffusion coefficients in the x and y directions, respectively;

Boundary Fitted Coordinate (BFC) system

In the Cartesian or rectilinear co-ordinate system, which is generally used in all global models, it is difficult to represent the complex coastline accurately, as grid size remains the same at any given location. To better resolve complex geometries in the horizontal directions, the model makes the computations on the boundary-fitted or generalized curvilinear Coordinate system This necessitates the transformation of the governing equations into boundary-fitted coordinates (ς,σ). However, in the model the (x, y) coordinates are transformed in such a way that their components are perpendicular to the (ς,σ) coordinate lines. This is accomplished by employing the chain rule transformation.

The suspended sediment transport equation can be written in BFC system as

$$\frac{\partial C}{\partial t}+u\left(\varsigma_x\frac{\partial C}{\partial \varsigma}+\eta_x\frac{\partial C}{\partial \eta}\right)+v\left(\varsigma_y\frac{\partial C}{\partial \varsigma}+\eta_y\frac{\partial C}{\partial \eta}\right)-\left[\varsigma_x^2.\frac{\partial^2 C}{\partial \varsigma^2}+2\varsigma_x\eta_x.\frac{\partial^2 C}{\partial \varsigma\partial\eta}+\eta_x^2\frac{\partial^2 C}{\partial \eta^2}\right]$$
$$-\left[\varsigma_y^2.\frac{\partial^2 C}{\partial \varsigma^2}+2\varsigma_y\eta_y.\frac{\partial^2 C}{\partial \varsigma\partial\eta}+\eta_y^2\frac{\partial^2 C}{\partial \eta^2}\right]-q_c=0$$

Where, $\varsigma_x,\varsigma_y,\sigma_x,\sigma_y,\varsigma_{xx},\varsigma_{yy},\sigma_{xx},\sigma_{yy}$ grid transformation parameters

Qc - source or sink term

The deposition and erosion fluxes are calculated by the formulae of krone and partheniades respectively.

$$Q_d=W_s\,c\left[1-\left(\frac{u^*}{u_d}\right)^2\right]$$

and

$$Q_e = M\left[\left(\frac{u^*}{u_e^*}\right)^2 - 1\right]$$

Where:

W_e	is the setting velocity	(m/s)
M	is the partheniades constant	
u^*_d and u^*_e	is the critical setting and erosion velocities	
u^*	is the friction velocity at the bottom	

The evolution of the bed level is calculated thus:

$$E = \frac{Q_d - Q_e}{C_{sf}} DT$$ at each time step (m)

Q_e	is the erosion flux	(Kg m-2s-1)
Q_d	is the deposition flux	(Kg m-2s-1)
Csf	being the concentration of the settled layer	(Kg/m^3)

More details about transformation of basic governing equation of flow can be found in Reddy (1994).

6.8.1 Model description

Hydrodyn-MUDSOFT can be used to predict transport of suspended particles of different size materials and bed load transport within water bodies with a free surface. The software can also calculate the deposit on the bottom and their entrainment into suspension by the process of erosion. The software is integrated with Hydrodyn-FLOSOFT to take into account advection due to currents. For each sediment size various physical phenomena such as transport by the current, diffusion, deposition, erosion, time dependent decay and sources terms were considered.

MUDSOFT solves the transport equation coupled from the hydrodynamics (FLOSOFT) of the modeled situation.

6.8.2 Modelling of sediment transport

Initial and boundary conditions

The initial conditions for the model are selected based on no suspended particles in the water column. The vertical density gradients due to salinity variation have been neglected since the water column is well mixed. The BFC technique has been adopted to take care of shoreline shape and make fine mesh near the coastline. The grid is non-uniform both in x and y directions and it is a fine mesh.

The open boundary conditions identified are western open boundary at Okha, eastern open boundary at Kandla and south and north boundaries are closed. The boundary conditions selected are as follows. (i) no sediment flux at Okha (ii) no sediment flux boundary conditions at Kandla and (iii) no flux across the coastal boundary. In this model, diffusion coefficients for horizontal exchange of momentum vary with the space.

7 MODELING OF THE MUDHWA-KOTDI CREEK SYSTEM

7.1 Introduction

In order to obtain better accuracy in the prediction of salinity and temperature variations due the flow regime, a finer mesh is adopted to represent the study area for modeling purpose. The study domain is between Latitude 22^0 43' 31" & 22^0 48' 33" and Longitude 69^0 27' 57", 69^0 35' 54" shown in fig. 7.1.1 along with terrain features. The domain is divided into 120 x 80 grids in "x" and "y" directions respectively, shown in Figure. 7.1.2.

7.2 Proposed intake and outfall

The tide levels at the boundaries of the smaller domain of interest (comprising Mudhwa and Kotdi Creek system) are extracted from the runs of the larger domain to serve as inputs for boundary conditions of the specific domain of Mudhwa-Kotdi creek system.

The alignments for the intake and outfall channel route have a part in the inter tidal zone and the remaining part in the sea, Fig. 7.2.1.

The inputs incorporated are i) the intake channel of 80 m width excavated to 3m below CD and approximately 5.5 km in length in subtidal and intertidal stretch. ii) a discharge channel of 60m width excavated to 1m below CD and approximately 3.0 km length from creek mouth incorporated by changing the depth contours accordingly. A continuous intake of 130m^3/s (470000 m^3/h) as withdrawal at the high water line and a continuous 129.7 m^3/s(467000 m^3/h) discharge at the high water line. The discharge water is expected to have temperature of less than 7°C above ambient sea water temperature. According to the salt balance the salinity of the effluent would be 0.8 ppt. However an increase of 3ppt was considered for the model runs. The model was run for 10 days comprising of both spring and neap tidal cycles. Nine observation points were set in the model domain to monitor the time series variations in salinity and temperature at hourly intervals. The spread fields of these parameters are also saved at hourly intervals.

An additional run with 9°C above ambient was also performed to delineate the dissipation of temperature due to atmospheric exchange.

The computation runs have been made for the proposed intake and outfall to predict the changes in the flow regime. The runs considering spring, neap, lowest low water and highest high water level have been made and results are presented graphically from Figures. 7.2.2 to 7.2.9.

7.3 Results of mud transport study

After 10 days of continuous run with the simultaneous intake and discharge in the respective channels the following were the observations:

(i) Erosion was noticed in the western side of the discharge channel to an extent of 11 to 33 cm. Erosion of 4 to 11 cm was also noticed in the western side of the intake channel. Erosion upto 4 cm was also predicted in the area of deep waters in the effluent plume in the ebb direction Figure 7.3.1. The erosion occurred in the first three hours of the run and later stabilized.

(ii) Deposition of sediment to an extent of 0.8 cm was predicted in shallow coastal areas to the east of the intake channel, to the east of the discharge channel and along the shallow stretch in the ebb direction Figure 7.3.2.

7.4 Temperature and salinity model runs

Temperature and salinity (Case 1)

This case envisages release of 467000 m^3/h of effluent with temperature of 35°C and salinity 39 ppt released at constant rate at the high water line into the channel dredged to 1m below CD up to the local natural contour of 1m below CD with a bottom width of 60 m.

(1) During spring mid high water the spread is towards the east with temperatures of 35°C in the open shore of the effluent channel Figure 7.4.1).

(2) During HW the effluent is confined and spread in the intertidal area (31-33°C) west of the discharge channel. No temperature increase found in the intake channel (Figure 7.4.2).

(3) During the ensuing ebb the effluent movement is towards west with a bigger spread as the impounded effluent gushes out from the channel (Figure 7.4.3).

(4) At low water the spread is almost 4 km long along the ebb direction. The temperatures in the patch were in 30-32°C range (Figure 7.4.4).

(5) During spring mid high water the salinities in the discharge channel and in the vicinity of the open coast remained high 38-39 ppt. Unlike the temperature the salinity spread was larger owing to the conservative nature. No change in the intake water salinities (Figure 7.4.5).

(6) During HW the salinities in the area between the mouths of intake and discharge channels remained between 38-38.7 ppt. The salinity at the intake was 37.67 to 37.89 ppt (Figure 7.4.6).

(7) During the ensuing ebb the salinities west of the discharge channel were high within 38.78 to 39 ppt range the salinities in the intake remained between 37.89 to 38.5 ppt range (Figure 7.4.7).

(8) At low water the entire saline patch moved westward with salinities ranging from 37.8 to 39 ppt. The intake channel showed patches of saline water with 37.4 - 37.9 ppt (Figure 7.4.8).

(9) During neap mid phase of high water the temperatures in the intake channel was 32 - 35°C and the open shore part of the channel and shallow area adjoining showed temperatures 30-32°C the intake channel was free of temperature increase (Figure 7.4.9).

(10) During HW the spread of temperature was along the western coast with 32-35°C in the channel and 29.5 - 32° near seaward end of the channel (Figure 7.4.10).

(11) During ensuing mid ebb the patch moved further west with temperatures almost reaching ambient in the tail part of the patch (Figure 7.4.11).

(12) In the low water the temperature structure was almost same with the patch confined to the area around the mouth of the effluent channel (Figure 7.4.12).

(13) During neap mid phase of high water the salinities in the channel are 39 ppt a long continuous patch of about 8 km x 1.5 km formed along the low water line. Salinities in the intake channel were in the range of 37.4 - 37.9 ppt (Figure 7.4.13).

(14) During HW the patch has become longer and wider with salinities ranging from 37 - 39 ppt along. The salinities in the intake channel were 37.6 to 37.9 ppt (Figure 7.4.14).

(15) During ensuing mid ebb the patch moved in the ebb direction along the shore with the same salinity structure as high water the intake salinities have decreased to 37.4 - 37.6 range(Figure 7.4.15).

(16) By the end of ebb tide the saline was has crossed the computational domain and the intake channel showed salinities 37.2 - 37.4 ppt(Figure 7.4.16).

At the end of 10 days the salinities structure almost showed that of the neap tide (6^{th} day) indicating that this structure more or less remains similar to different phases of the 6^{th} day. However, the salinities in the intake channel remained at 37.6 - 37.8 ppt (Figure 7.4.17).

The temperature structure was also similar to that of neap tide. The intake channel was found to be free of excess thermal pollution (Figure 7.4.18).

Temperature and salinity (Case 2)

This case envisages release of 46 7000 m^3/h of effluent with temperature of 37°C and salinity 39 ppt released at constant rate at the high water line into the channel dredged to 1m below CD up to the local natural contour of 1m below CD with a bottom width of 60 m.

An exercise to understand the temperature regime was done by considering the effluent of 37°C temperature and 39 ppt salinity The runs were performed for 10 days and the results are discussed here.

Though the patch sizes was marginally larger than that of the 35°C input the temperatures quickly dissipated and attained near ambient with in 100 m at the periphery of the patch (Figures 7.4.19-7.4.26).

Salinities, however, showed a small increase in all the cases indicating the dissipation of temperature due to evaporative cooling (Figures 7.4.27-7.4.34).

At the end of 10 days the salinities structure almost showed that of the neap tide (6^{th} day) indicating that this structure more or less remains similar to different phases of the 6^{th} day. However, the salinities in the intake channel remained at 37.6 - 39 ppt (Figure 7.4.35).

The temperature structure was also similar to that of neap tide. The intake channel was found to be free of excess thermal pollution (Figure 7.4.36).

The salinity being conservative does not dissipate and the patch is the area of overall impact.

A few stations were selected in the domain to represent the time series variation of both temperature and salinity.

Observation point 5: At the periphery of the largest patch near the mouth of the channel.
Observation point 6: The ebb (western) side of the effluent channel.
Observation point 7: The flood (eastern) side of the effluent channel.
Observation point 8: The intake point.
Observation point 9: Intake channel.

The results are shown graphically for 35°C and 39 ppt salinity in Figures 7.4.37 and 7.4.38. From these results it is observed that the temperature of the intake water is not affected though a small increase in salinity for about an hour is observed during neap high waters.

The results are shown graphically for 37°C and 39 ppt salinity in Figures 7.4.39 and 7.4.40. From these figures, it is evident that the temperature does not increase at the intake (Observation point 8), though an increase in salinity is observed during high waters. It can be inferred that the water is re-circulating and the temperature dissipation due to evaporative cooling may be only marginal increase in the salinities.

The model studies indicated that discharge upto 7°C above ambient with salinity of 39 ppt will cause no increase in temperature and salinity in the intake even after a long period and the salinity increase would be marginal and for a limited duration in neap tides particularly during high waters. This can be attributed to the smaller tidal prism available for dilution of the effluents for the conservative parameters.

From the model studies the following is inferred:

i) Temperatures are attaining near ambient in the area outside the 2kmx 5 km patch forming in the shallow and intertidal areas at the mouth of the discharge channel.

ii) The patch is getting elongated during floods towards the intake water channel, however, the intake channel at the intake point is free of thermal pollution.

iii) The salinity being a conservative property showed a continuous increase from spring to neap as the dilution water in the form of tidal prism decreased during this phase. With advancing spring this would shrink and would follow a cycle.

iv) The area under impact is coastal shallow water and intertidal area which amounts to about 10 km^2 would have these cyclical changes apart from the effluent.

v) The salinity changes are with in the natural variability of the area.

vi) Since this patch is in the coast and slowly reducing towards the sea, the organisms will avoid the area by natural instinct as they enter the periphery of the patch.

vii) The currents in the whole system remain grossly unchange even with the intake and discharge systems operating.

The temperature attains near ambient value as the effluent spreads due to loss of heat to the environment.

viii) From the above observations it is evident that the open channel system is a viable option.

8 POTENTIAL MARINE ENVIRONMENTAL IMPACTS

Major potential negative marine environmental impacts due to the proposed activities would be largely associated with the (a) construction of the seawater intake channel/laying of the seawater intake pipeline and marine structures, (b) construction of the effluent channel and (c) deterioration in ecological conditions due to constituents associated with the effluent. Evidently, potential negative impacts on the creek and coastal ecology can arise during the construction as well as the operational phases of the proposed project.

8.1 Construction phase

Adverse impacts of the proposed project on the creek and Gulf environment during construction phase would be due to (a) modifications in the hydrodynamic characteristics of the area, (b) degradation in water and sediment qualities, and (c) loss of biota.

8.1.1 Hydrodynamic characteristics

In the event of selection of channel option for seawater intake, dredging upto 3 m below CD and side slopes for stabilising the sides could potentially modify the local wave climate and the prevailing along-shore sediment transport, causing changes in local accretional / erosional trends. The adverse impact on a wider area of the creek however is unlikely.

The adverse impacts would be local, confined to a small nearshore segment of the creek and modifications to the hydrodynamic characteristics of the creek to the extent of increased inflow would occur. If the excavated channel is larger than the hydrodynamic requirement, sedimentation would take place in the channel till an equilibrium is attained.

The effluent release channel would tend to deepen as the water equivalent to the tidal prism of the creek preferentially uses the deepened channel during ebb. As a consequence the intertidal areas around the creek may experience slow but steady deposition.

The overall impact would be morphological change confined to the intertidal area fed by the Mudhwa creek

8.1.2 Water quality

Excavations in the intertidal and subtidal areas for making a channel or for laying pipelines and construction of structure for pumping seawater (if intake through a pipeline is envisaged) has high potential to disperse the bed sediment into the water column thereby increasing the SS in water and degrading the water quality locally.

From Section 4.4.1 it is evident that the subtidal and lower intertidal areas of Kotdi Creek and off Tunda are composed of sediment with a fair percentage of silt and clay. These patches would particularly generate fine SS when disturbed and may remain in suspension for a prolonged period under the influence of fairly strong currents in the dynamic environment of the Kotdi Creek and Gulf segment off Tunda, however, such transient pulses of high SS would be smothered fairly quickly and the background levels would prevail except in the project area. Moreover, SS in the Kotdi Creek and Gulf is inherently high and variable (Section 4.4) rendering the water turbid and muddy. The local increase in SS would be confined only to the construction phase and the baseline conditions would be re-established when the construction activity is terminated.

In areas where the sediment is polluted there is a fear of release of pollutants entrapped in sediment to the water column when the bed is disturbed thereby mixing interstitial water rich in contaminants with the overlying water. However, as the sediment of the Kotdi Creek and Gulf off Tunda is unpolluted (Section 4.4), there would not be deterioration in water quality on this account.

The sufficient distance (3.6 km) between the intake and discharge channels minimizes the risk of effluent entering the intake channel before attaining near ambient conditions of temperature and salinity.

8.1.3 Sediment quality

The sediment excavated for constructing the channels would be re-distributed by tidal circulation which may change the texture of the sediment of nearby areas, particularly of the intertidal region. The impact however would be minor.

The dredging to excavate the channel would generate huge quantities of dredge spoil. This needs to be disposed off at a selected spoil ground or used for

land filling of the site. However , this material should not be used in non-saline environments.

Misuse of the intertidal area by workforce employed during construction phase, can locally degrade the intertidal sediment by increasing BOD and populations of pathogens. The impact however would be minor and temporary and recovery would be quick when the source of this contamination is eliminated at the end of the construction phase.

8.1.4 Flora and fauna

Hectic construction activities in the intertidal and subtidal areas would influence the local biotic communities, particularly the macrobenthos along the corridors selected for seawater intake as well as release of effluent. As the sediment is not enriched in C_{org} (Section 4.4.3), its suspension in the water column is unlikely to deplete DO in this dynamic marine area and DO availability would not be a constraint for the biotic processes. The danger of biota getting exposed to pollutants released from sediment porewater ,when the bed is disturbed, is minimal since the sediment of Kotdi Creek is free from anthropogenic contaminants (Section 4.4).

The intertidal zone between Gulf and Kotdi Creek is largely sandy and devoid of vegetation except mangroves of stunted nature. Hence, a loss of about 500 plants of mangrove is envisaged. Some mangroves occur along the east shore of Kotdi Creek but those are at least 500 to 800 m away from the project site and hence unlikely to be adversely influenced.

An increase in turbidity due to enhanced levels of SS can negatively influence the photosynthesis and hence the primary productivity. However, the impact if any would be local, temporary and reversible with the phytoplankton community structure quickly reestablishing once the construction is completed.

A temporary and minor reduction in phytoplankton standing stock, if at all, and increase in turbidity is unlikely to produce any negative impact on zooplankton though a localised and marginal change in the community structure and population alternations may occur confined to the project area. Such changes are temporary and irrelevant to the overall secondary productivity of the Kotdi Creek.

Excavations for making the channels may affect benthic habitats along the selected corridors. The excavation for the 80 m width channel with appropriate side slopes would require about 130 m wide corridor. Hence, an area of 52.5 ha for 3.5 km length would be affected in intertidal and 2.0 km length in the subtidal area amounting to 22.5 ha would be subtidal.

Based on the results presented in Section 4.5.4 and the areas likely to be trenched/disturbed and probable loss of standing stock of macrobenthos during the construction phase is estimated as given below. However, actual loss would depend on the length from the finally decided seawater intake and effluent release site.

Activity	Habitat	Area (ha)	Population (no x 10^6)	Biomass (kg)
Seawater intake channel	Intertidal	52.5	729.8	7193
	Subtidal	22.5	112	135
	Total	75.0	842	7230
Effluent channel	Intertidal	26.25	892	23100
	Subtidal	6.75	37.4	46.75
	Total	33	840	23150

As evident from above the disturbance to creek habitat during the construction phase would be around 75 ha depending on which the losses were computed. Actual may vary slightly depending on the final alignment of seawater intake channel. Accordingly the estimated loss of benthic population and biomass would vary depending on the final disposal channel alignment. The loss of intertidal benthos both in terms of population and biomass would be more as compared to subtidal benthos due to better representation of faunal standing stock at the intertidal regions as compared to subtidal zone. The major components of benthos which would be affected are given below:

Activity	Polychaetes	Crustaceans	Molluscs
Intertidal (%)			
Seawater intake	24.3	31.3	43.1
Seawater release	11	66	16
Subtidal (%)			
Seawater intake	60 60	14 14	24 24
Seawater release	42	44	13

The above results indicate that polychaete is the major group which would be affected at the subtidal zone whereas molluscs and crustaceans are the major intertidal components which would be affected.

However, this loss would be temporary and the benthos would recolonise in due course after the construction activities are terminated. Moreover, the channel for seawater intake, would create an additional area of 0.2 ha by side slopes where selective benthic organisms would settle and grow. The overall loss of benthos which would be temporary and minor compared to the benthic potential of the Kotdi Creek and Gulf off Tunda , however, such temporary losses are not likely to be reflected on the overall biopotential of the Gulf system.

8.1.5 Miscellaneous

Aesthetics of the area would deteriorate due to the presence of construction machinery and materials, make-shift huts for labour force, cabins etc. Left over solid waste generated during construction would be a source of nuisance if not cleared from the site.

The extent of impact on the creek ecology would also depend on the duration of the construction phase. If the construction is prolonged due to time - overruns or improper planning, the adverse influence would increase accordingly.

The creek sustains sparse and stunted mangrove vegetation of about 1 plant for 100 m2 on average.

The mangrove areas along the E bank of the mouth region of the Kotdi Creek provide congenial environment for birds. These areas are sufficiently away from the project area and the associated populations of birds would not be affected by the noise generated during construction. However, stray birds using the intertidal area around the project site would be disturbed.

Marine reptiles and mammals common to the Gulf would not be affected due to construction activities since they keep away from such sites.

Since there are no commercial fishing operations in Kotdi Creek except shore based local fishing, the impact on fisheries would be minor and non-consequential.

8.2 Operational phase

Marine environmental implications during the operational phase of the project would be essentially confined to the i) impingement and entrainment of organisms during abstraction of sea water ii) release of biocides added to the water used in the plant and iii) adverse influence of release of effluent on the water quality, sediment quality and flora and fauna of the Gulf.

8.2.1 Impingement and entrainment

The water requirement for the project is huge and the biota will be lost once they enter the cooling water circulation system. The impingement occurs only if the currents generated by the intake are strong and suck the animals into forcefully. The wide and deep channel suggested for the intake will cause only weak currents and the larger organisms can swim back if screens are provided to stop them.

However small and planktonic organisms which do not have their own strong propulsions would be lost eventually. These organisms however have a large reproductive rates. Moreover, the local increase in temperature and salinity in the vicinity would alert the organisms from entering the area.

It is also predicted that some of the return coolant would enter the intake system and the faunal loss would be less proportionately.

8.2.2 Release of biocides

The return coolant will contain some residual chlorine used as biocide in the circulation system to prevent befouling.

8.2.3 Water quality

Probable impact of release of treated effluent at the designated site through an open channel on water quality is predicted based on probable dilution the effluent would attain and assuming conservative behaviour of constituents in the receiving water. The temperature is not a conservative property and decay due to evaporative and sensible heat losses reduces the impact outside the channel system. The temperature in a limited area comprising the discharge channel and its immediate vicinity will however have temperatures of 3-7°C above ambient. This increase may not be lethal to the organisms but proliferation of resistive organisms may change the community structure of the biota. The inter tidal area however experiences such temperatures and salinities even in the normal course.

8.2.4 Sediment quality

Some fraction of contaminants such as heavy metals, PHc, phenols etc if present in the effluent would be adsorbed onto the SS which is abundantly available in the proposed area of release thereby enriching the bed sediment on settling. However, due to high tidal dispersal and efficient advection by strong currents, this SS would be scattered over a large area. Hence increase in the concentration of contaminants in the creek sediment to level to cause harm to biota is unlikely.

8.2.5 Flora and fauna

The general water quality of the creek and Gulf segment would not be affected adversely, though limited degradation would result in a small area around the discharge channel. Hence, by and large, the biological characteristics of the creek and surrounding segments would not be affected adversely. Although the concentrations of some contaminants may remain higher in the vicinity of release, the predicted levels are sufficiently below the threshold concentrations to cause toxicity to flora and fauna of the effluent receiving segment.

Some marine organisms are sensitive to salinity changes and large variations in salinity can cause harm to them. It is evident from Tables 4.3.4 to 4.3.6 that the salinity in the segment between stations 4 and 6 varies from 34.6 to 37.9 ppt. Hence, the marine biota in Gulf segment would have adapted to such fluctuations which are larger than the predicted increase in salinity 1-2 within 2 km from discharge channel mouth. Hence, marine biota would not be affected due to a small increase in salinity except in the proximity of effluent release.

Increase in temperature of the receiving water due to release of warm effluent is another factor that needs evaluation. This is particularly important for the arid environment of the Kotdi Creek and adjoining region. The high air temperatures during May and October can increase the water temperature of the creek upto 35°C (Section 4.3.1) which may adversely affect the survival of several marine organisms. Hence, it should be ensured that the heat associated with the effluent dissipates rapidly on release. From the model studies it is estimated that the temperature of the water within 2 km from the seaward end of the channel would increase by about 2-4 °C. Such an increase in temperature is unlikely to adversely affect the biota of the effluent release site.

9 MITIGATION MEASURES AND EMP

The Kotdi Creek identified for setting-up seawater intake and creek segment of Mudhwa for effluent release facilities is a typical inshore marine zone of the Kachchh District. No endangered or rare species was encountered during field studies or reported for the inner creek. Further, fragile and sensitive habitats such as mangroves are absent in the immediate vicinity of the proposed development site. Hence, conventional methods generally recommended for marine areas can be employed for setting-up the seawater intake and effluent release facilities with standard mitigation measures to minimise the adverse impacts on marine ecology.

9.1 Construction phase

Construction of the sea water intake channel and return coolant discharge channel could change the pattern of littoral drift locally. This change should be minimised by suitably orienting the channel and adequately designing the side slopes based on model studies. Such a study would also aid in incorporating structural modifications if required, to minimise maintenance cost.

Except for the temporary destruction of macrobenthos along the corridors selected for seawater intake and discharge channels the impact on the creek ecology during construction phase would be largely confined to the duration over which the activities are spread. Hence, the key factor in minimising adverse impacts would be reduction in the construction period at the site and avoidance of spillage of activities beyond the specified geographical area which should be kept to a minimum.

There is a distinct advantage of reduction in time of marine construction operations by prefabricating the structures wherever possible and transporting them to the site. However, the fabrication yard should be located sufficiently away from the shore and transport of structures to the site should be through a predecided corridor.

Work force employed during construction often misuses the intertidal and supratidal areas. This should be avoided by establishing the temporary colonies of workers sufficiently away from the HTL and proper sanitation should be provided to them to prevent abuse of the intertidal region.

The noise level during transport and construction of marine facilities should be kept to a minimum.

The intertidal and nearshore subtidal areas should be restored to their original contours once the construction activities are completed. General clean-up along the corridor areas, creek segment etc should be undertaken and discarded materials including excavated soil should be removed from the site and the aesthetic quality of surroundings restored on completion of the construction phase.

The excavation of the channels will produce huge amounts of dredge spoil (approximately 2.8 and 1.3 million m^3 from intake and discharge channels respectively). This spoil should not be dumped in the inter tidal area. A suitable spoil ground is to be found or should be used for site filling.

9.2 Operational phase

Kotdi Creek and Gulf segment off Tunda represents an unpolluted marine environment, which should be maintained in future also. Hence, it should be ensured that the effluent released into the Gulf meets the prescribed GPCB criteria at all times. Since, the Gulf segment already sustains high salinity and water temperatures can rise upto 35°C, it should be ensured that their levels in the effluent are maintained as prescribed.

Impingement and entrainment of marine organisms, due to large quantity of intake, should be avoided by placing suitable nets across the intake channel and moving screen at the intake with suitable washing mechanism like water jets using sea water may be used and the collected biota may be directed suitably to nearby creeks/ a shallow water course may be provided to the east of the intake channel. The local fishing community should be encouraged to fish in the channel . However, destruction of very small organisms can not be avoided.

It is predicted that the effluent would attain near ambient temperatures and salinities with in 3-4 km when released through a channel based on the model predictions. Such calculations are based on average environmental conditions and a few assumptions which cannot be easily verified. Hence, the actual dilution attained should be measured through studies after the outfall becomes operational. The effluent release process can then be adequately modified to ascertain necessary dilution.

Kotdi Creek and surrounding segment of Gulf is not an important navigational route though local craft and fishing vessels operate in the region. Hence, as a

navigational safeguard, the seawater intake and effluent release locaticns should be adequately identified with marker buoys.

Use of the biocides should be kept at the minimum and their concentration at the outlet should be regularly tested. If required the use should be regulated.

Afforestation of mangroves should be taken up at suitable locations, preferably in the side slopes of intake channel to improve the mangrove vegetation and to stabilize the channel.

9.3 Environmental Management Plan (EMP)

It is necessary to monitor the area periodically and identify the perturbations if any to take appropriate follow-up action.

a) Baseline quality

To understand seasonal variations it is necessary to conduct periodic investigations, ideally monthly, but at least seasonally at carefully selected monitoring locations. These should include subtidal as well as intertidal segments. In the present case, the stations 4 to 9 should be adequate to represent the subtidal environment while intertidal transects in the vicinity of the plant utilities alongwith a transect sufficiently away from this area should be selected for evaluation of the intertidal ecology. Till a proper baseline is established, the data presented in this report can be considered for comparing the results of future monitorings. The monitoring however should be confined to the month in which the data are collected. Selected stations including the effluent disposal location should be sampled diurnally during the monitoring programme. The parameters to be monitored are listed below:

Physical processes: Tides, currents and circulation in the creek should be studied. Bathymetric surveys by echo sounding in both the intake and discharge channels should be undertaken to delineate erosion and deposition.

Water quality: Water samples obtained from 2 levels in the vertical when the depths exceed 3-m, should be studied for temperature, pH, SS, turbidity, salinity, DO, BOD, (or total organic carbon), nitrate, nitrite, ammonia, dissolved phosphate, PHc and phenols. For shallow waters, only surface samples can be analysed.

Sediment quality: Sediment from subtidal and intertidal regions should be analysed for texture, C_{org}, phosphorus, chromium, nickel, copper, zinc, cadmium, lead, mercury, arsenic and PHc.

Flora and fauna: Biological characteristics should be assessed based on primary productivity, phytopigments, phytoplankton populations and their generic diversity; biomass, population and group diversity of zooplankton; biomass, population and group diversity of benthos and fish quality.

b) Post-project monitoring

A comprehensive marine quality monitoring programme with periodic (Premonsoon and postmonsoon) investigations at predetermined locations (these should coincide with those used for the baseline quality) by a specialised agency is a practical solution to ensure quality data acquisition. This can be a continuation of the study designed for baseline quality and some parameters listed above should be included in the post-project monitoring programme.

The results of each monitoring should be carefully evaluated to identify changes if any, beyond the natural variability identified through the baseline studies. Gross deviation from the baseline may require a thorough review of the effluent disposal scheme to identify the causative factors leading to these deviations and accordingly, corrective measures to reverse the trend would be necessary.

10 SUMMARY AND CONCLUSION

CGPL has embarked on developing the infrastructure for a 4000 MW thermal power project proposed to be set up at Mundra and had invited bids for the construction and operation of the same. M/s TCE Consulting Engineers Ltd., the technical consultants to CGPL, has been awarded Technical Consulting for setting up a 4000 MW thermal power station. The studies presented in this report have been carried out by the NIO with the objectives of evaluating the prevailing hydrodynamics and ecological status of the coastal water adjacent to the project site, suggesting suitable mode and location for intake water and release of treated effluents in the Gulf of Kachchh, assessing the impact of seawater intake and effluent release and other project operations on marine ecology, and recommending suitable marine environmental management plan to minimize any adverse impact on marine area.

10.1 Project information

The project site is in the vicinity of Mundra SEZ about 25 km from the Mundra Port and 1.5 km from the coast of the Gulf of Kutch. The proposed project consists of five power plant units totaling to 4000 MW gross capacity, utilising imported coal as fuel. Fresh water for the plant, potable water, service water and feed water to the DM plant and other services will be met by the desalination plant of the MSEZ. A once through cooling system with sea water is preferred for the plant. The circulating system will be designed to attain temperature of less than +7°C above the ambient seawater temperature.

The effluents from the pre-treatment plant of the desalination plant, once through cooling system and the desalination plant reject water will be mixed in a common tank "brine/reject water tank" before discharging to sea at a suitable location decided by scientific investigations.

10.2 Gulf of Kachchh

The Gulf occupies an area of 7300 km^2, has maximum depth that varies from 20 m at the head (Kandla - Navlakhi) to 60 m in the outer regions. Kachchh District is industrially backward with a few industrial establishments.

Tides in the Gulf are of mixed, predominantly semidiurnal type with a large diurnal inequality. The tidal front enters the Gulf from the west and due to shallow inner regions and narrowing cross-section, the tidal amplitude increases considerably, upstream of Vadinar. The phase lag between Okha and Kandla is 2 h to 2 h 25 min while between Okha and Navlakhi it is 3 h to 3 h 20 min. Due to high tidal ranges in the inner regions, the vast mudflats and coastal lowlands that get submerged during high tide, are fully exposed during low tide. Circulation in the Gulf is mainly controlled by tidal flows and bathymetry, though wind effect also prevails to some extent. The maximum surface currents are moderate (0.7-1.2 m/s) but increase considerably (2.0-2.5 m/s) in the central portion of the Gulf. With high tidal range, negligible land run-off and irregular topography, the waters are vertically homogeneous in terms of salinity and temperature.

The annual variation of water temperature is between 23 and 30° C though localised higher temperatures upto 35° C can result in isolated water pools formed in shallow intertidal depressions, during low tide. SS is highly variable (5-700 mg/l), spatially as well as temporally, and largely result from the dispersion of fine sediment from the bed and the intertidal mudflats, by tidal movements. Average pH of the Gulf water is remarkably constant (8.0-8.3) and is within the range expected for the coastal tropical seas. The evaporation exceeds precipitation leading to salinities markedly higher than that of the typical seawater. This is particularly evident in the inner Gulf where salinities as high as 40 ppt commonly occur off Kandla and Navlakhi. The average DO is fairly high (3-5 ml/l) and the BOD is low (<0.1-4.0 mg/l) indicating good oxidising conditions. The nutrients (PO_4^{3-}-P, NO_3^--N, NO_2^--N, NH_4^+-N) are more or less uniformly distributed in the Okha-Sikka-Mundra segment and their concentrations indicate healthy natural waters. As expected for an unpolluted coastal environment, the concentrations of PHc and phenols are low.

The concentrations of heavy metals such as chromium, manganese, cobalt, nickel, copper, zinc, mercury and lead though variable, indicate natural background levels and there is no evidence of gross sediment contamination.

The concentrations of PHc are also low though large quantities of petroleum crude and its products are off-loaded at Vadinar and Kandla respectively.

The Gulf abounds in marine wealth and is considered as one of the biologically richest marine habitat along the west coast of India. The marine flora is highly varied, which includes sand dune vegetation, mangroves, seagrasses, macrophytes and phytoplankton. The Gulf has a vast intertidal area with rich biota. Sheltered bays, creeks and mud flats provide ideal sites for mangrove vegetation over an estimated area of about 1036 km^2.

The marine fauna of the Gulf is rich, both in variety and abundance. One of the most interesting biotic features of the Gulf is the presence of living corals, thriving as patches, rather than reefs, either on the intertidal sand stones or on the surface of wave-cut, eroded shallow banks along the southern shore of the Gulf. The Gulf has a variety of exploitable species of finfishes and shellfishes. Fishing grounds for Ghol, Karkara, Khaga, Dhoma, Magra and Musi exist in the Gulf. The Gulf region offers plenty of facilities for feeding, breeding and shelter to a variety of birds.

Because of its high biogeographical importance and rich flora and fauna, several areas along the southern Gulf are notified under the Marine National Park (16289 ha) and the Marine Sanctuary (45798 ha).

10.3 Site specific marine environment

The assessment domain of the present study involved the section of the Gulf between the Mudwah Point and Bocha creek. The development of Mundra Port is largely confined to the Navinal Island near the Mundra village. Bocha, Navinal, Baradi Mata and Kotdi creeks are the major tidal inlets in the region. These creeks are broad but shallow and navigable only during flood tide. The area proposed for the development of power plant of CGPL falls between two ephemeral rivulets namely Khari Nadi in the west and Wae a contributory of Nagavati river in the east. There are two moderate size villages Tunda (in the east) and Wandh (in the west) in the vicinity of the project site. The prominent vegetation in the area is mainly composed of Babool

(*Presopsis Julifolia*) and stray mangroves. Local fishing community uses the navigable creeks for their country crafts during high tide and use sandy beaches around for beaching their shallow draft crafts.

The time of occurrence of flood and ebb tide at Mundra lead by 27 and 46 min respectively with respect to the Kandla tide. The tidal range ratio (Mundra : Kandla) is 0.83 and 0.88 for spring and neap tides respectively. The tidal range in the Kotdi Creek varied from 1 to 3.5 m with the time lag of 5 to 10 min as compared to the phase of the tide at the Mundra Port. The tide off Tunda-Wandh is comparable in amplitude to that of Mundra.

The maximum current speed observed off the Kotdi Creek is 0.8 m/s. The U-component of the currents (Northward) is stronger than the V component indicating weak lateral transport, as expected. The maximum current speed varies from 0.5 to 1.2 m/s in the Gulf off the project site. The predominant direction of the current is 45° during ebb and 220° during ebb. The circulation off the project site is generally elliptical with the major axis in the east-west direction. The excursion lengths vary in 10 to 15 km range depending on the tidal phase (neap or spring).

The water quality around Mundra was assessed in Navinal, Bocha and Kotdi Creeks and the nearshore water off Mundra/Tunda during January and April 2006.

The water temperature varies in 18 – 31 °C range in the region. Under the influence of buffering action of $CO_3^{2-}/HCO_3^-/CO_2$ system the pH of water was fairly constant (8.0-8.3). The SS is variable; the maximum value recorded being 120mg/l.In the absence of freshwater inflow the salinity (ppt) in the creeks as well as the Gulf is markedly high (36 – 40 ppt). Surface to bottom variations are minor and the waters are well-mixed vertically. The DO varies from 1.0 to 6.2 ml/l in the creek and openshore but the average is generally above 3 ml/l suggesting for good ecological conditions. Low individual values sometimes recorded however indicate some stress conditions. The BOD (0.2-6.4 mg/l) is low and comparable with that of the Gulf in general. The

nutrients such as phosphate, nitrate, nitrite and ammonia as well as PHc and phenol are low and in the range expected for the Gulf. The overall assessment indicates that the water quality off Mundra has not measurably altered over the years.

The surface 1.5 m layer of the intertidal segment typically contains of 70 - 90% sand with silt and clay in minor proportions. The specific gravity of the sediment which does not vary significantly in texture upto the termination depth varies between 2.65 and 2.68. The concentrations of chromium, cobalt, nickel, copper, zinc, mercury, organic carbon, phosphorus and PHc are in the expected ranges for the Gulf indicating uncontaminated nature of the sediment.

The marine alga *Enteromorpha* sp commonly occurs in the intertidal area off the project site while seagrasses are dominated by *Halophila ovata* and *Halodule uninervis*. *Avicennia* the dominant mangroves in the region are generally dwarf and sparse about 4 km away from the project site. However, the height and density improves along the water ways in about 20 - 50 m belt which is about 11 km away from the project area. The seedling density is high along some creeks. Degraded stands of *Avicennia* occur towards the mouth of Kotdi and Baradi Mata Creeks. The major land portion proposed for the development falls under saline bank which is devoid of mangrove vegetation except for a few stray plants. The segments proposed for intake and discharge channels sustain sparse and stunted mangroves of *Avicennia marina*. No dunes or dune vegetation occur around the proposed intake and discharge channels.

The levels of chlorophyll *a* and phaeophytin vary in wide range in the coastal ecosystem off Mundra. The generic diversity of phytoplankton varies from 7 to 17 in the area. Overall, about 40 genera of phytoplankton are recorded with the dominance of *Thalassiosira, Thalassionema, Pleurosigma, Amphiprora, Biddulphia, Coscinodiscus Diploneis, Ditylum, Fragilaria, Gyrosigma, Melosira, Navicula, Nitzschia* and *Rhizosolenia*. The zooplankton standing stock in terms of biomass and population reveals good secondary

production in the coastal waters. The zooplankton community structure reveals the dominance of copepods and decapod larvae.The other common groups are foraminiferans, siphonophores, medusae, ctenophores, chaetognaths, polychaetes, ostracods, mysids, *Lucifer*, gastropods, lamellibranches and appendicularian. The intertidal macrobenthic standing stock in terms of population (av 3218/m^2) and biomass (av 26 g/m^2 wet wt) varied widely. Total faunal groups are comparable both in creeks and Gulf segment. The average standing stock of subtidal macrobenthos at the study area both in terms of biomass (av 1.7 g/m^2; wet wt) and population (580/m^2) is low.

During experimental fishing in January 2006 off the project site the fish catch rate varied between 8.0 and 18.5 kg/h. This catch consisted of 22 species of fishes, 7 species of prawn and 5 species of crab and Loligol squilla. *Harpadon nehereus, Coilia dussmieri, Johnius glaucus, Lepturacanthus savala, Mugil sephalus* and *Thryssa* sp. recorded as the most dominant species.

The Mundra region does not sustain reef building corals as the intertidal area is largely sandy or muddy. Coral growth in the subtidal region is also unlikely in view of the high suspended load in the water column, the conditions under which corals do not thrive. The saltpans, islands and intertidal coastal system with mangroves off Mundra offer plenty of facilities for feeding, breeding and shelter to a variety of birds. In the Gulf, the reptiles are mainly represented by marine turtles *Chelonia mydas* and *Lepidochelys olivacea*. No turtle however was sighted off Mundra during the study period. The mammals are chiefly represented by dolphin (*Dolphinus delphis*), whale (*Balanoptera* spp) and Dugong (*Dugong dugon*) in the Gulf especially along the Jamnagar coast. These were not sighted during the study period off Mundra.

10.4 Seawater intake

As the cooling water requirement for the project is large (470000 m^3/h) withdrawal of seawater by conventional well and pipe systems is unviable.

The alternative being drawl through a channel of 80 m width dredged up to 3m contour in the Gulf. To provide a 15° slope the channel would be 130 m wide at the surface during high water. With the projected intake the maximum current speeds in the channel would be about 0.54 m/s during spring low waters when the tide level is near zero and the area of cross section available for the intake is minimum. However, accretion particularly during monsoon months due to wave action can be high requiring periodic maintenance.

10.5 Effluent release

The effluent (467000 m^3/h) that will be largely return seawater will have a temperature of 7°C rise over the ambient. The salinity also will be marginally higher by 2-3 ppt.. The water would be lighter than the ambient water due to the higher temperatures of the effluent with a marginal increase in salinity. The suggested disposal is through a channel dredged and extended to meet the natural contour of 1m below CD.

The basic water quality model POLSOFT was used to estimate the capacity of the coastal waters of Tunda-Wandh and Kotdi-Mudhwa creek-systems to assimilate return cooling water. After 10 days of continuous run with the simultaneous intake and discharge in the respective channels the following were the observations:

Erosion was noticed in the western side of the discharge channel to an extent of 11 to 33 cm. Deposition of sediment to an extent of 0.8 cm was predicted in shallow coastal areas to the east of the intake channel, to the east of the discharge channel and along the shallow stretch in the ebb direction.

Variable increase in temperature of water is predicted in an area of 2kmx3km patch in the east direction during ebb, a smaller patch during floods. Near ambient temperatures are predicted outside this zone. The intake water did not show any rise in temperature. The salinity showed an increase both in the open sea and intake channel. This can be due to the conservative nature of salinity. The model studies indicated that discharge upto 7°C above ambient with salinity of 39 ppt will cause no increase in the intake even after a long

period and the salinity increase would be for a limited duration in spring tides particularly during high waters.

10.6 Potential marine environmental impacts

Major potential negative marine environmental impacts due to the proposed activities would be largely associated with the (a) construction of the seawater intake channel, (b) construction of the effluent channel and (c) deterioration in ecological conditions due to constituents associated with the effluent. Evidently, potential negative impacts on the creek and coastal ecology can arise during the construction as well as the operational phases of the proposed project.

Construction phase

Adverse impacts of the proposed project on the creek and Gulf environment during construction phase would be due to (a) modifications in the hydrodynamic characteristics of the area, (b) degradation in water and sediment qualities, and (c) loss of biota.

The construction of bunds in the upper intertidal area and dredging upto 3 m below CD and side slopes for stabilising the sides can potentially modify the local wave climate and the prevailing along-shore sediment transport, causing changes in local accretional/erosional trends. The adverse impact on a wider area of the creek however is unlikely.

Excavations in the intertidal and subtidal areas for making a channels has high potential to disperse the bed sediment into the water column thereby increasing the SS in water and degrading the water quality locally. The subtidal and lower intertidal areas of Kotdi Creek and off Tunda are composed of sediment with a fair percentage of silt and clay. These patches would particularly generate fine SS when disturbed. Such transient pulses of high SS would be smothered fairly quickly and the background levels would prevail except in the project area. Moreover, SS in the Kotdi Creek and Gulf is inherently high and variable rendering the water turbid and muddy. The local increase in SS would be confined only to the construction phase and the

baseline conditions would be re-established when the construction activity is terminated.

The sediment excavated for constructing the channels would be re-distributed by tidal circulation which may change the texture of the sediment of nearby areas, particularly of the intertidal region. The impact however would be minor. The dredging to excavate the channel would generate huge quantities of dredge spoil which will have to be adequately disposed.

Misuse of the intertidal area by workforce employed during construction phase, can locally degrade the intertidal sediment by increasing BOD and populations of pathogens. The impact however would be minor and temporary and recovery would be quick when the source of this contamination is eliminated at the end of the construction phase.

Hectic construction activities in the intertidal and subtidal areas would influence the local biotic communities, particularly the macrobenthos along the corridors selected for seawater intake as well as release of effluent. As the sediment is not enriched in C_{org}, its suspension in the water column is unlikely to deplete DO in this dynamic marine area and DO availability would not be a constraint for the biotic processes. The danger of biota getting exposed to pollutants released from sediment porewater, when the bed is disturbed, is minimal since the sediment of Kotdi Creek is free from anthropogenic contaminants.

An increase in turbidity due to enhanced levels of SS can negatively influence the photosynthesis and hence the primary productivity. However, the impact if any would be local, temporary and reversible with the phytoplankton community structure quickly reestablishing once the construction is completed. A temporary and minor reduction in phytoplankton standing stock, if at all, and increase in turbidity is unlikely to produce any negative impact on zooplankton though a localised and marginal change in the community structure and population alternations may occur confined to

the project area. Such changes are temporary and irrelevant to the overall secondary productivity of the region.

Excavations for making the channels would have significant negative impact on benthic habitats which would be destroyed along the selected corridors. The estimated losses are about 500 plants of mangroves, intertidal macrobenthic loss of about 30 t biomass and subtidal macrobenthic loss of 182 kg biomass. This loss would be temporary and the benthos would recolonise in due course after the construction activities are terminated. Moreover, the channel for seawater intake, would create an additional area where selective benthic organisms would settle and grow.

Aesthetics of the area would deteriorate due to the presence of construction machinery and materials, make-shift huts for labour force, cabins etc. Left over solid waste generated during construction would be a source of nuisance if not cleared from the site. The extent of impact on the creek ecology would also depend on the duration of the construction phase. If the construction is prolonged due to time - overruns or improper planning, the adverse influence would increase accordingly. Since there are no commercial fishing operations in Kotdi Creek except shore based local fishing, the impact on fisheries would be minor and non-consequential.

Operational phase

Marine environmental implications during the operational phase of the project would be essentially confined to the impingement and entrainment of organisms during abstraction of sea water and adverse influence of release of effluent on the water quality, sediment quality and flora and fauna of the Gulf.

The water requirement for the project is huge and the biota will be lost once they enter the cooling water circulation system. The wide and deep channel suggested for the intake would cause only weak currents and the larger organisms would swim back if screens are provided to stop them. Small and planktonic organisms would be killed when they enter the cooling system.

These organisms however have large reproductive rates and replenishments are quick through recruitment from adjacent areas.

The temperature in a limited area comprising the discharge channel and its immediate vicinity is predicted to be 3-7°C above ambient. This increase may not be lethal to the organisms but proliferation of resistive organisms may change the community structure of the localized zone. The inter tidal area however experiences such temperatures and salinities even in the normal course.

Some fraction of contaminants such as heavy metals, PHc, phenols etc if present in the effluent would be adsorbed onto the SS which is abundantly available in the proposed area of release thereby enriching the bed sediment on settling. However, due to high tidal dispersal and efficient advection by strong currents, this SS would be scattered over a large area. Hence increase in the concentration of contaminants in the creek sediment to level to cause harm to biota is unlikely.

10.7 Mitigation measures and EMP

The Kotdi Creek identified for setting-up seawater intake and creek segment of Mudhwa for effluent release facilities is a typical inshore marine zone of the Kachchh District. No endangered or rare species was encountered during field studies or reported in these creeks. Further, fragile and sensitive habitats such as mangroves are generally rare in the immediate vicinity of the proposed development site. Hence, conventional methods recommended for marine areas can be employed for setting-up the seawater intake and effluent release facilities with standard mitigation measures to minimise the adverse impacts on marine ecology.

Construction phase

Construction of bunds for protecting the sides of the water intake channel, could change the pattern of littoral drift locally. This change should be minimised by suitably orienting the channel and adequately designing the

protection bunds based on model studies. Such a study would also aid in incorporating structural modifications if required, to minimise maintenance cost.

Except for the temporary destruction of macrobenthos along the corridors selected for seawater intake and discharge channels the impact on the creek ecology during construction phase would be largely confined to the duration over which the activities are spread. Hence, the key factor in minimising adverse impacts would be reduction in the construction period at the site and avoidance of spillage of activities beyond the specified geographical area which should be kept to a minimum. There is a distinct advantage of reduction in time of marine construction operations.

Work force employed during construction often misuses the intertidal and supratidal areas. This should be avoided by establishing the temporary colonies of workers sufficiently away from the HTL and proper sanitation should be provided to them to prevent abuse of the intertidal region. The noise level during transport and construction of marine facilities should be kept to a minimum.

The intertidal and nearshore subtidal areas should be restored to their original contours once the construction activities are completed. General clean-up along the corridor areas, creek segment etc should be undertaken and discarded materials including excavated soil should be removed from the site and the aesthetic quality of surroundings restored on completion of the construction phase.

The excavation of the channels will produce huge amounts of dredge spoil. This spoil should not be dumped in the inter tidal area and a suitable stragegy must be decided for disposal of the material.

Operational phase

Kotdi Creek and Gulf segment off Tunda represents an unpolluted marine environment, which should be maintained in future also. Hence, it

should be ensured that the effluent released into the Gulf meets the prescribed GPCB criteria at all times.

Impingement and entrainment of marine organisms, due to large quantity of intake, should be avoided by placing suitable screens across the intake channel and moving screens with suitable washing mechanism. The local fishing community should be permitted to fish in the channel.

It is predicted that the effluent would attain near ambient temperatures and salinities with in 3-4 km when released through a channel based on the model predictions. Such calculations are based on average environmental conditions and a few assumptions which cannot be easily verified. Hence, the actual dilution attained should be measured through studies after the outfall becomes operational. The effluent release process can then be adequately modified to ascertain necessary dilution.

Kotdi Creek and surrounding segment of Gulf is not an important navigational route though local craft and fishing vessels operate in the region. Hence, as a navigational safeguard, the seawater intake and effluent release locations should be adequately identified with marker buoys.

Afforestation of mangroves should be taken up at suitable locations, preferably in the side slopes of intake channel to improve the mangrove vegetation and to stabilize the channel.

A comprehensive marine quality monitoring programme with periodic investigations at predetermined locations must be undertaken. The results of each monitoring should be carefully evaluated to identify changes if any, beyond the natural variability identified through the baseline studies. Gross deviation from the baseline may require a thorough review of the effluent disposal scheme to identify the causative factors leading to these deviations and accordingly, corrective measures to reverse the trend would be necessary.

Table 3.2.1: Details of cyclonic storms along North Gujarat coast (1893-1999).

Year	Month	Intensity	Point of Origin	Track followed
1893	Nov	Str-SStr	Arabian Sea	Veraval-Bhavnagar
1894	Oct	SStr	Arabian Sea	Jafarabad-S.Gujarat
1896	Nov	SStr	Indian Ocean	Off Jafarabad-Bhopal-Allahabad
1897	Jul	Depr	Arabian Sea	Off Jafarabad-Veraval-Gulf of Kachchh
1897	Sep	Depr	Off Diu	Veraval-Off Dwaraka-NW
1903	Jul	Str	Arabian Sea	Off Jafarabad-Veraval-North
1909	Sep	Depr	Bay of Bengal	Surat-Jafarabad-Kandla-NW
1920	Jun	SStr	Arabian Sea	Veraval-Ahmedabad
1925	Jun	Depr	Arabian Sea	Off Veraval-Kandla-Bhopal-Allahabad
1925	Jun	Depr	Arabian Sea	Bharuch-Bhavnagar-Okha
1926	Sep	Depr	Off Veraval	Veraval-N-W-N
1933	May	Depr	Arabian Sea	Veraval-N
1934	Oct	Depr	Arabian Sea	Dissipated Off Jafarabad
1935	Jun	Depr	Bay of Bengal	Gulf of Khambhat
1944	Aug	Str	Bihar	Ahmedabad-Kandla-Off Jafarabad-W
1944	Oct	Depr	Bay of Bengal	Pune-Mumbai-Off Jafarabad-Ahmedabad
1947	Apr	SStr	Off Cochin	Arabian Sea-Bharuch-along the West coast
1948	Sep	SStr	Bay of Bengal	Mumbai-Off Diu-Porbandar
1954	Jul	Depr	Off Jafarabad	Vadinar-Karachi
1959	Oct	Depr-Str	Arabian Sea	Jafarabad-Veraval-across the Arabian Sea-Oman
1960	Jul	Depr	Off Veraval	Off Dwarka-Mandwa
1962	Sep	Depr	Bay of Bengal	Surat-Jafarabad-Dwarka-Mandwa

Table 3.2.1 (Contd.2)

Year	Month	Intensity	Point of Origin	Track followed
1964	Aug	Str	Arabian Sea	Jafarabad
1969	Jun	Depr	Arabian Sea	Jafarabad-Bhavnagar
1973	Jul	Depr	Off Diu	Veraval-Porbandar-Vadinar-N
1975	Jun	Depr	Off Jafarabad	Okha-W
1976	May-Jun	SStr	Arabian Sea	Jafarabad-Ahmedabad
1982	Nov	Depr	Arabian Sea	Veraval-Ahmedabad-NE
1983	Jun	Depr	Off Veraval	Veraval-Rajkot
1985	Oct	Depr	Off Mumbai	Jafarabad-W of Bhavnagar Jafarabad-Surat-NE
1989	Jun	Depr	Off Veraval	Junagadh-Rajkot-Navlakhi-Vadinar-NW
1996	Jun	SStr	Kandla	Kandla-Rajkot
1996	Oct	SStr	Arabian Sea	Kandla-Veraval-Jafarabad
1998	June	SStr	Arabian Sea	Porbandar-Jamnagar-Kandla
1999	June	SStr	Arabian Sea	Porbandar-Dwarka-Jakhau

Intensity (Wind speed)
Depression (Depr) : Upto 61 km/h.
Storm (Str) : 62-87 km/h.
Severe Storm (SStr) : 89-117 km/h.

Table 3.3.1 (Contd 2)

Parameter	Level	Okha				Salaya		Vadinar		Sikka		
		Feb 1993	Mar 1995	Apr 2002	July2004	Feb 1995	Apr 2002	Mar 1994	Mar 1996	Apr 1994	Apr 2002	Apr 2003
P_{Total} (µmol/l)	S	-	-	-	-	-	-	0.8-3.2 (2.0)	-	-	-	-
	B	-	-	-	-	-	-	1.4-3.2 (2.3)	-	-	-	-
NO_3^--N (µmol/l)	S	1.2-4.4 (2.8)	6.9-7.9 (7.4)	4.2-10.7 (7.4)	13.0*	1.1-3.6 (2.3)	0.7-6.0 (3.3)	0.1-1.4 (0.6)	1.4-8.4 (4.3)	4.0-7.6 (5.3)	0.1-4.3 (2.2)	0.3-1.3 (0.8)
	B	1.4-4.1 (2.8)	5.4-6.1 (5.8)	3.3-6.8 (5.0)	11.8*	1.1-4.1 (2.6)	1.1-5.4 (3.2)	0.1-1.4 (0.9)	2.4-7.8 (4.1)	4.0-6.3 (5.1)	0.1-2.3 (1.2)	1.2-1.5 (1.4)
NO_2^--N (µmol/l)	S	0.1-0.4 (0.3)	0.5-0.6 (0.5)	0.2-0.7 (0.4)	0.8*	0.1-0.6 (0.4)	0.1-0.5 (0.3)	0.1-0.3 (0.2)	ND-0.4 (0.3)	0.2-0.5 (0.3)	0.1-0.2 (0.1)	0.2-0.2 (0.2)
	B	0.2-0.4 (0.3)	0.2-0.4 (0.3)	0.2-0.9 (0.5)	0.9*	0.1-0.6 (0.4)	0.2-0.4 (0.3)	0.1-0.6 (0.3)	ND-0.4 (0.3)	0.1-0.5 (0.3)	0.1-0.2 (0.1)	0.2-0.2 (0.2)
NH_4^+-N (µmol/l)	S	ND-2.9 (1.5)	0.1-0.4 (0.3)	0.1-0.2 (0.1)	2.4*	ND-10.5 (5.2)	0.1-0.1 (0.1)	0.5-0.9 (0.7)	0.1-0.9 (0.5)	0.1-1.2 (0.4)	0.1-0.2 (0.1)	0.9-2.0 (1.5)
	B	ND-2.0 (1.0)	ND-0.2 (0.1)	0.1-0.1 (0.1)	2.2*	ND-5.0 (2.5)	0.1-0.1 (0.1)	0.5-0.9 (0.7)	ND-2.9 (1.2)	0.1-0.6 (0.4)	0.1-0.1 (0.1)	ND-ND (ND)
N_{Total} (µmol/l)	S	-	-	-		-	-	13.4-26.6 (20.0)	-	-	-	-
	B	-	-	-		-	-	13.8-15.9 (14.9)	-	-	-	-
PHc (µmol/l)	1m	-	13.3*	1.0-5.7 (3.3)	54.2*	-	0.8-2.3 (1.5)	3.9-5.7 (4.8)	3-12 (7)	8-18 (10)	2.0-2.0 (2.0)	0.4-0.7 (0.6)
Phenols (µmol/l)	S	-	-	134-190 (163)	89*	-	68-132 (100)	9-20 (15)	31-48 (39)	5-13 (9)	61-168 (114)	24.5-32.6 (28.6)

Table 3.3.1: Water quality of the Gulf during premonsoon (1993-2004).

Parameter	Level	Okha				Salaya		Vadinar		Sikka		
		Feb 1993	Mar 1995	Apr 2002	July 2004	Feb 1995	April 2002	Mar 1994	Mar 1996	Apr 1994	Apr 2002	Apr 2003
Temp (°C)	S	25.5-26.5 (26.0)	25.3-25.5 (25.4)	24.9-27.5 (26.2)	31.0*	24.0-26.0 (25.0)	25.0-27.5 (26.2)	26.0-28.5 (27.0)	25.0-29.2 (27.1)	25.4-27.8 (26.8)	24.4-27.6 (26.0)	28.0-28.7 (28.4)
	B	25.8-26.5 (26.1)	24.9-25.0 (25.0)	24.9-27.5 (26.2)	30.4*	23.0-25.0 (24.0)	25.9-26.34 (26.3)	26.0-27.5 (27.0)	24.6-29.3 (26.8)	25.3-27.8 (26.6)	24.0-27.5 (25.8)	26.9-27.0 (27.0)
pH	S	8.0-8.3 (8.2)	8.0*	8.0-8.2 (8.1)	8.1*	7.9-8.2 (8.1)	8.2-8.4 (8.3)	7.8-8.0 (7.9)	8.0-8.3 (8.0)	8.0-8.1 (8.0)	8.0-8.4 (8.2)	8.1-8.1 (8.1)
	B	8.2-8.3 (8.3)	8.0*	8.2-8.2 (8.2)	8.1*	8.0-8.3 (8.2)	8.3-8.4 (8.3)	7.8-8.0 (8.0)	8.0-8.3 (8.2)	8.0-8.1 (8.1)	8.2-8.4 (8.3)	8.2-8.2 (8.2)
SS (mg/l)	S	27-31 (29)	17*	16-29 (23)	78	19-38 (28)	15-33 (24)	18-35 (22)	9-17 (13)	18-29 (23)	14-17 (16)	18-22 (20)
	B	31*	16*	16-35 (26)	84	21-46 (33)	16-56 (36)	22-26 (24)	8-20 (13)	19-32 (21)	16-50 (33)	6-18 (12)
Salinity (ppt)	S	37.2-38.5 (37.9)	36.2*	37.5-38 (37.7)	35.7*	36.1-37.5 (36.8)	37.6-38.4 (38.0)	37.4-38.6 (37.9)	36.6-37.4 (37.0)	37.1-37.7 (37.3)	36.9-38.5 (37.7)	39.2-39.4 (39.3)
	B	36.8-38.5 (37.7)	36.8*	37.5-38.0 (37.7)	35.6*	36.2-37.5 (36.8)	37.9-38.4 (38.1)	37.3-38.3 (37.9)	36.4-37.8 (37.2)	36.9-37.5 (37.2)	37.4-38.5 (37.9)	39.4-39.4 (39.4)
DO (ml/l)	S	2.9-3.6 (3.3)	4.0-4.3 (4.1)	2.2-5.2 (2.3)	4.1*	4.3-5.4 (4.8)	1.8-5.6 (3.7)	3.4-5.3 (4.6)	3.8-5.3 (4.6)	3.2-4.8 (4.4)	1.8-5.6 (3.7)	4.6-4.8 (4.7)
	B	2.9-3.3 (3.1)	4.6 (4.6)	2.5-5.8 (4.1)	4.4*	2.9-5.0 (3.9)	1.8-5.6 (3.7)	3.8-4.9 (4.4)	4.0-5.5 (4.7)	3.4-4.8 (4.3)	1.6-5.4 (3.5)	4.6-4.8 (4.7)
BOD (mg/l)	S	1.4-3.7 (2.5)	1.5*	0.2-3.5 (1.8)	3.8*	1.1-4.3 (2.7)	1.0-4.3 (2.6)	1.7-3.3 (2.5)	1.0-1.7 (1.4)	2.7-3.8 (3.2)	1.0-4.1 (2.5)	-
	B	0.2*	-	0.3-4.2 (2.2)	3.0*	0.3-0.6 (0.5)	<0.2-1.9 (1.0)	0.2-0.7 (0.5)	0.3-1.3 (0.8)	2.0-2.1 (2.1)	<0.2-3.4 (1.8)	0.6-0.9 (0.8)
PO_4^{3-}-P (µmol/l)	S	0.3-1.7 (1.0)	0.6-0.9 (0.7)	0.3-1.6 (0.9)	0.4*	0.7-1.4 (1.1)	0.4-1.1 (0.7)	ND-2.9 (0.5)	1.0-2.8 (1.7)	0.2-4.1 (0.8)	0.6-0.8 (0.7)	0.2-0.4 (0.3)
	B		0.5-2.2 (1.3)	0.6-1.4 (1.0)	0.6*	0.7-1.4 (1.1)	0.9-1.3 (1.1)	0.3-3.1 (0.8)	1.4-2.8 (2.1)	0.6-1.1 (0.7)	0.3-1.2 (0.7)	1.0-1.0 (1.0)

Table 3.3.1 (Contd 3)

Parameter	Level	Bedi	Navlakhi		Kandla		Mundra				
		Mar 1997	Mar 1996	Apr 2002	Feb 1998	Apr 2002	Mar 1997	Feb 1999	Mar 2000	Apr 2002	June 2003
Temp (°C)	S	21.5-24.5 (23.0)	25.9-26.5 (26.0)	27.8-30.5 (28.7)	22.5-24.0 (23.1)	27.0-29.0 (27.9)	22.9-24.0 (23.6)	23.3-28.5 (24.7)	22.0-25.5 (24.1)	25.3-27.5 (26.9)	28.4-29.8 (29.3)
	B	22.0-23.9 (23.0)	25.0-25.9 (25.5)	26.0-29.5 (28.5)	22.5-25.5 (23.4)	26.5-29.0 (27.7)	22.8-23.5 (23.1)	23.2-25.8 (24.2)	22.0-25.5 (23.6)	24.0-29.8 (27.0)	28.7-29.7 (29.2)
pH	S	8.1-8.3 (8.2)	8.1-8.2 (8.2)	8.0-8.3 (8.2)	7.8-8.0 (8.0)	8.0-8.2 (8.1)	8.1-8.2 (8.2)	7.7-8.2 (8.2)	8.1-8.3 (8.3)	8.2-8.2 (8.2)	7.9-8.0 (8.0)
	B	8.0-8.3 (8.2)	8.1-8.2 (8.2)	8.1-8.3 (8.2)	7.9-8.0 (8.0)	8.0-8.2 (8.1)	8.1-8.2 (8.2)	8.1-8.2 (8.2)	8.2-8.3 (8.3)	8.1-8.2 (8.2)	8.0-8.0 (8.0)
SS (mg/l)	S	21-45 (27)	30-41 (36)	75-275 (149)	105-214 (149)	80-366 (162)	25-33 (30)	22-32 (25)	20-72 (32)	16-25 (24)	178 190 (184)
	B	18-45 (28)	47-204 (126)	80-385 (214)	101-272 (184)	115-410 (217)	19-98 (53)	30-54 (40)	24-118 (61)	17-35 (27)	260-440 (350)
Salinity (ppt)	S	37.5-38.6 (38.1)	39.3-40.1 (39.7)	41.0-44.4 (42.7)	37.5-38.0 (37.8)	38.4-39.9 (39.4)	35.8-38.6 (37.6)	35.9-38.1 (37.3)	37.4-38.3 (37.9)	37.6-38.2 (38.0)	37.7-38.6 (38.4)
	B	37.3-38.6 (38.7)	38.5-40.1 (39.3)	41.5-45.0 (43.3)	37.4-37.9 (37.6)	38.4-40.2 (39.4)	36.1-38.5 (37.9)	36.0-38.2 (37.5)	37.6-39.0 (38.0)	37.5-38.3 (38.0)	37.7-38.6 (38.3)
DO (ml/l)	S	4.2-5.3 (4.6)	2.9-5.0 (3.9)	1.8-4.5 (3.1)	2.5-5.0 (4.0)	1.6-5.2 (3.6)	4.1-5.3 (4.9)	1.8-5.7 (3.9)	1.7-5.1 (3.6)	2.5-6.0 (3.9)	1.5 4.6 (3.8)
	B	4.3-5.0 (4.5)	4.3-5.0 (4.6)	2.0-4.7 (3.5)	2.5-4.8 (3.9)	1.8-4.9 (3.7)	3.7-5.1 (4.9)	1.8-5.7 (4.3)	1.7-5.3 (4.0)	4.0-5.9 (4.2)	1.9-4.4 (3.8)
BOD (mg/l)	S	1.0-3.1 (1.9)	<0.1-1.8 (0.9)	0.3-1.2 (0.7)	-	0.2-4.4 (2.7)	0.9-1.9 (1.3)	<0.1-4.4 (2.3)	0.8-3.4 (1.8)	0.6-3.4 (2.9)	2.1-2.7 (2.4)
	B	0.3-2.3 (1.6)	0.2-1.2 (0.7)	0.3-3.5 (2.0)	-	0.4-3.5 (2.2)	<0.1-1.8 (0.8)	<0.1-3.8 (1.8)	0.9-3.1 (1.2)	0.1-5.1 (4.9)	1.5-1.8 (1.7)
PO_4^{3-}-P µmol/l)	S	1.0-2.7 (1.8)	0.3-1.8 (1.2)	0.6-4.1 (2.0)	3.8-8.5 (6.7)	0.4-1.9 (1.2)	0.7-2.7 (1.3)	0.4-4.4 (1.8)	0.8-11.7 (1.9)	0.2-0.5 (0.3)	1.1-3.0 (1.8)
	B	0.9-3.2 (1.8)	1.6-2.7 (2.1)	1.0-3.5 (2.4)	2.8-8.5 (6.1)	1.5-2.2 (1.8)	1.2-1.9 (1.5)	0.6-3.2 (1.6)	0.9-3.1 (2.0)	0.2-0.7 (0.4)	1.6-2.8 (2.0)

Table 3.3.1 (Contd 4)

Parameter	Level	Bedi	Navlakhi		Kandla		Mundra				
		Mar 1997	Mar 1996	Nov 2002	Feb 1998	Apr 2002	Mar 1997	Feb 1999	Mar 2000	Apr 2002	June 2003
P_{Total} (µmol/l)	S	1.7-4.0 (2.6)	-	-	-	-	1.6-2.0 (1.8)	0.7-1.5 (1.2)	-	-	2.0-2.9 (2.5)
	B	1.8-5.4 (3.0)	-	-	-	-	1.7-1.8 (1.7)	1.1-1.7 (1.5)		-	2.4-2.5 (2.5)
NO_3^--N (µmol/l)	S	3.2-15.1 (6.7)	0.6-4.3 (2.4)	3.3-7.3 (5.3)	8.0-10.7 (9.4)	5.5-12.1 (7.7)	1.4-6.9 (4.0)	ND-3.4 (2.1)	1.1-4.9 (2.8)	18.0-18.5 (18.3)	1.0-5.1 (3.1)
	B	3.6-12.9 (6.1)	ND-1.0 (0.5)	3.4-8.7 (5.9)	7.4-9.9 (8.6)	5.0-8.3 (7.1)	2.7-5.4 (3.7)	0.3-6.6 (2.0)	1.3-5.4 (3.0)	5.0-20.2 (19.0)	1.2-4.6 (3.0)
NO_2^--N (µmol/l)	S	0.2-0.6 (0.4)	0.1-0.4 (0.3)	0.3-0.7 (0.5)	0.4-0.6 (0.5)	0.5-0.9 (0.7)	0.2-0.9 (0.4)	0.1-0.9 (0.4)	0.2-0.9 (0.5)	ND-0.2 (0.1)	0.2-0.5 (0.4)
	B	0.2-0.5 (0.4)	0.4-1.1 (0.7)	0.2-0.6 (0.4)	0.4-0.9 (0.6)	0.2-0.4 (0.3)	0.3-0.8 (0.5)	0.1-0.6 (0.5)	0.3-1.3 (0.5)	ND-0.3 (0.2)	0.2-0.4 (0.4)
NH_4^+-N (µmol/l)	S	0.1-1.2 (0.6)	0.9-1.2 (1.1)	0.2-0.5 (0.3)	0.2-0.9 (0.6)	0.2-1.9 (0.5)	0.5-1.7 (1.0)	0.4-6.4 (1.9)	ND-0.6 (0.4)	0.1-0.2 (0.2)	ND-1.9 (0.8)
	B	0.1-1.2 (0.4)	0.6-1.9 (1.2)	0.1-0.8 (0.4)	0.5-0.9 (0.7)	0.2-2.1 (0.5)	0.3-2.8 (1.4)	0.4-1.5 (1.0)	0.1-0.7 (0.5)	0.1-0.5 (0.3)	0.2-2.8 (1.4)
N_{Total} (µmol/l)	S	3.2-16.7 (6.9)	-	-	16.4-59.3 (29.6)	-	7.1-8.0 (7.8)	52.4-60.4 (55.9)	-	-	7.8-11.1 (9.5)
	B	3.3-16.4 (7.1)	-	-	17.1-82.9 (35.7)	-	5.6-8.6 (7.0)	37.6-57.1 (51.1)	-	-	7.3-8.5 (7.9)
PHc (µmol/l)	1m	1.5-4.8 (2.7)	1.0-2.1 (1.6)	1.9-5.9 (3.9)	2.6-3.5 (2.9)	1.4* (1.4)	2-3 (2)	0.7-4.4 (1.8)	1.3-9.9 (3.3)	3.3-4.1 (3.7)	4.5-4.7 (4.6)
Phenols (µmol/l)	S	7-29 (17)	1-25 (13)	16-114 (37)	39-60 (49)	73* (73)	ND-23 (15)	ND-176 (83)	ND-92 (35)	1.9-3.5 (2.7)	20-23 (22)

Average given in parenthesis
ND: Not Detected
* Single value

Table 3.3.2 : Water quality of the Gulf during postmonsoon (1993-2004)

Parameter	Level	Okha				Vadinar				Sikka		
		Nov 1995	Nov 1999	Nov 2002	Jan 2004	Nov 1994	Nov 1995	Jan 2000	Jan 2004	Dec 1993	Oct 1996	Nov 2002
Temp (°C)	S	25.0-25.1 (25.1)	26.0-26.0 (26.0)	25.5-28.8 (26.7)	23.6-23.6 (23.6)	28.8-29.0 (29.0)	24.0-30.0 (26.8)	22.5-22.5 (22.5)	22.0-22.0 (22.0)	25.1-25.9 (25.3)	29.0-29.8 (29.4)	25.0-27.4 (26.2)
	B	25.0-25.2 (25.1)	26.0-26.0 (26.0)	25.2-27.5 (26.5)	23.7-23.7 (23.7)	29.0-29.2 (29.1)	24.0-29.9 (26.7)	22.5-22.5 (22.5)	21.7-21.7 (21.7)	24.6-25.7 (25.1)	29.0-29.2 (29.1)	26.0-26.8 (26.4)
pH	S	8.1-8.1 (8.1)	8.0-8.0 (8.0)	8.1-8.3 (8.3)	8.2-8.2 (8.2)	8.1-8.2 (8.1)	8.0-8.3 (8.2)	8.2-8.3 (8.3)	8.2-8.2 (8.2)	8.1-8.3 (8.2)	8.1*-	8.2-8.3 (8.2)
	B	8.0-8.1 (8.1)	8.0-8.1 (8.0)	8.2-8.3 (8.3)	8.2-8.2 (8.2)	8.0-8.2 (8.1)	8.0-8.3 (8.1)	8.2-8.3 (8.3)	8.2-8.2 (8.2)	8.2-8.3 (8.3)	8.1*	8.3-8.3 (8.3)
SS (mg/l)	S	7-25 (16)	59*	4-10 (7)	22*	16-29 (22)	13-21 (16)	25-25 (25)	22*	15-23 (19)	40*	10-34 (22)
	B	14-24 (19)	68*	6-308 (69)	90*	18-29 (24)	8-16 (12)	23-24 (24)	58*	17-24 (21)	36*	20-36 (22)
Salinity (ppt)	S	35.4-35.7 (37.6)	36.8-36.9 (36.8)	37.1-38.4 (37.6)	36.0-36.2 (36.1)	34.3-34.6 (34.6)	36.2-37.8 (36.9)	37.4-38.0 (37.7)	37.0-37.0 (37.0)	37.1-38.5 (38.0)	36.3*	37.1-38.6 (37.8)
	B	37.4-37.7 (36.8)	36.7-36.8 (34.6)	37.1-38.2 (37.6)	35.7-35.9 (35.8)	34.3-34.6 (34.6)	36.6-37.4 (37.0)	37.4-39.6 (38.0)	37.0-37.0 (37.0)	35.5-37.8 (36.9)	36.5*	37.0-38.7 (37.8)
DO (ml/l)	S	4.3-4.7 (4.5)	3.6-3.8 (3.7)	2.5-4.9 (4.2)	4.5-4.5 (4.5)	4.1-4.8 (4.3)	4.0-5.5 (4.8)	5.3-5.7 (5.4)	4.5-4.8 (4.7)	3.6-5.4 (4.2)	4.3-4.5 (4.4)	2.6-4.7 (3.6)
	B	4.3-4.5 (4.4)	3.2-3.8 (3.5)	2.7-4.8 (4.2)	4.5-4.8 (4.7)	4.3-5.0 (4.4)	4.0-5.3 (4.6)	5.0-5.3 (5.3)	4.8-5.0 (4.9)	3.5-5.5 (4.1)	4.3-4.5 (4.4)	2.1-4.4 (3.2)
BOD (mg/l)	S	1.0-4.0 (3.0)	-	0.1-2.5 (0.8)	2.9*	1.5-2.5 (2.0)	0.8-1.8 (1.2)	2.9-3.6 (3.0)	1.0*	2.0-2.4 (2.2)	4.8*	<0.2-1.5 (0.8)
	B	0.3-1.5 (0.9)	-	0.1-1.5 (0.9)	2.9*	0.3-1.0 (0.7)	0.5-2.2 (1.0)	2.3-2.6 (2.5)	1.6*	0.7-1.6 (1.1)	2.6*	<0.2-1.1 (0.5)
PO_4^{3-}-P (µmol/l)	S	1.2-1.3 (1.3)	1.8-1.8 (1.8)	0.9-2.2 (1.9)	1.1-1.1 (1.1)	1.0-2.4 (1.4)	0.6-1.7 (1.1)	1.4-1.7 (1.6)	1.2-1.2 1.2	0.7-4.0 (1.6)	0.9-1.2 (1.1)	0.8-2.8 (1.8)
	B	1.3-1.3 (1.3)	2.1-2.2 (2.2)	0.8-2.3 (1.9)	1.1-1.1 (1.1)	0.1-2.7 (0.5)	0.7-2.3 (1.5)	1.7-1.8 (1.7)	1.2-1.4 1.3	1.2-1.8 (1.5)	- (1.9)*	1.5-2.3 (1.9)

Table 3.3.2 (Contd 2)

Parameter	Level	Okha				Vadinar				Sikka		
		Nov 1995	Nov 1999	Nov 2002	Jan 2004	Nov 1994	Nov 1995	Jan 2000	Jan 2004	Dec 1993	Oct 1996	Nov 2002
P_{Total} (µmol/l)	S	-	-	-	-	-	-	-	-	-	-	-
	B	-	-	-	-	-	-	-	-	-	-	-
NO_3^--N (µmol/l)	S	3.6-6.6 (5.1)	3.4-9.5 (9.0)	7.9-13.0 (9.5)	4.8-8.7 (6.8)	3.1-7.9 (5.5)	2.1-10.6 (6.7)	7.7-8.7 (8.2)	2.9-3.3 (3.1)	4.4-8.1 (6.5)	17.1-18.1 (17.6)	8.0-12.3 (10.1)
	B	4.6-7.2 (5.9)	9.3-9.7 (9.5)	7.1-12.1 (9.2)	6.5-6.9 (6.7)	3.3-7.3 (4.6)	4.2-11.1 (8.0)	7.2-10.0 (8.9)	2.7-3.6 (3.2)	3.7-8.1 (6.1)	16.5-18.9 (17.7)	7.5-11.5 (9.5)
NO_2^--N (µmol/l)	S	0.6-0.7 (0.7)	0.3-0.4 (0.4)	0.4-0.5 (0.4)	0.3-0.3 (0.3)	0.4-1.1 (0.8)	0.1-0.5 (0.3)	0.3-0.3 (0.3)	0.3-0.3 (0.3)	0.2-1.1 (0.4)	0.2-0.6 (0.4)	0.2-0.4 (0.3)
	B	0.6-0.7 (0.7)	0.2-0.2 (0.2)	0.4-0.6 (0.5)	0.2-0.3 (0.3)	0.6-0.9 (0.8)	0.1-0.4 (0.3)	0.3-0.4 (0.4)	0.2-0.3 (0.3)	0.1-2.8 (0.4)	0.4-0.6 (0.5)	0.1-0.7 (0.4)
NH_4^+-N (µmol/l)	S	ND	0.8-1.7 (1.3)	0.3-1.8 (0.6)	0.8-2.1 (1.5)	0.3-2.8 (1.1)	0.1-1.5 (0.6)	0.2-0.5 (0.3)	1.0-1.3 (1.2)	2.0-7.8 (3.7)	0.3-0.5 (0.4)	0.3-1.0 (0.6)
	B	-	0.6-0.8 (0.7)	0.2-7.8 (1.2)	ND-0.2 (0.2)	0.4-4.9 (1.3)	ND-1.2 (0.6)	0.1-0.2 (0.2)	ND-1.2 (0.6)	1.6-4.8 (3.2)	- (0.5)	0.1-0.8 (0.4)
N_{Total} (µmol/l)	S	-	56*	-	-	38.1-100.5 (69.3)	-	-	-	-	-	-
	B	-	62*	-	-	80.5-124.9 (102.7)	-	-	-	-	-	-
P ic (µg/l)	1m	0.5-0.7 (0.6)	1.8*	0.7-1.5 (1.2)	-	2-5 (4)	4-5 (5.0)	0.1-0.3 (0.2)	-	5-7 (6)	(2.3)*	0.9-1.7 (1.3)
Phenols (µg/l)	S	10-19 (15)	37*	1-15 (8)	-	28-34 (31)	18-42 (31)	11-31 (21)	-	19-22 (21)	(18)*	ND-21 (21)

Table 3.3.2 (Contd 3)

Parameter	Level	Bedi	Salaya	Navlakhi		Kandla			Mundra			
		Oct 1997	Nov 2002	Nov 1994	Nov 2002	Oct 1996	Nov 2002	Jan 2004	Sep 1999	Nov 2002	Oct 2003	Dec 2004
Temp (°C)	S	28.0-30.1 (29.2)	23.0-27.9 (25.4)	25.5-26.1 (25.8)	23.0-27.5 (25.7)	29.5-29.5 (29.5)	24.8-30.0 (27.2)	20.1-20.1 (20.1)	28.5-31.0 (29.9)	24.0-27.0 (25.5)	28.5-30.0 (28.8)	24.0-24.0 (24.0)
	B	28.0-30.9 (29.1)	23.0-26.4 (24.7)	24.7-26.5 (25.2)	24.0-27.0 (25.6)	29.5-30.5 (30.0)	24.9-29.0 (26.9)	19.9-19.9 (19.9)	28.5-31.6 (30.1)	23.2-26.9 (25.5)	28.0-29.9 (28.7)	23.5-23.5 (23.5)
pH	S	8.2-8.4 (8.3)	8.1-8.3 (8.2)	7.8-7.9 (7.9)	8.3-8.6 (8.5)	8.0-8.2 (8.1)	7.9-8.3 (8.2)	8.2-8.2 8.2	7.9-8.3 (8.2)	8.0-8.3 (8.1)	8.1-8.2 (8.1)	8.4-8.4 8.4
	B	8.2-8.4 (8.3)	8.2-8.3 (8.2)	(7.9)*	8.3-8.6 (8.5)	8.0-8.1 (8.0)	8.1-8.3 (8.2)	8.2-8.2 (8.2)	7.9-8.3 (8.2)	8.1-8.3 (8.2)	8.1-8.2 (8.2)	8.4-8.4 8.4
SS (mg/l)	S	32-63 (44)	28-304 (166)	(698)*	16-110 (742)	156-336 (244)	28-104 (60)	164*	49-170 (108)	30-162 (96)	38-86 (62)	44*
	B	26-136 (78)	208-490 (349)	(689)*	80-190 (126)	252-373 (312)	42-94 (72)	178*	70-207 (128)	108-214 (161)	72-166 (95)	60*
Salinity (ppt)	S	36.3-37.8 (37.1)	41.2-46.3 (43.7)	32.1-32.8 (32.4)	37.3-39.0 (38.1)	40.0-40.4 (40.2)	36.5-40.1 (38.3)	38.2-38.2 (38.2)	36.9-39.2 (38.2)	40.7-42.4 (41.5)	36.5-37.0 (36.7)	37.2-37.8 (37.5)
	B	36.3-37.8 (37.3)	41.6-45.8 (43.7)	32.1-32.1 (32.1)	37.5-39.0 (38.0)	40.2-40.2 (40.2)	37.4-40.1 (38.4)	38.0-38.0 (38.0)	37.1-39.0 (38.2)	41.0-42.3 (41.6)	36.2-37.0 (36.7)	37.4-37.6 (37.5)
DO (ml/l)	S	3.7-4.9 (4.3)	3.0-5.1 (4.0)	4.8-4.8 (4.8)	4.8-7.6 (6.2)	4.3-4.7 (4.5)	6.1-7.8 (6.9)	4.5-4.5 (4.5)	1.5-5.7 (3.6)	2.2-5.0 (3.6)	3.8-5.4 (4.5)	4.9-4.9 (4.9)
	B	3.5-4.7 (4.1)	2.6-5.0 (3.8)	4.8-5.0 (4.8)	3.6-7.6 (5.7)	4.7-4.7 (4.7)	5.8-8.0 (7.0)	4.5-4.8 (4.7)	2.0-5.1 (3.5)	2.2-5.3 (3.7)	2.9-5.2 (4.1)	4.7-4.9 (4.8)
BOD (mg/l)	S	2.2-6.3 (4.9)	0.9-1.4 (1.2)	(2.0)*	0.1-2.5 (0.8)	3.9-4.1 (4.0)	0.2-5.9 (2.1)	0.6*	<0.1-4.1 (1.4)	0.8-1.3 (1.0)	2.3-4.8 (3.6)	2.6*
	B	0.7-4.7 (2.5)	0.5-1.5 (1.0)	<0.1*	0.1-1.5 (0.9)	3.2-3.5 (3.4)	0.2-4.5 (1.6)	0.6*	<0.1-4.0 (0.9)	0.9-2.0 (1.4)	0.9-2.3 (1.6)	1.7*

Table 3.3.2 (Contd 4)

Parameter	Level	Bedi	Salaya	Navlakhi		Kandla			Mundra			
		Oct 1997	Nov 2002	Nov 1994	Nov 2002	Oct 1996	Nov 2002	Jan 2004	Sep 1999	Nov 2002	Oct 2003	Dec 2004
PO_4^{3-}-P (µmol/l)	S	1.0-3.0 (2.1)	0.2-2.0 (1.1	1.5-2.0 (1.7)	0.9-2.2 (1.9)	0.8-1.3 (1.1)	0.4-3.1 (1.7)	1.8-1.8 (1.8)	0.5-2.5 (1.4)	1.0-1.6 (1.3)	0.5-1.3 (0.9)	1.3-1.4 (1.4)
	B	1.3-5.2 (2.9)	1.2-4.1 (2.6)	2.0-2.1 (2.0)	0.8-2.3 (1.9)	1.2-1.6 (1.4)	1.9-2.6 (2.2)	2.0-2.1 (2.1)	0.7-3.0 (1.7)	1.6-2.1 (1.8)	0.8-1.3 (1.1)	1.5-1.7 (1.6)
P_{Total} (µmol/l)	S	1.6-3.8 (2.7)	-	-	-	-	-	-	-	-	-	-
	B	1.8-5.7 (4.2)	-	-	-	-	-	-	-	-	-	-
NO_3^--N (µmol/l)	S	2.9-16.7 (7.4)	6.9-15.2 (11.0)	25.4-38.4 (31.9)	8.8-12.3 (10.6)	7.3-9.9 (9.6)	5.4-18.7 (10.4)	10.5-12.1 (11.3)	0.7-10.0 (4.3)	6.9-28.6 (17.7)	1.3-3.7 (2.5)	4.3-5.4 (4.9)
	B	2.4-15.1 (8.9)	8.1-12.2 (10.1)	30.4-30.8 (30.6)	8.0-12.3 (9.8)	10.9-11.5 (11.2)	5.9-18.4 (10.4)	12.6-12.7 (12.7)	0.3-7.1 (4.0)	17.0-25.9 (21.4)	0.2-3.3 (2.0)	3.1-4.2 (3.7)
NO_2^--N (µmol/l)	S	0.1-1.5 (0.9)	0.3-0.7 (0.5)	0.1-0.2 (0.1)	0.1-0.3 (0.2)	0.8-0.9 (0.9)	0.1-0.5 (0.3)	ND-0.1 (0.1)	0.1-0.9 (0.4)	0.3-0.6 (0.4)	0.2-0.6 (0.4)	0.3-0.3 (0.3)
	B	0.3-1.6 (1.1)	0.2-0.9 (0.5)	0.1-0.1 (0.1)	0.1-0.3 (0.2)	0.6-0.9 (0.8)	0.2-0.5 (0.3)	ND-ND (ND)	0.2-1.0 (0.4)	0.2-0.8 (0.5)	0.1-0.3 (0.2)	0.3-0.3 (0.3)
NH_4^+-N (µmol/l)	S	0.4-2.1 (1.2)	0.5-2.4 (1.4)	0.8-3.0 (1.9)	0.3-1.5 (0.6)	0.5-1.1 (0.8)	0.2-1.3 (0.7)	2.1-2.6 (2.4)	ND-3.6 (0.6)	1.1-5.4 (3.2)	0.2-3.9 (1.6)	0.5-1.3 (0.9)
	B	0.4-3.9 (2.1)	ND-3.1 (1.5)	1.1-1.3 (1.2)	0.2-1.0 (0.6)	0.5-0.9 (0.7)	0.2-1.1 (0.5)	2.3-2.7 (2.5)	ND-2.1 (0.5)	0.7-2.1 (1.4)	0.1-1.4 (0.5)	0.1-0.2 0.2
N_{Total} (µmol/l)	S	3.7-17.9 (10.0)	-	-	-	-	-	-	-	-	8.7-12.8 (10.8)	-
	B	7.1-17.1 (13.3)	-	-	-	-	-	-	-	-	6.1-8.0 (7.1)	-
PHc (µmol/l)	1m	1.2-8.0 (5.1)	1.3-3.0 (2.1)	-	0.9-1.4 (1.1)	1.6-2.0 (1.8)	0.7-1.9 (1.1)	-	0.3-2.5 (1.1)	1.3-4.6 (2.9)	8.6-19.4 (14.0)	26.3*
Phenols (µmol/l)	S	6-32 (20)	ND-53 (27)		9-13 (15)	11-16 (14)	ND-44 (31)	-	ND-133 (38)	4-23 (13)	2-10 (6)	57*

Average given in parenthesis, ND: Not Detected, * Single value

Table 3.3.3 : Subtidal sediment quality of the Gulf during premonsoon (1994-2005)

Constituents	Premonsoon								
	Okha		Vadinar		Sikka				Bedi
	Mar 1999	Apr 2002	Apr 1994	Mar 1996	Apr 1994	Mar 1997	Apr 2002	Apr 2003	Mar 1997
Al (%)	0.8-2.0 (1.6)	1.8-8.1 (4.9)	3.7-9.6 (7.0)	5.0-6.2 (5.5)	-	1.5-5.7 (3.4)	4.7	0.4-8.4 (5.2)	2.9-6.6 (4.4)
Cr (µg/l)	12-39 (20)	20-112 (67)	30-87 (63)	41-59 (47)	27-127 (48)	28-112 (75)	68	6-51 (23)	48-189 (133)
Mn (µg/l)	257-1696 (639)	425-726 (580)	517-1229 (802)	287-512 (399)	443-936 (633)	408-987 (692)	590	508-3065 (1450)	493-775 (664)
Fe (%)	0.9-1.1 (1.0)	0.8-4.4 (2.5)	1.4-4.3 (3.2)	3.6-4.9 (4.1)	2.0-6.1 (3.0)	1.0-4.6 (3.2)	2.3	0.1-9.8 (3.3)	2.0-5.2 (3.8)
Co (µg/g)	20-29 (24)	1-29 (10)	24-44 (36)	2-78 (44)	37-65 (38)	11-36 (25)	9	12-47 (26)	28-53 (41)
Ni (µg/g)	11-17 (15)	10-60 (33)	31-61 (47)	59-70 (64)	21-75 (34)	11-67 (51)	29	32-112 (68)	24-67 (51)
Cu (µg/g)	8-16 (12)	5-34 (16)	32-70 (51)	41-51 (44)	24-90 (32)	9-52 (34)	19	11-97 (44)	16-72 (40)
Zn (µg/g)	17-25 (22)	13-92 (43)	44-134 (92)	48-94 (77)	39-101 (59)	15-84 (50)	23	109-401 (227)	39-122 (72)
Hg (µg/g)	0.04-0.12 (0.07)	0.009-0.04 (0.02)	-	-	-	0.09-0.40 (0.17)	0.009	ND-0.26 (0.07)	0.1-0.3 (0.2)
Pb (µg/g)	-	-	1-12 (7)	17-21 (20)	ND-5 (1.2)	-	-	-	-
C (%)	0.1-0.8 (0.3)	0.2-0.7 (0.7)	-	-	-	0.1-0.8 (0.4)	0.4	0.2-1.0 (0.6)	-
P (µg/g)	425-736 (646)	349-545 (455)	-	-	-	580-832 (731)	470	210-953 (525)	-
PHc (µg/g)	ND-3.1 (1.2)	0.7-1.4 (1.0)	0.2-2.3 (0.6)	0.2-0.4 (0.3)	0.3-1.0 (0.5)	0.08-0.33 (0.20)	0.7	0.1 (0.1)	0.3-1.0 (0.4)

Table 3.3.3 (Contd. 2)

Constituents	Premonsoon								
	Kandla			Mundra				Salaya	Navlakhi
	Mar 1996	Feb 1998	Apr 2002	Mar 1999	Mar 2000	Apr 2002	Jun 2003	April 2002	Apr 2002
Al (%)	1.7-6.9 (4.6)	1.7-7.9 (5.4)	7.5	0.5-9.3 (5.7)	2.4-8.5 (4.6)	8.7	1.4-9.6 (4.9)	6.8	7.3
Cr (µg/l)	9-103 (63)	26-76 (45)	98	7-175 (110)	26-139 (86)	140	27-123 (73)	87	113
Mn (µg/l)	594-1321 (985)	428-757 (597)	623	431-900 (700)	316-837 (603)	681	536-1182 (767)	677	808
Fe (%)	0.9-4.7 (2.9)	1.2-6.2 (4.1)	3.6	1.1-5.0 (3.5)	1.5-46 (38)	5.0	1.3-5.1 (3.6)	3.7	5.0
Co (µg/g)	9-31 (23)	16-32 (26)	18	15-70 (35)	15-39 (29)	27	ND-20 (8)	20	24
Ni (µg/g)	15-58 (41)	9-60 (38)	45	ND-68 (39)	15-59 (38)	64	7-59 (35)	48	65
Cu (µg/g)	11-45 (28)	6-51 (32)	31	6-47 (24)	6-44 (26)	54	5-44 (19)	29	50
Zn (µg/g)	18-89 (60)	12-77 (58)	50	14-106 (62)	33-92 (70)	76	31-151 (87)	61	74
Hg (µg/g)	0.13-0.26 (0.18)	0.07-0.13 (0.11)	0.04	0.07-0.66 (0.62)	0.19-0.76 (0.34)	0.02	ND-0.05 (0.03)	0.05	0.05
Pb (µg/g)	6.8-17.2 (12.3)	-	-	-	-	-	-	-	-
C (%)	-	-	0.7	0.1-0.9 (0.5)	0.1-0.7 (0.4)	0.9	ND-0.8 (0.4)	0.5	0.8
P (µg/g)	-	-	417	341-882 (607)	493-755 (633)	589	465-1822 (751)	581	629
PHc (µg/g)	0.2-21.6 (3.0)	0.1-0.4 (0.2	<0.1	0.1-2.8 (1.8)	0.7-1.7 (1.3)	0.2	ND-0.4 (0.2)	0.6	1.0

Dry wt basis except PHc which is wet wt basis, ND : Not Detected, Average in parenthesis

Table 3.3.4 : Subtidal sediment quality of the Gulf during postmonsoon (1993-2004)

Constituents	Postmonsoon									
	Okha				Vadinar			Sikka		
	Nov 95	Nov 99	Nov 2002	Nov 2004	Nov 94	Nov 95	Nov 2004	Dec 93	Oct 96	Nov 2002
Al (%)	0.8-3.4 (2.2)	1.6-4.3 (2.5)	0.4-5.1 (2.8)	3.7-6.1 (4.5)	4.1-9.6 (6.9)	4.7-5.8 (5.2)	2.1-11.0 (6.9)	-	4.8-5.2 (5.0)	5.0-7.8 (6.4)
Cr (µg/g)	18-49 (31)	ND-55 (19)	9-92 (51)	36-68 (48)	30-69 (52)	38-65 (49)	40-118 (94)	29-104 (68)	80-137 (102)	154-197 (176)
Mn (µg/g)	340-700 (592)	290-470 (389)	607-610 (609)	365-497 (415)	743-1222 (924)	720-1010 (815)	210-1103 (596)	497-900 (775)	1117-1539 (1258)	817-1054 (936)
Fe (%)	1.5-3.0 (2.4)	0.9-2.6 (1.5)	0.3-3.3 (1.8)	1.4-2.1 (1.7)	1.4-3.5 (2.7)	1.9-3.6 (2.7)	0.8-5.6 (3.8)	2.0-6.5 (4.8)	4.1-4.7 (4.7)	4.7-5.8 (5.3)
Co (µg/g)	7-27 (19)	21-38 (30)	ND-8 (4)	4-96 (35)	24-44 (34)	20-70 (45)	6-23 (17)	37-65 (54)	31-48 (37)	ND-18 (9)
Ni (µg/g)	13-29 (20)	10-28 (17)	ND-34 (17)	14-28 (19)	38-61 (49)	33-50 (38)	35-73 (55)	21-75 (58)	65-86 (70)	58-67 (63)
Cu (µg/g)	8-26 (16)	5-24 (12)	5-43 (24)	20-21 (21)	33-70 (52)	36-65 (48)	7-59 (41)	27-90 (73)	50-85 (62)	64-92 (78)
Zn (µg/g)	21-32 (28)	15-44 (25)	62-69 (66)	27-63 (41)	79-134 (110)	69-131 (101)	63-154 (126)	39-101 (75)	88-93 (91)	83-85 (84)
Hg (µg/g)	0.01-0.10 (0.04)	-	0.06-0.09 (0.07)	0.05-0.17 (0.09)	-	-	ND-0.02 (0.01)	-	-	0.09-0.11 (0.10)
Pb (µg/g)	2-15 (10)	-	-	-	6-12 (9)	6-10 (8)	-	ND	3.5-11.8 (8.5)	-
C (%)	-	0.1-1.6 (0.5)	0.2-0.6 (0.4)	0.4-0.7 (0.6)	-	-	-	-	-	0.5-0.8 (0.7)
P (µg/g)	-	410-709 (555)	626-688 (657)	594-738 (657)	694-815 (771)	-	76-985 (701)	-	-	650-704 (677)
PHc (µg/g)	ND-0.3 (0.1)	0.3-0.8 (0.4)	-	0.4-1.0 (0.7)	ND-0.9 (0.4)	0.2-1.0 (0.3)	0.2-1.0 (0.4)	0.3-1.0 (0.6)	0.3-0.5 (0.4)	-

Table 3.3.4 (Contd 2)

Constituents	Postmonsoon									
	Bedi	Navlakhi		Kandla		Mundra				Salaya
	Oct 97	Nov 94	Nov 2002	Oct 96	Nov 2002	Sep 99	Nov 2002	Oct 2003	Dec 2004	Nov 2002
Al (%)	2.9-6.6 (4.4)	-	6.6	2.9-6.3 (4.4)	7.0	2.5-6.7 (5.6)	0.4	1.3-4.8 (3.1)	1.4-9.6 (4.3)	5.9
Cr (µg/g)	48-189 (133)	75-194 (100)	94	50-103 (69)	83	18-80 (53)	12	18-41 (30)	27-123 (73)	86
Mn (µg/g)	493-775 (664)	549-1188 (944)	834	797-1321 (1033)	838	361-832 (684)	353	312-490 (401)	536-1182 (766)	611
Fe (%)	2.0-5.2 (3.8)	1.4-3.6 (2.4)	3.8	1.6-3.4 (2.6)	3.5	1.5-4.7 (3.8)	0.5	0.8-2.4 (1.6)	1.3-5.1 (3.6)	3.3
Co (µg/g)	28-53 (41)	34-39 (36)	7	14-29 (23)	10	11-34 (28)	ND	2-8 (5)	ND-20 (8)	8
Ni (µg/g)	24-67 (51)	37-63 (51)	47	20-58 (40)	41	15-59 (46)	ND	6-21 (14)	7-59 (35)	39
Cu (µg/g)	16-72 (46)	24-46 (34)	36	11-36 (25)	34	3-39 (27)	7	10-16 (13)	5-44 (20)	41
Zn (µg/g)	39-122 (72)	33-157 (78)	96	34-88 (61)	93	13-79 (61)	15	20-48 (34)	31-151 (87)	68
Hg (µg/g)	0.1-0.3 (0.2)	Nd-0.40 (0.20)	0.11	0.13-0.26 (0.18)	0.08	0.3-0.69 (0.44)	0.08	-	ND-0.01 (0.01)	0.12
Pb (µg/g)	-	7.0-11.0 (10.0)	-	8.6-17.2 (12.9)		-	-	-	-	-
C (%)	-	-	0.7	-	0.6	0.1-0.8 (0.6)	0.1	0.1-0.2 (0.2)	ND-0.2 (0.1)	1.0
P (µg/g)	-	-	786	-	703	337-1402 (1027)	327	102-275 (189)	469-1822 (812)	1049
PHc (µg/g)	0.3-1.0 (0.4)	0.2-1.2 (0.5)	-	0.7-1.4 (1.0)	-	0.1-0.4 (0.3)	-	-	ND-0.2 (0.1)	-

Dry wt basis except PHc which is wet wt basis, ND : Not Detected, Average in parenthesis

Table 3.3.5 : List of algae recorded along the intertidal zone of the Gulf.

Name	Status*
Chlorophyceae	
Boodlea composita	C
Bryopsis indica	C
B. plumose	C
B. ramulosa	C
Caulerpa crassifolia	C
C. cupressoides	C
C. racemosa	C
C. scalpelliformis	C
C. sertularioides	C
C. taxiformes	C
C. verticillata	C
Chaetomorpha indica	C
Chamaedoris auirculata	C
Cladophora glomerata	C
C. prolifera	C
Codium decorticatum	R
C. dwarkensis	C
C. elongatum	C
Dictyosphaeria cavernosa	C
Enteromorpha intenstinalis	C
Halideda tuna	C
Pseudobryopsis mucronata	R
Spongomorpha sp.	C
Udoea indica	C
Ulva fasciata	C
U. lactuca	C
U. reticulata	R
Valonia utricularis	R
Valloniopsis spachynema	R

Table 3.3.5 (Contd 2)

Name	Status*
Valonia utricularis	R
Valloniopsis spachynema	R
Phaeophyceae	
Colpomenia sinuosa	C
Cystoceira indica	C
Dictyota atomaria	C
D. bartayrisiana	R
D. cervicornis	R
D. ciliolate	C
D. dichotoma	C
D. divaricata	R
Dictyopteris australis	C
D. woodwardii	C
Ectocarpus sp.	C
Hinskia mitchelle	C
Hormophysa triquetra	R
Hydroclathrus clathratus	R
Iyengaria stellata	C
Myriogloea sciurus	R
Nemacystus decipiens	R
Padina gymnospora	R
P. tetrastromatica	C
Pocockiella sp.	C
Rosenvingia intricata	R
Sargassum johnstonii	C
S. tenerrimum	C
S. plagiophyllum	R
S. swartzii	C
S. wisghtii	R
Spathoglossum asperum	R
S. variabile	C

Table 3.3.5 (Contd 3)

Name	Status
Stoechospermum marginatum	C
Spathoglossum asperum	R
S. variabile	C
Stoechospermum marginatum	C
Turbinaria ornata	R
Rhodophyceae	
Acanthophora delilei	C
A. specifera	R
Amphiroa fragilissima	R
Asparogopsis taxiformis	C
Botroycladia leptapoda	C
Calaglossa bombayance	R
Ceramium sp.	C
Champia indica	C
Chondria ornata	R
C.dasyphylla	R
Coelarthrum opuntia	C
Corallina officinalis	C
Corynomorpha prismatica	R
Cryptopleur sp.	R
Dasya sp.	R
Desmia hornmanni	R
Gastroclonium iyengarii	R
Galaxaura oblongata	C
Gelidiella acerosa	C
Gelidiospsis gracilis	C
Gigartina sp	R
Gracilaria corticata	R
G. pygmaea	C
Gastroclonium iyengarii	R
Galaxaura oblongata	C
Gelidiella acerosa	C

Table 3.3.5 (Contd 4)

Name	Status
Gelidiospsis gracilis	C
Gigartina sp	R
Gracilaria corticata	R
G. pygmaea	C
G. verrucossa	R
Grateloupia inica	C
G. felicina	R
Haloplegma sp.	R
Halymenia floresia	R
H. porphyroides	C
H. venusta	C
Helminthocladia clayadosii	C
Heterosiphonia muelleri	C
Hypnea cervicornis	C
H. musciformis	C
Hypoglossum spathulatum	R
Laurencia papillosa	C
L. pedicularioides	C
Liagora cerenoides	R
Lophocladia lallemandi	R
Neurymenia fraxinifolia	R
Polysiphonia sp.	C
Rhodymenia australis	C
R. palmate	C
Scinaia indica	C
S. furcellata	R
Sebdenia polydactyla	C
Spyridia alternans	C
Soleria robusta	C

*C: common; R : rare
Source: Saurashtra University (1991)

Table 3.3.6 : Biological characteristics of the Gulf during premonsoon (1981-2005).

Parameter	Okha				
	April 1981	March 1995	March 1999	April 2002	April 2003
Phytoplankton					
Chlorophyll a (mg/m^3)	1.1-6.9 (4.3)	0.5-1.1 (0.7)	0.5-1.1 (0.6)	0.5-2.7 (1.1)	0.1-0.2 (0.2)
Phaeophytin (mg/m^3)	-	0.4-1.3 (0.7)	0.4-1.3 (0.7)	0.1-0.6 (0.2)	0.5-0.8 (0.6)
Cell counts ($nox10^3/l$)	-	36.6-45.6 (41.1)	49.2-775.2 (412.2)	16.5-116.5 (48.5)	15.3-24.0 (20.5)
Total genera (no)	-	8-8 (8)	7-8 (8)	14-21 (17)	15-19 (18)
Zooplankton					
Biomass ($ml/100m^3$)	0.3-0.6 (0.5)	0.4-0.7 (0.5)	6.9-7.2 (7.0)	0.3-7.5 (2.7)	1.5-4.5 (3.2)
Population ($nox10^3/100m^3$)	-	0.2-0.4 (0.3)	0.4-1.0 (0.7)	2.0-29.3 (14.1)	6.5-13.0 (8.5)
Total groups (no)	-	6-8 (7)	10-11 (11)	9-20 (15)	12-13 (13)
Macrobenthos					
Biomass (g/m^2, wet wt)	-	0.1	<0.1	0.1	2.2-3.7 (3.2)
Population (no/m^2)	2700	200	13	341	375-1250 (828)
Total groups (no)	9	4	1	9	3-8 (7)

Table 3.3.6(Contd 2)

Parameter	Vadinar			
	April 1994	March 1996	April 2002	May 2005
Phytoplankton				
Chlorophyll a (mg/m^3)	1.1-1.1 (1.1)	1.1-2.7 (1.3)	0.5-1.6 (0.8)	0.2-0.6 (0.3)
Phaeophytin (mg/m^3)	0.8-1.6 (1.0)	0.1-3.8 (1.5)	0.2-1.3 (0.8)	0.1-1.7 (0.5)
Cell counts ($nox10^3/l$)	47.2 (47.2)	15.8-42.8 (29.4)	2.5-29.6 (11.9)	6.1-71.2 (21.8)
Total genera (no)	25 (25)	9-11 (10)	8-21 (13)	10-22 (17)
Zooplankton				
Biomass ($ml/100m^3$)	12.1-18.9 (15.5)	3.0 (3.0)	<0.1-3.7 (1.2)	0.9-12.5 (4.6)
Population ($nox10^3/100m^3$)	12.8-16.8 (14.8)	1.6 (1.6)	0.2-23.9 (6.2)	1.6-36.3 (12.3)
Total groups (no)	13-15 (14)	11 (11)	12-20 (16)	6-19 (16)
Macrobenthos				
Biomass (g/m^2, wet wt)	6.1	3.0	10.3	3.1
Population (no/m^2)	2725	1392	3693	739
Total groups (no)	9	8	17	6

Table 3.3.6(Contd 3)

Parameter	Sikka						
	April 1994	March 1997	May 2001	April 2002	April 2003	February 2005	April 2005
Phytoplankton							
Chlorophyll a (mg/m^3)	1.1-2.7 (1.6)	0.5-1.1 (0.8)	0.5-4.8 (1.6)	0.5-1.1 (0.6)	1.1-0.2 (0.2)	0.2-0.4 (0.3)	0.2-0.4 (0.2)
Phaeophytin (mg/m^3)	0.3-3.1 (1.2)	0.1-0.6 (0.3)	0.1-6.2 (1.0)	0.2-1.3 (0.8)	0.5-0.8 (0.6)	0.5-1.2 (0.7)	0.1-0.7 (0.3)
Cell counts ($nox10^3/l$)	35.0-61.0 (58.0)	25.2-41.2 (33.2)	0.5-719 (122)	6.2-28.0 (14.6)	15.3-24.0 (20.5)	10.8-51.6 (28.4)	4.0-54.4 (10.1)
Total genera (nc)	4-18 (9)	6-7 (7)	5-21 (18)	12-23 (18)	15-19 (18)	11-16 (14)	8-20 (12)
Zooplankton							
Biomass ($ml/100m^3$)	0.8-13.3 (3.3)	1.5-1.5 (1.5)	1.8-28.2 (8.4)	0.3-8.5 (4.1)	1.5-4.5 (3.2)	0.1-10.0 (2.0)	0.3-22.8 (6.8)
Population ($nox10^3/100m^3$)	1.9-44.8 (9.9)	3.4-4.7 (4.1)	6.9-118 (31.9)	1.9-49.3 (22.8)	6.5-13.0 (8.5)	0.2-28.8 (5.6)	2.4-13.2 (19.1)
Total groups (no)	7-14 (12)	10-14 (12)	11-15 (14)	11-20 (16)	12-13 (13)	4-15 (12)	6-16 (10)
Macrobenthos							
Biomass (g/m^2, wet wt)	25.5	116.0	<0.1-3.04 (0.75)	2.7 (2.7)	2.2-3.7 (3.2)	0.1-4.11 (1.7)	0.2-19.2 (7.2)
Population (no/m^2)	2525	8050	50-834 (292)	1782 (1782)	375-1250 (828)	100-1850 (918)	50-2925 (1138)
Total groups (no)	11	10	1-5 (3)	10 (10)	3-8 (7)	3-9 (6)	2-8 (6)

Table 3.3.6(Contd 4)

Parameter	Bedi	Navlakhi	
	March 1997	February 1987	April 2002
Phytoplankton			
Chlorophyll *a* (mg/m^3)	0.5-5.9 (1.5)	0.5-3.8 (1.6)	0.5-1.1 (0.7)
Phaeophytin (mg/m^3)	0.1-7.6 (1.5)	0.1-0.8 (0.4)	0.2-1.3 (0.8)
Cell counts ($nox10^3/l$)	38.0-936.0 (159.0)	-	1.7-13.5 (7.2)
Total genera (no)	7-15 (10)	-	7-19 (11)
Zooplankton			
Biomass ($ml/100m^3$)	0.5-25.5 (6.4)	18.8-95.0 (53.3)	0.5-3.2 (1.9)
Population ($nox10^3/100m^3$)	1.6-220.0 (48.1)	59.0-192.0 (117.3)	2.8-34.1 (16.9)
Total groups (no)	5-15 (10)	-	11-20 (15)
Macrobenthos			
Biomass (g/m^2, wet wt)	7.8	<0.1	<0.1
Population (no/m^2)	2944	72	25
Total groups (no)	9	-	1

Table 3.3.6(Contd 5)

Parameter	Kandla			
	February 1987	March 1996	February 1998	April 2002
Phytoplankton				
Chlorophyll a (mg/m^3)	0.1-0.5 (0.4)	0.5-0.5 (0.5)	0.5-2.1 (1.1)	0.5-2.1 (1.1)
Phaeophytin (mg/m^3)	0.1-1.7 (1.0)	0.2-0.6 (0.3)	0.1-1.7 (1.0)	0.3-1.3 (0.8)
Cell counts ($nox10^3/l$)		4.6-170.0 (67.7)	30.2-45.1 (36.2)	8.4-22.4 (14.5)
Total genera (no)		7-15 (11)	6-8 (7)	9-19 (13)
Zooplankton				
Biomass ($ml/100\ m^3$)	17.0-56.3 (37.0)	4.4-18.5 (11.5)	3.8-24.1 (14.3)	1.6-6.3 (3.2)
Population ($nox10^3/100\ m^3$)	31.0-98.5 (67.0)	4.2-18.7 (11.4)	13.7-117.1 (42.4)	11.8-139 (40.0)
Total groups (no)	-	10-11 (11)	7-13 (10)	11-17 (14)
Macrobenthos				
Biomass (g/m^2, wet wt)	6.4	0.4	<0.2	<0.1
Population (no/m^2)	264	978	26	143
Total groups (no)	3	8	2	5

Table 3.3.6(Contd 6)

Parameter	Mundra				
	March 1997	March 1999	March 2000	April 2002	June 2003
Phytoplankton					
Chlorophyll *a* (mg/m^3)	0.3-1.1 (0.8)	0.5-2.7 (0.9)	0.5-1.6 (0.8)	0.5-1.6 (0.9)	0.2-4.1 (1.0)
Phaeophytin (mg/m^3)	0.2-0.8 (0.4)	0.1-1.7 (0.6)	0.1-0.6 (0.4)	0.1-1.3 (0.7)	0.1-1.6 (0.5)
Cell counts ($nox10^3/l$)	62.4-293.0 (189.4)	33.6-133.2 (79.6)	14.0-196.0 (57.0)	16.6-82.8 (45.8)	12.9-427 (90.8)
Total genera (no)	7-14 (12)	6-14 (10)	8-14 (11)	20-26 (24)	8-13 (10)
Zooplankton					
Biomass ($ml/100m^3$)	0.4-72.7 (32.0)	0.8-8.0 (4.3)	0.2-28.2 (6.4)	0.2-25.3 (9.1)	0.9-9.6 (2.7)
Population ($nox10^3/100m^3$)	1.6-144.1 (74.8)	2.1-40.4 (19.6)	1.9-145.1 (25.0)	2.2-156 (45.5)	7.7-58.9 (18.7)
Total groups (no)	9-16 (12)	6-16 (12)	6-17 (10)	9-21 (15)	12-18 (15)
Macrobenthos					
Biomass (g/m^2, wet wt)	4.4	0.2-2.0 (0.8)	0.1-43.1 (4.3)	12.8	0-4.5 (0.4)
Population (no/m^2)	5700	302-515 (380)	100-20600 (2100)	3494	0-1300 (240)
Total groups (no)	7	5-5 (5)	2-7 (4)	15	0-6 (3)

Average given in parenthesis

Table 3.3.7 : Biological characteristics of the Gulf during postmonsoon (1984-2004)

Parameter	Okha					
	December 1981	November 1995	November 1999	November 2002	January 2003	January 2004
Phytoplankton						
Chlorophyll *a* (mg/m^3)	2.7-4.3 (3.5)	1.1-1.1 (1.1)	1.1-1.1 (1.1)	0.5-1.6 (0.7)	0.5-0.5 (0.5)	0.2-0.4 (0.3)
Phaeophytin (mg/m^3)	-	0.2-0.6 (0.3)	0.1-0.4 (0.2)	0.1-1.4 (0.6)	0.2-1.0 (0.5)	0.1-0.3 (0.2)
Cell counts ($nox10^3/l$)	-	27.0-54.8 (41.8)	68.0-80.0 (74.0)	-	1.2-54 (21.0)	3.1-60.0 (19.0)
Total genera (no)	-	13-16 (15)	10-11 (11)	-	9-19 (12)	10-17 (12)
Zooplankton						
Biomass ($ml/100m^3$)	0.5-0.9 (0.7)	0.4-0.8 (0.6)	0.4-1.0 (0.7)	0.2-2.6 (1.6)	2.2-8.2 (4.6)	1.0-56.9 (25.2)
Population ($nox10^3/100m^3$)	-	0.5-0.5 (0.5)	6.9-7.2 (7.0)	0.6-22.8 (8.3)	26.1-86 (54.9)	20.5-69.4 (45.8)
Total groups (no)	-	7-14 (12)	10-11 (11)	10-19 (16)	15-21 (16)	12-20 (15)
Macrobenthos						
Biomass (g/m^2; wet wt)	-	<0.1	0.5	1.89	0.5-24.9 (15.2)	0.2-5.2 (3.3)
Population (no/m^2)	775	89	352	1963	600-2025 (1307)	213-2900 (1597)
Total groups (no)	5	3	4	10	2-6 (5)	2-6 (4)

Table 3.3.7 (Contd 2)

Parameter	Vadinar						
	November 1994	November 1995	January 2000	November 2002	January 2003	January 2004	November 2004
Phytoplankton							
Chlorophyll *a* (mg/m^3)	0.5-0.5 (0.5)	0.5-1.1 (0.7)	0.5-1.1 (0.8)	0.5-1.6 (0.6)	0.5-0.5 (0.5)	0.2-0.2 (0.2)	0.2-0.2 (0.2)
Phaeophytin (mg/m^3)	0.2-1.0 (0.6)	0.1-0.6 (0.4)	0.1-0.6 (0.4)	0.1-1.3 (0.4)	0.2-1.0 (0.6)	0.1-0.2 (0.2)	0.2-1.0 (0.5)
Cell counts ($nox10^3/l$)	-	9.4-32.7 (17.1)	17.2-28.8 (22.0)	3.8-26.4 (9.9)	9.6-70.0 (36.6)	2.0-20.1 (11.7)	2.0-36.0 (7.6)
Total genera (no)	-	10-12 (11)	8-13 (11)	10-18 (14)	9-21 (14)	11-18 (15)	7-18 (12)
Zooplankton							
Biomass ($ml/100m^3$)	2.1-6.4 (4.6)	1.6 (1.6)	0.6-7.3 (4.0)	0.4-2.5 (1.3)	4.2-11.9 (8.2)	0.1-1.9 (1.0)	0.3-6.7 (1.7)
Population ($nox10^3/100m^3$)	3.7-52.7 (23.7)	7.2 (7.2)	8.7-41.1 (24.9)	2.5-12.2 (7.4)	23.4-125 (66.5)	0.2-9.6 (6.8)	1.4-37.1 (12.5)
Total groups (no)	11-15 (13)	10 (10)	7-8 (8)	9-20 (16)	20-23 (22)	8-12 (9)	11-17 (14)
Macrobenthos							
Biomass (g/m^2; wet wt)	-	1.2	0.2	1.26	0.0-35.5 (10.0)	<0.1-7.2 (2.6)	2.0
Population (no/m^2)	-	339	126	1163	0-7425 (2581)	25-1826 (471)	570
Total groups (no)	-	3	3	9	0-9 (5)	2	5

Table 3.3.7 (Contd 3)

Parameter	Sikka			
	December 1993	December 2000	November 2002	November 2003
Phytoplankton				
Chlorophyll *a* (mg/m^3)	0.5-4.3 (1.8)	0.5-3.7 (1.3)	0.5-1.1 (0.6)	0.2-0.6 (0.3)
Phaeophytin (mg/m^3)	0.1-2.8 (0.9)	0.1-1.5 (0.6)	0.2-1.0 (0.4)	0.1-1.0 (0.6)
Cell counts ($nox10^3/l$)	4.0-252 (90.0)	8.0-267 (85.4)	-	3.6-59.2 (21.4)
Total genera (no)	4-12 (7)	8-13 (11)	-	7-10 (9)
Zooplankton				
Biomass ($ml/100m^3$)	3.9-29.9 (11.0)	5.0-32.4 (20.7)	0.5-5.7 (2.5)	2.4-11.4 (7.8)
Population ($nox10^3/100m^3$)	1.93-71.3 (44.5)	12.8-83.4 (43.3)	2.3-37.0 (13.5)	27.8-91 (67.5)
Total groups (no)	10-13 (12)	13-19 (16)	11-20 (16)	13-17 (15)
Macrobenthos				
Biomass (g/m^2; wet wt)	12.8	0.02-2.1 (1.0)	14.4	2.2-3.7 (3.2)
Population (no/m^2)	10914	150-777 (483)	544	375-1250 (828)
Total groups (no)	11	2-9 (4)	8	3-8 (6)

Table 3.3.7 (Contd 4)

Parameter	Bedi		Navlakhi		
	October 1997	November 2002	November 1986	November 1994	November 2002
Phytoplankton					
Chlorophyll *a* (mg/m^3)	0.5-1.6 (1.0)	0.5-1.6 (1.0)	1.1-4.6 (2.2)	0.5-1.6 (0.9)	0.5-1.6 (0.6)
Phaeophytin (mg/m^3)	1.3-1.6 (1.4)	0.1-0.5 (0.4)	0.1-1.9 (1.0)	0.1-0.8 (0.4)	0.1-0.8 (0.4)
Cell counts ($nox10^3/l$)	0.2-14.8 (7.5)	3.8-56.1 (22.5)	-	9.0-18.9 (13.1)	6.0-31.4 (14.5)
Total genera (no)	6-7 (7)	10-16 (13)	-	7-9 (8)	8-20 (13)
Zooplankton					
Biomass ($ml/100m^3$)	1.8-7.5 (4.6)	3.9-8.9 (6.6)	13.2-55.2 (30.4)	1.8-13.5 (5.6)	0.8-5.4 (3.5)
Population ($nox10^3/100m^3$)	9.9-14.9 (12.4)	12.8-24.5 (19.4)	2.0-13.0 (6.8)	4.4-31.4 (14.5)	5.5-38.3 (15.1)
Total groups (no)	10-11 (11)	16-19 (17)	-	10-15 (12)	12-19 (16)
Macrobenthos					
Biomass (g/m^2; wet wt)	0.1	5.7	0.1-43.1 (4.3)	0.1	<0.1-0.1
Population (no/m^2)	125	1125	100-20600 (2100)	60	13-125 (82)
Total groups (no)	1	12	2-7 (4)	15	0-6 (3)

Table 3.3.7 (Contd 5)

Parameter	Kandla					
	November 1986	October 1996	November 2002	January 2003	December 2004	January 2004
Phytoplankton						
Chlorophyll *a* (mg/m^3)	0.5-1.1 (0.8)	2.1-4.3 (3.2)	0.5-1.1 (0.8)	0.5-1.1 (0.9)	0.2-0.2 (0.2)	0.2-0.2 (0.2)
Phaeophytin (mg/m^3)	1.0-1.3 (0.6)	0.1-0.6 (0.8)	0.2-1.9 (0.6)	1.2-2.3 (1.6)	0.2-1.0 (0.6)	0.1-0.5 (0.3)
Cell counts ($nox10^3/l$)	-	25.2-37.5 (30.4)	3.6-28.1 (17.6)	37.4-138.4 (103.0)	0.8-45.2 (31.8)	3-11.2 (6.0)
Total genera (no)	-	5-9 (7)	5-14 (10)	9-11 (10)	2-14 (7)	8-12 (11)
Zooplankton						
Biomass ($ml/100m^3$)	8.2-13.7 (11.8)	1.8-5.2 (3.5)	3.1-9.9 (5.2)	3.3-6.1 (4.7)	2.1-8.8 (5.9)	1.2-1.7 (1.5)
Population ($nox10^3/100m^3$)	21.0-32.9 (25.5)	1.2-63.6 (32.4)	16.6-102.1 (40.7)	61.0-63.7 (62.4)	4.5-89.0 (42.6)	4.1-6.7 (5.4)
Total groups (no)	-	8-12 (10)	12-21 (18)	17-17 (17)	14-19 (17)	9-10 (10)
Macrobenthos						
Biomass (g/m^2, wet wt)	0.2	0.4	0.1	0.1	1.2	0.1-1.1 (0.6)
Population (no/m^2)	60	276	6.9	75	177	100-138 (119)
Total groups (no)	2	3	4	2	2	3-5 (4)

Table 3.3.7 (Contd 6)

Parameter	Mundra				
	September 1999	November 2002	January 2003	October 2003	January 2004
Phytoplankton					
Chlorophyll *a* (mg/m^3)	1.1-3.7 (2.6)	0.5-1.1 (0.5)	0.5-1.6 (1.0)	0.2-3.4 (1.0)	0.2-0.2 (0.2)
Phaeophytin (mg/m^3)	0.4-2.8 (1.3)	0.2-0.6 (0.3)	0.1-4.2 (1.8)	0.1-1.5 (0.4)	0.1-0.8 (0.3)
Cell counts ($nox10^3/l$)	96.0-169.0 (150.0)	4.2-24.1 (11.2)	13-148 (53.8)	26-337 (111)	3.7-34.0 (14.6)
Total genera (no)	6-12 (9)	7-17 (11)	12-18 (15)	9-22 (15)	12-18 (14)
Zooplankton					
Biomass ($ml/100m^3$)	0.1-2.5 (0.8)	4.5-15.4 (7.2)	4.0-6.8 (5.7)	1.1-21.8 (5.2)	0.8-3.0 (1.8)
Population ($nox10^3/100m^3$)	0.1-11.0 (2.7)	7.5-60.6 (29.3)	58.2-150.3 (84.3)	11.7-81.5 (38.1)	6.3-22.0 (13.6)
Total groups (no)	9-19 (12)	13-19 (15)	16-17 (17)	12-17 (15)	8-14 (10)
Macrobenthos					
Biomass (g/m^2, wet wt)	0.6	0.3	0.1-15.5 (4.6)	1.4	1.4-2.7 (2.0)
Population (no/m^2)	713	325	125-1425 652	350	550-1450 (75)
Total groups (no)	2	8	2-6 (4)	2	4-6 (5)

Average given in parenthesis.

Table 3.3.8 : Mangrove areas and status of occurrence of major species of Gujarat

District	1992	1998
Mangroves areas (km^2)		
Kachchh	601.8	938.0
Jamnagar	13.12	98.3
Junagad	0.8	0.3
Bhavnagar	14.5	6.2
Bharuch	10.9	17.1
Surat	7.8	5.0
Valsad	-	5.0
Total	**767.0**	**1066.9**
Status of occurrence of major species		
Species	**1950**	**1998**
Avicennia sp	Common	Common
Rhizosolenia	Common	Vulnerable
Aegiceras sp	Common	Endangered
Ceriops tagal	Common	Vulnerable
Sonneratia apetala	Common	Vulnerable
Bruigeria sp.	Common	Absent
* Based on satellite data		

Table 3.3.9: Distribution of corals in the Gulf

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Esammocora digitata	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Acropora humilis	-	-	+	+	-	-	+	+	-	-	-	-	-	-	-
A.squamosa	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Montipora explanata	+	-	+	+	-	+	+	-	+	+	+	+	+	+	+
M.venosa	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
M.turgescons	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
M.hispida	+	+	-	+	+	-	+	+	+	+	+	-	-	-	+
M.foliosa	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
M.monasteriata	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-
Coscinaraea monile	+	+	+	+	+	+	+	+	+	-	-	-	-	-	+
Siderastrea savignyana	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pseudosiderastrea tayami	+	-	-	-	-	-	+	+	+	+	+	+	+	+	+
Goniopora planulata	+	+	-	-	+	+	+	-	+	+	-	+	-	-	+
G.minor	-	-	-	+	-	-	+	-	-	-	-	-	-	-	+
G.nigra	+	+	-	+	+	+	+	-	-	+	-	-	-	-	+
Porites leutea	+	+	+	+	-	-	+	-	-	-	-	+	-	-	+
P.lichen	+	-	-	-	-	-	+	-	+	-	-	+	-	+	+
P.compressa	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+
Favia speciosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
F.favus	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Favites complanata	+	+	+	+	+	+	+	-	-	+	-	-	-	+	+

Table 3.3.9 (Contd 2)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
F.melicerus	+	-	+	-	-	-	-	-	+	-	-	-	-	+	+
Goniastrea pectinata	+	+	+	+	+	+	+	-	+	+	+	-	+	+	+
Platygyra sinensis	+	+	+	+	-	-	-	-	-	+	-	-	-	+	+
Hydnophora exesa	+	+	+	+	-	-	-	-	-	+	-	-	+	-	+
Plesiastrea versipora	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-
Leptastrea purpurea	-	-	-	-	-	-	-	-	-	-	-	Sikka point			
Cyphastrea serailia	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+
Symphyllia radian	-	+	-	+	-	+	-	-	+	-	-	-	-	-	-
Acanthastrea simplex	+	+	+	+	-	-	-	-	+	+	-	-	-	-	+
Mycedium elephantotus	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Paracyathus stokesi	+	-	-	-	-	-	-	-	-	-	-	-	-	10	m
Polycyathus verrilli	+	-	+	-	-	-	+	-	-	-	-	-	-	-	-
Tubastraea aurea	+	+	+	+	+	-	-	-	+	+	-	-	-	-	-
Turbinaria crater	+	+	-	+	-	-	+	-	-	-	-	-	-	-	+
T.peltata	-	+	+	+	+	+	+	-	-	+	-	-	+	+	+

1 : Okha
2 : Dholio Gugar
3 : Dona
4 : Boria
5 : Mangunda
6 : Savaj
7 : Paga
8 : Manmarudi Langamarudi
9 : Ajad
10: Bural reef
11 : Dhani
12 : Kalumbhar reef
13: Narara reef
14 : Goose reef
15 : Pirotan island

Source: Pillai, C.S.G. and M.I. Patel (1988)

Table 3.3.10 : List of waterbirds in the Gulf.

English name	Scientific name	Status in habitat	
		Salt pans	Gulf
Podicipedidae			
Great Crested Grebe	*Podiceps cristatus*	LM	-
Blacknecked Grebe	*Podiceps nigricollis*	M	-
Pelecanidae			
White Pelican	*Pelecanus onocrotalus*	LM	LM
Dalmatian Pelican	*Pelecanus crispus*	M	M
Phalacrocoracidae			
Cormorant	*Phalacrocorax carbo*	LM	LM
Indian Shag	*Phalacrocorax fuscicolli*	LM	LM
Little Cormorant	*Phalacrocorax niger*	LM	R
Darter	*Anhinga rufa*	LM	R
Ardeidae			
Grey Heron	*Ardea cinerea*	LM	R
Purple Heron	*Ardea purpurea*	LM	-
Little Green Heron	*Ardeola striatus*	LM	R
Pond Heron	*Ardeola grayii*	LM	R
Cattle Egret	*Bubulcus ibis*	-	LM
Large Egret	*Ardea alba*	LM	R
Smaller Egret	*Egretta intermedia*	LM	-
Little Egret	*Egretta garzetta*	LM	-
Indian Reef Heron	*Egretta gularis*	LM	R
Night Heron	*Nycticorax mycticorax*	LM	R
Ciconiidae			
Painted Stork	*Mycteria leucocephala*	LM	R
Blacknecked Stork	*Ephippiorhynchus asiaficus*	LM	LM
Threskiornithidae			
White Ibis	*Threskiornis aethiopica*	LM	R
Black Ibis	*Pseudibis papillasa*	-	R
Spoonbill	*Platalea leucorodia*	LM	R

Table 3.3.10 (Contd 2)

English name	Scientific name	Status in habitat	
		Salt pans	Gulf
Phoenicopteridae			
Flamingo	*Phoenicopterus roseus*	LM	LM
Lesser Flamingo	*Phoeniconatas minor*	LM	R
Anatidae			
Ruddy Shel duck	*Tadorna ferruginea*	-	M
Pintail	*Anas acuta*	M	M
Common Teal	*Anas crecca*	M	-
Spotbill Duck	*Anas poecilorhyncha*	LM	LM
Shoveller	*Anas clypeata*	M	-
Accipitridae			
Brahminy Kite	*Haliastur indus*	LM	R
Marsh Harrier	*Circus aeruginosus*	M	M
Osprey	*Pandian haliaetus*	M	M
Gruidae			
Common Crane	*Grus grus*	M	M
Demoiselle Crane	*Anthropoides virgo*	M	M
Rallidae			
Coot	*Fulica atra*	LM	LM
Jacanidae			
Pheasant - tailed Jacana	*Hydrophasianus chirurgus*	LM	-
Haematopodidae			
Oystercatcher	*Haematopus stralegus*	M	M
Charadriidae			
Redwattled Lapwing	*Vanellus indicus*	R	R
Grey Plover	*Pluvialis sugotarola*	M	M
Eastern Golden Plover	*Pluvialis dominica*	-	M

Table 3.3.10 (Contd 3)

English name	Scientific name	Status in habitat*	
		Salt pans	Gulf
Large Sand Plover	*Charadrius leschenaultii*	M	M
Ringed Plover	*Charadrius hiaticula*	R	-
Kentish plover	*Charadrius alexandrinus*	R	R
Lesser Sand Plover	*Charadrius mongolus*	M	M
Whimbrel	*Numenius phaeopus*	M	M
Curlew	*Numenius arquata*	M	M
Blacktailed Godwit	*Limosa limosa*	M	-
Bartailed Godwit	*Limosa lapponica*	M	M
Spotted Redshank	*Tringa erythropus*	M	M
Common Redshank	*Tringa totanus*	M	M
Marsh Sandpiper	*Tringa stagnatilis*	M	M
Greenshank	*Tringa nebularia*	M	M
Green Sandpiper	*Tringa ochropus*	M	M
Wood Sandpiper	*Tringa glareola*	M	-
Terek Sandpiper	*Tringa terek*	M	M
Common Sandpiper	*Tringa hypoleucos*	M	M
Turnstone	*Arenaria interpres*	M	M
Knot	*Calidris carutus*	-	M
Eastern Knot	*Calidris tenuirostris*	-	V
Sanderling	*Calidris alba*	-	M
Eastern Little Stint	*Calidris ruficollis*	-	V
Little Stint	*Calidris minuta*	M	M
Dunlin	*Calidris alpina*	M	M
Curlew-Sandpiper	*Calidris testacea*	M	M
Broadbilled Sandiper	*Limicola falcinellus*	M	M
Ruff and Reeve	*Philomachus pugnax*	M	M
Rednecked Phalarope	*Phalaropus lobatus*	M	M
Recurvirostidae			
Blackwinged Stilt	*Himantopus himantopus*	R	-
Avocet	*Recurvirostra avosetta*	LM	-

Table 3.3.10 (Contd 4)

English name	Scientific name	Status in habitat	
		Salt pans	Gulf
Dromadidae			
Crab Plover	*Dromas ardeola*	M	M
Burhinidae			
Great Stone Plover	*Esacus magnirostris*	LM	R
Laridae			
Herring Gull	*Larus argentatus*	M	M
Lesser Blackbacked			
Gull	*Larus fuscus*	M	M
Blackheaded	*Larus ichthyaetus*	M	M
Brownheaded Gull	*Larus brunnicephalus*	M	M
Blackheaded Gull	*Larus ridibunds*	M	M
Slenderbilled Gull	*Larus genei*	M	M
Whiskered Tern	*Chiildonias hybrida*	M	M
Whitewinged Black	*Chiildonias leucopterus*	M	M
Tern			
Gullbilled Tern	*Gelochelidon nilotica*	M	M
Caspian Tern	*Hdroprogne caspia*	LM	LM
Common Tern	*Sterna hirunda*	M	M
Whitecheeked Tern	*Sterna repressa*	M	M
Brownwinged Tern	*Sterna anaethetus*	M	M
Little Tern	*Sterna albitrons*	M	M
Saunders Little Tern	*Sterna saundersi*	LM	R
Large Crested Tern	*Sterna bergii*	M	M
Indian Lesser Crested Tern	*Sterna bengalenis*	M	M
Sandwich Tern	*Sterna sandvicensis*	M	M
Indian skimmer	*Rynchops albicollis*	LM	LM

Table 3.3.10 (Contd 5)

English name	Scientific name	Status in habitat	
		Salt pans	Gulf
Alcedinidae			
Common Kingfisher	*Alcedo atthis*	LM	LM
Whitebreast	*Halcyon smyrnensisq*	LM	LM
Blackcapped kingfisher	*Halcyon pileata*	M	M

R : Resident, has been recorded breeding during the study.
LM : Local migrant, has not been recorded breeding during the study, but is known to nest within the state.
M : Migrant, does not breed in this area, spends the winter here and also sometimes the summer.
V : Not normally found in the area, one to few records only.

Source : Saurashtra University (1991).

Table 4.3.1 Water quality at station 1 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Max	Avg	Min	Max	Avg
Temperature (°C)	S	19.0	20.0	19.0	28.9	29.0	29.0
	B	19.0	20.0	19.0	28.5	28.5	28.5
		20.5	20.5	20.5	(28.8)	(28.8)	(28.8)
PH	S	8.1	8.1	8.1	8.0	8.0	8.0
	B	8.1	8.1	8.1	8.0	8.0	8.0
SS (mg/l)	S	-	-	-	-	-	28*
	B	-	-	-	-	-	28*
Salinity (ppt)	S	37.2	37.2	37.2	37.2	37.4	37.3
	B	37.2	37.2	37.2	37.0	37.2	37.1
DO (ml/l)	S	4.9	5.1	4.9	4.5	4.8	4.6
	B	4.9	5.1	4.9	4.8	5.0	4.9
BOD (mg/l)	S	1.4	1.7	1.4	-	-	4.2*
	B	1.4	1.4	1.4	-	-	1.6*
PO_4^{3-}-P (µmol/l)	S	1.0	1.6	1.0	0.6	0.7	0.7
	B	1.3	1.6	1.3	1.0	1.0	1.0
PTotal (µmol/l)	S	-	-	-	-	-	-
	B	-	-	-	-	-	-
NO_3^--N (µmol/l)	S	5.1	6.7	5.1	2.4	3.5	3.0
	B	5.1	6.7	5.1	2.0	2.9	2.5
NO_2^--N (µmol/l)	S	0.4	0.5	0.4	0.3	0.3	0.3
	B	0.4	0.5	0.4	0.3	0.3	0.3
NH_4^+-N (µmol/l)	S	0.1	0.4	0.1	0.7	1.2	0.9
	B	0.2	0.4	0.2	0.7	0.8	0.8
NTotal (µmol/l)	S	-	-	-	-	-	-
	B	-	-	-	-	-	-
PHc (µg/l)	1m	-	-	-	-	-	26.5*
Phenols (µg/l)	S	*	-	*	-	-	26.6*

Air temperature (°C) given in parenthesis *Single value

Table 4.3.2: Water quality at station 2 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Min	Avg	Min	Min	Avg
Temperature (°C)	S	21.0	22.0	21.5	28.0	28.1	28.1
	B	21.0	22.0	21.3	2975	27.5	27.5
		23.0	23.0	23.0	(29.5)	(29.5)	(29.5)
PH	S	8.1	8.1	8.1	7.9	7.9	7.9
	B	8.1	8.1	8.1	8.0	8.0	8.0
SS (mg/l)	S	-	-	58*	-	-	26*
	B	-	-	60*	-	-	22*
Salinity (ppt)	S	37.0	37.2	37.1	36.6	36.8	36.7
	B	37.0	37.2	37.0	36.8	36.8	36.8
DO (ml/l)	S	4.9	5.1	5.0	4.8	5.0	4.9
	B	5.1	5.1	5.1	4.8	5.0	4.9
BOD (mg/l)	S	1.1	1.4	1.2	-	-	4.5*
	B	1.4	1.4	1.4	-	-	1.6*
PO_4^{3-}-P (µmol/l)	S	1.2	1.8	1.5	0.4	0.6	0.5
	B	1.5	1.8	1.7	1.2	1.2	1.2
PTotal (µmol/l)	S	-	-	2.2*	-	-	-
	B	-	-	2.3*	-	-	-
NO_3^--N (µmol/l)	S	8.5	9.2	8.7	5.1	7.2	6.2
	B	8.5	8.7	8.6	5.0	6.0	5.5
NO_2^--N (µmol/l)	S	0.3	0.3	0.3	0.4	0.5	0.5
	B	0.3	0.3	0.3	0.4	0.4	0.4
NH_4^+-N (µmol/l)	S	ND	0.2	0.1	0.7	0.9	0.8
	B	ND	0.1	0.1	0.6	0.6	0.6
NTotal (µmol/l)	S	-	-	33.9*	-	-	-
	B	-	-	21.3*	-	-	-
PHc (µg/l)	1m	-	-	17.2*	-	-	17.2*
Phenols (µg/l)	S	-	-	3.1*	-	-	64.1*

Air temperature (°C) given in parenthesis *Single value

Table 4.3.3: Water quality at station 3 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Min	Avg	Min	Min	Avg
Temperature (°C)	S	21.5	22.0	21.8	27.7	27.8	27.8
	B	21.5	22.0	21.7	27.5	27.6	27.6
		24.0	24.0	24.0	(28.8)	(28.8)	(28.8)
PH	S	8.1	8.1	8.1	8.0	8.0	8.0
	B	8.1	8.1	8.1	8.0	8.0	8.0
SS (mg/l)	S	-	-	56*	-	-	28*
	B	-	-	70*	-	-	16*
Salinity (ppt)	S	37.0	37.2	37.0	36.5	36.5	36.5
	B	37.0	37.2	37.0	36.6	36.6	36.6
DO (ml/l)	S	4.9	5.1	5.0	4.8	5.0	4.9
	B	4.9	5.1	5.0	4.8	5.0	4.9
BOD (mg/l)	S	0.5	0.8	0.6	-	-	3.6*
	B	0.5	0.5	0.5	-	-	-
PO_4^{3-}-P (µmol/l)	S	1.6	1.8	1.7	0.8	0.8	0.8
	B	1.6	1.7	1.6	1.1	1.1	1.1
PTotal (µmol/l)	S	-	-	2.3*	-	-	-
	B	-	-	2.2*	-	-	-
NO_3^--N (µmol/l)	S	8.0	9.1	8.6	5.0	5.3	5.1
	B	8.0	8.7	8.5	4.4	5.5	5.0
NO_2^--N (µmol/l)	S	0.3	0.3	0.3	0.4	0.4	0.4
	B	0.3	0.3	0.3	0.3	0.4	0.4
NH_4^+-N (µmol/l)	S	ND	0.3	0.2	0.6	1.5	1.1
	B	ND	0.3	0.2	0.6	0.7	0.7
NTotal (µmol/l)	S	-	-	52.8*	-	-	-
	B	-	-	64.6*	-	-	-
PHc (µg/l)	1m	-	-	13.2*	-	-	28.1*
Phenols (µg/l)	S	-	-	6.2*	-	-	30.2

Air temperature (°C) given in parenthesis *Single value

Table 4.3.4: Water quality at station 4 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Min	Avg	Min	Min	Avg
Temperature (°C)	S	19.0	20.5	19.9	26.7	27.7	26.9
	B	19.0	20.5	19.8	26.7	29.0	27.3
		22.0	26.0	24.0	(28.6)	(29.0)	(28.8)
PH	S	8.1	8.3	8.1	7.9	8.0	8.0
	B	8.1	8.2	8.1	8.0	8.0	8.0
SS (mg/l)	S	36	38	37	42	56	49
	B	40	40	40	32	46	39
Salinity (ppt)	S	37.1	37.7	37.4	36.4	37.7	36.8
	B	37.1	37.7	37.4	35.4	37.2	36.4
DO (ml/l)	S	4.7	5.6	5.3	4.5	5.0	4.6
	B	4.7	5.6	5.3	4.5	5.0	4.6
BOD (mg/l)	S	1.2	1.5	1.4	2.3	3.9	3.1
	B	1.2	1.5	1.4	0.6	1.0	0.8
PO_4^{3-}-P (µmol/l)	S	1.2	2.3	1.9	0.4	1.5	0.8
	B	1.2	2.3	1.9	1.0	1.4	1.2
PTotal (µmol/l)	S	1.9	2.0	2.0	-	-	-
	B	2.2	2.2	2.2	-	-	-
NO_3^--N (µmol/l)	S	6.2	12.6	8.9	4.7	6.8	5.4
	B	5.2	12.6	9.1	2.5	5.7	4.8
NO_2^--N (µmol/l)	S	0.3	0.5	0.4	0.3	0.5	0.4
	B	0.3	0.5	0.4	0.3	0.5	0.4
NH_4^+-N (µmol/l)	S	0.1	0.9	0.5	0.2	0.4	0.3
	B	0.1	0.9	0.4	0.3	0.5	0.4
NTotal (µmol/l)	S	72.0	75.9	74.0	-	-	-
	B	53.3	63.5	58.4	-	-	-
PHc (µg/l)	1m	19.2	19.6	19.4	9.2	10.4	9.8
Phenols (µg/l)	S	0.7	49.7	25.2	24.5	42.2	33.4

Air temperature (°C) given in parenthesis *Single value

Table 4.3.5: Water quality at station 5 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Max	Avg	Min	Max	Avg
Temperature (°C)	S	20.0	22.9	21.2	25.9	26.5	26.2
	B	20.0	22.9	21.2	25.7	27.1	26.2
		18.2	26.2	23.4	(26.5)	(29.0)	(27.9)
PH	S	8.1	8.2	8.2	7.8	7.9	7.9
	B	8.1	8.2	8.2	7.9	7.9	7.9
SS (mg/l)	S	30	36	33	24	26	25
	B	30	34	32	24	26	25
Salinity (ppt)	S	37.1	37.9	37.3	36.6	37.7	37.0
	B	37.1	37.5	37.3	34.6	37.7	36.7
DO (ml/l)	S	2.0	5.4	5.1	4.5	5.2	4.7
	B	2.0	5.4	5.1	4.3	5.0	4.8
BOD (mg/l)	S	2.1	4.0	3.2	1.9	2.3	2.1
	B	2.1	4.0	3.2	0.6	1.3	1.0
PO_4^{3-}-P (µmol/l)	S	0.7	1.8	1.5	0.2	1.5	0.6
	B	0.7	1.8	1.5	1.1	1.3	1.2
PTotal (µmol/l)	S	2.2	2.3	2.3	-	-	-
	B	1.9	2.2	2.1	-	-	-
NO_3^--N (µmol/l)	S	6.6	10.4	8.4	0.4	4.8	3.0
	B	6.6	10.4	8.5	2.9	4.0	3.2
NO_2^--N (µmol/l)	S	0.3	0.4	0.4	0.3	0.7	0.4
	B	0.3	0.4	0.4	0.3	0.6	0.5
NH_4^+-N (µmol/l)	S	0.2	1.2	0.5	0.4	0.9	0.6
	B	0.2	1.2	0.5	0.1	1.1	0.6
NTotal (µmol/l)	S	72.4	76.3	74.4	-	-	-
	B	61.1	150	105.6	-	-	-
PHc (µg/l)	1m	2.4	11.3	6.9	17.6	45.7	31.7
Phenols (µg/l)	S	18.0	61.9	40.0	4.6	21.6	13.1

Air temperature (°C) given in parenthesis *Single value

Table 4.3.6: Water quality at station 6 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Max	Avg	Min	Max	Avg
Temperature (°C)	S	20.8	23.2	22.3	25.8	26.4	26.1
	B	20.8	23.0	22.2	25.6	26.4	25.9
		22.8	25.0	24.2	(26.0)	(27.8)	(27.3)
PH	S	8.0	8.2	8.1	8.0	8.0	8.0
	B	8.1	8.2	8.2	8.0	8.0	8.0
SS (mg/l)	S	58	82	70	30	36	33
	B	64	214	139	30	32	31
Salinity (ppt)	S	36.5	37.2	36.9	36.7	37.3	37.0
	B	36.5	37.2	36.9	36.7	37.3	36.9
DO (ml/l)	S	4.0	5.4	4.9	4.5	4.8	4.6
	B	4.0	5.4	4.8	4.1	4.8	4.6
BOD (mg/l)	S	ND	4.3	1.7	2.3	2.6	2.4
	B	ND	2.1	0.8	1.9	3.6	2.7
PO_4^{3-}-P (µmol/l)	S	0.4	1.9	1.5	0.8	1.4	1.1
	B	0.8	1.9	1.6	1.2	2.0	1.5
PTotal (µmol/l)	S	1.9	2.1	2.0	-	-	-
	B	1.8	2.1	2.0	-	-	-
NO_3^--N (µmol/l)	S	4.7	7.6	6.6	2.4	4.7	3.4
	B	4.7	7.6	6.5	2.3	4.0	3.2
NO_2^--N (µmol/l)	S	0.2	0.4	0.3	0.3	0.6	0.4
	B	0.2	0.4	0.3	0.4	0.5	0.5
NH_4^+-N (µmol/l)	S	0.6	6.1	1.3	0.2	0.8	0.4
	B	0.6	6.1	1.2	0.3	1.0	0.6
NTotal (µmol/l)	S	53.5	86.7	70.1	-	-	-
	B	52.0	61.3	56.7	-	-	-
PHc (µg/l)	1m	13.7	21.7	17.7	10.6	24.9	17.8
Phenols (µg/l)	S	9.4	49.0	29.2	12.0	41.0	26.5

Air temperature (°C) given in parenthesis *Single value

Table 4.3.7: Water quality at station 7 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Max	Avg	Min	Max	Avg
Temperature (°C)	S	18.0	18.5	18.3	25.0	27.6	26.4
	B	18.0	18.5	18.2	27.0	27.4	27.2
		17.5	18.0	17.8	(25.0)	(30.8)	(28.1)
PH	S	8.1	8.1	8.1	7.9	8.0	8.0
	B	8.1	8.1	8.1	8.0	8.0	8.0
SS (mg/l)	S	-	-	34*	26	44	34
	B	-	-	32*	24	32	28
Salinity (ppt)	S	37.3	37.7	37.5	37.3	40.0	38.5
	B	37.3	37.7	37.5	37.1	37.5	37.3
DO (ml/l)	S	5.3	5.5	5.4	4.1	4.8	4.4
	B	5.3	5.5	5.5	4.5	4.5	4.5
BOD (mg/l)	S	1.1	1.1	1.1	0.6	3.6	0.6
	B	1.1	1.1	1.1	-	-	0.6
PO_4^{3-}-P (µmol/l)	S	1.7	1.7	1.7	1.0	3.1	1.6
	B	1.7	1.7	1.7	1.9	2.1	2.0
PTotal (µmol/l)	S	-	-	2.2*	-	-	-
	B	-	-	2.0*	-	-	-
NO_3^--N (µmol/l)	S	6.5	7.6	7.0	ND	3.8	1.4
	B	6.6	7.6	7.2	1.7	1.8	1.7
NO_2^--N (µmol/l)	S	0.4	0.6	0.5	0.4	0.8	0.6
	B	0.5	0.6	0.5	0.7	0.8	0.8
NH_4^+-N (µmol/l)	S	0.3	0.8	0.6	0.4	1.0	0.6
	B	0.3	0.8	0.5	0.7	0.9	0.8
NTotal (µmol/l)	S	-	-	87.2*	-	-	-
	B	-	-	64.6*	-	-	-
PHc (µg/l)	1m	-	-	26.1*	14.9	17.7	16.3
Phenols (µg/l)	S	-	-	63.8*	21.8	32.2	26.9

Air temperature (°C) given in parenthesis *Single value

Table 4.3.8: Water quality at station 8 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Max	Avg	Min	Max	Avg
Temperature (°C)	S	20.0	21.3	20.7	28.1	28.2	28.2
	B	20.0	21.3	20.4	27.6	27.6	27.6
		22.0	22.0	22.0	(29.0)	(29.0)	(29.0)
PH	S	8.0	8.1	8.1	7.9	8.0	8.0
	B	8.0	8.1	8.1	8.0	8.0	8.0
SS (mg/l)	S	-	-	64*	-	-	30*
	B	-	-	68*	-	-	26*
Salinity (ppt)	S	37.4	37.8	37.6	36.6	37.2	36.9
	B	37.4	37.8	37.6	36.5	36.8	36.6
DO (ml/l)	S	1.8	2.4	2.1	4.8	5.0	4.9
	B	1.8	2.4	2.1	4.8	4.8	4.8
BOD (mg/l)	S	-	-	-	-	-	3.6*
	B	-	-	-	-	-	1.6*
PO_4^{3-}-P (µmol/l)	S	1.6	1.8	1.7	0.9	1.0	1.0
	B	1.7	1.8	1.8	1.3	1.4	1.4
PTotal (µmol/l)	S	-	-	2.2*	-	-	-
	B	-	-	2.4*	-	-	-
NO_3^--N (µmol/l)	S	5.7	5.9	5.9	6.3	8.2	7.2
	B	5.7	5.9	5.8	5.0	6.9	6.0
NO_2^--N (µmol/l)	S	0.4	0.5	0.5	0.4	0.5	0.5
	B	0.5	0.5	0.5	0.4	0.4	0.4
NH_4^+-N (µmol/l)	S	0.1	0.4	0.2	0.9	1.0	1.0
	B	0.1	0.2	0.1	0.6	1.0	0.8
NTotal (µmol/l)	S	-	-	67.2*	-	-	-
	B	-	-	47.2*	-	-	-
PHc (µg/l)	1m	-	-	22.6*	-	-	18.1*
Phenols (µg/l)	S	-	-	9.1*	-	-	23.0*

Air temperature (°C) given in parenthesis *Single value

Table 4.3.9: Water quality at station 9 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Max	Avg	Min	Max	Avg
Temperature (°C)	S	19.9	20.1	20.0	26.8	26.9	26.9
	B	19.9	20.1	20.0	27.0	27.0	27.0
		20.5	20.5	20.5	(28.5)	(28.5)	(28.5)
PH	S	8.0	8.1	8.1	7.9	7.9	7.9
	B	8.0	8.1	8.1	8.0	8.0	8.0
SS (mg/l)	S	-	-	44*	-	-	20*
	B	-	-	48*	-	-	18*
Salinity (ppt)	S	37.0	37.2	37.0	36.8	37.0	36.9
	B	37.0	37.2	37.0	37.0	37.2	37.1
DO (ml/l)	S	2.0	3.1	2.8	4.8	4.8	4.8
	B	2.0	3.1	2.7	4.3	4.8	4.6
BOD (mg/l)	S	-	-	-	-	-	5.2*
	B	-	-	-	-	-	-
PO_4^{3-}-P (µmol/l)	S	1.5	1.6	1.6	0.4	0.5	0.5
	B	1.5	1.6	1.6	1.2	1.3	1.2
PTotal (µmol/l)	S	-	-	2.3*	-	-	-
	B	-	-	2.1*	-	-	-
NO_3^--N (µmol/l)	S	5.9	7.2	6.3	2.6	3.8	3.2
	B	5.9	6.3	6.0	4.6	4.6	4.6
NO_2^--N (µmol/l)	S	0.2	0.3	0.3	0.2	0.3	0.3
	B	0.2	0.3	0.3	0.4	0.4	0.4
NH_4^+-N (µmol/l)	S	0.2	0.3	0.3	1.1	1.3	1.2
	B	0.2	0.3	0.3	0.5	0.7	0.6
NTotal (µmol/l)	S	-	-	75.0*	-	-	-
	B	-	-	44.3*	-	-	-
PHc (µg/l)	1m	-	-	11.7*	-	-	13.2*
Phenols (µg/l)	S	-	-	31.7*	-	-	9.8*

Air temperature (°C) given in parenthesis *Single value

Table 4.3.10: Water quality at station 10 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Max	Avg	Min	Max	Avg
Temperature (°C)	S	22.0	22.5	22.3	27.5	27.5	27.5
	B	22.0	22.5	22.2	27.5	27.5	27.5
		23.8	23.8	23.8	(28.5)	(28.5)	(28.5)
PH	S	8.2	8.2	8.2	8.0	8.0	8.0
	B	8.2	8.2	8.2	8.0	8.0	8.0
SS (mg/l)	S	-	-	30*	-	-	44*
	B	-	-	62*	-	-	44*
Salinity (ppt)	S	36.5	36.9	36.7	37.4	38.4	37.7
	B	36.5	36.7	36.6	37.2	37.2	37.2
DO (ml/l)	S	4.7	5.5	5.1	4.5	4.8	4.6
	B	5.1	5.5	5.2	4.9	4.8	4.8
BOD (mg/l)	S	-	-	-	-	-	2.9*
	B	-	-	-	-	-	0.6*
PO_4^{3-}-P (µmol/l)	S	0.3	2.2	1.4	0.5	1.0	0.8
	B	1.2	2.2	1.7	1.5	1.6	1.6
PTotal (µmol/l)	S	-	-	2.2*	-	-	-
	B	-	-	2.5*	-	-	-
NO_3^--N (µmol/l)	S	6.1	11.0	8.2	3.1	3.8	3.4
	B	6.5	11.0	8.9	2.3	3.2	2.8
NO_2^--N (µmol/l)	S	0.3	0.6	0.4	0.5	0.5	0.5
	B	0.3	0.6	0.4	0.5	0.6	0.6
NH_4^+-N (µmol/l)	S	ND	0.7	0.2	0.4	0.4	0.4
	B	ND	0.1	0.1	0.5	0.6	0.6
NTotal (µmol/l)	S	-	-	17.2*	-	-	-
	B	-	-	22.4*	-	-	-
PHc (µg/l)	1m	-	-	11.1*	-	-	13.8*
Phenols (µg/l)	S	-	-	33.6*	-	-	26.2*

Air temperature (°C) given in parenthesis *Single value

Table 4.3.11: Water quality at station 11 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Max	Avg	Min	Max	Avg
Temperature (°C)	S	22.0	22.8	22.4	27.0	27.0	27.0
	B	22.0	22.8	22.3	26.0	26.0	26.0
		24.8	24.8	24.8	(28.1)	(28.1)	(28.1)
PH	S	8.1	8.2	8.2	8.0	8.0	8.0
	B	8.1	8.2	8.2	8.0	8.0	8.0
SS (mg/l)	S	-	-	40*	-	-	126*
	B	-	-	36*	-	-	120*
Salinity (ppt)	S	36.7	38.8	37.3	37.2	37.2	37.2
	B	36.7	38.8	37.5	37.0	37.0	37.0
DO (ml/l)	S	5.0	5.7	5.3	4.5	4.5	4.5
	B	5.0	5.7	5.3	4.5	4.7	4.6
BOD (mg/l)	S	-	-	-	-	-	2.3*
	B	-	-	-	-	-	1.0*
PO_4^{3-}-P (µmol/l)	S	0.6	1.7	1.2	1.2	1.4	1.3
	B	0.6	1.7	1.3	1.7	1.9	1.8
PTotal (µmol/l)	S	-	-	2.5*	-	-	-
	B	-	-	2.4*	-	-	-
NO_3^--N (µmol/l)	S	10.1	11.5	10.7	3.5	3.6	3.6
	B	10.1	11.5	10.7	2.0	2.3	2.2
NO_2^--N (µmol/l)	S	0.3	0.4	0.3	0.4	0.6	0.5
	B	0.3	0.4	0.4	0.6	0.6	0.6
NH_4^+-N (µmol/l)	S	ND	0.6	0.4	0.6	0.6	0.6
	B	ND	0.5	0.3	0.5	0.8	0.7
NTotal (µmol/l)	S	-	-	24.3*	-	-	-
	B	-	-	45.9*	-	-	-
PHc (µg/l)	1m	-	-	24.0*	-	-	15.9*
Phenols (µg/l)	S	-	-	33.8*	-	-	22.6*

Air temperature (°C) given in parenthesis *Single value

Table 4.3.12: Water quality at station 12 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Max	Avg	Min	Max	Avg
Temperature (°C)	S	21.8	22.6	22.1	27.5	27.5	27.5
	B	21.8	22.6	22.1	27.0	27.0	27.0
		24.8	24.8	24.8	(28.5)	(28.5)	(28.5)
PH	S	8.2	8.2	8.2	8.1	8.1	8.1
	B	8.2	8.2	8.2	8.1	8.1	8.1
SS (mg/l)	S	-	-	24*	-	-	104*
	B	-	-	62*	-	-	120*
Salinity (ppt)	S	36.9	37.1	37.0	37.2	37.2	37.2
	B	36.9	37.1	37.0	36.8	37.4	37.1
DO (ml/l)	S	5.0	5.0	5.0	4.5	4.5	4.5
	B	5.0	5.0	5.0	4.5	4.7	4.6
BOD (mg/l)	S	-	-	-	-	-	3.6*
	B	-	-	-	-	-	0.6*
PO_4^{3-}-P (µmol/l)	S	0.8	2.0	1.3	0.8	1.2	1.0
	B	0.8	2.0	1.5	1.7	1.8	1.8
PTotal (µmol/l)	S	-	-	2.5*	-	-	-
	B	-	-	2.4*	-	-	-
NO_3^--N (µmol/l)	S	8.1	10.8	9.5	1.9	2.1	2.0
	B	8.1	10.8	9.1	1.4	1.7	1.6
NO_2^--N (µmol/l)	S	0.4	0.6	0.5	0.5	0.5	0.5
	B	0.4	0.6	0.4	0.5	0.6	0.6
NH_4^+-N (µmol/l)	S	ND	1.0	0.5	0.5	0.7	0.6
	B	ND	1.0	0.5	0.5	0.8	0.7
NTotal (µmol/l)	S	-	-	30.0*	-	-	-
	B	-	-	35.2*	-	-	-
PHc (µg/l)	1m	-	-	17.2*	-	-	19.0*
Phenols (µg/l)	S	-	-	14.6*	-	-	1.4*

Air temperature (°C) given in parenthesis *Single value

Table 4.3.13: Water quality at station 13 off Mundra during January 2006 and April 2006

Parameter	Level	January 2006			April 2006		
		Min	Max	Avg	Min	Max	Avg
Temperature (°C)	S	21.8	22.1	22.0	28.0	28.1	28.1
	B	21.8	22.0	21.9	28.0	28.0	28.0
		24.5	24.5	24.5	(28.9)	(28.9)	(28.9)
PH	S	8.2	8.2	8.2	8.1	8.1	8.1
	B	8.2	8.2	8.2	8.1	8.1	8.1
SS (mg/l)	S	-	-	32*	-	-	54*
	B	-	-	32*	-	-	54*
Salinity (ppt)	S	37.1	37.3	37.1	37.0	37.2	37.1
	B	37.1	37.1	37.1	37.0	37.2	37.1
DO (ml/l)	S	4.6	5.4	5.0	4.7	4.7	4.7
	B	4.6	5.4	5.0	4.5	4.7	4.6
BOD (mg/l)	S	-	-	-	-	-	2.9*
	B	-	-	-	-	-	1.0*
PO_4^{3-}-P (µmol/l)	S	1.5	1.8	1.7	0.9	1.0	1.0
	B	1.6	1.8	1.7	1.8	1.8	1.8
PTotal (µmol/l)	S	-	-	2.5*	-	-	-
	B	-	-	2.3*	-	-	-
NO_3^--N (µmol/l)	S	8.8	10.6	9.8	1.8	2.3	2.1
	B	8.8	9.9	9.6	1.5	2.3	1.9
NO_2^--N (µmol/l)	S	0.4	0.5	0.5	0.4	0.4	0.4
	B	0.4	0.5	0.5	0.6	0.6	0.6
NH_4^+-N (µmol/l)	S	0.2	0.5	0.3	0.6	0.6	0.6
	B	0.2	0.3	0.3	0.6	0.7	0.7
NTotal (µmol/l)	S	-	-	43.3*	-	-	-
	B	-	-	55.2*	-	-	-
PHc (µg/l)	1m	-	-	16.7*	-	-	17.4*
Phenols (µg/l)	S	-	-	4.6*	-	-	21.4*

Air temperature (°C) given in parenthesis *Single value

Table 4.3.14: Water quality at station 7 (Kotdi Creek) during September 1999

Parameter	Level	Min	Max	Av
Temperature (°C)	S	29.8	31.0	30.4
	B	29.0	31.6	30.8
		(29.5)	(34.0)	(31.3)
PH	S	7.9	8.4	8.2
	B	7.9	8.1	8.0
SS (mg/l)	S	49	160	105
	B	70	98	84
Salinity (ppt)	S	38.4	38.9	38.7
	B	38.0	38.8	38.5
DO (ml/l)	S	1.5	5.3	3.4
	B	2.0	5.1	2.7
BOD (mg/l)	S	<0.2	4.1	2.0
	B	<0.2	0.2	0.2
PO_4^{3-}-P (µmol/l)	S	0.5	1.9	1.2
	B	0.7	2.2	1.4
PTotal (µmol/l)	S	-	-	-
	B	-	-	-
NO_3^--N (µmol/l)	S	0.1	10.0	5.0
	B	0.4	7.0	3.7
NO_2^--N (µmol/l)	S	0.2	0.9	0.6
	B	0.2	1.0	0.5
NH_4^+-N (µmol/l)	S	ND	3.6	1.8
	B	0.3	1.5	0.6
NTotal (µmol/l)	S	9	26	18
	B	21	39	30
PHc (µg/l)	1m	0.1	0.5	0.3
Phenols (µg/l)	S	38	133	86

Air temperature (°C) given in parenthesis
*Single value

Table 4.3.15: Water quality of Bocha Creek off during 1998-2005

Parameter	June 1998	March 1999	March 2000	June 2003	October 2003	December 2004	May 2005
Temperature (°C)	29.5-30.8 (30.1)	22.0-27.1 (24.4)	25.0-25.8 (25.6)	28.9-29.2 (29.0)	28.7-29.5 (29.0)	23.8-23.9 (23.9)	28.8-29.0 (28.9)
pH	8.2-8.3 (8.2)	8.0-8.3 (8.2)	8.0-8.1 (8.1)	8.0-8.0 (8.0)	8.1-8.2 (8.2)	8.3-8.4 (8.4)	8.2-8.3 (8.3)
SS (mg/l)	122-251 (182)	33-445	42-125 (84)	108-176 (138)	44-94 (72)	24-26 (25)	30-34 (32)
Salinity (ppt)	36.3-41.4 (39.9)	36.2-38.4 (37.0)	38.4-38.7 (38.5)	38.5-38.7 (38.5)	36.5-38.1 (37.3)	37.6-38.2 (38.0)	39.2-39.5 (39.4)
DO (ml/l)	4.0-5.5 (4.4)	2.2-5.3 (3.5)	3.2-4.4 (3.9)	2.7-4.3 (3.7)	3.8-4.7 (4.4)	5.3-5.5 (3.4)	3.8-4.3 (4.0)
BOD (mg/l)	1.8-5.6 (3.5)	<0.2-5.1 (3.1)	1.1-3.9 (2.4)	0.1-2.0 (1.0)	2.2-2.9 (2.6)	2.3-3.1 (2.7)	0.5-3.5 (2.0)
PO_4^{3-}P (µmol/l)	0.9-2.2 (1.5)	0.9-1.7 (1.3)	1.1-1.7 (1.4)	2.2-3.6 (3.6)	0.3-1.3 (1.0)	0.9-1.3 (1.2)	0.3-0.8 (0.5)
NO_3^-N (µmol/l)	3.8-33.5 (6.3)	0.1-5.7 (1.4)	0.6-0.9 (0.8)	2.3-3.5 (3.2)	1.9-3.2 (2.4)	1.6-5.5 (3.6)	1.2-2.1 (1.6)
NO_2^-N (µmol/l)	0.3-1.0 (0.6)	0.5-0.7 (0.5)	0.3-0.4 (0.3)	0.2-0.4 (0.3)	0.2-0.4 (0.4)	0.3-0.4 (0.4)	0.5-0.6 (0.6)
NH_4^+-N (µmol/l)	0.2-4.9 (1.3)	0.9-2.2 (1.3)	0.1-0.3 (0.2)	ND-0.2 (0.1)	0.3-1.9 (0.9)	ND-0.3 (0.2)	1.2-2.2 (1.7)
NTotal (µmol/l)	5.6-54.6 (18.1)	25.2-44.0 (30.8)	50.9-70.9 (60.9)	6.6-12.1 (10.4)	8.0-11.3 (10.2)	-	-
PHc (µg/l)	0.6-1.5 (0.9)	1.0-3.1 (1.8)	2.7 (2.7)	1.1-1.5 (1.3)	6.8-7.1 (7.0)	9.6*	1.5*
Phenols (µg/l)	8-39 (24)	98-111 (108)	38 (38)	17-24 (21)	21-30 (26)	47*	12*

Average value given in parenthesis *Single value

Table 4.3.16: Water quality of Navinal Creek off during 1998-2005

	June 1998	March 1999	March 2000	June 2003	October 2003	December 2004	May 2005
Temperature (°C)	28.5-29.8 (29.0)	25.1-27.0 (26.7)	22.0-27.0 (24.0)	28.5-31.5 (29.2)	28.0-29.7 (29.1)	23.0-23.7 (23.4)	28.2-30.1 (28.8)
pH	8.0-8.2 (8.1)	8.1-8.3 (8.3)	8.1	7.9-8.0 (8.0)	8.0-8.3 (8.2)	8.4	8.2-8.5 (8.3)
SS (mg/l)	236-614 (357)	66-166 (94)	43-94 (65)	80-288 (144)	30-596 (89)	18-24 (21)	80-150 (115)
Salinity (ppt)	36.8-40.7 (39.9)	36.9-40.0 (37.5)	37.2-38.0 (37.6)	38.5-39.0 (38.8)	35.3-37.1 (36.7)	38.2-38.6 (38.4)	37.7-38.5 (38.1)
DO (ml/l)	3.5-4.6 (4.4)	2.9-5.2 (4.0)	18-5.1 (4.2)	2.5-4.5 (3.5)	3.4-5.4 (4.4)	5.3-5.5 (5.4)	1.8-5.0 (3.4)
BOD (mg/l)	2.9-5.2 (4.4)	2.9-4.0 (2.4)	<0.2-2.8 (1.8)	0.3-4.4 (2.5)	0.9-5.1 (3.4)	5.4*	1.2-2.2 (1.7)
PO_4^{3-}-P (µmol/l)	1.3-2.7 (1.8)	0.5-1.8 (1.2)	1.5-2.4 (1.9)	0.9-2.3 (1.8)	0.4-2.1 (1.1)	1.1-1.2 (1.1)	0.9-2.8 (1.9)
NO_3^--N (µmol/l)	4.9-7.7 (6.9)	0.1-1.4 (0.6)	3.5-7.8 (5.4)	0.4-3.9 (3.0)	ND-7.0 (1.6)	2.0-3.4 (2.7)	0.2-8.1 (2.8)
NO_2^--N (µmol/l)	0.5-0.9 (0.7)	0.4-0.7 (0.6)	0.3-0.7 (0.5)	0.2-0.6 (0.5)	0.2-0.8 (0.4)	0.2-0.3 (0.3)	0.8-1.3 (1.1)
NH_4^+-N (µmol/l)	0.6-1.4 (1.0)	0.6-2.2 (1.1)	0.1-1.9 (0.4)	0.1-3.2 (0.4)	0.1-4.1 (0.7)	0.2-0.4 (0.3)	0.7-3.0 (1.6)
NTotal (µmol/l)	7.6-38.4 (20.6)	31.2 -53.7 (42.1)	-	8.0-73.9 (21.9)	7.6-25.0 (11.7)	-	-
PHc (µg/l)	0.9-1.9 (1.2)	0.9-1.7 (1.3)	1.9-21.0 (11.9)	0.2-2.2 (0.9)	3.7-7.3 (5.0)	26.0*	12.0*
Phenols (µg/l)	8-29 (21)	88-120 (104)	13-141 (64)	38-49 (41)	22-29 (29)	70*	61*

Average value given in parenthesis
*Single value

Table 4.3.17: Water quality of Baradi Mata Creek off during 1998-2005

Parameter	March 1999	October 2003	December 2004	May 2005
Temperature (°C)	24.9-27.6 (26.6)	29.0-31.0 (30.0)	19.0-22.8 (20.9)	28.5-29.1 (28.8)
pH	8.1-8.3 (8.3)	8.1	8.2-8.4 (8.3)	8.3-8.4 (8.4)
SS (mg/l)	49-123 (69)	38-46 (42)	34-42 (38)	36-108 (72)
Salinity (ppt)	36.5-37.2 (36.9)	36.5-37.0 (36.8)	37.6-40.4 (39.0)	38.4-40.6 (39.5)
DO (ml/l)	5.5-6.2 (5.6)	4.5-4.9 (48)	2.4-5.5 (4.0)	4.1-4.6 (4.4)
BOD (mg/l)	1.5-4.4 (2.8)	0.7-5.4 (3.1)	0.2-1.3 (0.8)	0.7-3.0 (2.4)
PO_4^{3-}-P (µmol/l)	0.5-1.5 (1.1)	0.2-1.4 (0.8)	0.3-1.1 (0.7)	0.8-1.8 (1.3)
NO_3^--N (µmol/l)	0.6-2.0 (1.2)	0.1-0.4 (0.3)	0.4-2.7 (1.6)	0.7-1.5 (1.1)
NO_2^--N (µmol/l)	0.1-0.4 (0.3)	0.1-0.2 (0.1)	0.2-0.4 (0.3)	0.3-0.9 (0.6)
NH_4^+-N (µmol/l)	1.6-5.1 (2.9)	0.3-2.8 (1.6)	0.3-0.8 (0.6)	0.7-1.2 (1.0)
NTotal (µmol/l)	31.2-47.7 (41.3)	9.8-13.4 (11.6)	-	-
PHc (µg/l)	0.8*	2.2*	12.0-17.8 (15.0)	5.7-31.0 (19.9)
Phenols (µg/l)	91-95 (93)	39*	55-63 (59)	7-19 (13)

Average value given in parenthesis
*Single value

Table 4.3.18: Water quality of Gulf off Mundra/Wandh during 1998-2005

Parameter	June 1998	March 1999	March 2000	June 2003	October 2003	December 2004	May 2005
Temperature (°C)	28.0-28.8 (28.5)	23.1-28.5 (24.7)	21.5-25.5 (24.0)	28.4-30.0 (29.1)	27.7-30.8 (29.7)	27.0-30.1 (29.0)	22.2-24.6 (23.4)
pH	8.2	7.7-8.3 (8.2)	8.0-8.4 (8.2)	7.9-8.0 (8.0)	8.0-8.2 (8.2)	8.1-8.4 (8.3)	8.2-8.5 (8.3)
SS (mg/l)	189-387 (292)	20-170 (69)	20-282 (87)	102-440 (145)	26-166 (89)	44-168 (106)	20-78 (49)
Salinity (ppt)	41.0-41.7 (41.3)	35.9-38.2 (37.3)	37.4-39.3 (38.2)	37.7-39.0 (38.6)	36.1-37.7 (36.6)	37.5-40.5 (39.1)	37.1-38.6 (38.0)
DO (ml/l)	2.0-4.6 (3.9)	1.8-6.2 (4.7)	1.7-5.3 (3.9)	1.9-4.6 (3.4)	2.9-5.2 (4.4)	1.0-4.8 (3.2)	3.1-6.0 (4.6)
BOD (mg/l)	1.3-3.1 (2.3)	<0.2-4.7 (2.2)	0.2-3.4 (1.3)	0.5-4.6 (2.4)	0.9-5.1 (3.3)	1.2-6.4 (3.3)	1.3-5.7 (3.5)
PO_4^{3-}-P (µmol/l)	0.8-1.8 (1.5)	0.4-4.4 (1.7)	0.2-11.7 (1.9)	1.1-3.0 (1.7)	0.5-2.7 (1.1	0.3-3.1 (1.7)	0.6-1.9 (2.5)
NO_3^--N (µmol/l)	4.4-6.6 (5.8)	ND-6.6 (1.9)	1.1-13.3 (3.4)	1.0-5.1 (3.0)	0.2-7.3 (3.1)	0.1-14.4 (7.3)	0.1-5.7 (2.90
NO_2^--N (µmol/l)	0.2-0.6 (0.4)	0.1-1.9 (0.4)	0.2-1.3 (0.5)	0.2-0.9 (0.5)	ND-0.7 (0.3)	0.2-1.0 (0.6)	0.1-0.4 (0.3)
NH_4^+-N (µmol/l)	0.2-0.6 (0.4)	0.4-6.4 (1.4)	ND-23.5 (1.3)	ND-4.4 (1.1)	ND-14.5 (0.8)	0.5-3.4 (2.0)	0.1-1.8 (1.0)
NTotal (µmol/l)	10.3-26.2 (20.6)	27.9-64.9 (51.1)	-	4.5-12.3 (8.1)	5.6-27.1 (8.8)	-	-
PHc (µg/l)	0.6-0.9 (0.8)	0.4-4.4 (1.3)	1.2-9.9 (2.5)	4.1-4.7 (4.6)	0.8-19.4 (4.6)	3.0-22.2 (12.6)	10.3-26.3 (12.2)
Phenols (µg/l)	4-7 (6)	ND-176 (86)	ND-106 (44)	18-44 (28)	6-66 (41)	11-44 (28)	13-59 (36)

Average value given in parenthesis
*Single value

Table 4.4.1: Sediment quality off Mundra/Wandh during January 2006

Sr No	Station Code	Sand (%)	Silt (%)	Clay (%)	Al (%)	Cr (µg/g)	Mn (µg/g)	Fe (%)	Co (µg/g)	Ni (µg/g)	Cu (µg/g)	Zn (µg/g)	PHc (µg/g)
		Subtidal											
1	1	25.0	65.0	10.0	2.6	25	385	3.3	13	16	14	101	0.2
2	2	49.4	33.2	17.4	1.2	20	296	2.1	11	9	10	97	0.2
3	3	5.6	88.6	5.8	3.5	46	641	5.1	19	27	20	132	0.2
4	4	5.1	87.7	7.2	1.4	28	334	3.6	32	16	13	109	0.1
5	5	5.2	86.2	8.6	1.7	61	307	6.5	11	44	31	767	0.2
6	6	3.3	86.1	10.6	3.7	68	719	8.4	13	55	36	244	0.8
7	7	24.3	67.3	84	4.2	49	602	6.8	28	53	23	258	0.4
8	9	66.6	19.8	13.6	4.8	69	928	8.9	38	61	42	250	0.4
9	10	48.8	37.0	14.2	2.8	46	630	5.6	21	25	18	203	0.4
		Intertidal											
10	TR-I	55.2	28.6	16.2	2.1	29	315	2.9	13	16	12	102	0.4
11	TR-II	61.0	25.4	13.6	1.6	17	319	2.5	12	13	11	97	0.9
12	TR-III	85.4	13.4	1.4	13	28	498	1.4	12	14	11	123	0.7
13	TR-IV	79.4	16.0	4.6	4.6	25	408	1.9	15	22	15	130	0.3
14	TR-V	84.4	2.6	13.0	9.0	32	393	2.5	23	28	19	94	0.3

*Dry wt basis except PHc which is in wet wt.

Table 4.4.2: Sediment quality at station 7 (Kotdi Creek) during September 1999

Metal	Min	Max	Av
Al (%)	6.7	9.7	8.2
Cr (µg/g)	95	175	135
Mn (µg/g)	608	1091	850
Fe (%)	3.2	6.3	4.8
Co (µg/g)	31	52	42
Ni (µg/g)	18	34	26
Cu (µg/g)	25	95	60
Zn (µg/g)	101	104	103
Hg (µg/g)	-	-	0.04
C (%)	-	-	0.3
P(µg/g)	588	736	662
PHc (µg/g)	0.1	0.5	0.3

*Dry wt basis except PHc which is in wet wt.
Average value given in parenthesis

Table 4.4.3: Water quality of Bocha Creek off during 1998-2005

Metal	June 1998	March 1999	March 2000	June 2003	October 2003	December 2004	May 2005
Al (%)	6.4-6.7 (6.6)	9.2-9.3 (9.3)	(8.5)	7.6-7.9 (7.8)	7.0-7.3 (7.2)	8.2	7.1
Cr (µg/g)	61-80 (71)	171-172 (172)	(139)	149-351 (250)	79-80 (80)	50	92
Mn (µg/g)	752-832 (792)	886-900 (893)	(837)	813-1288 (1051)	664-746 (705)	714	807
Fe (%)	4.3-4.7 (4.5)	4.8-5.0 (4.9)	(4.6)	5.1-10.8 (8.0)	4.5-4.9 (4.7)	5.0	4.9
Co (µg/g)	33-34 (34)	42-43 (43)	(39)	22-46 (34)	20-21 (21)	ND	22
Ni (µg/g)	53-59 (56)	66-68 (67)	(59)	59-103 (81)	58-60 (59)	57	80
Cu (µg/g)	33-39 (36)	(47)	(44)	45-157 (101)	47-50 (49)	-	40
Zn (µg/g)	71-79 (75)	98-106 (102)	(92)	123-173 (148)	93-97 (95)	151	77
Hg (µg/g)	0.30-0.53 (0.42)	0.20-0.24 (0.22)	(0.3)	0.29-0.38 (0.34)	-	ND	-
C (%)	0.7-0.8 (0.8)	0.8-0.9(0.9)	-	0.9-2.0 (15)	0.8-1.0 (0.9)	0.7	0.8
P(µg/g)	1337-1344 (1341)	807-882 (845)	(693)	815-877 (846)	343-736 (540)	1822	906
PHc (µg/g)	0.1-0.4 (0.3)	1.8-2.4 (2.1)	-	0.7-0.9 (0.8)	-	0.3	0.4

*Dry wt basis except PHc which is in wet wt.
Average value given in parenthesis

Table 4.4.4: Sediment quality of Navinal Creek off during 1998-2005

Metal	June 1998	March 1999	March 2000	June 2003	October 2003	December 2004	May 2005
Al (%)	6.0-6.4 (6.2)	7.6-7.9 (7.8)	(5.7)	7.0-7.5 (7.3)	5.8-6.7 (6.3)	6.9	7.2
Cr (µg/g)	50-54 (52)	136-139 (138)	(136)	140-193 (167)	98-105 (101)	123	90
Mn (µg/g)	718-758 (738)	823-847 (835)	(660)	726-783 (755)	597-672 (635)	1162	820
Fe (%)	4.2-4.4 (4.3)	(4.4)	(4.3)	4.7-4.8 (4.8)	3.6-4.0 (3.8)	5.1	4.4
Co (µg/g)	31-33 (32)	(37)	(36)	19-20 (20)	16-19 (18)	20	22
Ni (µg/g)	49-54 (52)	53-56 (55)	(54)	54-56 (55)	50-52 (51)	59	87
Cu (µg/g)	28-34 (31)	38	(40)	39-41 (40)	38-39 (39)	44	42
Zn (µg/g)	71-73 (72)	84-85 (85)	(79)	94-101 (98)	72-88 (80)	84	85
Hg (µg/g)	0.33-0.69 (0.51)	0.11-0.88 (0.50)	(0.2)	0.19-0.25 (0.22)	-	0.05	-
C (%)	0.7-0.8 (0.8)	(0.9)	-	0.7-0.8 (0.8)	0.7-1.0 (0.9)	0.8	0.9
P(µg/g)	715-1402 (1059)	788-827 (808)	(755)	581-639 (610)	191-365(278)	790	956
PHc (µg/g)	0.4	1.8-2.3 (2.1)	-	(1.2)	-	0.4	0.4

*Dry wt basis except PHc which is in wet wt.
Average value given in parenthesis

Table 4.4.5: Sediment quality of Gulf off Mundra/Wandh during 1998-2005

Metal	June 1998	March 1999	March 2000	June 2003	October 2003	December 2004	May 2005
Al (%)	1.5-4.2 (2.9)	0.6-7.6	(3.5)	0.6-5.9	1.3-4.8	1.8-4.9 (3.3)	1.9-6.2 (4.6)
Cr (µg/g)	28-66 (47)	7-150	(62)	15-75	18-41	73-102 (75)	19-60 (47)
Mn (µg/g)	408-546 (477)	431-772	(610)	454-621	312-490	555-995 (716)	274-730 (554)
Fe (%)	1.0-3.2 (2.1)	1.1-4.6	(2.6)	1.0-3.8	0.8-2.4	1.7-4.4 (3.2)	1.0-4.2 (2.9)
Co (µg/g)	11-21 (16)	15-41	(29)	0.7-14	2-8	3-16 (9.7)	4-16 (12)
Ni (µg/g)	11-22 (17)	ND-52	(29)	7-36	6-21	12-51 (26)	16-64 (45)
Cu (µg/g)	9-31 (20)	6-43	(20)	7-22	10-16	8-34 (19)	8-31 (22)
Zn (µg/g)	15-56 (36)	14-88	(66)	27-85	20-48	39-111 (71)	13-100 (55)
Hg (µg/g)	0.12-0.17 (0.15)	0.7-0.48	(0.5)	0.22-0.40	-	0.04-0.14 (0.09)	-
C (%)	0.1-0.3 (0.2)	0.1-0.7	-	0.2-0.8	0.1-0.23	0.2-0.5 (0.3)	0.1-0.6 (0.3)
P(µg/g)	337-746	341-802	(588)	291-637	102-275	465-883 (674)	474-857 (731)
PHc (µg/g)	0.3	0.1-2.8	-	0.6-1.0	-	0.1-0.4 (0.3)	0.1-0.3 (0.2)

*Dry wt basis except PHc which is in wet wt.
Average value given in parenthesis

Table 4.5.1 : (a) Mangrove areas and status of occurrence of major species of Gujarat (b) Composition and ecological status of mangroves and obligate halophytes off Mundra.

(a)*

District	1992	1998
Mangroves areas (km^2)		
Kachchh	601.8	938.0
Jamnagar	13.12	98.3
Junagad	0.8	0.3
Bhavnagar	14.5	6.2
Bharuch	10.9	17.1
Surat	7.8	5.0
Valsad	-	5.0
Total	**767.0**	**1066.9**
Status of occurrence of major species		
Species	**1950**	**1998**
Avicennia	Common	Common
Rhizosolenia	Common	Vulnerable
Aegiceras sp	Common	Endangered
Ceriops tagal	Common	Vulnerable
Sonneratia apetala	Common	Vulnerable
Bruigeria *sp.*	Common	Absent
**** Based on satellite data***		

(b)*

Species	Habit	Habitat	Ecological status
Mangroves			
Avicennia marina	Tree, shrubs	Intertidal	Dominant
Rhizophora mucronata	Tree	Intertidal	Stray
Salvodora persica	Tree, shrubs	Supralittoral	Common
Obligate Halophyta			
Sesuvium portulacastrum	Runner	Lower Supralittoral	Common
Salicarnia brachiata	Shrub	Supralittoral	Common
Sueda maritime	Shrub	Supralittoral	Rare

Table 4.5.2 : Range and average (parenthesis) of phytoplankton pigments off Mundra/ Wandh during January 2006

Station	Chlorophyll a (mg/m^3)		Phaeophytin (mg/m^3)		Chl a/Phaeo	
	S	B	S	B	S	B
1	12.4-14.1 (13.3)	3.8-8.8 (6.3)	9.2-9.4 (9.3)	6.3-10.2 (8.3)	1.3-1.5 (1.4)	0.6-0.9 (0.8)
2	0.4-1.7 (1.1)	0.4-1.9 (1.2)	0.7-1.8 (1.3)	1.4-2.1 (1.9)	0.2-2.5 (1.4)	0.2-1.4 (0.8)
3	0.2-0.4 (0.3)	0.2-0.2 (0.2)	0.2-2.0 (1.1)	0.2-2.2 (1.2)	0.1-0.2 (0.2)	0.1-0.1 (0.1)
4	0.2-0.6 (0.4)	0.2-0.4 (0.3)	1.0-1.6 (1.3)	0.9-1.4 (1.2)	0.1-0.6 (0.4)	0.1-0.5 (0.3)
5	0.2-0.4 (0.3)	0.2-0.4 (0.3)	0.5-3.8 (1.6)	0.4-1.9 (1.2)	0.1-0.9 (0.3)	0.1-0.8 (0.4)
6	0.2-0.9 (0.3)	0.2-0.6 (0.4)	1.1-1.9 (1.6)	1.5-3.7 (2.6)	0.1-0.8 (0.3)	0.1-0.3 (0.2)
7	0.4-1.7 (1.1)	0.2-1.1 (0.7)	1.3-2.4 (1.9)	1.2-2.2 (1.7)	0.2-1.3 (0.2)	0.1-0.9 (0.5)
8	0.4-1.1 (0.8)	0.4-0.6 (0.5)	1.8-2.3 (2.1)	1.8-3.5 (2.7)	0.2-0.6 (0.4)	0.2-0.2 (0.2)
9	0.2-0.6 (0.4)	0.4-0.4 (0.4)	1.0-1.4 (1.2)	0.8-0.9 (0.9)	0.9-0.6 (0.4)	0.5-0.6 (0.6)
10	0.6-0.9 (0.8)	0.4-0.9 (0.7)	0.6-0.7 (0.7)	0.8-2.4 (1.6)	0.9-1.3 (1.1)	0.2-1.1 (0.7)
11	0.4-1.5 (1.0)	0.6-0.6 (0.6)	0.4-1.7 (1.1)	0.1-1.5 (0.8)	0.3-3.3 (1.8)	0.3-0.4 (0.4)
12	0.2-0.4 (0.2)	0.2-0.2 (0.2)	1.4-2.2 (1.8)	2.3-2.3 (2.3)	0.1-0.3 (0.2)	0.1-0.1 (0.1)
13	0.9-1.1 (1.0)	1.1-1.1 (1.1)	0.9-1.1 (1.0)	0.9-1.0 (1.0)	0.8-1.2 (1.0)	1.0-1.2 (1.1)

Table 4.5.3 : Distribution of phytoplankton pigment off Mundra/Wandh during January 2006.

Station	Date	Time/ Tide	Chlorophyll a (mg/m³)		Phaeophytin (mg/m³)		Ratio of Chl a to Phaeo	
			S	B	S	B	S	B
1	07.01.06	1030 (Eb)	14.1	8.8	9.2	10.2	1.5	0.9
		1045 (Eb)	12.4	3.8	9.4	6.3	1.3	0.6
2	07.01.06	1130 (Eb)	0.4	0.4	1.8	2.1	0.2	0.2
		1145 (Eb)	1.7	1.9	0.7	1.4	2.5	1.4
3	07.01.06	1245 (Eb)	0.4	0.2	2.0	2.2	0.2	0.1
		1300 (Eb)	0.2	0.2	0.2	0.2	0.1	0.1
4	09.01.06	0900 (Fl)	0.6	0.4	1.2	0.9	0.6	0.5
		1100 (Eb)	0.6	0.2	1.0	1.7	0.6	0.1
		1300 (Eb)	0.2	0.4	1.6	0.9	0.1	0.5
		1500 (Eb)	0.2	0.2	1.0	1.4	0.2	0.1
5	10.01.06	0900 (Fl)	0.2	0.2	1.4	1.9	0.1	0.1
		1100 (Fl)	0.4	0.2	0.5	0.4	0.9	0.6
		1300 (Eb)	0.2	0.2	1.7	1.3	0.2	0.4
		1500 (Eb)	0.4	0.4	1.2	1.1	0.4	0.4
		1700 (Eb)	0.4	0.4	3.8	1.4	0.1	0.3
		1900 (Eb)	0.2	0.4	1.6	0.9	0.1	0.5
		2000 (Fl)	0.4	0.2	1.2	1.1	0.4	0.8

Table 4.5.3 (Contd 2)

Station	Date	Time/ Tide	Chlorophyll a (mg/m³)		Phaeophytin (mg/m³)		Ratio of Chl a to Phaeo	
			S	B	S	B	S	B
6	05.01.06	1200 (Eb)	0.9	0.6	1.1	2.9	0.8	0.2
		1400 (Fl)	0.2	0.2	1.6	3.7	0.1	0.1
		1600 (Fl)	0.2	0.2	1.9	2.2	0.1	0.1
		1800 (Fl)	0.2	0.4	1.9	1.5	0.1	0.3
7	09.01.06	0800 (Eb)	1.7	1.1	1.3	1.2	1.3	0.9
		0815 (Eb)	0.4	0.2	2.4	2.2	0.2	0.1
8	08.01.06	1030 (Eb)	1.1	0.6	1.8	3.5	0.6	0.2
		1045 (Eb)	0.4	0.4	2.3	1.8	0.2	0.2
9	02.01.06	0930 (Eb)	0.6	0.4	1.0	0.9	0.6	0.5
		0945 (Eb)	0.2	0.4	1.4	0.8	0.1	0.6
10	02.01.06	0930 (Fl)	0.9	0.4	0.6	2.4	1.3	0.2
		0945 (Fl)	0.6	0.9	0.7	0.8	0.9	1.1
11	11.01.06	1115 (Eb)	0.4	0.6	1.7	0.1	0.3	6.0
		1130 (Eb)	1.5	0.6	0.4	1.5	3.3	0.4
12	11.01.06	1315 (Eb)	0.2	0.2	2.2	2.3	0.1	0.1
		1330 (Eb)	0.4	0.2	1.4	2.3	0.3	0.1
13	11.01.06	1400 (Eb)	0.9	1.1	1.1	0.9	0.8	1.2
		1415 (Eb)	1.1	1.1	0.9	1.0	1.2	1.0

Table 4.5.4 : Range and average (parenthesis) of phytopigments off Mundra/Wandh during 1998 to 2006.

Station	Level	July 1998	March 1999	September 1999	March 2000	June 2003	October 2003	December 2004	May 2005	January 2006
Chlorophyll *a* (mg/m^3)										
Bocha Creek	S	1.6-2.7 (2.1)	0.5-2.7 (2.2)	-	1.6-2.7 (2.2)	2.1-2.4 (2.3)	1.7-1.7 (1.7)	1.1-1.1 (1.1)	1.1-1.5 (1.3)	0.9-1.1 (1.0)
	B	1.1-1.6 (1.3)	0.5-0.5 (0.5)	-	1.6-3.2 (2.4)	1.1-1.3 (1.2)	1.5-1.7 (1.6)	3.8-3.8 (3.8)	1.3-1.3 (1.3)	1.1-1.1 (1.1)
Navinal Creek	S	2.1-4.8 (5.4)	0.5-2.7 (1.6)	-	1.1-2.1 (1.6)	0.4-1.5 (1.0)	0.2-1.1 (0.7)	2.8-2.8 (2.8)	0.6-2.1 (1.4)	0.2-0.4 (0.2)
	B	2.7-5.3 (4.2)	-	-	1.1-2.1 (1.5)	0.4-1.3 (1.0)	0.2-1.5 (0.6)	7.5-7.5 (7.5)	0.2-1.5 (0.9)	0.2-0.2 (0.2)
Baradi Mata Creek	S	2.7-3.2 (3.0)	2.7-2.7 (2.7)	-	-	2.4-4.1 (3.3)	1.7-2.9 (1.9)	2.6-11.8 (7.6)	0.9-1.7 (1.2)	0.6-0.9 (0.8)
	B	2.1-3.2 (2.7)	0.5-2.7 (1.6)	-	-	3.5-4.3 (4.0)	1.5-2.4 (2.0)	2.4-38.5 (20.5)	0.2-3.2 (1.5)	0.4-0.9 (0.7)
Gulf	S	1.1-4.3 (2.4)	0.5-4.8 (1.3)	-	0.5-3.2 (1.7)	0.2-2.1 (0.8)	0.2-1.9 (0.8)	0.2-12.8 (10.9)	0.2-1.3 (0.6)	0.2-14.1 (2.0)
	B	1.6-2.1 (2.0)	0.5-3.2 (1.7)	-	0.5-2.1 (1.1)	0.2-4.1 (1.1)	0.2-3.4 (1.2)	0.6-10.7 (9.1)	0.2-2.1 (0.9)	0.2-8.8 (1.1)
Kotdi Creek	S	-	-	12.8-16.0 (14.4)	-	-	-	-	-	0.4-1.7 (1.1)
	B	-	-	-	-	-	-	-	-	0.2-1.1 (0.7)

Table 4.5.4 (Contd 2)

Station	Level	July 1998	March 1999	September 1999	March 2000	June 2003	October 2003	December 2004	May 2005	January 2006
Phaeophytin (mg/m^3)										
Bocha Creek	S	1.1-1.4 (1.2)	0.2-1.1 (0.6)	-	0.3-0.6 (0.5)	0.2-0.4 (0.3)	0.5-0.8 (0.7)	0.1-0.3 (0.2)	2.7-3.7 (3.2)	0.9-1.1 (1.0)
	B	0.4-1.0 (0.7)	0.2-0.2 (0.2)	-	0.2-1.0 (0.6)	0.4-0.9 (0.7)	0.9-1.0 (1.0)	0.9-1.1 (1.0)	2.5-2.8 (2.7)	0.9-1.1 (1.0)
Navinal Creek	S	0.1-1.0 (1.5)	0.1-3.5 (1.4)	-	1.0-1.0 (1.0)	0.5-0.3 (0.4)	0.2-0.5 (0.4)	0.4-0.5 (0.5)	2.2-6.2 (4.2)	1.4-2.2 (1.8)
	B	0.6-2.2 (1.5)	0.2-0.7 (0.4)	-	-	1.0-1.3 (1.2)	0.2-0.8 (0.5)	1.2-1.5 (1.4)`	2.7-6.4 (4.6)	2.3-2.3 (2.3)
Baradi Mata Creek	S	1.7-2.2 (2.0)	0.3-1.1 (0.7)	-	-	0.3-0.4 (0.4)	0.3-0.4 (0.4)	0.4-2.6 (1.6)	3.1-4.0 (3.7)	0.6-0.7 (0.7)
	B	1.3-2.7 (2.0)	0.3-0.9 (0.6)	-	-	0.7-0.8 (0.8)	0.5-1.0 (0.8)	1.0-4.0 (2.6)	5.2-10.4 (7.7)	0.8-2.4 (1.6)
Gulf	S	0.9-2.1 (1.3)	0.1-1.5 (0.4)	-	0.1-0.8 (0.3)	0.1-0.8 (0.4)	0.1-0.8 (0.3)	0.1-26.7 (2.3)	0.6-7.2 (2.5)	0.2-9.4 (2.3)
	B	1.0-1.6 (1.3)	0.1-2.7 (0.7)	-	0.1-1.2 (0.7)	0.1-1.9 (0.8)	0.1-1.5 (0.7)	0.6-26.4 (3.2)	0.4-6.0 (2.6)	0.1-10.2 (2.3)
Kotdi Creek	S	-	-	3.3-3.4 (3.4)	-	-	-	-	-	1.3-2.4 (1.9)
	B	-	-	-	-	-	-	-	-	1.2-2.2 (1.7)

Table 4.5.5: Range and average (parenthesis) of phytoplankton population off Mundra/Wandh during January 2006.

Station	Date	Cell count (nox10^3/l)		Total genera (no)		Major genera	
		S	B	S	B	S	B
1	07.01.06	1344.7*	5761.5*	8*	7*	*Thalassiosira* *Fragilaria* *Gyrosigma* *Leptocylindrus*	*Thalassiosira* *Fragilaria* *Nitzschia* *Gyrosigma*
2	07.01.06	48.0*	40.8*	18*	16*	*Melosira* *Skeletonema* *Coscinodiscus* *Thalassiosira*	*Melosira* *Thalassiosira* *Navicula* *Biddulphia*
3	07.01.06	28.8*	32.8*	15*	18*	*Melosira* *Thalassiosira* *Thalassionema* *Biddulphia*	*Chaetoceros* *Bacillaria* *Navicula* *Melosira*
4	09.01.06	12.8-13.6 (13.2)	11.2-19.2 (15.2)	10-10 (10)	9-11 (10)	*Navicula* *Thalassiosira* *Diploneis* *Fragilaria*	*Fragilaria* *Guinardia* *Thalassiothrix* *Biddulphia*
5	10.01.06	8.0-10.4 (9.2)	11.2-36.8 (24)	10-12 (11)	11-16 (14)	*Thalassiosira* *Rhizosolenia* *Coscinodiscus* *Nitzschia*	*Fragilaria* *Thalassionema* *Coscinodiscus* *Thalassiosira*
6	05.01.06	20.8*	18.4*	14*	11*	*Nitzschia* *Coscinodiscus* *Melosira* *Thalassiosira*	*Thalassiosira* *Navicula* *Coscinodiscus* *Thalassionema*
7	09.01.06	97.6*	13.6*	13*	8*	*Thalassiosira* *Fragilaria* *Biddulphia* *Navicula*	*Nitzschia* *Melosira* *Fragilaria* *Thalassiosira*

Table 4.5.5 (Contd 2)

Station	Date	Cell count ($nox10^3/l$)		Total genera (no)		Major genera	
		S	B	S	B	S	B
8	08.01.06	16.8*	51.2*	9*	15*	*Melosira* *Skeletonema* *Coscinodiscus* *Thalassionema*	*Fragilaria* *Thalassiosira* *Thalassionema* *Ditylum*
9	08.01.06	18.4*	27.2	13*	14*	*Thalassionema* *Nitzschia* *Biddulphia* *Coscinodiscus*	*Fragilaria* *Coscinodiscus* *Melosira* *Thalassiosira*
10	08.01.06	12.0*	13.6*	11*	12*	*Melosira* *Coscinodiscus* *Biddulphia* *Thalassiosira*	*Pseudoguinardia* *Nitzschia* *Coscinodiscus* *Diploneis*
11	11.01.06	5.2*	4.8*	11*	10*	*Thalassiosira* *Thalassionema* *Navicula* *Nitzschia*	*Thalassionema* *Thalassiosira* *Coscinodiscus* *Ditylum*
12	11.01.06	12.0*	32.8*	10*	15*	*Thalassionema* *Rhizosolenia* *Diploneis* *Coscinodiscus*	*Thalassionema* *Chaetoceros* *Nitzschia* *Biddulphia*
13	11.01.06	9.6*	19.2*	8*	17*	*Biddulphia* *Nitzschia* *Thalassiosira* *Rhizosolenia*	*Thalassiosira* *Nitzschia* *Navicula* *Gyrosigma*

* Single reading.

Table 4.5.6 : Distribution of phytoplankton population off Mundra/Wandh during January 2006.

Station	Date	Time (Tide)	Cell count (no.x10^3/l)		Total genera (no)	
			S	B	S	B
1	07.01.06	1030 (Eb)	1344.7	5761.5	8	7
2	07.01.06	1130 (Eb)	48.0	40.8	18	16
3	07.01.06	1245 (Eb)	28.8	32.8	15	18
4	09.01.06	0900 (Fl)	12.8	19.2	10	10
		1530 (Eb)	13.6	11.2	9	11
5	10.01.06	1600 (Eb)	8.0	11.2	10	11
		1000 (Fl)	10.4	36.8	12	16
6	05.01.06	1200 (Eb)	20.8	18.4	14	11
7	09.01.06	0800 (Fl)	97.6	13.6	13	8
8	08.01.06	1030 (Eb)	16.8	51.2	9	15
9	08.01.06	0930 (Eb)	18.4	27.2	13	14
10	08.01.06	1115 (Fl)	12.0	13.6	11	12
11	11.01.06	1230 (Eb)	5.2	4.8	11	10
12	11.01.06	1315 (Eb)	12.0	32.8	10	13
13	11.01.06	1330 (Eb)	9.6	19.2	8	17

Table 4.5.7 : Range and average (parenthesis) of phytoplankton population off Mundra/Wandh during 1998-2006.

Station	Parameter	Level	July 1998	August 1998	March 1999	September 1999	March 2000
Bocha Creek	Cell count ($nox10^3/l$)	S	12.3-26.5 (17.4)	16.0-132.2 (70.7)	47.6-187.2 (89.8)	-	12.0-18.9 (14.85)
		B	12.0 (12)	-	48-51.2 (49.6)	-	22.1 (22.1)
	Total genera (no)	S	4-9 (5)	5-14 (9)	9-11 (10)	-	11-17 (14)
		B	5 (5)	-	9-10 (10)	-	15 (15)
	Major genera	S	*Nitzschia*	*Hemiaulus* *Surirella*	*Navicula* *Nitzschia* *Thalassiosira* *Biddulphia*	-	*Nitzschia* *Navicula* *Rhizosolenia*
		B	*Nitzschia*	-	*Nitzschia*	-	*Nitzschia* *Thalassiosira* *Navicula*
Navinal Creek	Cell count ($nox10^3/l$)	S	13.8-16.0 (14.9)	25.3-92.6 (50.0)	50.4-61.2 (58.8)	-	3.1-19.4 (9.8)
		B	4.0-6.5 (5.3)	-	-	-	7.0-16.0 (11.0)
	Total genera (no)	S	5-5 (5)	6-7 (7)	8-11 (10)	-	10-13 (11)
		B	4-4 (4)	-	-	-	8-16 (12)
	Major genera	S	*Fragilaria* *Nitzschia*	*Fragilaria* *Thalassiosira*	*Thalassiothrix* *Nitzschia* *Thalassionema* *Coscinodiscus*	-	*Thalassiosira* *Coscinodiscus* *Nitzschia* *Fragilaria* *Navicula*
		B	*Nitzschia* *Coscinodiscus*	-	-	-	*Nitzschia* *Thalassiosira* *Fragilaria* *Gyrosigma* *Navicula*

Table 4.5.7 (Contd 2)

Station	Parameter	Level	June 2003	October 2003	December 2004	May 2005	January 2006
Bocha Creek	Cell count (nox10^3/l)	S	145.2-234 (189.6)	172.2-206.4 (189.3)	134.2	14.0-160.4 (97.0)	9.6
		B	75.6-201.6 (138.6)	134.4-168 (151.2)	389.6	4.8-256.8 (133.2)	19.2
	Total genera (no)	S	14-18 (16)	17-23 (20)	21	9-11 (10)	8
		B	8-14 (11)	13-22 (18)	17	5-12 (10)	17
	Major genera	S	*Nitzschia* *Thalassiosira* *Skeletonema*	*Thalassiosira* *Thalassionema*	*Chaetoceros* *Bacillaria* *Melosira* *Nitzschia*	*Skeletonema* *Nitzschia* *Thalassionema* *Thalassiosira*	*Biddulphia* *Nitzschia* *Thalassiosira* *Rhizosolenia*
		B	*Nitzschia* *Navicula* *Thalassiosira*	*Thalassiosira* *Nitzschia*	*Chaetoceros* *Nitzschia* *Rhizosolenia* *Navicula*	*Skeletonema* *Thalassiosira* *Navicula* *Nitzschia*	*Thalassiosira* *Nitzschia* *Navicula* *Gyrosigma*
Navinal Creek	Cell count (nox10^3/l)	S	124.2-135.0 (129.6)	105.4-113.4 (109.4)	289	256	12.0
		B	102.4-188 (105.6)	52.0-147.6 (98.8)	759.2	444.8	32.8
	Total genera (no)	S	14-14 (14)	19-22 (21)	15	9	10
		B	9-11 (10)	17-19 (18)	15	11	15
	Major genera	S	*Thalassiosira* *Nitzschia* *Navicula* *Coscinodiscus*	*Thalassiosira* *Fragilaria* *Nitzschia* *Coscinodiscus*	*Chaetoceros* *Skeletonema* *Rhizosolenia* *Nitzschia*	*Skeletonema* *Thalassionema* *Rhizosolenia* *Thalassiosira*	*Thalassionema* *Rhizosolenia* *Diploneis* *Coscinodiscus*
		B	*Nitzschia* *Thalassiosira* *Coscinodiscus* *Navicula*	*Fragilaria* *Nitzschia* *Thalassiosira* *Biddulphia*	*Chaetoceros* *Rhizosolenia* *Navicula* *Nitzschia*	*Skeletonema* *Thalassionema* *Thalassiosira* *Thalassiothrix*	*Thalassionema* *Chaetoceros* *Nitzschia* *Biddulphia*

Table 4.5.7 (Contd 3)

Station	Parameter	Level	July 1998	August 1998	March 1999	September 1999	March 2000
Baradi Ma a Creek	Cell count (nox10^3/l)	S	-	197-413 (318.33)*	61.2	-	-
		B	-	188-336 (289.8)	60.8	-	-
	Total genera (no)	S	-	11-13 (12)	8	-	-
		B	-	11-12 (12)	11	-	-
	Major genera	S	-	*Fragillaria*	*Nitzschia* *Navicula* *Fragillaria*	-	-
		B	-	*Fragillaria*	*Nitzschia* *Coscinodiscus* *Navicula* *Fragilaria*	-	-
Gulf (Mundra)	Cell count (nox10^3/l)	S	5.7-6.8 (6.3)	4.8-36.5 (19.1)	57.0-75.2 (67.9)	-	2.1-18.9 (10)
		B	3.5-3.7 (3.6)	-	36.4-87.0 (62.3)	-	1.4-19.6 (10)
	Total genera (no)	S	2-3 (3)	3-8 (5)	7-13 (10)	-	8-14 (110)
		B	2-2 (2)	-	8-13 (11)	-	8-16 (11)
	Major genera	S	*Nitzschia* *Pleurosigma*	*Nitzschia* Thalassiosira	*Coscinodiscus* *Synedra* *Thalassiosira*	-	*Nitzschia* *Thalassiosira* *Navicula*
		B	*Nitzschia* *Coscinodiscus*	-	*Thalassiosira* *Coscinodiscus* *Synedra*	-	*Nitzschia* *Thalassiosira* *Rhizosolenia*

Table 4.5.7 (Contd 4)

Station	Parameter	Level	June 2003	October 2003	December 2004	May 2005	January 2006
Baradi Mata Creek	Cell count (nox10^3/l)	S	196.0	183.6	285-1194 (807)	52.8-104.8 (78.8)	12.0
		B	132.0	154.4	236-3817 (2027)	16.0-92.8 (54.4)	13.6
	Total genera (no)	S	13	19	13-16 (14)	8-19 (14)	11
		B	13	21	14-19 (16)	11-12 (12)	12
	Major genera	S	*Thalassiosira Navicula Nitzschia Rhizosolenia*	*Thalassiosira Fragillaria Nitzschia*	*Chaetoceros Rhizosolenia Navicula Nitzschia*	*Skeletonema Nitzschia Thalassionema*	*Melosira Coscinodiscus Biddulphia Thalassiosira*
		B	*Nitzschia Navicula Skeletonema Coscinodiscus*	*Nitzschia Thalassiosira Chaetoceros*	*Chaetoceros Rhizosolenia Nitzschia*	*Skeletonema Thalassiosira*	*Pseudoguinarida Nitzschia Coscinodiscus Diploneis*
Gulf (Mundra)	Cell count (nox10^3/l)	S	12.9-204 (70.8)	26-202 (89.3)	41-12781 (2111)	31.2-18.2 (82.3)	5.2-1345 (167)
		B	33.8-427.2 (110.9)	34.6-339 (134)	58-10476 (1566)	18.0-624 (110)	4.8-5762 (664)
	Total genera (no)	S	8-13 (10)	9-22 (16)	12-22 (17)	10-14 (12)	8-18 (12)
		B	9-13 (11)	9-22 (16)	13-19 (16)	9-17 (13)	7-18 (13)
	Major genera	S	*Coscinodiscus Navicula Nitzschia Thalassiosira*	*Nitzschia Thalassiosira Rhizosolenia*	*Chaetoceros Nitzschia Rhizosolenia Thalassiosira*	*Skeletonema Nitzschia Thalassiothrix Navicula*	*Thalassiosira Coscinodiscus Navicula Rhizosolenia*
		B	*Coscinodiscus Navicula Nitzschia Thalassiosira*	*Nitzschia Thalassiosira Fragilaria*	*Chaetoceros Nitzschia Rhizosolenia Melosira*	*Nitzschia Thalassiothrix Navicula Coscinodiscus*	*Thalassiosira Coscinodiscus Navicula Fragillaria*

Table 4.5.7 (Contd 5)

Station	Parameter	Level	July 1998	August 1998	March 1999	September 1999	March 2000
Kotdi Creek	Cell count (nox10^3/l)	S	-	-	-	1140-1789 (1465)	-
		B	-	-	-	-	-
	Total genera (no)	S	-	-	-	13-14 (14)	-
		B	-	-	-	-	-
	Major genera	S	-	-	-	*Thalassiosira Nitzschia Fragilaria Hemiaulus*	-
		B	-	-	-	-	-

Table 4.5.7 (Contd 6)

Station	Parameter	Level	June 2003	October 2003	December 1004	May 2005	January 2006
Kotdi Creek	Cell count ($nox10^3/l$)	S	-	-	-	-	97.6
		B	-	-	-	-	13.6
	Total genera (no)	S	-	-	-	-	13
		B	-	-	-	-	8
	Major genera	S	-	-	-	-	*Thalassiosira Fragilaria Biddulphia Navicula*
		B	-	-	-	-	*Nitzschia Melosira Fragilaria Thalassiosira.*

Table 4.5.8 : Abundance of phytoplankton off Mundra/Wandh during January 2006.

Name of the genera	Station												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Amphiprora	+	-	+	-	+	+	-	+	+	+	-	-	+
Amphora	+	-	-	-	+	-	-	-	-	-	-	-	-
Asteromphalus	-	-	-	-	+	+	-	-	-	-	-	-	-
Bacillaria	-	+	+	-	+	-	-	+	-	+	-	+	-
Bellerochea	-	-	-	-	-	-	-	-	-	-	-	-	-
Biddulphia	-	+	+	+	+	+	+	+	+	+	+	+	+
Chaetoceros	-	+	+	-	-	-	-	-	-	-	-	+	+
Coscinodiscus	-	+	+	+	+	+	+	+	+	+	+	+	+
Cylindrotheca	-	-	-	-	-	-	+	-	+	+	-	-	+
Cyclotella	-	-	-	+	-	-	-	-	-	-	-	-	-
Diploneis	-	-	-	+	+	-	-	+	+	+	+	+	-
Dictyocha	-	+	-	-	-	-	-	-	-	-	-	-	-
Ditylum	-	+	+	-	+	+	+	+	+	+	+	+	+
Eucampia	-	-	-	-	-	-	-	-	-	-	-	-	+
Fragillaria	+	+	+	+	+	-	+	+	+	+	+	+	+
Guinardia	-	-	-	+	-	-	-	-	-	-	-	-	-
Gyrosigma	+	+	+	+	+	+	+	+	+	-	-	+	+
Hemiaulus	-	-	-	-	-	-	+	-	-	-	-	-	-
Hyalodiscus	-	+	+	-	-	-	-	-	-	-	-	-	-
Leptocylindrus	+	-	-	-	-	-	-	-	-	-	-	-	
Licmophora	-	-	-	-	+	+	-	-	-	-	-	-	-
Melosira	-	+	+	-	-	+	+	+	+	+	+	+	-
Meuniera	-	-	-	-	-	-	-	-	-	+	-	-	-
Navicula	+	+	+	+	+	+	+	+	+	-	+	+	+
Nitzschia	+	+	+	+	+	+	+	-	+	+	+	+	+
Peridinium	-	-	+	+	-	-	-	-	-	-	-	+	-
Pleurosigma	+	+	+	+	+	+	+	+	+	+	+	+	+
Protoperidinium	-	-	-	-	-	-	-	+	-	-	-	-	-
Pseudoguinardia	-	-	-	-	-	+	-	-	-	+	-	-	+
Rhizosolenia	-	+	+	+	+	+	+	+	+	+	+	+	+
Skeletonema	-	+	-	-	-	-	-	+	-	-	-	-	-
Stauroneis	-	+	-	-	-	-	-	-	-	-	-	-	-
Streptotheca	-	-	-	-	+	-	-	+	+	-	-	-	-
Surirella	-	+	-	-	+	-	+	+	+	-	+	+	-
Synedra	-	+	+	-	-	+	-	-	-	-	-	-	+
Thalassionema	+	+	+	-	+	+	-	+	+	+	+	+	+
Thalassiosira	+	+	+	+	+	+	+	+	+	+	+	+	+
Thalassiothrix	+	+	+	+	-	-	-	-	-	-	-	-	-
Trichodesmium	-	-	-	-	-	-	-	-	-	-	-	+	-
Tropido neis	-	-	-	-	+	-	-	-	-	-	-	-	-
Unidentified	-	-	-	-	+	+	+	-	-	-	-	+	-
Total genera	11	12	19	14	21	17	15	18	17	16	13	19	18

Table 4.5.9 : Range and average (parenthesis) of zooplankton off Mundra/Wandh during January 2006.

Station (Date)	Biomass (ml/100 m³)	Population (nox10³/100 m³)	Total groups (no)	Major group (%)
1 (07.01.2006)	6.1-12.6 (9.4)	44.4-141.0 (92.7)	17-21 (19)	Copepods (54.8), foraminiferans (16.4), decapod larvae (8.5), chaetognaths (6.5), ostracods (5.4), gastropods (4.6), lamellibranchs (3.6), siphonophores (0.1), medusae (0.1), ctenophores (0.1), others (0.1).
2 (07.01.2006)	3.1-8.0 (5.6)	26.6-46.2 (36.4)	16-19 (18)	Copepods (46.0), decapod larvae (21.9), chaetognaths (8.8), foraminiferans (8.1), lamellibranchs (7.2), gastropods (6.8), siphonophores (0.4), ctenophores (0.2), polychaetes (0.2), medusae (0.1), ostracods (0.1), fish larvae (0.1), others (0.1).
3 (07.01.2006)	3.5-5.5 (4.5)	25.2-32.1 (28.6)	14-15 (15)	decapod larvae (62.6), copepods (35.9), chaetognaths (0.4), gastropods (0.3), foraminiferans (0.2), siphonophores (0.2), ctenophores (0.1), polychaetes (0.1), lamellibranchs (0.1), others (0.1).
4 (09.01.2006)	1.9-5.5 (3.1)	5.1-34.7 (21.4)	14-18 (17)	Copepods (53.9), decapod larvae (24.2), gastropods (7.2), chaetognaths (6.4), lamellibranchs (5.2), ctenophores (1.5), appendicularians (0.6), siphonophores (0.2), medusae (0.2), polychaetes (0.2), foraminiferans (0.1), ostracods (0.1) others (0.2).

Table 4.5.9 (Contd 2)

Station (Date)	Biomass (ml/100 m³)	Population (nox10³/100 m³)	Total groups (no)	Major group (%)
5 (10.01.2006)	1.6-13.1 (5.0)	5.1-29.7 (18.5)	14-20 (16)	Copepods (61.3), gastropods (13.5), decapod larvae (8.1), chaetognaths (6.8), ostracods (5.8), siphonophores (1.2), medusae (0.9), polychaetes (0.8), ctenophores (0.6), appendicularians (0.4), foraminiferans (0.2), lamellibranchs (0.1), fish larvae (0.1), mysids (0.1), others (0.7).
6 (05.01.2006)	2.2-9.5 (5.5)	10.6-40.7 (25.4)	14-19 (17)	Copepods (61.5), decapod larvae (15.2), polychaetes (12.4), chaetognaths (8.1), ostracods (0.6), mysids (0.6), siphonophores (0.3), ctenophores (0.3), medusae (0.2), gastropods (0.2), lamellibranchs (0.2), appendicularians (0.2), foraminiferans (0.1), others (0.1).
7 (08.01.2006)	2.1-2.9 (2.5)	14.4-18.8 (16.6)	16-18 (17)	Copepods (69.1), decapod larvae (25.8), chaetognaths (2.4), gastropods (0.6), polychaetes (0.5), foraminiferans (0.4), siphonophores (0.2), medusae (0.2), ctenophores (0.2), ostracods (0.1), lamellibranchs (0.1), appendicularians (0.1), fish larvae (0.1), others (0.2).

Table 4.5.9 (Contd 3)

Station (Date)	Biomass (ml/100 m³)	Population (nox10³/100 m³)	Total groups (no)	Major group (%)
8 (08.01.2006)	3.8-8.1 (5.9)	15.3-24.1 (18.6)	15-18 (17)	Copepods (52.8), decapod larvae (21.0), gastropods (12.1), chaetognaths (6.6), ctenophores (2.4), ostracods (2.5), siphonophores (1.4), lamellibranchs (0.4), foraminiferans (0.2), medusae (0.1), polychaetes (0.1), appendicularians (0.1), fish eggs (0.1), fish larvae (0.1), others (0.1).
9 (08.01.2006)	2.2-10.6 (6.4)	14.7-19.3 (17.0)	13-17 (15)	Copepods (59.7), decapod larvae (35.2), gastropods (2.1), chaetognaths (1.3), ctenophores (0.6), siphonophores (0.3), polychaetes (0.2), fish larvae (0.2), medusae (0.1), appendicularians (0.1), others (0.2).
10 (11.01.2006)	1.9-3.0 (2.5)	1.7-3.2 (2.4)	11-15 (13)	Copepods (70.2), gastropods (9.8), ostracods (9.1), decapod larvae (3.2), lamellibranchs (3.2), foraminiferans (2.0), siphonophores (1.1), chaetognaths (0.8), polychaetes (0.3), amphipods (0.1), others (0.2).
11 (11.01.2006)	3.6-4.9 (4.3)	11.6-15.5 (13.5)	14-15 (15)	Copepods (52.9), decapod larvae (44.4), gastropods (1.1), chaetognaths (1.0), ostracods (0.2), foraminiferans (0.1), lamellibranchs (0.1), fish eggs (0.1), others (0.1).

Table 4.5.9 (Contd 4)

Station (Date)	Biomass (ml/100 m^3)	Population (nox10^3/100 m^3)	Total groups (no)	Major group (%)
12 (11.01.2006)	3.3-4.5 (3.9)	4.9-5.8 (5.3)	13-16 (15)	Copepods (73.0), decapod larvae (21.0), gastropods (1.4), siphonophores (0.8), lamellibranchs (0.8), fish eggs (0.8), chaetognaths (0.7), polychaetes (0.6), foraminiferans (0.3), appendicularians (0.3), stomatopods (0.2), others (0.1).
13 (11.01.2006)	2.3-6.7 (4.5)	3.7-10.4 (7.0)	14-18 (16)	Copepods (46.7), decapod larvae (40.8), gastropods (5.3), lamellibranchs (2.7), fish eggs (2.7), chaetognaths (0.6), foraminiferans (0.4), polychaetes (0.2), siphonophores (0.1), fish larvae (0.1), isopods (0.1), marine insects (0.1) others (0.1).

Table 4.5.10 : Distribution of zooplankton off Mundra/Wandh during January 2006.

Station (Date)	Time (h)/Tide	Biomass (ml/100 m³)	Population (no x 10³/100 m³)	Total groups (no)	Major group (%)
1 (07.04.06)	1030 (Eb)	12.6	141.0	17	Copepods (55.2), foraminiferans (18.5), decapod larvae (9.2), chaetognaths (5.7), ostracods (4.2), gastropods (3.9), lamellibranchs (3.1), ctenophores (0.1), medusae (0.1), siphonophores (0.1), others (0.1).
	1045 (Eb)	6.1	44.4	21	Copepods (53.7), foraminiferans (10.6), ostracods (8.9), chaetognaths (8.3), gastropods (6.6), decapod larvae (6.0), lamellibranchs (5.2), siphonophores (0.2), medusae (0.1), ctenophores (0.1), mysids (0.1), others (0.2).
2 (07.04.06)	1130 (Eb)	8.0	26.6	19	Copepods (51.8), decapod larvae (26.2), chaetognaths (9.6), lamellibranchs (6.5), foraminiferans (4.5), siphonophores (0.3), gastropods (0.3), ctenophores (0.2), ostracods (0.2), polychaetes (0.1), fish larvae (0.1), medusae (0.1), others (0.1).
	1145 (Eb)	3.1	46.2	16	Copepods (42.8), decapod larvae (19.4), gastropods (10.6), foraminiferans (10.1), chaetognaths (8.4), lamellibranchs (7.5), siphonophores (0.4), polychaetes (0.21), ctenophores (0.2), medusae (0.1), ostracods (0.1), fish larvae (0.1), others (0.1).

Table 4.5.10 (Contd 2)

Station (Date)	Time (h)/Tide	Biomass (ml/100 m^3)	Population (nox10^3/100 m^3)	Total groups (no)	Major group (%)
3 (07.04.06)	1245 (Eb)	3.5	25.2	14	Decapod larvae (63.7), copepods (34.4), chaetognaths (0.6), siphonophores (0.3), gastropods (0.2), foraminiferans (0.2), lamellibranchs (0.1), polychaetes (0.1), ctenophores (0.1), fiah larvae (0.1), others (0.1).
	1300 (Eb)	5.5	32.1	15	Decapod larvae (61.8), copepods (37.0), chaetognaths (0.3), gastropods (0.3), foraminiferans (0.2), polychaetes (0.1), lamellibranchs (0.1), siphonophores (0.1), others (0.1).
4 (09.04.06)	0900 (Fl)	5.5	31.2	18	Copepods (58.5), decapod larvae (35.0), ctenophores (2.5), chaetognaths (1.8), appendicularians (1.1), gastropods (0.3), foraminiferans (0.2), medusae (0.2), polychaetes (0.1), mysids (0.1), fish larvae (0.1), siphonophores (0.1), others (0.1).
	1100 (Eb)	2.4	14.4	18	Copepods (67.1), decapod larvae (27.4), chaetognaths (3.2), gastropods (1.1), ctenophores (0.8), siphonophores (0.3), others (0.1).

Table 4.5.10 (Contd 3)

Station (Date)	Time (h)/Tide	Biomass (ml/100 m³)	Population (no x 10³/100 m³)	Total groups (no)	Major group (%)
4 (09.04.06)	1300 (Eb)	2.7	34.7	16	Copepods (43.5), gastropods (16.2), decapod larvae (13.6), lamellibranchs (12.6), chaetognaths (12.1), ctenophores (0.5), siphonophores (0.4), polychaetes (0.4), appendicularians (0.3), medusae (0.20, ostracods (0.1), others (0.1).
	1500 (Eb)	1.9	5.1	14	Copepods (60.8), decapod larvae (21.9), gastropods (5.6), chaetognaths (5.0), ctenophores (4.2), foraminiferans (0.5), appendicularians (0.4), polychaetes (0.4), lamellibranchs (0.3), medusae (0.3), siphonophores (0.2), ostracods (0.2), others (0.2).
5 (10.04.06)	0900 (Fl)	3.1	17.1	16	Copepods (86.6), decapod larvae (5.4), ctenophores (2.4), polychaetes (1.6), medusae (1.4), chaetognaths (1.3), gastropods (0.4), lamellibranchs (0.4), foraminiferans (0.3), cumaceans (0.1), others (0.1).
	1100 (Fl)	2.6	15.2	14	Copepods (63.4), chaetognaths (18.8), decapod larvae (13.9), gastropods (1.3), siphonophores (1.0), ctenophores (0.6), medusae (0.4), foraminiferans (0.3), polychaetes (0.1), others (0.2).

Table 4.5.10 (Contd 4)

Station (Date)	Time (h)/Tide	Biomass (ml/100 m³)	Population (no x 10³/100 m³)	Total groups (no)	Major group (%)
5 (10.04.06)	1300 (Eb)	1.6	5.0	14	Copepods (80.7), decapod larvae (14.5), gastropods (1.8), chaetognaths (0.7), foraminiferans (0.6), appendicularians (0.3), siphonophores (0.3), ostracods (0.3), ctenophores (0.3), polychaetes (0.2), medusae (0.1), lamellibranchs (09.1), others (0.1).
	1500 (Eb)	3.5	21.1	15	Copepods (63.3), decapod larvae (14.9), chaetognaths (10.5), gastropods (9.9), ctenophores (0.5), foraminiferans (0.3), appendicularians (0.2), polychaetes (0.1), fish larvae (0.1), ostracods (0.1), others (0.1).
	1700 (Eb)	3.6	14.4	15	Copepods (60.0), decapod larvae (16.7), chaetognaths (12.9), gastropods (8.1), ctenophores (1.0), foraminiferans (0.4), medusae (0.4), siphonophores (0.3), appendicularians (0.1), others (0.1).
	2000 (Fl)	7.4	27.1	19	Copepods (61.4), gastropods (15.3), ostracods (12.5), siphonophores (4.5), chaetognaths (4.5), mysids (0.4), decapod larvae (0.3), medusae (0.4), lamellibranchs (0.2), polychaetes (0.2), fish larvae (0.1), foraminiferans (0.1), ctenophores (0.1), amphipods (0.1), appendicularians ().1), others (0.1).

Table 4.5.10 (Contd 5)

Station (Date)	Time (h)/Tide	Biomass (ml/100 m³)	Population (nox10³/100 m³)	Total groups (no)	Major group (%)
5 (10.04.06)	1900 (Fl)	13.1	29.7	20	Copepods (41.7), gastropods (32.5), ostracods (13.9), decapod larvae (3.7), medusae (2.3), polychaetes (2.3), chaetognaths (1.4), appendicularians (1.3), mysids (0.3) fish larvae (0.1), siphonophores (0.1), ctenophores (0.1), others (0.21).
6 (05.01.06)	1200 (Eb)	7.7	14.1	19	Copepods (83.1), chaetognaths (7.1), polychaetes (6.2), decapod larvae (1.1), ctenophores (0.4), foraminiferans (0.5), lamellibranchs (0.3), medusae (0.3), mysids (0.3), appendicularians (0.3), siphonophores (0.2), gastropods (0.1), ostracods (0.1), others (0.2).
	1400 (Fl)	2.5	36.3	14	Copepods (62.8), polychaetes (31.6), chaetognaths (2.5), decapod larvae (1.0), siphonophores (0.5), ctenophores (0.5), appendicularians (0.3), gastropods (0.2), ostracods (0.2), medusae (0.2), lamellibranchs (0.1), others (0.1).
	1600 (Fl)	9.5	40.7	18	Copepods (45.1), decapod larvae (36.1), chaetognaths (15.3), mysids (1.5), ostracods (1.1), polychaetes (0.6), medusae (0.1), ctenophores (0.1), others (0.1).

Table 4.5.10 (Contd 6)

Station (Date)	Time (h)/Tide	Biomass (ml/100 m^3)	Population (no x 10^3/100 m^3)	Total groups (no)	Major group (%)
6 (05.01.06)	1800 (FI)	2.2	10.6	17	Copepods (92.1), decapod larvae (2.3), chaetognaths (1.2), polychaetes (1.1), lamellibranchs (0.8), siphonophores (0.6), gastropods (0.5), ostracods (0.3), foraminiferans (0.3), medusae (0.3), mysids (0.2), lamellibranchs (0.1), others (0.2).
7 (09.01.06)	0800 (FI)	2.9	18.8	16	Copepods (67.4), decapod larvae (26.9), chaetognaths (2.5), gastropods (0.7), foraminiferans (0.6), siphonophores (0.2), ctenophores (0.2), medusae (0.2), ostracods (0.2), appendicularians (0.1), fish larvae (0.1), others (0.1).
	0815 (FI)	2.1	14.4	18	Copepods (71.2), decapod larvae (24.4), chaetognaths (2.4), gastropods (0.5), siphonophores (0.3), ctenophores (0.2), foraminiferans (0.2), fish larvae (0.2), polychaetes (0.2), medusae (0.1), mysids (0.1), lamellibranchs (0.1), others (0.1).

Table 4.5.10 (Contd 7)

Station (Date)	Time (h)/Tide	Biomass (ml/100 m³)	Population (no x 10³/100 m³)	Total groups (no)	Major group (%)
8 (08.01.06)	1030 (Eb)	8.1	13.3	15	Copepods (52.7), decapod larvae (15.8), chaetognaths (10.3), gastropods (10.3), ostracods (4.4), ctenophores (3.5), siphonophores (1.5), lamellibranchs (0.4), appendicularians (0.3), fish larvae (0.2), foraminiferans (0.1), medusae (0.1), polychaetes (0.1), mysids (0.1), others (0.2).
	1045 (Eb)	3.8	24.0	18	Copepods (52.6), decapod larvae (23.9), gastropods (13.1), chaetognaths (4.5), ctenophores (1.8), siphonophores (1.4), ostracods (1.4), lamellibranchs (0.5), appendicularians (0.2), fish eggs (0.2), fish larvae (0.1), polychaetes (0.1), others (0.2).
9 (08.01.06)	0930 (Eb)	2.2	19.3	13	Copepods (51.2), decapod larvae (46.2), chaetognaths (1.3), polychaetes (0.2), siphonophores (0.2), ctenophores (0.2), appendicularians (0.1), medusae (0.1), others (0.1).
	0945 (Eb)	10.6	14.7	17	Copepods (70.9), decapod larvae (20.1), gastropods (4.8), chaetognaths (1.4), ctenophores (1.2), siphonophores (0.4), fish larvae (0.4), polychaetes (0.2), medusae (0.2), foraminiferans (0.1), appendicularians (0.1), others (0.2).

Table 4.5.10 (Contd 8)

Station (Date)	Time (h)/Tide	Biomass (ml/100 m³)	Population (no x 10³/100 m³)	Total groups (no)	Major group (%)
10 (11.01.06)	1115 (Fl)	3.0	3.2	15	Copepods (64.7), gastropods (14.2), ostracods (11.0), lamellibranchs (4.7), decapod larvae (2.1), foraminiferans (1.7), chaetognaths (0.5), siphonophores (0.5), polychaetes (0.2), amphipods (0.2), others (0.1).
	1130 (Fl)	1.9	1.7	11	Copepods (80.9), ostracods (5.3), decapod larvae (5.3), foraminiferans (2.6), siphonophores (2.2), chaetognaths (1.4), gastropods (1.3), polychaetes (0.7), lamellibranchs (0.2), others (0.1).
11 (11.01.06)	1230 (Eb)	3.6	15.5	15	Copepods (52.3), decapod larvae (46.1), gastropods (0.5), chaetognaths (0.3), ostracods (0.2), lamellibranchs (0.1), medusae (0.1), siphonophores (0.1), polychaetes (0.1), fish eggs (0.1), others (0.1).
	1245 (Eb)	4.9	11.6	14	Copepods (53.6), decapod larvae (42.0), chaetognaths (1.9), gastropods (1.9), foraminiferans (0.2), fish eggs (0.21), others (0.2).

Table 4.5.10 (Contd 9)

Station (Date)	Time (h)/Tide	Biomass (ml/100 m³)	Population (nox10³/100 m³)	Total groups (no)	Major group (%)
12 (11.01.06)	1315 (Eb)	4.5	5.8	13	Copepods (91.9), decapod larvae (3.5), gastropods (1.2), lamellibranchs (0.9), chaetognaths (0.8), fish eggs (0.6), siphonophores (0.3), polychaetes (0.3), foraminiferans (0.2), appendicularians (0.1), ostracods (0.1), others (0.1).
	1330 (Eb)	3.3	4.9	16	Copepods (50.7), decapod larvae (41.7), gastropods (1.6), siphonophores (1.2), polychaetes (1.0), fish eggs (0.9), lamellibranchs (0.8), chaetognaths (0.5), appendicularians (0.4), stomatopods (0.4), foraminiferans (0.3), marine insects (0.3), others (0.1).
13 (11.01.06)	1400 (Eb)	2.3	3.7	14	Copepods (51.5), decapod larvae (32.5), gastropods (7.2), fish eggs (3.6), chaetognaths (2.4), lamellibranchs (1.9), foraminiferans (0.6), fish larvae (0.2), stomatopods (0.1), others (0.2).
	1415 (Eb)	6.7	10.4	18	Copepods (45.0), decapod larvae (43.8), gastropods (4.6), lamellibranchs (2.9), fish eggs (2.3), foraminiferans (0.6), polychaetes (0.2), siphonophores (0.2), isopods (0.1), marine insects (0.1), ostracods (0.1), fish larvae (0.1), medusae (0.1), others (0.2).

Table 4.5.11 : Range and average (parenthesis) of zooplankton off Mundra/Wandh during 1998-2006.

Station	Parameter	July 1998	August 1998	March 1999	September 1999	March 2000
Bocha Creek	Biomass (ml/100 m^3)	0.4-14.2 (4.9)	1.4-6.5 (3.4)	0.9-262.7 (92)	-	0.4-25.1 (15.6)
	Population (nox10^3/100 m^3)	5.2-45.2 (27.7)	26.7-97.4 (46.5)	3.7-280.3 (116.6)	-	5.2-141.5 (74.4)
	Total groups (no)	6-13 (11)	7-12 (11)	6-17 (12)	-	6-9 (8)
	Major Group	Decapods copepods chaetognaths fish larvae *Acetes* sp. *Lucifer sp.*	Decapods copepods *Lucifer sp.* fish larvae *Acetes* sp. chaetognaths	Mysids decapods copepods gastropods	-	Decapods copepods
Navinal Creek	Biomass (ml/100 m^3)	7.7-17.1 (13.3)	2.8-14.0 (7.6)	2.7-343.5 (93.0)	-	0.4-10.2 (4.3)
	Population (nox10^3/100 m^3)	38.3-156.1 (98.4)	25.8-51.0 (36.9)	7.0-571.9 (163.5)	-	4.1-62.8 (21.7)
	Total groups (no)	10-13 (11)	9-13 (11)	4-15 (11)	-	8-13 (10)
	Major Group	Copepods decapods chaetognaths fish larvae *Acetes* sp. *Lucifer sp.*	Decapods copepods chaetognaths *Lucifer sp.* *Acetes* sp. fish larvae	Mysids decapods copepods gastropods	-	Copepods decapods mysids ostracods amphipods chaetognaths

Table 4.5.11 (Contd 2)

Station	Parameter	June 2003	October 2003	December 2004	May 2005	January 2006
Bocha Creek	Biomass (ml/100 m^3)	2.0-6.1 (4.3)	0.5-2.6 (1.5)	11.5-12.2 (11.9)	1.2-10.9 (5.5)	2.3-6.7 (4.5)
	Population (nox10^3/100 m^3)	35.7-95.8 (64.4)	2.7-42.9 (22.9)	26.2-34.7 (30.4)	4.3-50.2 (19.8)	3.7-10.4 (7.0)
	Total groups (no)	15-19 (18)	11-20 (16)	18-21 (20)	11-17 (15)	14-18 (16)
	Major Group	Decapods copepods fish larvae chaetognaths	Decapods copepods medusae	Copepods decapods gastropods mysids	Decapods copepods, gastropods chaetognaths ostracods	Copepods decapods gastropods lamellibranchs fish eggs
Navinal Creek	Biomass (ml/100 m^3)	2.5-4.7 (3.3)	2.2-6.0 (3.9)	8.4-9.0 (8.7)	13.0-17.1 (15.1)	3.3-4.5 (3.9)
	Population (nox10^3/100 m^3)	12.0-87.2 (61.7)	4.7-48.1 (28.1)	17.2-17.5 (17.3)	35.3-105.1 (70.2)	4.9-5.8 (5.3)
	Total groups (no)	15-18 (17)	12-20 (17)	16-17 (17)	14-15 (15)	13-16 (15)
	Major Group	Decapods copepods polychaetes chaetognaths fish larvae *Lucifer sp.*	Decapods copepods gastropods ostracods medusae *Lucifer sp.*	Decapods Copepods mysids gastropods appendicularia ns	Decapods copepods, mysids gastropods chaetognaths ostracods	Copepods decapods gastropods siphonophores lamellibranchs fish eggs.

Table 4.5.11 (Contd 3)

Station	Parameter	July 1998	August 1998	March 1999	September 1999	March 2000
Baradi Mata Creek	Biomass (ml/100 m^3)	-	0.1-137 (41.3)	8.4-18.8 (13.6)	-	-
	Population (nox10^3/100 m^3)	-	0.2-124.3 (27.23)	43.9-151.5 (97.7)	-	-
	Total groups (no)	-	7-16 (11)	10-13 (12)	-	-
	Major Group	-	Copepods decapods mysids	Mysids decapods gastropods copepods	-	-
Gulf (Mundra)	Biomass (ml/100 m^3)	7.4-38.4 (16.7)-	0.4-12.7 (5.2)	1.2-124.2 (13.5)	-	0.4-8- (9.3)
	Population (nox10^3/100 m^3)	19.9-28.5 (29.7)	4.4-105.3 (16.9)	2.5-152.2 (34.0)	-	5.3-234.6 (4.2)
	Total groups (no)	11-13 (12)	9-13 (10)	7-18 (13)	-	6-18 (11)
	Major Group	Copepods decapods chaetognaths *Acetes* sp. *Lucifer* sp. fish larvae	Copepods decapods fish larvae *Lucifer* sp.	Copepods decapods	-	Copepods decapods chaetognaths

Table 4.5.11 (Contd 4)

Station	Parameter	June 2003	October 2003	December 2004	May 2005	January 2006
Baradi Mata Creek	Biomass (ml/100 m^3)	2.9-3.2 (3.1)	0.5-2.9 (1.7)	1.9-27.3 (9.5)	19.2-31.0 (24.5)	1.9-3.0 (2.5)
	Population (nox10^3/100 m^3)	40.9-49.7 (45.3)	3.6-6.8 (5.2)	6.5-261.3 (74.0)	67.8-136.4 (94.7)	1.7-3.2 (2.4)
	Total groups (no)	15-17 (16)	13-19 (16)	16-19 (17)	11-12 (12)	11-15 (13)
	Major Group	Decapods copepods chaetognaths fish larvae	Decapods copepods gastropods foraminiferans	Copepods decapods mysids foraminiferans	Decapods copepods lamellibranchs mysids	Copepods gastropods Ostracods decapods lamellibranch
Gulf (Mundra)	Biomass (ml/100 m^3)	0.9-9.6 (2.7)	1.1-21.8 (5.2)	3.0-23.2 (7.2)	0.8-109.9 (12.3)	2.2-13.1 (5.2)
	Population (nox10^3/100 m^3)	7.7-58.1 (18.7)	11.7-815 (38.1)	5.1-58.1 (20.7)	3.2-232.3 (37.4)	5.1-141.0 (30.2)
	Total groups (no)	12-18 (15)	12-17 (15)	13-19 (16)	12-18 (16)	13-21 (17)
	Major Group	Copepods decapods chaetognaths fish larvae	Copepods decapods chaetognaths	Copepods decapods chaetognaths gastropods mysids	Copepods decapods mysids chaetognaths ostracods	Copepods decapods gastropods chaetognaths

Table 4.5.11 (Contd 5)

Station	Parameter	July 1998	August 1998	March 1999	September 1999	March 2000
Kotdi Creek	Biomass (ml/100 m^3)	-	-	-	2.0-2.2 (2.1)	-
	Population (nox10^3/100 m^3)	-	-	-	6.4-25.4 (15.9)	-
	Total groups (no)	-	-	-	14-16 (15)	-
	Major Group	-	-	-	Decapods copepods cladocera fish eggs mysids fish larvae	-

Table 4.5.11 (Contd 6)

Station	Parameter	June 2003	October 2003	December 2004	May 2005	January 2006
Kotdi Creek	Biomass (ml/100 m^3)	-	-	-	-	2.1-2.9 (2.5)
	Population (nox10^3/100 m^3)	-	-	-	-	14.4-18.8 (16.6)
	Total groups (no)	-	-	-	-	16-18 (17)
	Major Group	-	-	-	-	Copepods decapods chaetognaths gastropods polychaetes foraminiferans

Table 4.5.12 : Abundance of zooplankton off Mundra/Wandh during January 2006.

FAUNAL GROUP	STATION												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Foraminiferans	+	+	+	+	+	+	+	+	+	+	+	+	+
Siphonophores	+	+	+	+	+	+	+	+	+	+	+	+	+
Medusae	+	+	+	+	+	+	+	+	+	-	+	+	+
Ctenophores	+	+	+	+	+	+	+	+	+	-	+	-	+
Chaetognaths	+	+	+	+	+	+	+	+	+	+	+	+	+
Polychaetes	+	+	+	+	+	+	+	+	+	+	+	+	+
Cladocerans	-	-	-	-	-	+	-	-	-	-	-	-	-
Ostracods	+	+	+	+	+	+	+	+	+	+	+	+	+
Copepods	+	+	+	+	+	+	+	+	+	+	+	+	+
Cumaceans	+	+	+	+	+	-	-	+	+	+	-	+	+
Amphipods	-	-	+	+	+	+	-	+	-	+	+	+	+
Mysids	+	+	-	+	+	+	+	+	-	+	-	-	-
Lucifer sp.	+	+	-	+	+	+	+	-	+	+	-	-	-
Decapod larvae	+	+	+	+	+	+	+	+	+	+	+	+	+
Stomatopods	+	+	-	-	+	+	-	-	+	-	-	+	+
Pteropods	+	-	-	+	-	-	-	-	-	-	-	-	-
Cephalopods	-	+	-	-	-	+	-	-	-	-	-	-	-
Gastropods	+	+	+	+	+	+	+	+	+	+	+	+	+
Lamellibranchs	+	+	+	+	+	+	+	+	+	+	+	+	+
Appendicularians	+	+	+	+	+	+	+	+	+	+	+	+	+
Fish eggs	+	+	-	+	-	+	+	+	+	-	+	+	+
Fish larvae	+	+	+	+	+	+	+	+	+	-	+	-	+
Isopods	+	-	-	-	+	+	+	-	+	-	+	-	+
Acetes sp.	-	-	-	+	+	+	+	-	+	-	-	-	+
Marine insects	+	+	+	+	+	-	+	-	-	+	+	+	+
Others	-	-	-	+	-	-	-	-	-	-	+	-	

(+ : Present; - : Absent)

Table 4.5.13 : Range and average (parenthesis) of decapod larvae, Acetes sp, Lucifer sp off Mundra/Wandh during January 2006

Station	Decapod larvae		*Acetes* sp		*Lucifer* sp	
	Counts (no/100 m^3)	Incidence (%)	Counts (no/100 m^3)	Incidence (%)	Counts (no/100 m^3)	Incidence (%)
1	2679-13006 (7843)	100	-	0	1-4 (3)	100
2	6957-8957 (7957)	100	-	0	3-3 (3)	100
3	16023-19817 (17920)	100	-	0	-	0
4	1127-10916 (5173)	100	0-6 (2)	25	2-5 (2)	50
5	80-3140 (1496)	100	1-1 (1)	28.4	1-2 (1)	56.8
6	153-14694 (3868)	100	1-7 (2)	50	1-16 (10)	75
7	3514-5060 (4287)	100	0-2 (1)	50	0-1 (1)	50
8	2092-5737 (3915)	100	-	0	-	0
9	2954-8972 (5963)	100	0-3 (2)	50	0-4 (2)	50
10	53-87 (70)	100	-	0	1-1 (1)	100
11	4853-7141 (5997)	100	-	0	-	0
12	201-2036 (1119)	100	-	0	-	0
13	1199-4547 (2873)	100	0-3 (2)	50	-	0

Table 4.5.14 : Range and average (parenthesis) of total counts (no/100 m^3) - A and percentage composition –B; of decapod larvae, *Acetes* sp and *Lucifer* sp off Mundra/Wandh during 1998 –2006.

Station	Parameter	July 1998	August 1998	March 1999	March 2000	June 2003
Bocha Creek	**Decapod larvae**					
	A	4118-31139 (16619)	16991-95298 (46953)	1480-32912 (18859)	2677-23629 (13525)	24131-66228 (45522)
	B	16.8-83.6 (63.7)	63.7-97.8 (89.7)	8.0-51.1 (29.2)	-	67.5-76.7 (70.1)
	Percentage of incidence	100	100	100	100	100
	***Acetes* sp**					
	A	11-64 (31)	12-215 (81)	12-4362 (1432)	3-1190 (318)	0-4 (2)
	B	0.02-0.9 (0.19)	0.067	-	1.4-12.9 (7.1)	0-0.01 (0.005)
	Percentage of incidence	100	100	61	100	50
	***Lucifer* sp**					
	A	12-78 (25)	-	-	*1 (1)	229-820 (540)
	B	0.05-1.5 (0.2)	-	-		0.6-0.9 (0.9)
	Percentage of incidence	75	-	-	100	100

Table 4.5.14 (Contd 2)

Station	Parameter	October 2003	December 2004	May 2005	January 2006
Bocha Creek	**Decapod larvae**				
	A	2346-42467 (22228)	6014-12277 (9146)	553-21212 (10495)	1199-4547 (2873)
	B	88.1-99.2 (95.1)	-	-	-
	Percentage of incidence	100	100	100	100
	***Acetes* sp**				
	A	0-2 (1)	0-4 (2)	0	0-3 (2)
	B	0-0.01 (0.01)	-	-	-
	Percentage of incidence	25	50	0	50
	***Lucifer* sp**				
	A	0-49 (15)	2-6 (4)	5-733 (132)	-
	B	0-0.17 (0.06)	-	-	-
	Percentage of incidence	75	100	100	0

Table 4.5.14 (Contd 3)

Station	Parameter	July 1998	August 1998	March 1999	March 2000	June 2003
Navinal Creek	**Decapod larvae**					
	A	1082-26256 (17057)	1943-36810 (21394)	17-57035 (25851)	2-21953 (3992)	4135-75814 (47997)
	B	11.9-28.2 (19.9)	58.8-82.6 (69.6)	7.8-53.9 (23.2)	0.04-47.8 (17.3)	34.3-86.9 (77.8)
	Percentage of incidence	100	100	100	100	100
	***Acetes* sp**					
	A	45-127 (84)	38-1255 (412)	4-28 (8)	0-34 (6)	-
	B	0.05-0.1 (0.08)	0.05-0.1 (1.08)	<0.01-0.5 (0.02)	0.0-0.07 (0.01)	-
	Percentage of incidence	100	75	57.0	-	-
	***Lucifer* sp**					
	A	4-21 (6)	384-431 (380)	1-2 (1)	0-1 (1)	23-200 (117)
	B	<0.01-0.05 (0.01)	0.8-1.4 (1.08)	0.002-0.003 (<0.01)	0.0-0.2	0.2-0.23 (0.2)
	Percentage of incidence	50	100	43	-	-

Table 4.5.14 (Contd 4)

Station	Parameter	October 2003	December 2004	May 2005	January 2006
Navinal Creek	**Decapod larvae**				
	A	1935-31689 (18602)	9459-9874 (9667)	14682-36806 (25744)	201-2036 (1119)
	B	41.5-65.9 (66.2)	-	-	-
	Percentage of incidence	100	100	100	100
	***Acetes* sp**				
	A	1-25 (5)	0	0	-
	B	0.003-0.2 (0.02)	-	-	-
	Percentage of incidence	71	0	0	0
	***Lucifer* sp**				
	A	2-479 (109)	14-15 (15)	23-65 (44)	-
	B	0.03-1.4 (0.4)	-	-	-
	Percentage of incidence		100	100	0

Table 4.5.14 (Contd 5)

Station	Parameter	July 1998	August 1998	March 1999	March 2000	June 2003
Baradi Mata Creek	**Decapod larvae**					
	A	-	11559-21818 (16688)	10884-47273 (29079)	-	25637-44339 (34988)
	B	-	73.9-81.9 (77.9)	24.8-31.2 (28.0)	-	62.7-89.2 (77.2)
	Percentage of incidence	-	100	100	-	100
	***Acetes* sp**					
	A	-	920-2424 (1672)	-	-	-
	B	-	6.5-8.2 (7.3)	-	-	-
	Percentage of incidence	-	100	-	-	-
	***Lucifer* sp**					
	A	-	253-346 (299)	1-3 (2)	-	93-137 (115)
	B	-	1.1-1.8 (1.5)	<0.01-<0.1 (<0.1)	-	0.2-0.3 (0.3)
	Percentage of incidence	-	100	100	-	100

Table 4.5.14 (Contd 6)

Station	Parameter	October 2003	December 2004	May 2005	January 2006
Baradi Mata Creek	**Decapod larvae**				
	A		2055-101622 (44809)	62785-136214 (91517)	53-87 (70)
	B		-	-	-
	Percentage of incidence		100	100	100
	***Acetes* sp**				
	A		0-7 (3)	0-5 (2)	53-87 (70)
	B		-	-	-
	Percentage of incidence		75	50	100
	***Lucifer* sp**				
	A	0-1	0-2 (1)	7-14	1-1 (1)
	B	0-0.02 (0.01)	-	-	-
	Percentage of incidence	50	50	100	100

Table 4.5.14 (Contd 7)

Station	Parameter	July 1998	August 1998	March 1999	March 2000	June 2003
Gulf (Mundra)	Decapod larvae					
	A	952-2857 (235.3)	557-99441 (11566)	658-100048 (5143)	12-70870 (6638)	112-24177 (3156)
	B	4.8-12.4 (9.3)	9.2-97.4 (37.3)	4.7-47.3 (28.4)	0.01-61.4 (16.75)	0.8-47.3 (16.1)
	Percentage of incidence	100	100	100	100	100
	Acetes sp					
	A	292-952 (625)	6-1604 (292)	2-3688 (112)	0-81 (14)	0-93 (8)
	B	1.0-4.1 (2.5)	0.09-6.2 (2.3)	<0.01-5 (0.17)	0-1.4 (0.57)	0-0.2 (0.04)
	Percentage of incidence	100	91.6	80.5	53.6	75
	Lucifer sp					
	A	10-222 (107)	11-691 (240)	*1 (1)	0-12 (2)	0-78 (23)
	B	0.03-0.5 (0.3)	0.2-12.5 (2.9)	*<0.01 (<0.01)	0-0.1 (<0.01)	0-0.5 (0.28)
	Percentage of incidence	100	100	50	40	91.6

Table 4.5.14 (Contd 8)

Station	Parameter	October 2003	December 2004	May 2005	January 2006
Gulf (Mundra)	**Decapod larvae**				
	A	65-48801 (7423)	457-48462 (4139)	100	80-19817 (6681)
	B	0.2-81.7 (19.0)	-	-	-
	Percentage of incidence	100	100	100	100
	***Acetes* sp**				
	A	0-262 (19)	0-6 (1)	0-9	0-7 (1)
	B	0.01-0.5 (0.07)	-	-	-
	Percentage of incidence	75	48	30	44.4
	***Lucifer* sp**				
	A	2-301 (53)	0-12 (3)	0-415 (70)	1-16 (1)
	B	0.01-0.5 (0.13)	-	-	-
	Percentage of incidence	97.3	78.6	95	66.6

Table 4.5.14 (Contd 9)

Station	Parameter	October 2003	December 2004	May 2005	January 2006
Kotdi Creek	Decapod larvae				
	A	-	-	-	3514-5060 (4287)
	B	-	-	-	-
	Percentage of incidence	-	-	-	100
	Acetes sp				
	A	-	-	-	0-2 (1)
	B	-	-	-	-
	Percentage of incidence	-	-	-	50
	Lucifer sp				
	A	-	-	-	0-1 (1)
	B	-	-	-	-
	Percentage of incidence	-	-	-	50

Table 4.5.15: Total counts, average (parenthesis) and incidence of fish eggs and fish larvae off Mundra/Wandh during January 2006.

Station	Fish eggs		Fish larvae	
	Counts (no/100 m^3)	Frequency of occurrence	Counts (no/100 m^3)	Frequency of occurrence
1	5-9 (7)	100	6-23 (15)	100
2	2-3 (2)	100	30-38 (34)	100
3	-	0	12-22 (17)	100
4	0-4 (1)	25	5-29 (17)	100
5	-	0	0-65 (19)	71
6	4-7 (6)	50	5-10 (8)	100
7	4-7 (6)	100	1-24 (13)	100
8	2-47 (25	100	27-28 (28)	100
9	1-1 (1)	100	10-58 (34)	100
10	-	0	-	0
11	2-18 (10)	100	-	0
12	38-45 (42)	100	-	0
13	123-240 (182)	100	7-9 (8)	100

Table 4.5.16 : Range and average (parenthesis) of total counts (no/100 m^3)- A, and percentage composition –B, of fish eggs and fish larvae off Mundra/Wandh during 1998 – January 2006.

Station	Parameter	July 1998	August 1998	March 1999	March 2000	June 2003	October 2003	December 2004	May 2005	January 2006
Bocha Creek	**Fish eggs**									
	A	1-3 (2)	0-4 (2)	5-238 (43)	2-9 (6)	3-87 (25)	0-1 (1)	55-59 (57)	0-5 (1)	123-240 (182)
	B	<0.01-<0.01 (<0.01)	0-0.1 (0.3)	<0.007-3.1 (0.31)	0.04-0.1 (0.07)	0.01-0.09 (0.03)	0.0-04 (0.02)	-	-	-
	Percentage of incidence	100	58.5	100	100	100	75	100	22	100
	Fish larvae									
	A	3-63 (40)	133-401 (239)	1-13 (3)	0-17 (5)	586-7427 (3251)	0-10 (5)	5-7 (6)	11-469 (102)	7-9 (8)
	B	0.02-0.9 (0.21)	0.06-	-	1.4-12.9 (7.1)	0-0.01 (0.005)	0-0.01 (0.01)	-		-
	Percentage of incidence	100	100	100	75	100	75	100		100
Navinal Creek	**Fish eggs**									
	A	0-1 (1)	2-18 (7)	3	0-5 (1)	0-8 (1)	0-1 (0.1)	74-86 (80)	66-240 (153)	38-45 (42)
	B	<0.01 (<0.01)	<0.1-0.06 (0.02)	0.01-0.16 (0.03)	0.0-0.07 (<0.01)	0.0-0.01 (<0.01)	0-0.01 (<0.01)	-	-	-
	Percentage of incidence	25	50	86	25	1	14	100	100	100
	Fish larvae									
	A	14-386 (119)	82-220 (138)	3-29 (8)	0-20 (5)	76-1378 (838)	2-71 (21)	0-2 (1)	43-45 (44)	-
	B	0.01-1.0 (0.26)	0.2-0.9 (0.4)	0.01-0.16 (0.03)	0-0.16 (<0.1)	0.6-2.3 (0.4)		-	-	-
	Percentage of incidence	100	100	71	75	100	86	50	100	0

Table 4.5.16 (Contd 2)

Station	Parameter	July 1998	August 1998	March 1999	March 2000	June 2003	October 2003	December 2004	May 2005	January 2006
Baradi Mata Creek	**Fish eggs**									
	A	-	0-1 (1)	-	-	-	-	1-35 (9)	-	-
	B	-	0-<0.01 (<0.01	-	-	-	-	-	-	-
	Percentage of incidence	-	50	-	-	-	-	100	-	-
	Fish larvae									
	A	79-140 (110)	-	-	-	-	-	0-104 (15)	43-234 (120)	-
	B	0.3-0.9 (0.6)	-	-	-	-	-	-	-	-
	Percentage of incidence	-	100	-	-	-	-	62.5	100	-
Gulf (Mundra)	**Fish eggs**									
	A	8-21 (13)	3-56 (19)	1-60 (12)	0-27 (5)	0-11 (4)	1-41 (5)	0-188 (19)	0-38 (9)	0-47 (6)
	B	0.03-0.09 (0.05)	0.0-3 (0.16)	<0.01-0.2 (0.03)	0.0-0.36 (0.05)	0-0.1 (0.04)	<0.01-0.1 (0.02)	-	-	-
	Percentage of incidence	100	100	100	65.86	64.3	61	87	51	77.7
	Fish larvae									
	A	14-386 (119)	82-220 (138)	3-29 (8)	0-20 (5)	76-1378 (838)	2-71 (21)	0-2 (1)	43-45 (44)	0-65 (19)
	B	0.01-1.0 (0.26)	0.2-0.9 (0.4)	0.01-0.16 (0.03)	0-0.16 (<0.1)	0.6-2.3 (0.4)		-	-	-
	Percentage of incidence	100	100	71	75	100	86	50	100	88.8

Table 4.5.16 (Contd 3)

Station	Parameter	July 1998	August 1998	March 1999	March 2000	June 2003	October 2003	December 2004	May 2005	January 2006
Kotdi Creek	Fish eggs									
	A	-	-	-	-	-	-	-	-	4-7 (6)
	B	-	-	-	-	-	-	-	-	-
	Percentage of incidence	-	-	-	-	-	-	-	-	100
	Fish larvae									
	A	-	-	-	-	-	-	-	-	1-24 (13)
	B	-	-	-	-	-	-	-	-	-
	Percentage of incidence	-	-	-	-	-	-	-	-	100

Table 4.5.17: Range and average (parenthesis) of intertidal macrobenthic fauna off Mundra/Wandh during January 2006.

Transect	Biomass (g/m^2; wet wt.)	Population (no/m^2)	Faunal groups (no)	Major group
I	0-963.2 (92.84)	0-17952 (4052)	0-7 (3)	Polychaetes
I A	0-22.49 (5.92)	0-1760 (550)	0-3 (2)	Pelecypods, amphipods, brachyurans.
I B	0-120.20 (32.45)	0-13376 (6116)	0-6 (4)	Polychaetes
II	0-171.6 (26.29)	0-3344 (499)	0-5 (2)	Amphipods
III	0.35-79.72 (13.08)	880-11088 (523)	1-6 (3)	Pelecypods, Amphipods, Pelecypods
IV	0-11.25 (4.88)	0-5808 (1511)	0-4 (2)	Polychaetes, amphipods.
V	0-78.32 (22.86)	0-6336 (2097)	0-5 (2)	Polychaetes
VI	0.07-36.08 (13.74)	1056-14960 (6409)	2-7 (4)	Pelecypods
VII	5.84-30.27 (24.26)	2288-24464 (7201)	3-6 (3)	Polychaetes, pelecypods
Overall average	0-963.2 (28.3)	0-24464 (3218)	0-7 (3)	Polychaetes, Amphipods, Pelecypods

Table 4.5.18: Range and average (parenthesis) of intertidal macrobenthic fauna at substations off Mundra during January 2006.

Transect	Biomass (g/m^2; wet wt.)	Population (no/m^2)	Faunal groups (no)	Major group
I HW	4.89-18.69 (9.30)	1408-5104 (3256)	2-3 (2)	Polychaetes, isopods.
MW	0-963.2 (240.7)	0-17952 (4499)	0-7 (2)	Amphipods, pelecypods.
LW	1.76-86.79 (28.53)	1584-8624 (4400)	2-6 (4)	Polychaetes
I A HW	3.06-22.49 (11.19)	704-1760 (792)	2-3 (3)	Pelecypods, brachyurans.
LW	0-1.30 (0.65)	0-528 (308)	0-3 (1)	Amphipods
I B HW	23.80-40.65 (31.71)	2640-13376 (9152)	3-6 (5)	Polychaetes, pelecypods.
LW	0-120.20 (33.20)	0-6512 (3080)	0-7 (3)	Polychaetes
II HW	-	-	-	-
MW	0-2.08 (1.0)	0-220 (132)	0-3 (2)	Isopods, amphipods..
LW	0-18-171.6 (77.88)	352-3344 (1364)	1-5 (3)	Amphipods
III HW	0.35-0.70 (0.57)	880-1408 (1100)	1-2 (1)	Isopods
MW	12.73-39.97 (28.35)	7392-8976 (8272)	3-4 (3)	Pelecypods
LW	1.94-79.72 (10.22)	1232-11088 (6314)	2-6 (5)	Polychaetes, amphipods.
IV HW	-	-	-	-
MW	2.82-11.25 (10.41)	1936-5808 (2992)	3-4 (3)	Polychaetes, amphipods.
LW	1.05-11.14 (4.23)	1408-1936 (1540)	2-4 (3)	Isopods

Table 4.5.18 (Contd 2)

Transect	Biomass (g/m^2; wet wt.)	Population (no/m^2)	Faunal groups (no)	Major group
V HW	0-78.32 (24.85)	0-1232 (572)	0-2 (1)	Brachyurans
MW	0-35.60 (14.09)	0-4224 (1980)	0-5 (2)	Polychaetes
LW	6.68-54.51 (28.84)	880-6336 (3740)	1-5 (3)	Polychaetes
VI HW	6.42-27.13 (13.90)	5456-14960 (11132)	3-4 (4)	Pelecypods, isopods.
MW	4.43-30.55 (14.46)	4400-11792 (5720)	2-6 (3)	Pelecypods
LW	0.07-36.08 (12.87)	1056-3520 (2376)	3-7 (4)	Amphipods, cumaceans.
VII HW	5.84-63.71 (24.38)	2640-4224 (3388)	3-4 (4)	Brachyurans, polychaetes.
MW	16.39-30.98 (19.72)	6336-24464 (12936)	3-4 (4)	Pelecypods.
LW	26.21-30.27 (28.68)	2288-10560 (5280)	3-6 (4)	Pelecypods, polychaetes.
Overall Average	0-1063.68 (26.50)	0-244464 (4865)	0-7 (3)	Polychaetes, pelecypods, amphipods.

Table 4.5.19: Range and average (parenthesis) of intertidal macrobenthos off Mundra/Wandh during 1998 to 2006.

Station	Parameters	July 1998	March 1999	March 2000	June 2003	October 2003	December 2004	May 2005	January 2006
Bocha Creek	Biomass (g/m^2)	0.01-13.2 (3.7)	0.1-11.1 (3.0)	-	3.9-18.4 (11.8)	1.2-7.8 (3.4)	1.7-17.4 (8.4	0.1-21.5 (8.3)	5.84-30.27 (24.26)
	Population ($nox10^3/m^2$)	0.01-1.8 (0.8)	0.3-2.5 (1.6)	-	0.7-3.0 (1.6)	0.4-1.5 (0.9)	1.8-11.6 (5.3)	0.5-5.1 (2.7)	2.2-24.5 (7.2)
	Total groups (no)	2-8 (5)	3-9 (5)	-	4-5 (5)	2-5 (3)	3-6 (5)	2-4 (3)	3-6 (3)
	MG*	Polychaetes, crustaceans, molluscs.	Polychaetes, crustaceans, molluscs.	-	Crustaceans, polychaetes,	Polychaetes, brachyurans.	Polychaetes, tanaidaceans, amphipods.	Polychaetes, isopods.	Polychaetes, pelecypods
Navinal Creek	Biomass (g/m^2)	3.0-20.5 (8.1)	0.7-50.6 (13.7)	3.6-58.7 (24.1)	1.5-109.8 (36.9)	1.4-17.7 (6.7)	0.1-27.6 (12.7)	1.0-38.9 (16.6)	-
	Population ($nox10^3/m^2$)	0.5-1.4 (1.0)	0.7-6.8 (2.8)	1.4-133.1 (45.6)	0.7-6.5 (1.9)	0.2-1.2 (0.5)	0.4-9.7 (3.8)	1.4-8.8 (4.2)	-
	Total groups (no)	1-8 (5)	3-8 (6)	4-6 (5)	2-7 (4)	2-4 (2)	2-6 (4)	2-5 (4)	-
	MG*	Polychaetes, crustaceans, mollusks.	Polychaetes, crustaceans, mollusks.	Polychaetes, crustaceans, mollusks.	Polychaetes, crustaceans, mollusks.	Polychaetes, brachyurans, amphipods.	Polychaetes, nemertines.	Polychaetes, brachyurans.	-
Baradi-mata Creek	Biomass (g/m^2)	1.9-39.1 (23.6)	37.7-135.8 (70.6)	9.4-58.6 (19.4)	-	0-9-14.7 (5.9)	<0.1-3.8 (1.0)	<0.1-9.0 (3.5)	0.07-36.08 (13.74)
	Population ($nox10^3/m^2$)	3.1-7.3 (4.5)	7.1-48.4 (19.5)	0.2-133.1 (23.5)	-	0.2-2.8 (1.1)	0.1-1.3 (0.7)	0.1-3.2 (0.8)	1.1-15.0 (6.4)
	Total groups (no)	8-10 (9)	5-9 (7)	5-8 (7)	-	2-6 (3)	2-7 (4)	1-5 (3)	2-7 (4)
	MG*	Polychaetes, crustaceans, molluscs.	Polychaetes, crustaceans, molluscs.	Polychaetes, crustaceans, molluscs.	-	Polychaetes, amphipods, brachyurans.	Polychaetes, isopods, amphipods.	Isopods, polychaetes.	Pelecypods
Gulf (Mundra)	Biomass (g/m^2)	0-340.7 (75.2)	0-74.6 (14)	3.3-76.9 (26.8)	4.0-22.8 (11.8)	0.03-47.0 (8.4)	<0.1-84.8 (5.6)	<0.1-55.4 (6.5)	0-963.2 (28.33)
	Population ($nox10^3/m^2$)	0-3.3 (1.0)	0-13.9 (2.5)	0.1-57.0 (8.9)	0.2-4.5 (1.2)	0.02-3.1 (0.9)	<0.1-18.8 (2.7)	0.1-6.6 (1.2)	0-18.0 (2.2)
	Total groups (no)	0.7 (3)	2-10 (6)	1-5 (4)	4-7 (5)	1-4 (3)	1-7 (4)	1-7 (4)	0-7 (3)
	MG*	Polychaetes, crustaceans, molluscs.	Polychaetes, crustaceans, molluscs.	Polychaetes, crustaceans, molluscs.	Polychaetes, crustaceans, molluscs.	Polychaetes, brachyurans, amphipods.	Amphipods, polychaetes, isopods.	Polychaetes, isopods, amphipods.	Polychaetes, amphipods, pelecypods.

Table 4.5.19 (Contd 2)

Station	Parameters	July 1998	March 1999	March 2000	June 2003	October 2003	December 2004	May 2005	January 2006
Kotdi Creek	Biomass (g/m^2)	-	-	-	-	-	-	-	0-78.32 (22.86)
	Population ($nox10^3/m^2$)	-	-	-	-	-	-	-	0-6.3 (2.1)
	Total groups (no)	-	-	-	-	-	-	-	0-5 (2)
	MG*	-	-	-	-	-	-	-	Polychaetes

* MG- Major Group

Table 4.5.20 : Distribution of intertidal macrofauna off Mundra/Wandh during 1998 to 2006.

Faunal groups	Station												
	1			1 A		1B		2			3		
	Hw	Mw	Lw	Hw	Lw	Hw	Lw	Hw	Mw	Lw	Hw	Mw	Lw
Anthozoans	-	+	-	-	-	-	-	NIL	-	-	-	-	-
Gastropods	-	+	+	+	+	+	+		-	+	-	-	+
Pelecypods	+	+	+	+	-	+	+		+	-	-	+	-
Polychaetes	+	+	+	-	-	+	+		-	+	-	+	+
Cumaceans	-	-	+	-	-	-	+		-	+	-	-	-
Isopods	+	-	-	+	-	+	+		+	+	+	-	+
Amphipods	+	+	+	-	+	+	+		+	+	+	+	+
Bracyurans	-	+	+	+	+	+	+		+	-	-	+	-
Ophiuroids	-	-	-	-	-	-			-	-	-	-	-
Miscellaneous	-	+	-	-	-	-	+		+	-	-	-	+

Table 4.5.20 (Contd 2)

Faunal groups	Station											
	4			5			6			7		
	Hw	Mw	Lw	Hw	Mw	Lw	Hw	Mw	Lw	Hw	Mw	Lw
Anthozoans	NIL	-	-	-	-	-	-	-	-	-	-	-
Gastropods		+	-	-	-	-	+	+	-	-	+	-
Pelecypods		+	+	-	+	+	+	+	+	+	+	+
Polychaetes		+	+	-	+	+	+	+	+	+	+	+
Cumaceans		-	-	-	-	-	+	+	+	-	-	-
Isopods		+	+	-	+	+	+	+	+	+	-	-
Amphipods		+	+	-	+	+	+	+	+	-	+	+
Bracyurans		+	-	+	-	+	+	+	-	+	-	+
Ophiuroids		-	-	-	-	-	-	-	-	-	+	-
Miscellaneous		-	-	-	-	-	-	-	-	-	-	-

(+) Present; (-) Absent

Table 4.5.21: Range and average (parenthesis) of subtidal macrobenthic fauna off Mundra/Wandh during January 2006.

Subtidal	Biomass (g/m^2; wet wt.)	Population (no/m^2)	Faunal groups (no)	Major group
1	0.15-0.70 (0.39)	125-650 (325)	1-3 (2)	Polychaetes
2	0-2.25 (0.57)	0-2900 (731)	0-8 (2)	Amphipods
3	Hard substratum			
4	0.6-2.07 (1.26)	500-1050 (775)	2-10 (4)	Amphipods pelecypods
5	0.09-3.36 (1.0)	150-1575 (744)	3-8 (5)	Amphipods polychaetes
6	Hard substratum			
7	0.31-0.75 (0.56)	350-725 (450)	4-6 (5)	Polychaetes, pelecypods
8	0-1.57 (0.74)	0-2275 (925)	0-6 (4)	Amphipods polychaetes
9	0-0.25 (0.07)	0-175 (75)	0-2 (1)	Polychaetes
10	0.03-4.08 (1.83)	50-575 (338)	2-3 (3)	Polychaetes
11	0.47	100	3	Pelecypods
12	0.03-15.03 (3.81)	50-2075 (669)	1-6 (3)	Polychaetes, amphipods
13	0-3.10 (1.59)	0-2075 (938)	0-7 (3)	Polychaetes pelecypods
Overall average	0-15.03 (1.11)	0-2900 (552)	0-10 (3)	Polychaetes, amphipods

Table 4.5.22 : Standing stock of subtidal macrobenthos off Mundra/Wandh during 1998 –2006.

Station	Parameter	July 1998	March 1999	September 1999	March 2000
Bocha Creek	Biomass (g/m^2, wet wt)	0.5-0.7 (0.6)	0.5-1.2 (0.9)	-	1.0-1.8 (0.9)
	Population (no)	200-700 (500)	1125-1200 (1177)	-	140-300 (214)
	Total groups (no)	1-2 2	3-6 (5)	-	2-3 (3)
	Major Group	Polychaetes	Polychaetes macrurans	–	Polychaetes
Navinal Creek	Biomass (g/m^2; wet wt)	0.1-5.1 (2.6)	29.2-63.1 (46.2)	-	0-0.18 (0.1)
	Population (no)	140-1900 (1030)	8000-17700 (12800)	-	0-1502 (751)
	Total groups (no)	1-6 (4)	7-7 (7)	-	3-3 (3)
	Major Group	Polychaetes	Macrurans, polychaetes, brachyurans, copepods, isopods.	-	Polychaetes, amphipods, brachyurans.
Baradi Matha Creek	Biomass (g/m^2; wet wt)	-	-	-	-
	Population (no/m^2)	-	-	-	-
	Total groups (no)	-	-	-	-
	Major Group	-	-	-	-

Table 4.5.22 (Contd 2)

Station	Parameter	June 2003	October 2003	December 2004	May 2005	January 2006
Bocha Creek	Biomass (g/m^2, wet wt)	0.5-7.1 (3.1)	0.02-4.0 (1.1)	1.1-3.2 (2.0)	0.1-1.9 (0.7)	0-3.10 (1.59)
	Population (no/m^2)	430-1400 (800)	30-950 (440)	1500-4300 (2300)	200-900 (500)	0-2075 (938)
	Total groups (no)	1-4 (2)	1-4 (2)	3-4 (3)	2-3 (3)	0-7 (3)
	Major Group	Polychaetes	Polychaetes	Polychaetes, nemertines.	Polychaetes, Amphipods.	Polychaetes, pelecypods.
Navinal Creek	Biomass (g/m^2; wet wt)	0.0-16.13 (4.0)	0-5.0 (0.6)	0.2-1.8 (1.0)	0.9-28.4 (16.4)	<0.1-15.03 (3.81)
	Population (no/m^2)	0-580 (160)	0-500 (110)	400-1200 (700)	1000-3200 (2400)	50-2075 (669)
	Total groups (no)	0-4 (2)	0-4 (2)	3-5 (4)	1-2 (2)	1-6 (3)
	Major Group	Polychaetes, brachyurans.	Polychaetes	Nemertines amphipods.	Polychaetes, isopods.	Polychaetes, amphipods.
Baradi Matha Creek	Biomass (g/m^2; wet wt)	-	-	0.4-42.8 (9.9)	0.4-3.8 (2.2)	<0.1-4.08 (1.83)
	Population (no/m^2)	-	-	200-170 (800)	200-1700 (700)	50-575 (338)
	Total groups (no)	-	-	2-6 (4)	1-3 (2)	2-3 (3)
	Major Group	-	-	Amphipods, isopods.	Polychaetes.	Polychaetes.

Table 4.5.22 (Contd 3)

Station	Parameter	July 1998	March 1999	September 1999	March 2000
Gulf (Mundra)	Biomass (g/m^2, wet wt)	0.5	0.2-46.3 (13.3)	-	0.5-11.5 (4.3)
	Population (no)	470	12-78600 (20000)	-	300-173300 (44920)
	Total groups (no)	3	4-7 (6)	-	4-7 (6)
	Major Group	Polychaetes	Polychaetes, amphipods, pelecypods.	-	Polychaetes, amphipods, pelecypods.
Kotdi Creek	Biomass (g/m^2; wet wt)	-	-	1.2	-
	Population (no)	-	-	17176	-
	Total groups (no)	-	-	4	-
	Major Group	-	-	Polychaetes, cumaceans, isopods, pelecypods.	-

Table 4.5.22 (Contd 4)

Station	Parameter	June 2003	October 2003	December 2004	May 2005	January 2006
Gulf (Mundra)	Biomass (g/m^2, wet wt)	0.0-4.47 (0.42)	0.0-6.01 (1.36)	<0.1-13.1 (1.6)	0.0-9.2 (1.0)	0-3.36 (0.5)
	Population (no)	0-1300 (240)	0-1200 (290)	100-1800 (500)	0-600 (200)	0-2900 (408)
	Total groups (no)	0-4 (2)	0-4 (2)	1-4 (3)	0-4 (2)	0-10 (3)
	Major Group	Polychaetes, amphipods.	Polychaetes	Polychaetes, amphipods.	Polychaetes, amphipods.	Polychaetes, amphipods, pelecypods.
Kotdi Creek	Biomass (g/m^2; wet wt)	-	-	-	-	0.31-0.75 (0.56)
	Population (no)	-	-	-	-	350-725 (450)
	Total groups (no)	-	-	-	-	4-6 (5)
	Major Group	-	-	-		Polychaetes, pelecypods.

Table 4.5.23 : Distribution of subtidal macrofauna off Mundra/Wandh during January 2006.

Faunal group	Station												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Nematodes	-	+	HARD SUBSTRATUM ↓	+	-	HARD SUBSTRATUM ↓	-	+	-	-	-	-	-
Chaetognaths	+	-		-	-		-	-	-	-	-	-	-
Gastropods	-	-		-	-		-	+	-	-	-	-	-
Pelecypods	+	+		+	+		+	+	-	+	+	+	+
Polychaetes	+	+		+	+		+	+	+	+	-	+	+
Pycnogonids	-	-		+	+		-	-	-	+	-	+	-
Ostracods	-	+		+	+		+	-	+	-	-	+	-
Copepods	-	-		-	+		-	-	-	-	+	-	-
Cumaceans	+	+		+	+		-	+	-	+	-	+	+
Tanaidaceans	-	+		+	+		+	+	-	+	-	+	-
Isopods	-	-		-	-		+	+	-	-	-	+	+
Amphipods	+	+	↑ HARD SUBSTRATUM	+	+	↑ HARD SUBSTRATUM	+	+	+	+	+	+	+
Decapod larvae	-	-		-	+		-	-	-	-	-	-	-
Brachyurans	-	+		+	+		+	-	-	-	-	-	+
Ophiuroids	-	-		-	-		-	-	-	+	-	+	+
Unidentified	-	-		+	+		-	-	-	-	-	-	-

(+) Present; (-) Absent

Table 4.5.24 : Marine fish landings (t x10^3/y) of Gujarat State and districts adjoining the Gulf.

Year	State				Total contribution
		Jamnagar	Rajkot	Kachchh	By districts (%)
1965-66	109.9	4.2	--	2.4	6.0
1966-67	115.2	2.8	--	3.0	5.0
1967-68	124.9	3.8	--	3.3	5.7
1968-69	131.7	2.8	--	2.3	3.8
1969-70	140.0	2.9	--	2.7	4.0
1970-71	151.2	4.7	--	3.9	5.7
1971-72	147.0	5.5	--	4.1	6.5
1972-73	151.2	4.6	--	4.8	6.2
1973-74	177.6	6.8	--	6.9	7.7
1974-75	157.4	3.0	0.3	4.3	4.8
1975-76	208.3	5.1	2.2	3.8	5.3
1976-77	225.4	21.7	1.3	5.4	12.6
1977-78	176.9	14.5	0.4	6.3	12.0
1978-79	230.0	21.8	2.7	6.3	13.4
1979-80	206.7	24.8	0.6	5.7	15.0
1980-81	218.9	32.3	1.7	4.4	17.5
1981-82	220.6	34.2	2.0	6.3	19.3
1982-83	192.7	29.7	0.5	13.8	22.8
1983-84	223.3	27.4	1.3	23.3	17.3
1984-85	290.7	31.5	0.7	34.3	22.9
1985-86	306.6	25.2	1.7	35.4	20.3
1986-87	315.9	28.0	0.5	31.3	18.9
1987-88	327.6	40.2	0.5	29.7	21.5
1988-89	414.1	44.2	2.8	46.9	22.7
1989-90	432.4	45.4	2.5	49.6	22.5
1990-91	500.5	54.3	1.8	65.4	24.3
1991-92	530.0	63.5	2.7	61.8	24.1
1992-93	609.1	66.2	1.1	63.0	21.4
1993-94	619.8	58.9	1.5	63.2	19.9
1994-95	645.3	58.9	1.5	76.8	21.0
1995-96	598.4	68.1	1.0	72.6	23.7
1996-97	660.1	76.2	0.9	76.7	23.3
1997-98	702.4	56.0	0.8	71.8	18.3
1998-99	551.7	28.6	0.2	69.7	17.9
1999-00	671.0	71.7	0.8	75.0	22.0
2000-01	620.5	72.6	1.7	64.7	22.4
2001-02	650.8	83.4	2.1	80.0	25.4
2002-03	743.4	102.8	1.5	80.7	24.9
2003-04	609.1	37.9	1.7	72.0	18.3
2004-05	585.0	45.9	1.9	64.7	19.2

Source: Department of Fisheries, Government of Gujarat

Table 4.5.25 : Composition of marine fish landings (t/y) of Kachchh District during 1997-98, 1998-99, 2000-01, 2002-03 and 2004-05.

Name of fish	1997-98	1998-99	2000-01	2002-03	2003-04	2004-05
White pomfret	1110	801	924	1022.4	1103.9	725.3
Black pomfret	35	33	140	45.5	74.9	77.3
Bombay duck	15011	12354	13547	14152.0	12264.2	10021.4
Thread fin	737	944	351	1331.9	1048.5	380.5
Jew fish	1124	1372	520	1780.4	1496.0	802.1
Hilsa	225	208	142	221.9	181.2	36.9
Other clupeids	2116	1762	1947	2242.2	2380.0	2240.8
Coilia	5603	6028	3829	5801.2	6088.2	6117.8
Shark	3415	2686	2118	3817.7	2986.1	1629.6
Mullet	2132	1864	878	786.9	1361.9	1348.7
Cat fish	1367	1782	1030	2428.6	1896.2	1476.3
Eel	79	134	153	236.5	146.0	299.0
Leather jacket	113	88	144	161.8	93.6	158.9
Seer fish	238	406	192	345.5	421.3	316.1
Indian salmon	201	329	158	223.8	149.1	241.4
Ribbon fish	3294	1950	2556	3076.9	2964.4	2601.2
Silver bar	518	453	528	796.9	1324.3	1517.6
Perches	254	215	298	728	409.3	408.9
Small scienides	23848	26742	22685	4432..0	4435.6	4545.7
Shrimp	4810	5512	5008	6659.1	6351.2	5364.3
Prawns (medium)	1732	1302	1260	1226.3	1631.9	780.1
Prawns (Jumbo)	166	191	372	239.7	292.8	215.8
Lobster	33	43	88	120.1	49.0	23.1
Crabs	140	42	229	40.6	37.0	44.2
Levta	1	0	20	0.4	-	-
Squid fish	22	14	38	22.1	19.0	18.1
Others	3463	2429	5541	28778.7	22789.9	23162.3
Total	**71787**	**69685**	**64696**	**80714.3**	**71995**	**64680.2**

Source: Department of Fisheries, Government of Gujarat

Table 4.5.26 : Monthwise composition of marine fish landings (t) of Kachchh District during 2002-03.

Name of fish	April 02	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan 03	Feb	Mar	Total
White pomfret	74.5	74.5	-	-	0.8	192.3	79.0	104.6	136.8	99.2	93.9	96.6	952.0
Black pomfret	5.3	-	-	-	-	4.0	3.6	7.7	5.5	15.7	1.8	1.8	45.5
Bombay duck	844.5	1009.0	-	-	-	93.2	1429.6	3101.3	2527.7	2606.5	2047.9	1146.9	14806.5
Thread fin	237.2	47.4	-	-	-	22.1	29.0	66.4	109.2	160.5	226.6	404.8	1301.2
Jew fish	245.8	44.2	-	-	1.7	48.6	103.3	108.5	150.4	302.8	321.7	417.7	1744.6
Hilsa	11.2	-	-	-	-	8.6	18.1	26.1	32.9	30.6	50.1	44.2	221.9
Other clupeids	140.3	67.7	0.7	-	17.2	87.6	154.7	450.4	313.4	182.5	182.8	677.5	2274.9
Coilia	260.1	424.5	-	-	2.2	60.7	412.3	1139.0	1004.0	1165.1	1095.8	514.6	6078.3
Shark	294.2	42.4	0.2	-	20.5	133.6	261.3	590.9	689.7	889.8	450.9	425.1	3798.5
Mullet	61.5	47.1	6.3	-	74.8	125.5	125.2	95.6	54.7	92.2	40.6	55.0	778.4
Cat fish	257.0	95.5	1.7	-	24.5	93.8	175.4	253.5	224.7	387.2	273.4	701.8	2445.3
Eel	32.1	-	-	-	-	0.6	13.5	43.8	50.0	27.4	44.6	24.6	236.5
Leather jacket	5.3	-	-	-	-	9.5	19.8	20.9	26.4	43.2	16.7	20.0	161.8
Seer fish	15.6	-	-	-	-	23.6	54.4	61.2	64.5	51.1	46.6	28.5	345.5
Indian salmon	8.9	4.7	-	-	-	17.1	30.4	28.3	32.1	34.9	39.8	27.6	223.8

Table 4.5.26 (Contd 2)

Name of fish	April 97	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan 98	Feb	Mar	Total
Ribbon fish	203.7	-	-	-	2.1	100.6	169.1	590.7	618.7	641.0	510.1	241.4	3077.3
Silver bar	143.0	90.4	0.1	-	0.2	18.1	83.7	85.6	71.0	85.3	96.9	185.2	859.5
Perches	24.7	14.0	-	-	0.5	32.8	263.0	105.9	112.5	58.1	71.0	45.5	728.0
Small scienides	308.8	32.7	-	-	5.8	496.1	399.7	691.8	794.8	541.3	706.3	447.1	4424.5
Shrimps	454.5	206.7	1.0	-	16.7	540.5	532.8	1132.7	1161.5	1051.4	1010.1	689.7	6797.5
Prawns (medium)	144.6	48.9	1.6	-	1.7	158.4	67.2	190.6	230.3	105.3	181.2	114.2	1243.9
Prawns (jumbo)	11.1	-	-	-	0.2	29.8	12.0	36.9	34.6	63.7	30.3	21.3	239.7
Lobster	2.0	-	-	-	-	7.4	22.5	25.6	24.0	16.7	12.1	9.7	120.1
Crabs	14.8	0.2	-	-	-	2.1	3.9	5.1	5.1	3.4	3.5	2.5	40.6
Levta	0.4	-	-	-	-	-	-	-	-	-	-	-	0.4
Squid fish	1.2	-	-	-	-	1.4	2.3	3.7	4.3	4.2	3.2	1.7	22.1
Miscellaneous	2047.9	83.3	2.9	-	23.3	1790.3	2560.4	4713.3	5359.9	4619.5	4622.0	2988.4	28811.2
Total	**5849.9**	**2333.0**	**14.4**	-	**192.2**	**4098.1**	**6981.2**	**13679.8**	**13838.5**	**13278.7**	**12980.1**	**933.4**	**81779.4**

Source : Department of Fisheries, Government of Gujarat

Table 4.5.27 : Marine fish landings (t x 10^3/y) of Kachchh District and its comparison with the landing at Mundra.

Year	Kachchh District	Mundra	Percentage of district landings
1991-92	61.8	2.4	3.9
1992-93	63.0	0.4	0.6
1993-94	63.2	0.8	1.2
1994-95	76.8	0.6	0.8
1995-96	72.7	2.7	3.8
1996-97	76.7	-	-
1997-98	71.8	1.3	1.8
1998-99	69.7	1.7	2.4
1999-00	75.0	-	-
2000-01	64.7	0.4	0.6
2001-02	80.2	1.4	1.7
2002-03	81.8	1.6	2.0
2003-04	72.1	1.6	2.2
2004-05	64.7	1.6	2.5

Source : Department of fisheries, Government of Gujarat

Table 4.5.28 : Composition of marine fish landings (t/y) at Mundra/wandh during 1994-2003

Name of fish	94-95	95-96	97-98	2000-01	01-02	02-03
White pomfret	19.2	68.4	18.0	10.5	11.5	15.8
Black pomfret	3.3	13.0	-	-	-	2.5
Bombay duck	205.1	1040.0	540.5	122.6	602.7	737.5
Jew fish	14.8	43.3	6.2	-	13.2	36.9
Other clupeids	--	--	9.3	19.3	9.1	18.1
Coilia	171.3	549.4	323.3	52.7	219.0	292.5
Shark	12.7	25.4	6.3	8.5	32.9	42.2
Mullet	17.2	--	24.9	17.5	5.0	19.0
Cat fish	9.0	9.6	11.9	23.7	68.6	80.7
Eel	--	--	--	-	2.3	-
Leather jacket	--	--	2.2	-	1.8	2.5
Seer fish	7.1	14.1	12.7	4.0	12.1	21.1
Ribbon fish	2.1	--	3.3	10.6	6.5	24.3
Silver bar	2.6	6.9	5.6	2.3	19.4	47.6
Small sciaenids	7.3	5.5	13.2	3.8	7.9	2.4
Prawns (medium)	13.9	6.6	10.0	24.2	208.8	132.2
Lobster	--	0.5	1.1	1.9	2.9	-
Crabs	8.5	1.0	0.9	3.1	-	-
Levta	--	1.8	--	-	-	-
Others	73.8	212.5	227.4	47.3	158.2	170.0
Total	623.5	2730.4	1263.9	351.7	1381.6	1645.3

Source : Department of fisheries, Government of Gujarat

Table 4.5.29 : Monthwise composition of marine fish landings (t) at Mundra during 2002-03.

Name of fish	April 02	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan 03	Feb	Mar	Total
White pomfret	-	-	-	-	-	4.8	1.8	4.0	1.3	3.0	-	1.0	15.8
Bombay duck	34.5	22.0	-	-	-	43.3	70.2	222.8	30.1	229.3	50.4	34.9	737.5
Jew fish	5.7	-	-	-	-	6.0	7.5	-	-	17.6	-	-	36.9
Other clupeids	-	-	-	-	1.0	-	3.0	8.1	-	4.2	-	1.9	18.1
Coilia	21.8	17.1	-	-	-	16.2	48.2	60.8	16.3	73.1	33.6	5.4	292.5
Shark	10.3	8.8	-	-	0.3	3.5	5.4	5.7	-	7.1	-	1.1	42.2
Mullet	-	-	0.4	-	2.1	1.7	7.7	4.6	-	2.5	-	-	19.0
Catfish	9.7	7.8	0.2	-	0.4	5.2	5.6	9.5	16.7	10.6	12.6	2.3	80.7
Leather jacket	2.5	-	-	-	-	-	-	-	-	-	-	-	2.5
Seer fish	-	-	-	-	-	5.2	4.6	2.2	7.6	1.5	-	-	21.1
Ribbon fish	-	-	-	-	-	2.2	2.2	10.8	-	5.9	-	3.3	24.3
Silver bar	6.2	4.9	-	-	-	2.2	2.2	4.9	5.4	7.9	12.6	1.4	47.6
Small scienides	-	-	-	-	-	-	2.4	-	-	-	-	-	2.4
Shrimps	-	-	-	-	1.2	5.6	7.1	4.1	-	4.4	-	2.8	25.1
Prawns (medium)	29.2	17.6	0.2	-	-	-	0.8	1.4	40.2	1.0	42.0	-	132.1
Lobster	-	-	-	-	-	-	-	-	-	-	-	-	-
Crabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Miscellaneous	19.5	11.8	0.3	-	1.1	22.5	20.4	12.2	20.0	13.8	21.0	4.8	147.5
Total	**139.5**	**90.1**	**1.1**	**-**	**6.1**	**118.4**	**189.1**	**350.7**	**137.7**	**381.8**	**172.2**	**58.6**	**1645.3**

Source : Department of Fisheries, Government of Gujarat

Table 4.5.30 : Composition of marine fish landings (t) around Mundra during 2002-03.

Name of fish	Navinal	Jarpara	Mundra	Chenkhedia	Luni	Bhadreshwar	Kukadasar
White pomfret	6.6	3.7	15.8	-	23.4	48.8	8.7
Black pomfret	-	-	2.5	-	-	0.3	-
Bombay duck	394.2	89.6	737.5	-	538.5	559.0	582.8
Thread fin	-	-	-	-	-	15.4	-
Jew fish	34.0	7.8	36.9	-	16.3	20.5	18.8
Hilsa	0.1	9.7	4.2	-	15.1	-	10.3
Other clupeids	24.2	17.6	18.1	29.6	56.0	90.3	17.8
Coilia	159.7	81.0	292.4	14.9	210.7	206.7	208.1
Shark	22.2	32.7	42.2	14.0	41.5	247.3	28.0
Mullet	30.0	12.6	19.0	80.4	45.2	8.4	10.1
Cat fish	35.7	51.2	80.7	23.8	66.1	65.1	63.5
Eel	1.7	-	-	-	-	-	1.0
Seer fish	9.3	3.0	21.1	-	13.3	0.8	21.7
Indian salmon	6.1	8.7	11.4	-	6.7	-	8.4

Table 4.5.30 (Contd 2)

Name of fish	Navinal	Jarpara	Mundra	Chenkhedia	Luni	Bhadreshwar	Kukadasar
Ribbon fish	13.1	4.4	24.3	-	42.0	57.7	9.1
Silver bar	17.0	5.9	47.6	1.4	29.8	2.7	23.3
Perches	-	-	-	-	-	1.4	-
Small sciaenids	7.2	5.7	2.4	1.0	88.2	167.6	2.0
Shrimps	30.7	24.8	25.1	27.4	91.1	142.3	51.8
Prawns (medium)	1.4	47.0	132.2	0.4	14.5	16.3	113.2
Prawn (Jumbo)	-	-	-	-	-	-	29.8
Lobster	-	1.2	-	-	-	-	2.8
Crabs	-	-	-	2.4	2.2	7.8	-
Miscellaneous	-	125.0	132.0	44.3	183.8	188.6	120.7
Total	843.9	531.9	1645.3	239.5	1489.4	1618.7	1220.4

Source : Department of Fisheries, Government of Gujarat

Table 4.5.31 : Monthwise marine fish landings (t) around Mundra during 2002-03.

Landing centre	April 02	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan 03	Feb	Mar	Total
Navinal	41.4	3.0	1.2	-	3.0	15.0	80.5	96.0	108.3	369.4	72.0	54.0	843.9
Jarpara	163.4	-	1.3	-	5.7	1.0	23.8	21.1	57.4	74.0	45.5	138.9	532.0
Mundra	139.5	90.1	1.1	-	6.0	118.4	189.0	350.7	137.7	381.8	172.2	58.6	1645.3
Chenkhedia	21.2	4.8	2.0	-	9.9	30.0	52.6	26.0	14.9	35.2	20.7	22.9	239.5
Luni	111.6	17.0	1.4	-	6.5	85.0	196.2	135.0	178.1	305.5	301.3	152.0	1489.4
Bhadreshwar	86.5	12.5	2.0	-	7.7	76.7	415.3	255.8	114.8	156.2	223.4	267.8	1618.7
Kukadasar	90.3	201.4	-	-	-	2.8	439.3	172.4	129.0	129.1	103.0	73.8	1220.4

Source: Department of fisheries, Government of Gujarat

Table 4.5.32 : Districtwise fishing villages, fishermen, boats and fishing gears (2003) of Kachchh District.

Parameter	
Length of coast line (km)	406
Percentage of the state of the coast line	25.4
Fishing villages/cities (no)	73
Fishermen families (no)	3650
Total fishermen population (no)	18664
Active fishermen (no)	10615
Fishing boats (mechanised) (no)	1219
Fishing boats (non-mechanised) (no)	291
Total fishing gears (nets) (no)	25917
Trawlers (no)	11
Gill netters (no)	188
Others (no)	1019

Source : Department of Fisheries, Government of Gujarat.

Table 4.5.33: Villagewise fishermen, boats and fishing gears around Mundra.

Village	Total fishermen				Fishing boats		
	Families	Gents	Ladies	Total	Mechanised	Non-mechanised	Total
Navinal	22	62	53	115	9	-	9
Jarpara	101	307	278	585	20	-	20
Dharab	16	54	47	101	-	-	-
Mundra	71	180	146	326	80	-	80
Chenkhedia	74	248	230	478	24	-	24
Luni	227	619	660	1279	65	1	66
Bhadreshwar	194	541	554	1095	95	-	95
Total	**705**	**2011**	**1968**	**3979**	**293**	**1**	**294**

Source: Department of Fisheries, Government of Gujarat.

Table 4.5.34 : Species composition of fish catch off Mundra during January 2006.

Station/ (Date)	Time(h)/ (Tide)	Catch kg/hr	Total species (no)	Common species
3 (07.01.06)	0800 (Fl)	14.5	F-12 P-3 O-3	Fishes : *Coilia dussumieri, Johnius glaucus, Polynemus heptadactylus, Otolithes* sp, *Harpadon nehereus, Thryssa hamiltoni, Arius caelatus, Scolidon laticaudus, Pampus argenteus, Ilisha* sp., *Otolithes brunneus* (biaurates), *Pampus chinensis.* Prawn : *Parapenaeopsis sculptilis, Exopalaemon styliferus, Exhippolysmata ensirostris.* Others : *Neptunes pelagicus, Charybdis annulata,* Squilla.
6 (05.01.06)	1100 (Eb)	8.0	F-11 P-4 O-3	Fishes : *Harpadon nehereus, Coilia dussumieri, Pampus argenteus, Arius caelatus, Sillago sihama, Lepturacanthus savala, Johnius glaucus, Terapon theraps, Secutor insidictor, Hilsa kelee, Otolithes* sp. Prawn : *Metapenaeus dobsoni, Exopalaemon ensirostris, Metapenaeus* sp, *Penaeus* sp. Others : *Neptunes pelagicus*, Loligo, Squilla.
9 (08.01.06)	0930 (Eb)	18.5	F-13 P-3 O-4	Fishes : *Mugil* sp, *Scomberomorus guttatus, Otolithes* sp, *Ilisha megaloptera, Mugil cephalus, Coilia dussumieri, Thryssa* sp. Prawns : *Penaeus indicus, Parapenaeopsis sculptilis, Metapenaeus* sp. Others : *Matuta planipes, Charybdis cruciata,* Squilla.

Table 4.5.34 (Contd 2)

Station/ (Date)	Time(h)/ (Tide)	Catch kg/hr	Total species (no)	Common species		
2 (31.12.04)	1115 (Eb)	2.2	F-6 P-2 O-2	Fishes	:	*Coilia dussumieri, Harpadon nehereus, Pampus argenteus, Polynemus heptadactylus, Lepturacanthus savala, Sillago sihama, Arius caelatus, Hilsa* sp, *Ilisha* sp, *Johnius glaucus, Saurida tumbil, Thryssa mystac, Cynoglossus arel.*
				Prawns	:	*Exopalaemon styliferus, Exhippolysmata ensirostris,, Parapenaeopsis* sp.,
				Others	:	*Charybdis annulata, Charybdis cruciata,* Loligo, Squilla.

Table 4.5.35: Comparison of fish catch off Mundra during 1998 to 2005.

Period/Parameter	Navinal Creek	Bocha Creek	Gulf
July 1998 i) Total catch (kg/h) ii) Total species (no) iii) Major species	15.5 F – 8; P – 1; O – 1. Fishes: *Acanthopagrus* sp, *Mugil cephalus*, *Eleutheronema tetradactylum*, *Secutor insidiator*, *Crenidens crenidens*. Prawns: *Penaeus indicus* Others : *Charybdis annulata*	- - -	- - -
March 1999 i) Total catch (kg/h) ii) Total species (no) iii) Major species	8.5 F – 6; P – 2; O – 1. Fishes: *Mugil* sp, *Thryssa dussumieri*, *Harpadon nehereus*, *Johnius* sp, *Otolithoides biauritus*. Prawns: *Parapenaeopsis sculptilis*, *Penaeus* sp. Others : Crabs	- - -	17.3 F – 7; P – 3; O – 1. Fishes: *Scoliodon laticaudatus*, *Harpadon nehereus*, *Coilia dussumieri*, *Lepturacanthus savala*, *Pampus argenteus*, *Arius* sp, *Otolithoides biauritus*. Prawns: *Parapenaeopsis sculptilis* *Parapenaeopsis Stylifera*, *Penaeus* sp. Others : Crabs Others : *Matuta planipes*

Table 4.5.35 (Contd 2)

Period/Parameter	Navinal Creek	Bocha Creek	Gulf
March 2000 i) Total catch (kg/h) ii) Total species (no) iii) Major species	10.0 F – 12; P – 6; O – 1. Fishes: *Pampus argenteus*, *Harpadon nehereus*, *Otolithes* sp, *Ilisha* sp, *Coilia dussumieri*, *Cynoglossus arel*, *Johnius glaucus*, *Thryssa vitrirostris*. Prawns: *Parapenaeopsis sculptilis*, *Metapenaeus brevicornis*, *Solenocera crassicornis*, *Exhippolysmata* sp. Others : *Charybdis annulata*.	- - -	22.2 F – 13; P – 2; O – 3. Fishes: *Pampus chinensis*, *Harpadon nehereus*, *Lepturacanthus savala*, *Cynoglossus arel*, *Lagocephalus* sp, *Scoliodon laticaudus*, *Johnius glaucus*, *Arius caelatus*, *Lagocephalus* sp, *Otolithoides biauritus*, *Thryssa vitrirostris*. Prawns: *Parapenaeopsis Sculptilis*, *Metapenaeus* sp. Others : *Charybdis annulata*, *Matuta planipes*.
June 2003 i) Total catch (kg/h) ii) Total species (no) iii) Major species	4.7 F – 7; P – 1; O – 1. Fishes: *Ilisha megaloptera*, *Mugil* sp, *Strongylura strongylura*, *Trichiurus lepturus*, *Lagocephalus* sp, *Sillago sihama*, *Pomadasys otivaceus*. Prawns: *Penaeus* sp. Others : *Charybdis lucifera*.	4.7 F – 6; P – 2; O – 1. Fishes: *Thryssa mystax*, *Sillago sihama*, *Ilisha megaloptera*, *Trichurus lepturus*, *Mugil* sp, *Arius* sp. Prawns: *Penaeus* sp. Others : *Charybdis lucifera*. *Cynoglossus arel*, *Johnius glaucus*, *Thryssa vitrirostris*.	9.2 F – 9; P – 2; O – 1. Fishes: *Trichurus lepturus*, *Tenunlosa toil*, *Thryssa mystax*, *Mugil* sp, *Sillago sihama*, *Leiognathus* sp, *Lutijianidae*, *Cynoglossus arel*. Prawns: *Penaeus* sp, *Metapenaeus* sp. Others: *Charybdis* sp.

Table 4.5.35 (Contd 3)

Period/Parameter	Navinal Creek	Bocha Creek	Gulf
October 2003 i) Total catch (kg/h) ii) Total species (no) iii) Major species	3.5 F – 4; P – 0; O – 1. Fishes: *Mugil* sp, *Nibea maculata,* *Arius* sp. *Rhabdodargus* sp Others : *Scylla* sp.	4.0 F – 5; P – 0; O – 1. Fishes: *Coilia dussumieri,* *Nibea maculata,* *Thryssa mystax,* *Pampus argenteus,* *Thryssa hamiltoni* Others : *Charybdis cruciata.*	17.3 F – 11; P – 4; O – 3. Fishes: *Otholithoides biauritus,* *Johnius* sp, *Pampus argenteus,* *Harpadon nehereus,* *Coilia dussumieri,* *Trichiurus lepturus,* *Scolidon laticaudus.* *Lepturacanthus savala,* *Pampus chinensis.* *Johnius glaucus,* Prawns: *Metapenaeus brevicornis,* *Exopalaemon styliferus,* *Parapenaeopsis sculptilis,* Others : *Charybdis cruciata,* Loligo, Squilla.

Table 4.5.35 (Contd 4)

Period/Parameter	Navinal Creek	Bocha Creek	Gulf
December 2004 i) Total catch (kg/h) ii) Total species (no) iii) Major species	2.9 F – 4; P – 0; O – 1. Fishes: *Mugil cephalus, Coilia dussumieri, Polynemus heptadactylus, Otolothes* sp, *Scomberomorus guttatus, Ilisha megaloptera, Thryssa hamiltonii, Johnius glaucus.* Prawns: *Penaeus indicus, Metapenaeus* sp, *Parapenaeopsis sculptilis.* Others : *Charybdis annulata,* Squilla. *Scylla* sp.	2.4 F – 7; P – 3; O – 3. Fishes: *Johnius glaucus, Coilia dussumieri, Mugil cephalus, Polynemus heptadactylus, Ilisha megaloptera, Thryssa* sp, *Scomberomorus guttatus,* Prawns: *Penaeus indicus, Parapenaeopsis sculptilis. Metapenaeus* sp, Others: *Matuta planipes, Charybdis annulata.*	10.2 F – 14; P – 4; O – 4. Fishes: *Harpadon nehereus, Pampus argenteus, Pampus chinensis, Arius* sp, *Arius caelatus, Coilia dussumieri, Lepturacanthus savala, Johnius glaucus, Thryssa sussumieri, Therapon theraps, Scolidon laticaudus, Sillago sihama.* Prawns: *Exhippolysmata ensirostris Metapenaeus brevicornis, Metapeneus* sp. Others: *Charybdis annulata, Scylla serrata, Matuta planipes.*

Table 4.5.35 (Contd 5)

Period/Parameter	Navinal Creek	Bocha Creek	Gulf
May 2005 i) Total catch (kg/h) ii) Total species (no) iii) Major species	3.9 F – 9; P – 3; O – 3. Fishes: *Coilia dussumieri*, *Harpadon nehereus*, *Otolothes* sp, *Thryssa* sp, *Johnius glaucus*, *Ilisha megaloptera*, *Mugil* sp, *Trypauchen vagina*. Prawns: *Solenocera crassicornis*, *Parapenaeopsis stylifera*, *Metapenaeus* sp, *Exopalaemon styliferus*. Others : *Matuta planipes*, *Charybdis annulata*.	3.5 F – 9; P – 3; O – 4. Fishes: *Lepturacanthus savala*, *Harpadon nehereus*, *Ilisha megaloptera*, *Johnius glaucus*, *Mugil cephalus*, *Otolothes* sp, *Coilia dussumieri*, *Trypauchen vagina*. Prawns: *Solenocera crassicornis*, *Metapenaeus* sp, *Parapenaeopsis* sp. Others: *Matuta planipes*, *Charybdis annulata*.	16.9 F – 16; P – 4; O – 4. Fishes: *Harpadon nehereus*, *Coilia dussumieri*, *Pampus chinensis*, *Pampus argenteus*, *Lepturacanthus savala*, *Arius* sp, *Arius caelatus*, *Scolidon laticaudus*, *Trypauchen vagina*, *Ilisha megaloptera*, *Thryssa vitrirostris*, *Otolothes* sp, *Saurida tumbil*. Prawns: *Parapenaeopsis stylifera*, *Solenocera crassicornis*, *Penaeus* sp, *Metapenaeus dobsoni*. Others: *Charybdis cruciata*, *Charybdis annulata*, *Matuta planipes*.

Table 4.5.36 : Check list of birds recorded in the study area (Mundra)

No	Scientific name	Common english name	T/W	Abundance status	Migratory status
	Family & species				
	Phasianidae				
1	*Francolinus pondicerianus*	Grey francolin	T	C	R
2	*Pavo cristatus*	Indian peafowl	T	C	R
	Picidae				
3	*Dendrocopos mahrattensis*	Yellow-crowned woodpecker	T	VR	R
	Upupidae				
4	*Upupa epops*	Common hoopoe	T	R	R
	Coraciidae				
5	*Coracias garrulus*	European roller	T	R	M
6	*Coracias benghalensis*	Indian roller	T	C	R
	Alcedinidae				
7	*Alcedo hercules*	Common kingfisher	W	R	R
8	*Halcyon amayroptera*	White throated kingfisher	W	R	R
	Meropidae				
9	*Merops orientalis*	Green bee-eater	T	A	R
10	*Merops persicus*	Blue-cheeked bee-eater	T	R	RM
	Cuculidae				
11	*Eudynamys scolopacea*	Indian Koel	T	C	R
	Centropodidae				
12	*Centropus sinensis*	Greater coucal	T	R	R
	Psittacidae				
13	*Psittacula krameri*	Rose-ringed parakeet	T	C	R
	Apodidae				
14	*Apus affinis*	House swift	T	R	R
	Strigidae				
15	*Bubo nipalensis*	Spot-bellied eagle-owl	T	R	R
16	*Athene brama*	Spotted owlet	T	C	R

Table 4.5.36 (Contd 2)

No	Scientific name	Common english name	T/W	Abundance status	Migratory status
	Caprimulgidae				
17	*Caprimulgus indicus*	Sykes's nightjar	T	R	RM
18	*Caprimulgus asiaticus*	Indian nighjar	T	R	R
	Columbidae				
19	*Columba livea*	Blue rock pigeon	T	A	R
20	*Streptopelia senegalensis*	Laughing dove	T	A	R
21	*Streptopelia tranquebarica*	Red collared-dove	T	R	R
22	*Streptopelia decaocto*	Eurasian collared-dove	T	C	R
	Otididae				
23	*Chlamydotis macqueeni*	Houabara bustrad	T	VR	M
	Gruidae				
24	*Grus leucogeranus*	Common crane	W/T	C	M
	Pteroclidae				
25	*Pterocles alchata*	Chestnut-bellied sandgrouse	T	C	R
	Scolopaciadae				
26	*Limosa limosa*	Black-tailed godwit	W	R	M
27	*Limosa lapponica*	Bar-tailed godwit	W	C	M
28	*Numenius phaeopus*	Whimbrel	W	A	M
29	*Numenius arquata*	Eurasian curlew	W	A	M
30	*Tringa erythropus*	Spotted redshank	W	R	M
31	*Tringa totanus*	Common redshank	W	A	RM
32	*Tringa stagnatilis*	Marsh sandpiper	W	C	M
33	*Tringa nebularia*	Common greenshank	W	C	R
34	*Tringa glareola*	Wood sandpiper	W	R	M
35	*Xenus cinereus*	Terek sandpiper	W	C	W
36	*Actitis hypoleucos*	Common sandpiper	W	A	RM

Table 4.5.36 (Contd 3)

No	Scientific name	Common english name	W/T	Abundance status	Migratory status
37	*Calidris tenuirostris*	Sanderling	W	C	M
38	*Calidris minuta*	Little stint	W	R	M
39	*Calidris temminckii*	Temminck's stint	W	R	M
40	*Calidris alpina*	Dunlin	W	C	M
41	*Philomachus pugnax*	Ruff	W	R	M
42	*Phalaropus lobatus*	Red-necked phalarope	W	R	M
43	*Vanellus malarbaricus*	Yellow-wattled lapwing	T	R	R
44	*Vanellus indicus*	Red-wattled lapwing	W/T	A	R
	Charadriidae				
45	*Haematopus ostralegus*	Eurasian oystercatcher	W	R	M
46	*Himantopus himantopus*	Blackwinged stilt	W	R	R
47	*Recurvirostra avosetta*	Pied avocet	W	R	RM
48	*Pluvialis apricaria*	Eurasian golden plover	W	R	M
49	*Pluvialis squatarola*	Grey plover	W	R	M
50	*Charadrius hiaticula*	Common ringed plover	W	C	RM
51	*Charadrius alexandrinus*	Kentish plover	W	C	RM
52	*Charadrius leschenaultii*	Greater sand plover	W	C	M
	Glareolidae				
53	*Dromas ardeola*	Crab-plover	W	R	M
	Laridae				
54	*Rynchops albicollis*	Indian skimmer	W	VR	R
55	*Larus argentatus*	Herring gull	W	VR	R
56	*Larus brunnicephalus*	Brown-headed gull	W	R	RM
57	*Larus genei*	Slender Billed tern	W	A	RM
58	*Gelochelidon nilotica*	Gull-billed tern	W	A	RM
59	*Sterna caspia*	Capian tern	W	R	RM

Table 4.5.36 (Contd 4)

No.	Scientific name	Common english name	T/W	Abundance status	Migratory status
60	*Sterna aurantia*	River tern	W	C	R
61	*Sterna bergii*	Great crested tern	W	R	R
62	*Sterna albifrons*	Little tern	W	R	R
63	*Chlidonias hybridus*	Whiskered tern	W	C	RM
	Acipitridae				
64	*Pandion haliaetus*	Osprey	W/T	VR	RM
65	*Pernis ptilorhyncus*	Oriental honey buzzard	T	VR	RM
66	*Elanus caeruleus*	Black-shouldered kite	T	VR	R
67	*Haliastur indus*	Brahminy kite	T	VR	R
68	*Circaehr gallicus*	Shorat-toed snake-eagle			
69	*Circus aeruginosus*	Eurasian marsh harrier	T/W	VR	M
70	*Circus macrourus*	Pallid harrier	T	VR	M
71	*Accipiter nisus*	Eurasian sparrowhawk	T	R	M
72	*Aquila rapax*	Tawny eagle	T	VR	R
73	*Hieraaetus fasciatus*	Bonelli's eagle	T	VR	R
	Falconidae				
74	*Falco tinnunculus*	Common kestrel	T	VR	RM
75	*Falco chicquera*	Red-headed merlin	T	VR	R
76	*Falco subbuteo*	Northern hobby	T	VR	RM
77	*Falco jugger*	Lagger falcon	T	VR	RM
	Ardeidae				
78	*Egretta garzetta*	Little egret	W	C	R
79	*Egretta gularis*	Western reef heron	W		RM
80	*Ardea cinerea*	Grey heron	W		RM
81	*Casmerodius albus*	Great egret	W		RM
82	*Mesophoyx intermedia*	Intermediate egret	W		RM
83	*Bubulcus ibis*	Cattle egret	T		R
84	*Ardeola grayii*	Indian pond-heron	W		R

Table 4.5.36 (Contd 5)

No	Scientific name	Common english name	T/W	Abundance status	Migratory status
85	*Phoenicopterus ruber*	Greater flamingo	W		R
86	*Phoenicopterus minor*	Lesser flamingo	W		R
	Threskiornithidae				
87	*Threskiornis melanocephalus*	Asian white ibis	W		R
88	*Pseudibis papillosa*	Black ibis	W/T		R
89	*Platalea leucorodia*	Eurasian spoonbill	W		RM
	Pelecanidae				
90	*Pelecanus crispus*	Dalmatian pelican	W		M
	Ciconiidae				
91	*Mycteria leucocephala*	Painted stork	W		RM
	Laniidae				
92	*Lanius collurio*	Rufous-tailed shrike	T		M
93	*Lanius vittatus*	By-backed shrike	T		R
94	*Lanius schach*	Long-tailed shrike	T		R
95	*Lanius excubitor*	Great grey shrike	T		RM
	Corvidae				
96	*Corvus slendens*	House crow	T		R
97	*Corvus macrorhynchos*	Jungle crow	T		R
98	*Pericrocotus cinnamomeus*	Small minivet	T		R
99	*Dicrurus macrocercus*	Black drongo	T		R
100	*Aegithina tiphia*	Marshall's lora	T		R
101	*Tephrodornis pondicerianus*	Lesser woodshrike	T		R
	Muscicapidae				
102	*Ficedula zanthopygia*	Red-throated flycatcher	T		M
103	*Saxicoloides fulicate*	Indian robin	T		R
104	*Phoenicurus ochruros*	Black redstart	T		M
105	*Oenanthe pleschanka*	Pied wheatear	T		M

Table 4.5.36 (Contd 6)

No	Scientific name	Common english name	T/W	Abundance status	Migratory status
106	*Oenanthe deserti*	Desert wheather	T		M
107	*Oenanthe isabellina*	Isabelline wheather	T		M
	Sturnidae				
108	*Strunus pagodarum*	Brahminy starling	T		R
109	*Strunus roseus*	Rosy starling	T		M
110	*Acridotheres tristis*	Common myna	T		R
111	*Acridotheres ginginianus*	Bank myna	T		R
	Hirundinidae				
112	*Hirundo rustica*	Barn swallow	T	R	RM
113	*Hirundo smithii*	Wire-tailed swallow	T	R	R
114	*Hirundo daurica*	Red-rumped swallow	T	C	R
	Pycnonotidae				
115	*Pycnonotus leucotis*	White-eared bulbul	T	A	R
116	*Pycnonotus cafer*	Red-ventled bulbul	T	C	R
	Cisticolidae				
117	*Prinia buchanani*	Rufous-fronted prinia	T	C	R
118	*Prinia sylvatica*	Jungle prinia	T	R	R
	Zosterops				
119	**Zosterops *palpebrosus***	Oriental white-eye	T	C	R
	Sylviidae				
120	*Acrocephalus dumetorum*	Blyth's reed warbler	T	C	M
121	*Acrocephalus arundinaceus*	Great reed warbler	T	C	M
122	*Hippolais caligata*	Booted warbler	T	VR	M
123	*Orthotomus sutorius*	Common tailorbird	T	A	R
124	*Turdoides caudatus*	Common babbler	T	A	R
125	*Sylvia curruca*	Lesser whitethroat	T	A	M

Table 4.5.36 (Contd 7)

No	Scientific name	Common English name	T/W	Abundance status	Migratory status
126	*Sylvia hortensis*	Orphean warbler	T	R	M
	Alaudidae				
127	*Mirafra cantillans*	Singging bush- lark	T	R	R
128	*Eremopterix grisea*	Ashy- crowned sparrow-lark	T	R	R
129	*Calandrella cheleensis*	Asian short- toed lark	T	C	M
130	*Calandrella raytal*	Sand short-toed lark	T	C	M
131	*Galerida cristata*	Crested lark	T	R	R
132	*Alauda gulgula*	Eastern skylark	T	VR	R
	Nectariniidae				
133	*Nectarinia asiatica*	Purple sunbird	T	A	R
	Passeridae				
134	*Passer domesticus*	House sparrow	T	A	R
135	*Passer sp.*	Yellow throated sparrow			
136	*Motacilla cinerea*	Grey wagtail			
137	*Motacilla alba*	White wagtail	W/T	VR	M
138	*Anthus campestris*	Tawny pipit	T	VR	M
139	*Ploceus philippinus*	Baya weaver	T	C	R
140	*Lonchura malabarica*	Plain munia	T	A	R

T/W T: Terrestrial bird, W : Water bird, Abundance status – A: Abundance, C: Common, R : Rare, VR : Very rare.

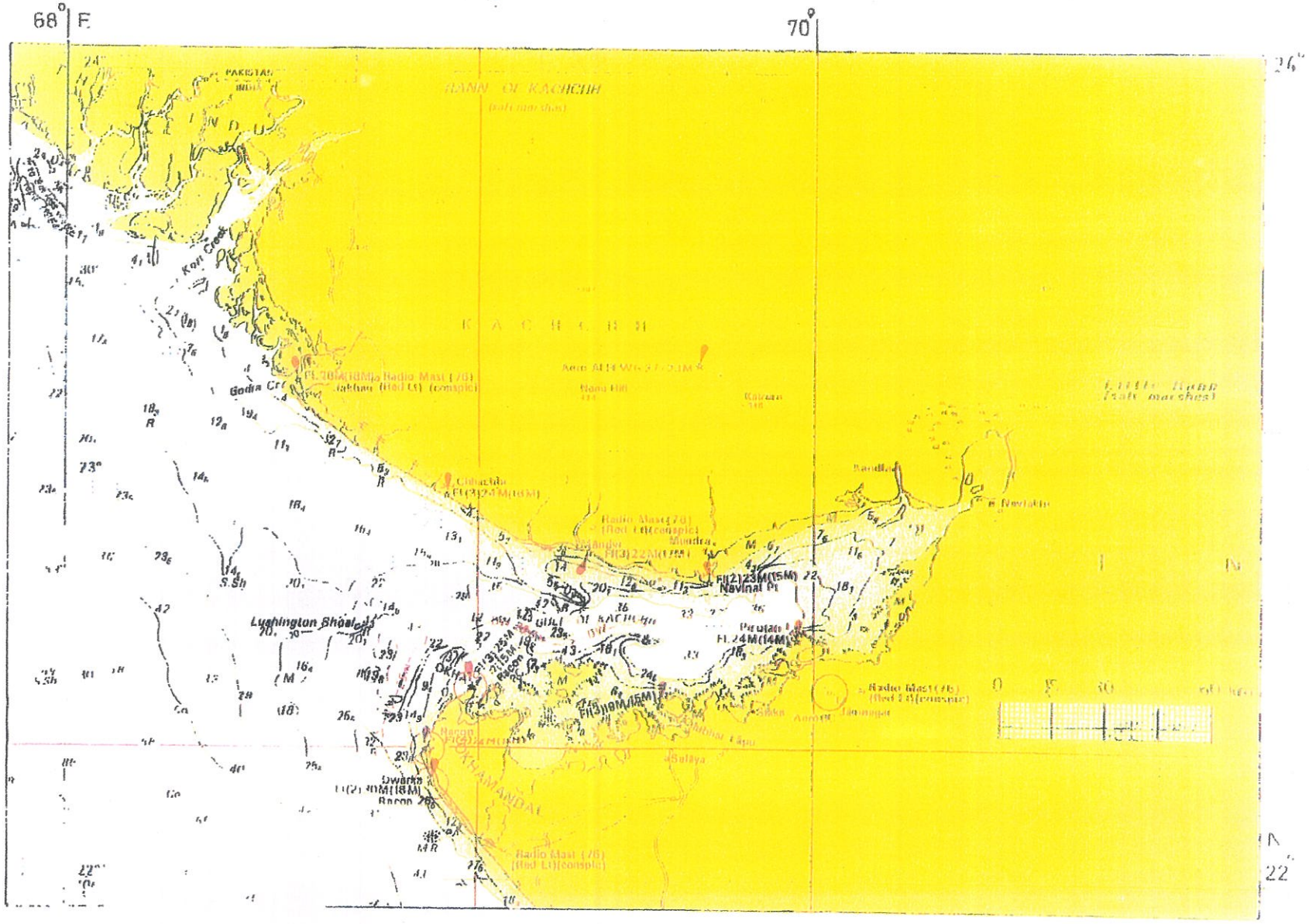


Figure 1.4.1: Gulf and the surrounding region

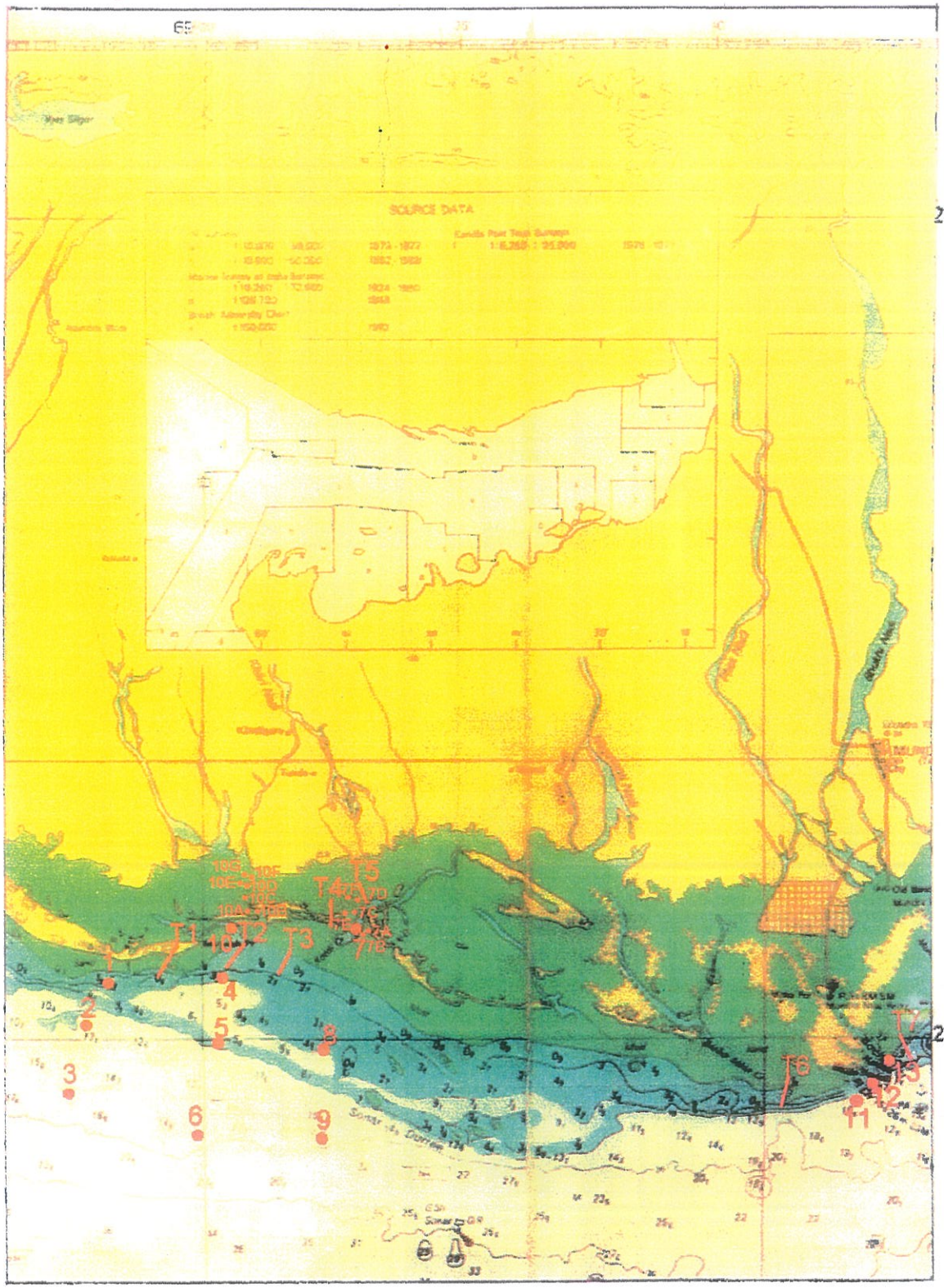


Figure 1.4.2: Sampling locations

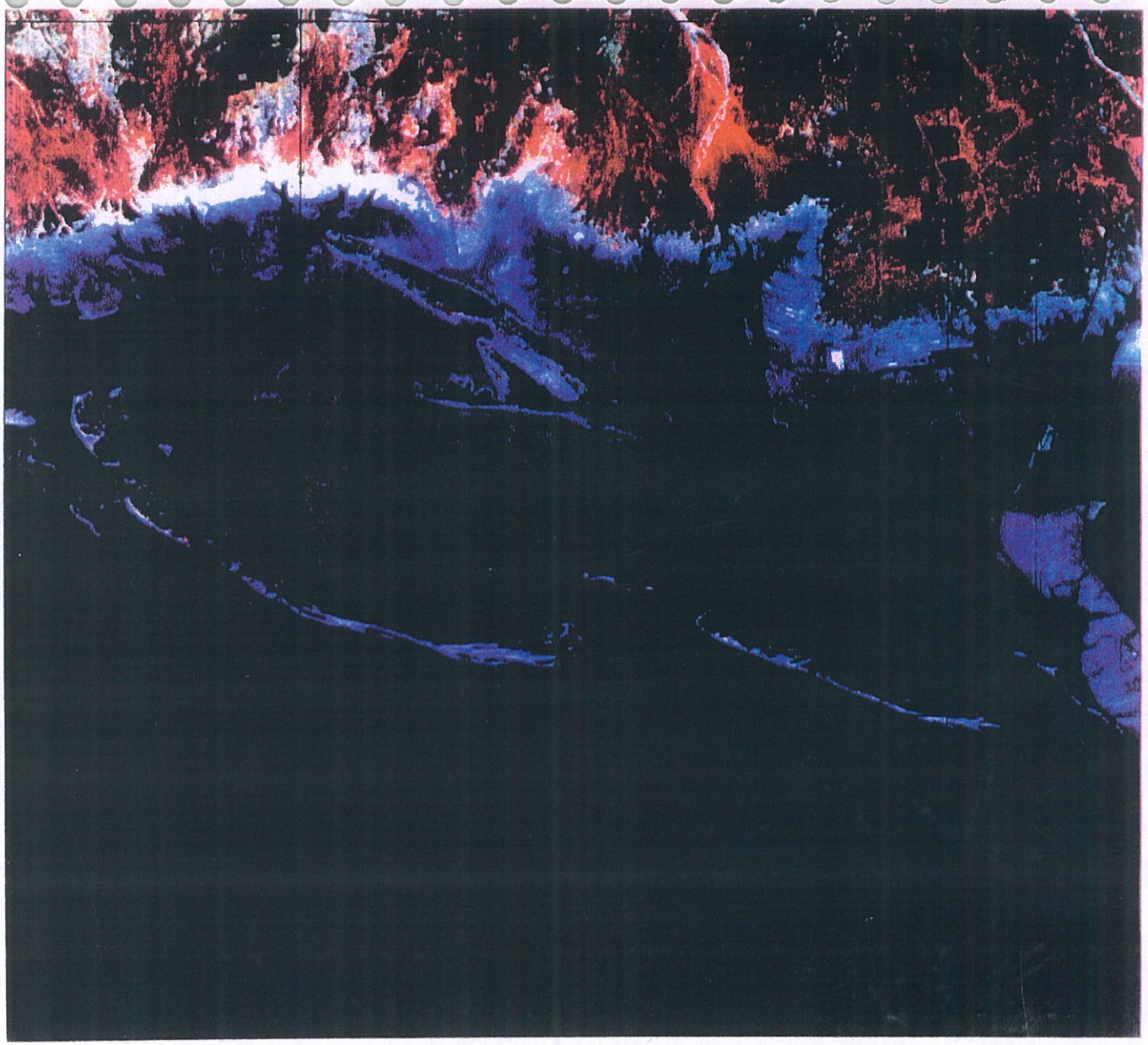


Figure 2.0.2: Satellite imagery of the gulf segment off Mundra/Wandh

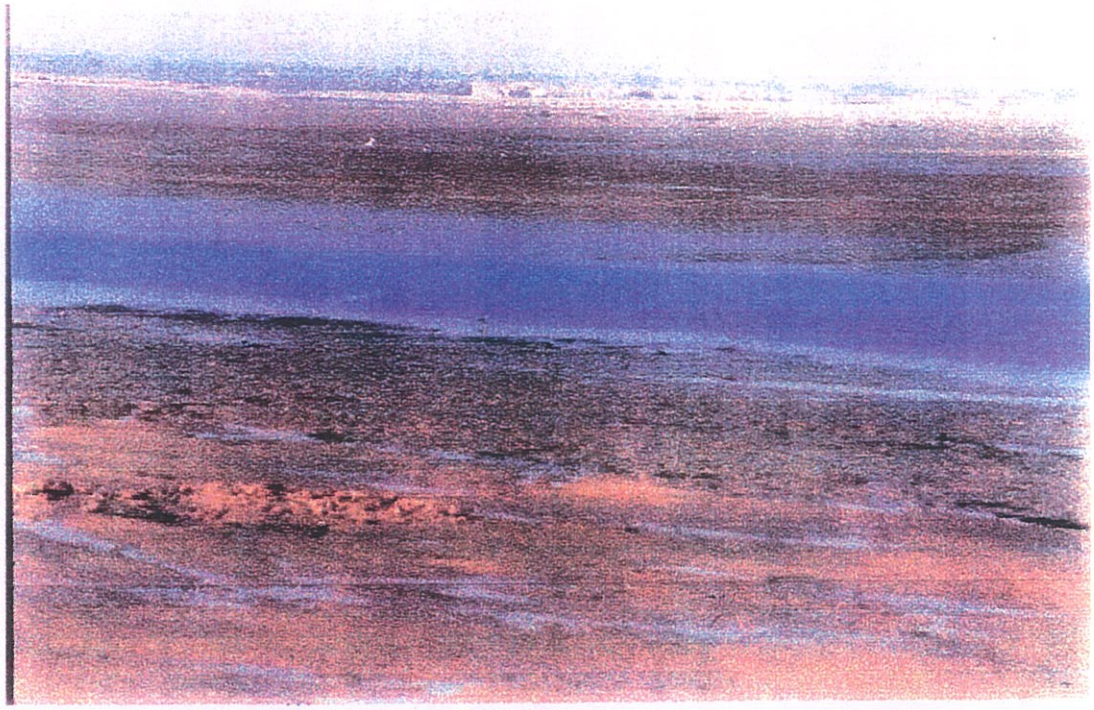


Figure 2.2.1: Photograph showing Wandh village and Kotdi creek

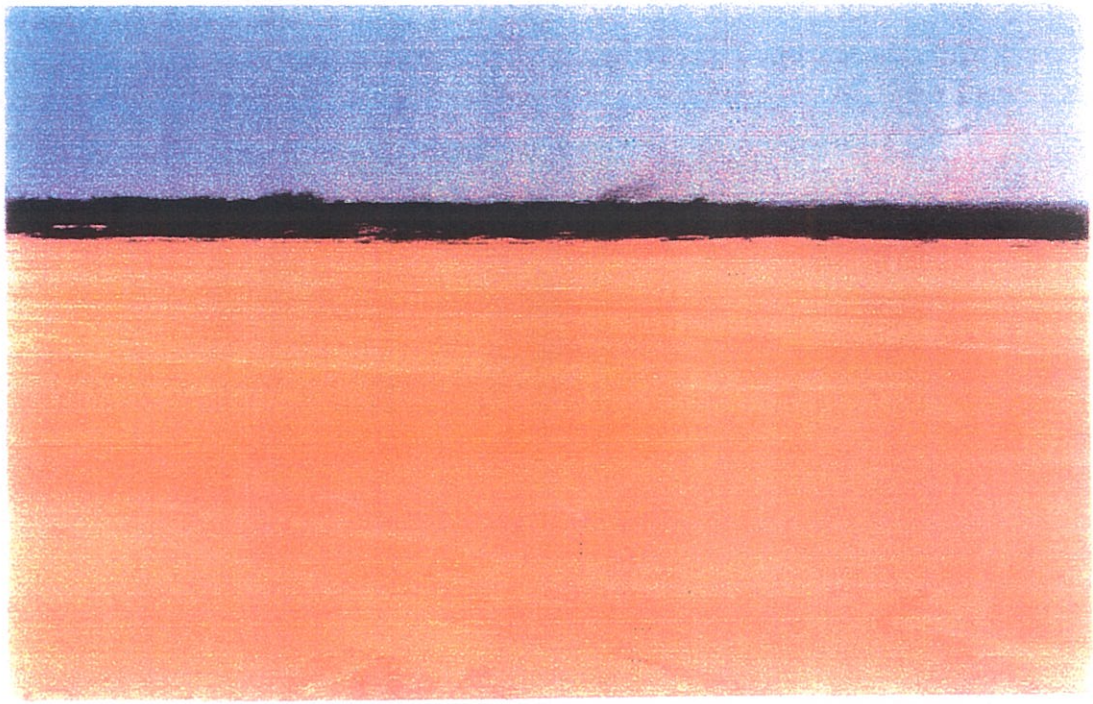


Figure 2.2.2: Photograph showing proposed site and adjoining region of Kotdi creek

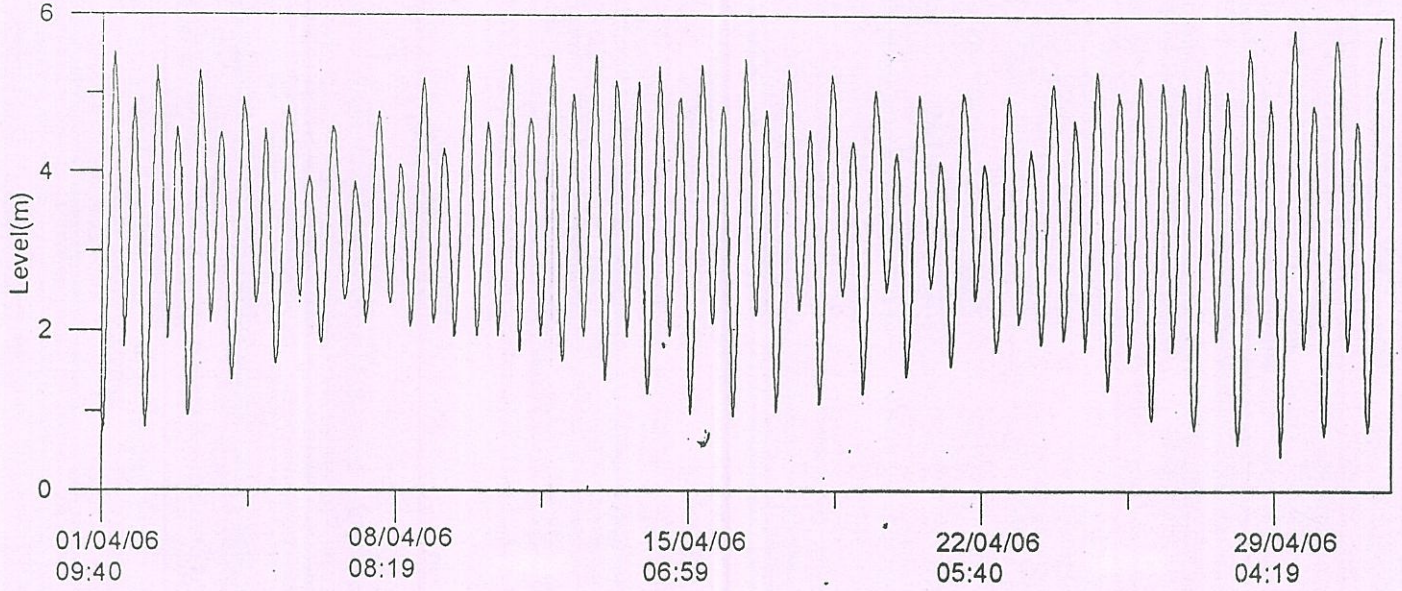


Figure 4.2.2: Observed tide at Kotdi creek 1-30 April 2005

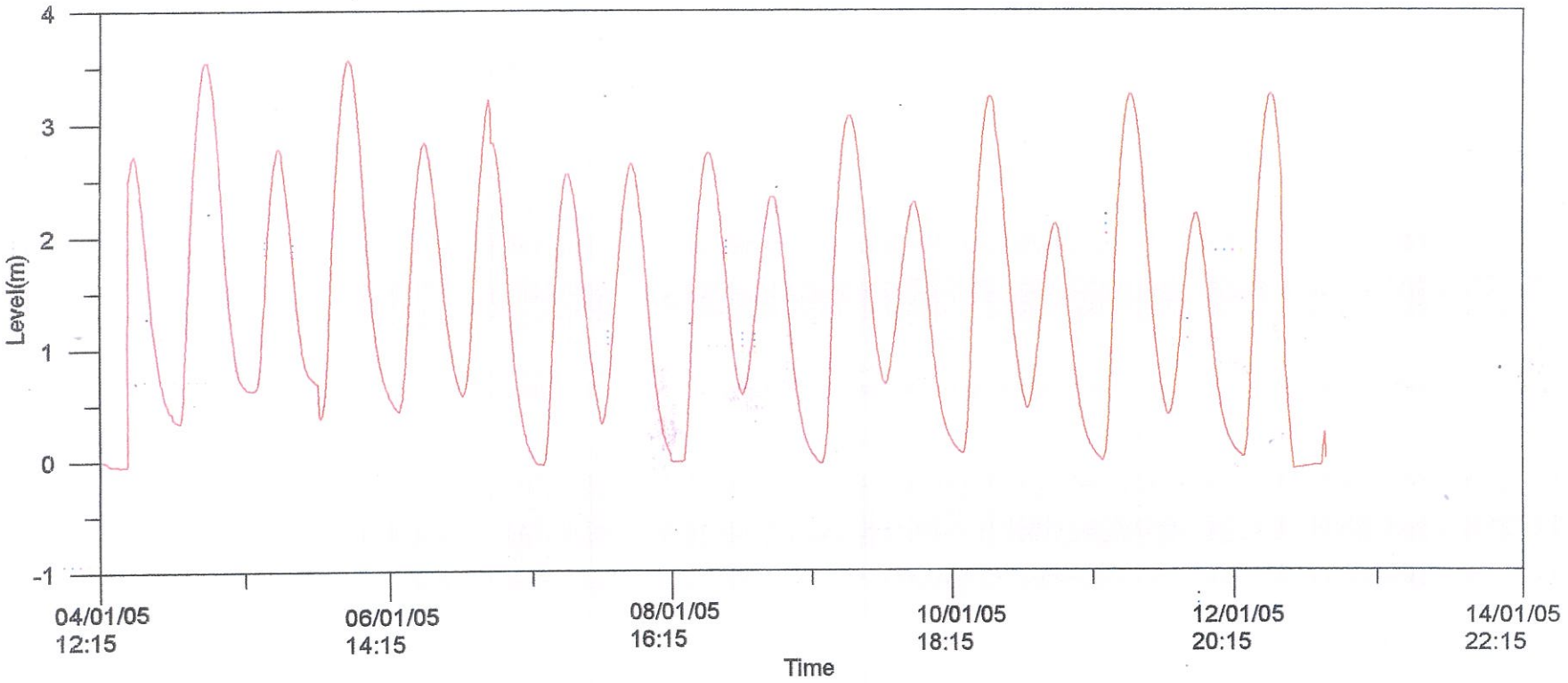


Figure 4.2.1: Tide collected at Kotdi creek during 4-12 January 2005

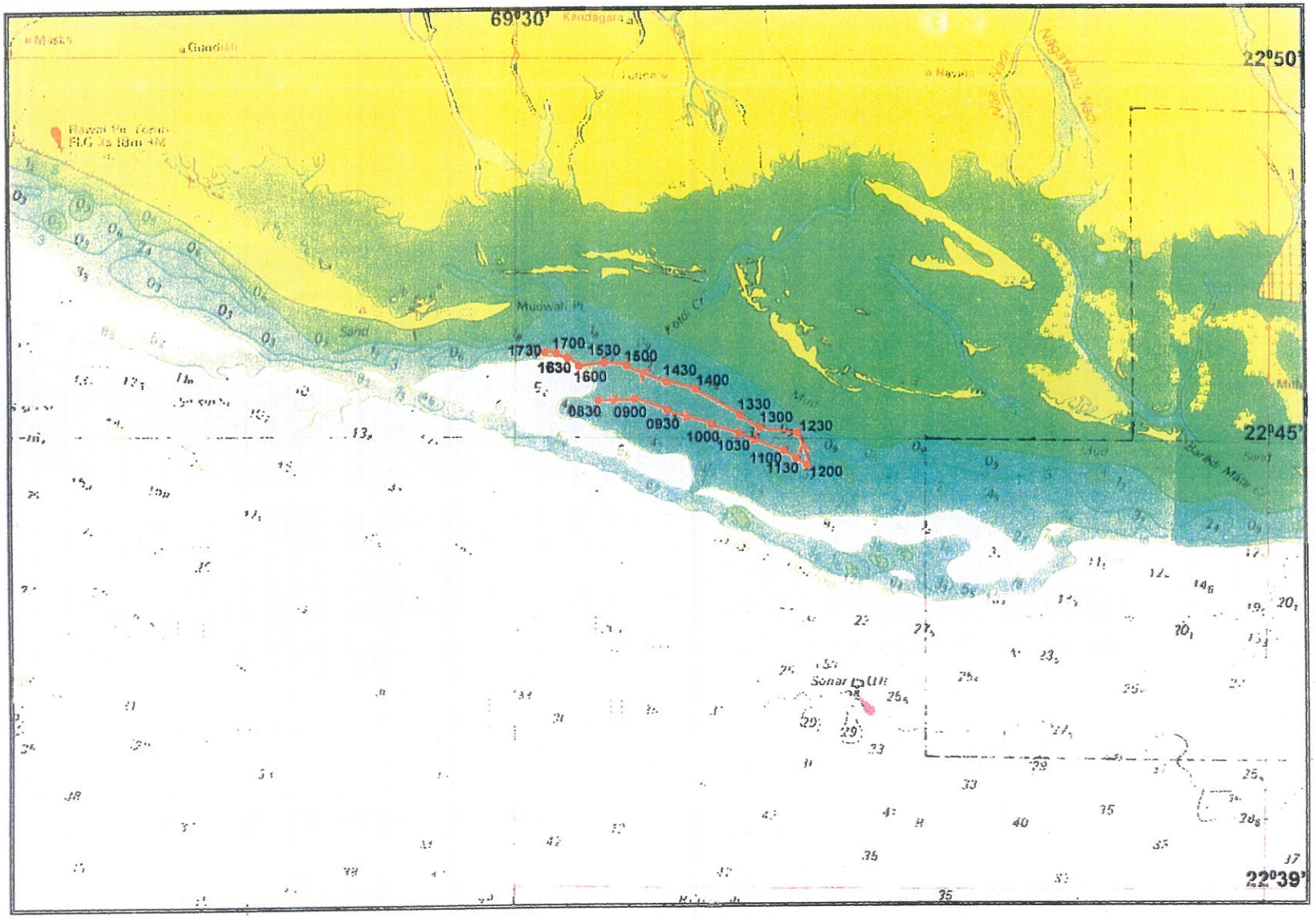


Figure 4.2.3: Drogue path at station 5(Ebb-Flood-Ebb) during January 2006

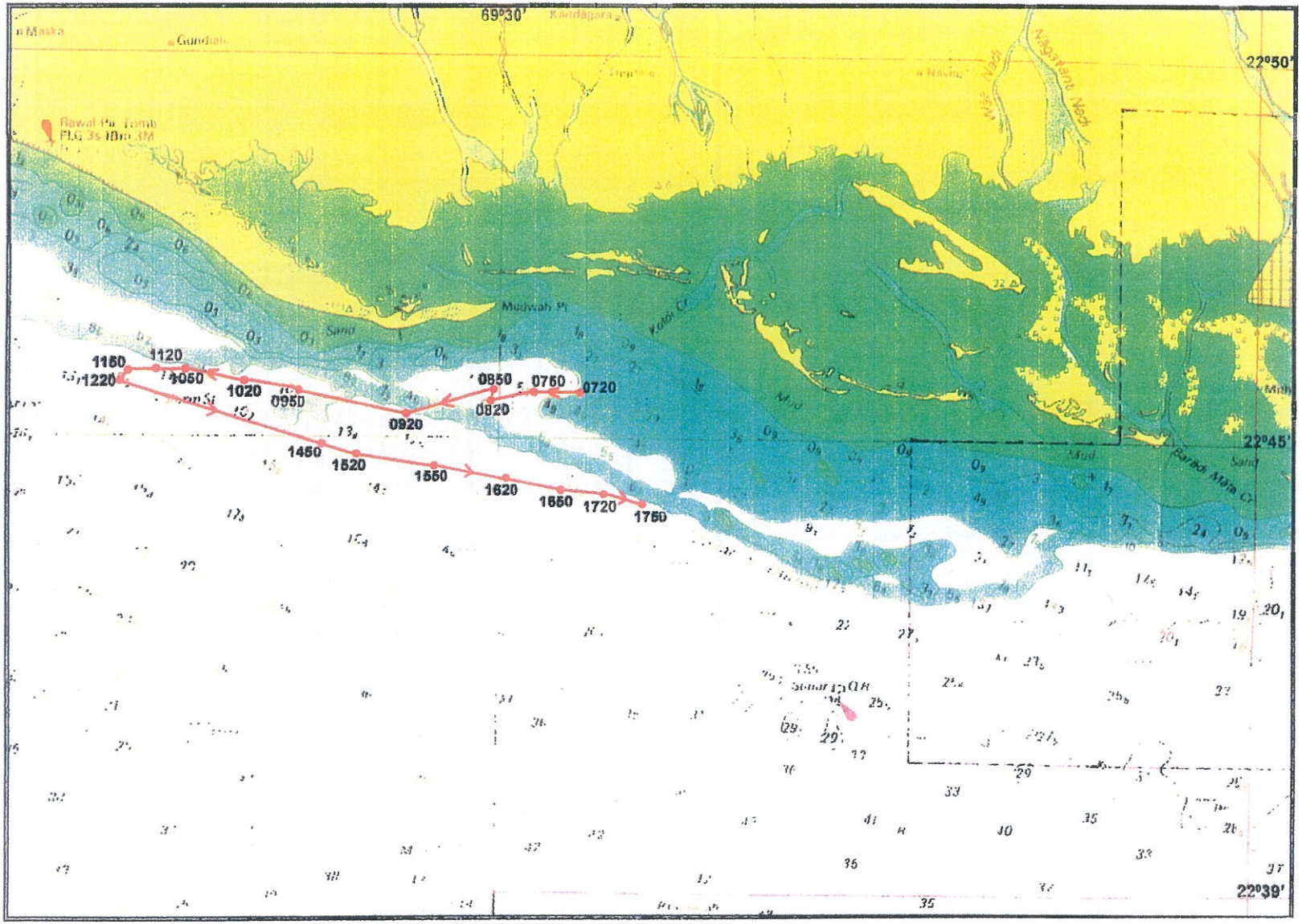


Figure 4.2.4: Drogue path at station 5(Flood-Ebb-Flood) during January 2006

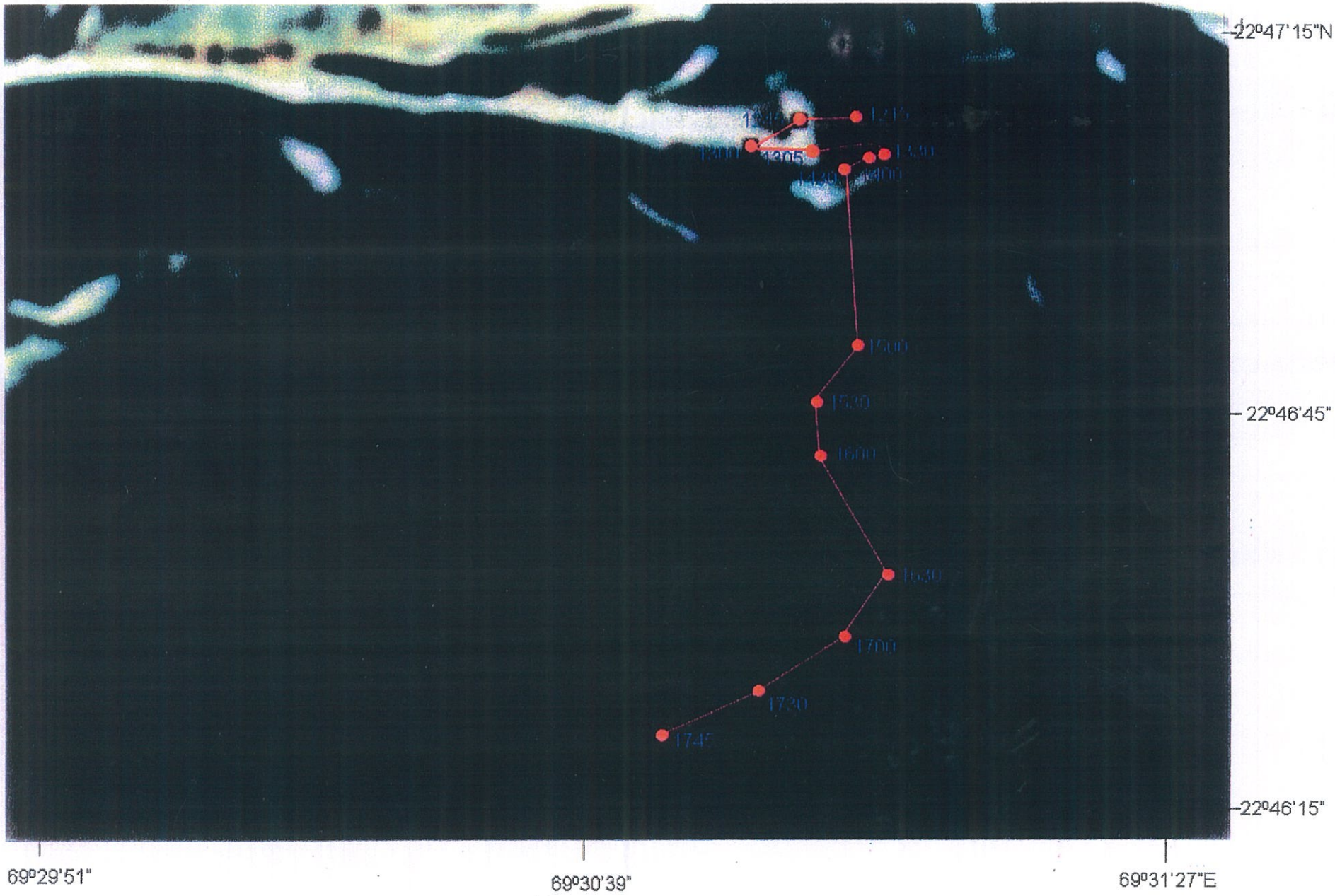


Figure 4.2.5: Drogue path at station 10(Flood-Ebb-Flood) during November 2006

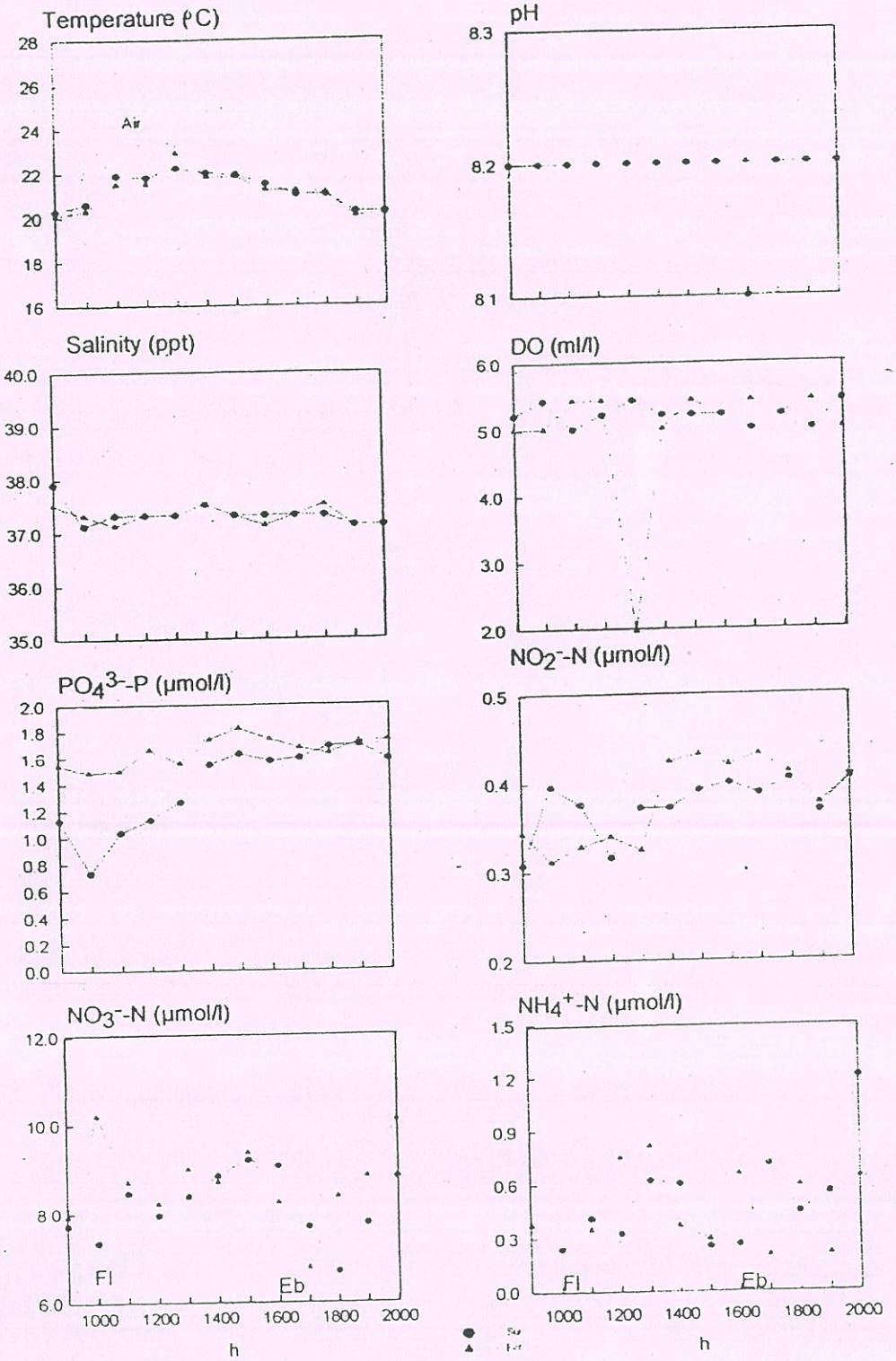


Figure 4.3.1: Water quality at station 5 on 10 January 2006

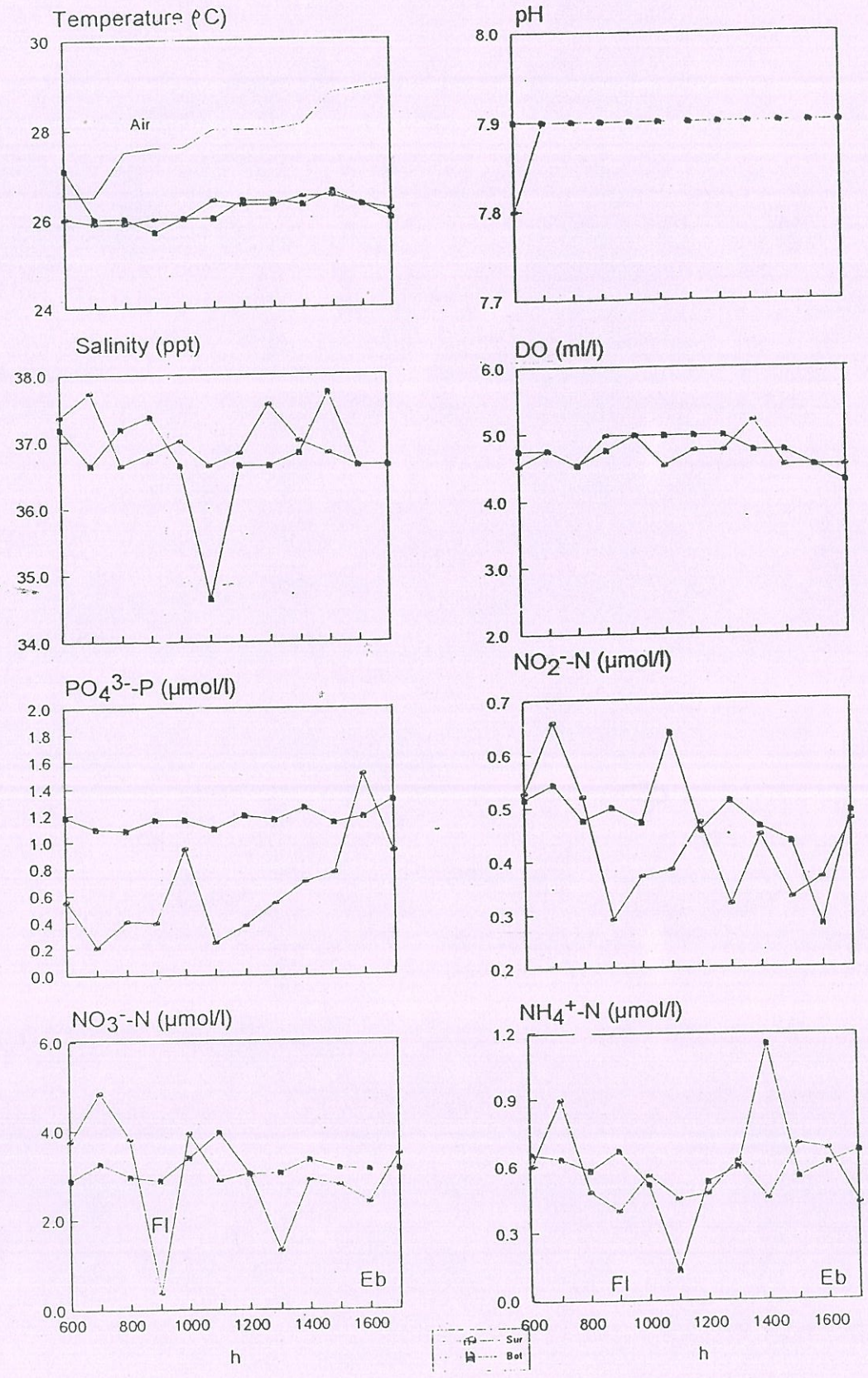


Figure 4.3.2: Water quality at station 5 on 7 April 2006

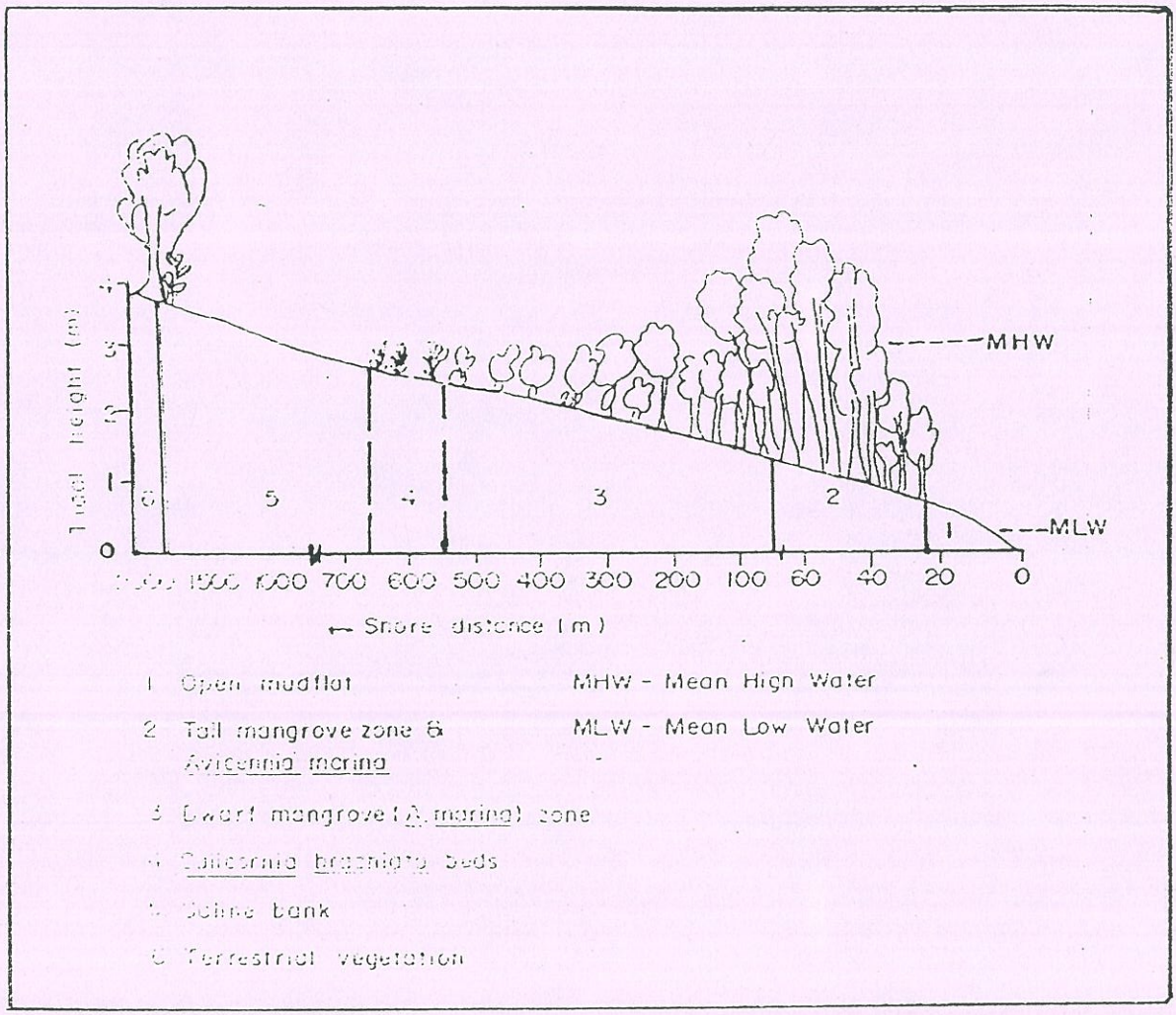


Figure 4.5.1: General distribution of mangroves and another vegetation along Kotdi-Baradimata creeks complex

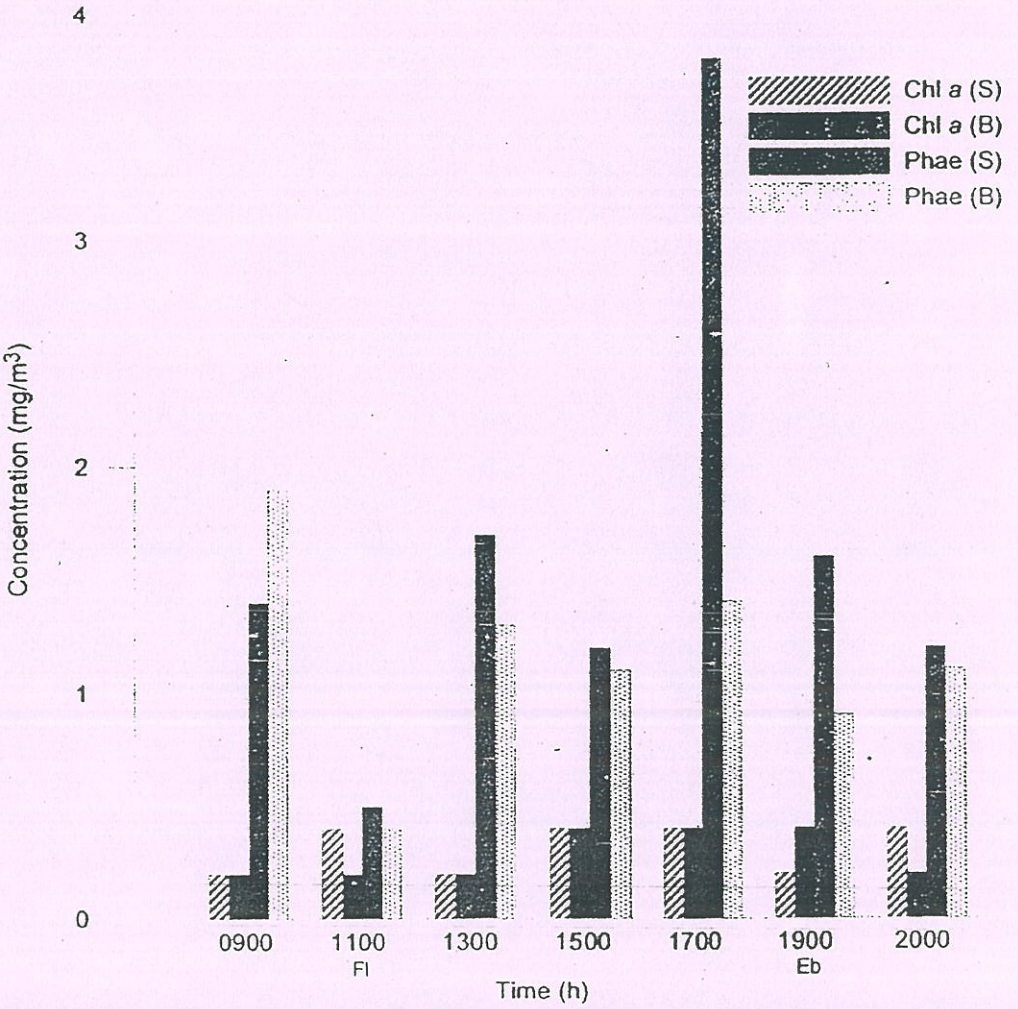


Figure 4.5.2: Temporal variation of phytopigments at station 5 off Wandh on 10 January 2006

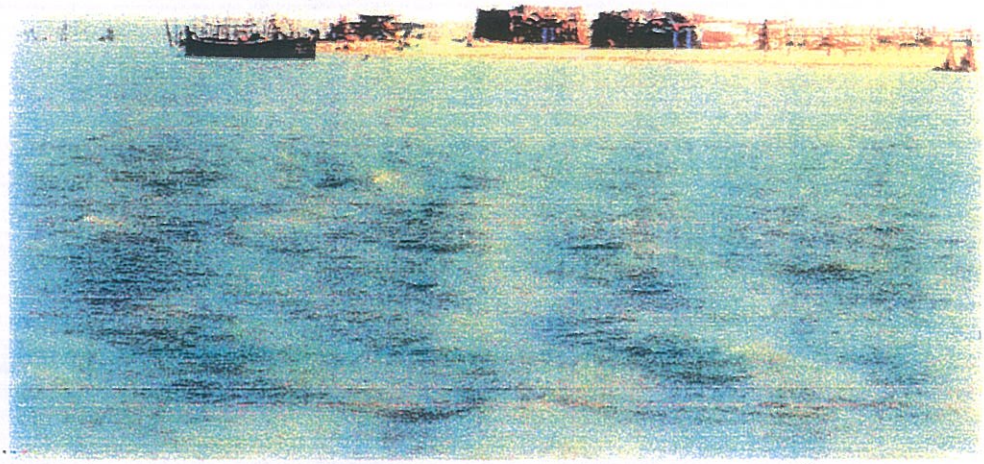


Figure 4.5.3: Fish landing center at the mouth of Kotdi creek



Figure 4.5.4: A view of minor fishing activities at Kotdi creek



Figure 5.1.1: A view of mouth segment of Kotdi creek (Proposed intake point)

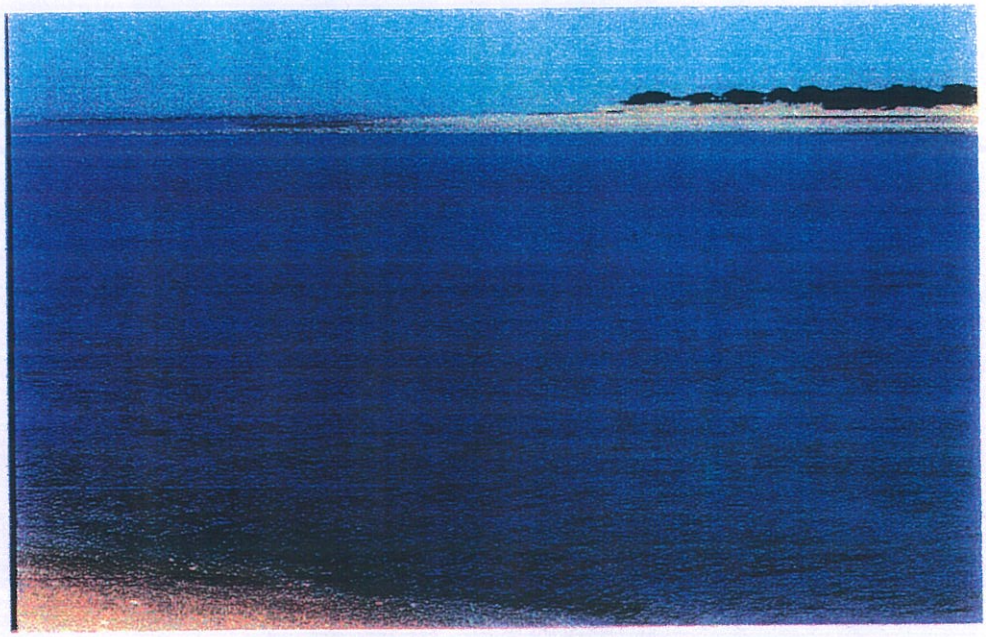


Figure 5.1.2: A view of mid segment of Kotdi creek

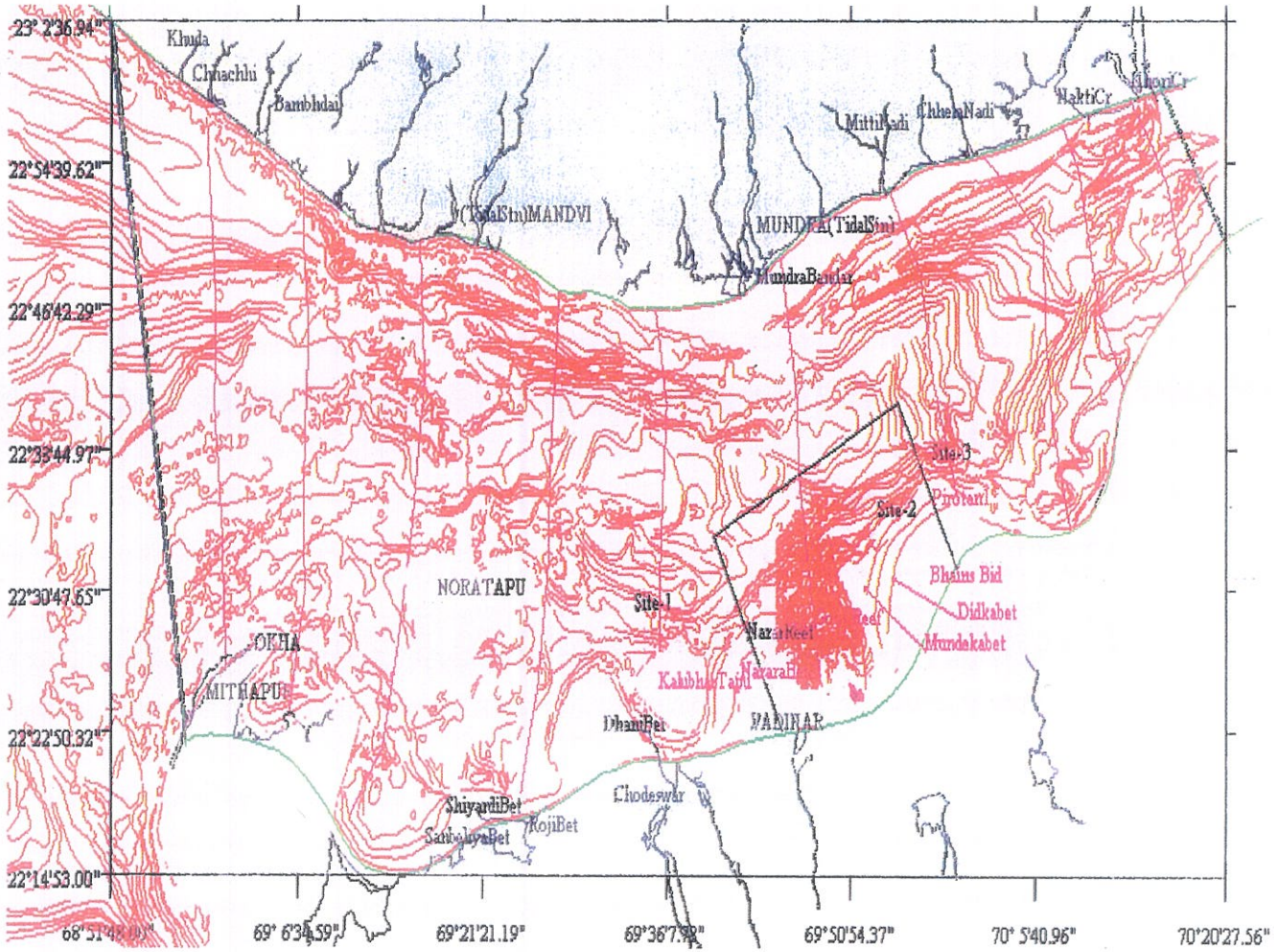


Figure 6.5.1 : Larger Domain



Figure 6.2.1: A view of gulf segment off Wandh during ebb tide



Figure 6.2.2: A view of gulf segment off Wandh during flood tide

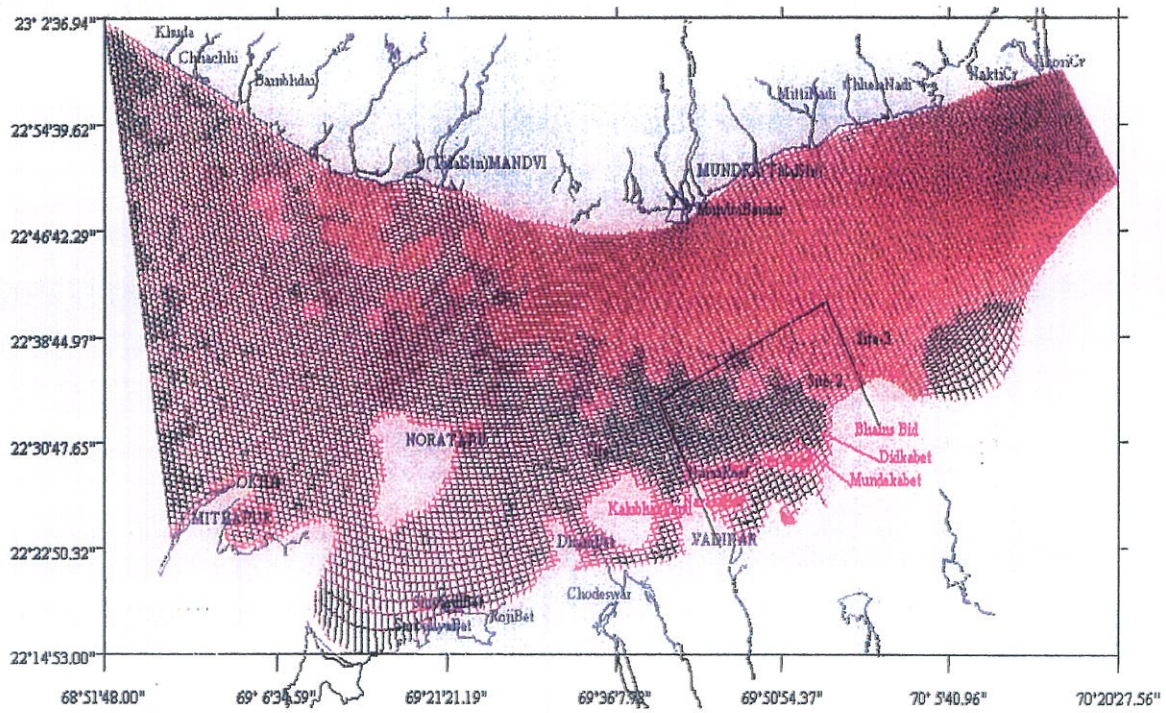


Figure 6.5.2 : Interpolated bathymetry depths larger domain

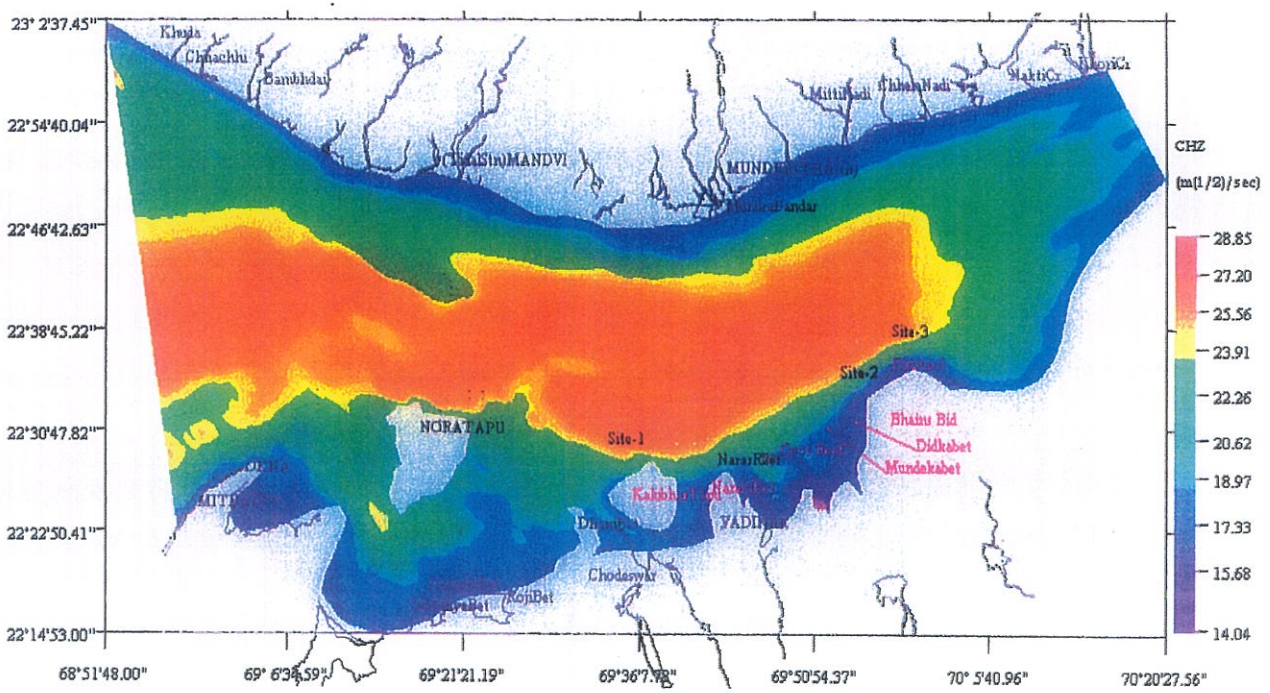


Figure 6.5.3 : Chezy's coefficient for larger domain.

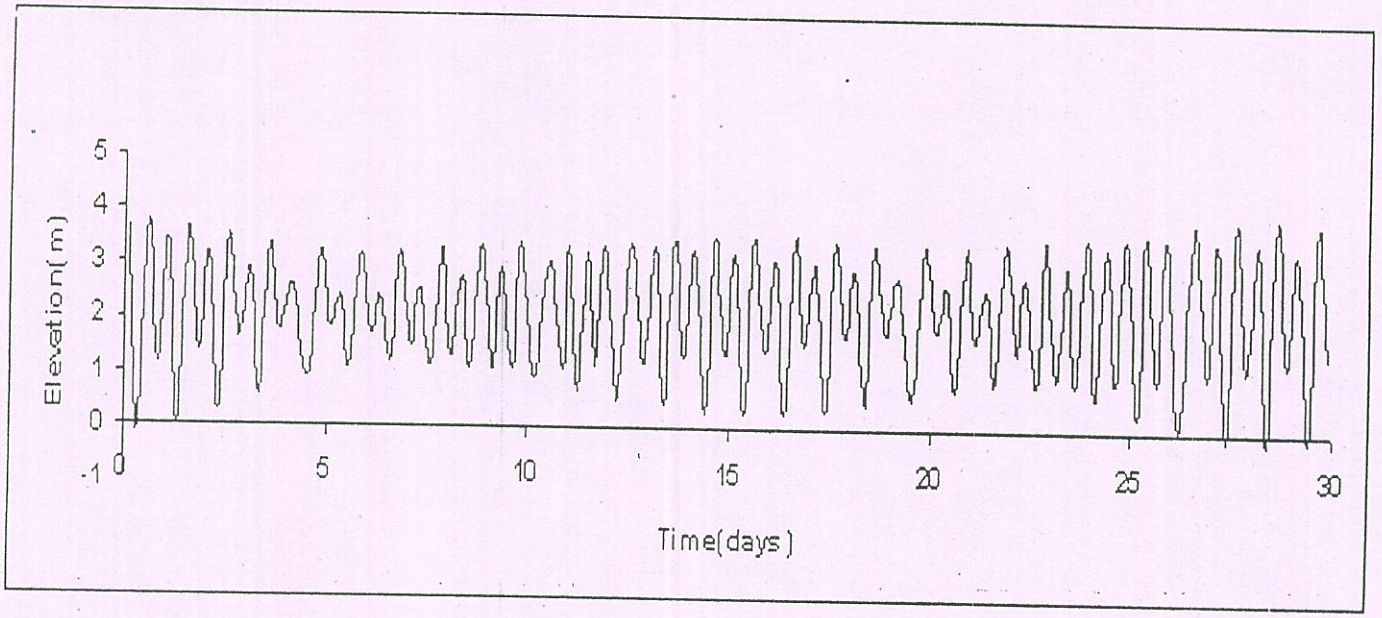


Figure 6.5.4 : Observed tides at Okha during January.

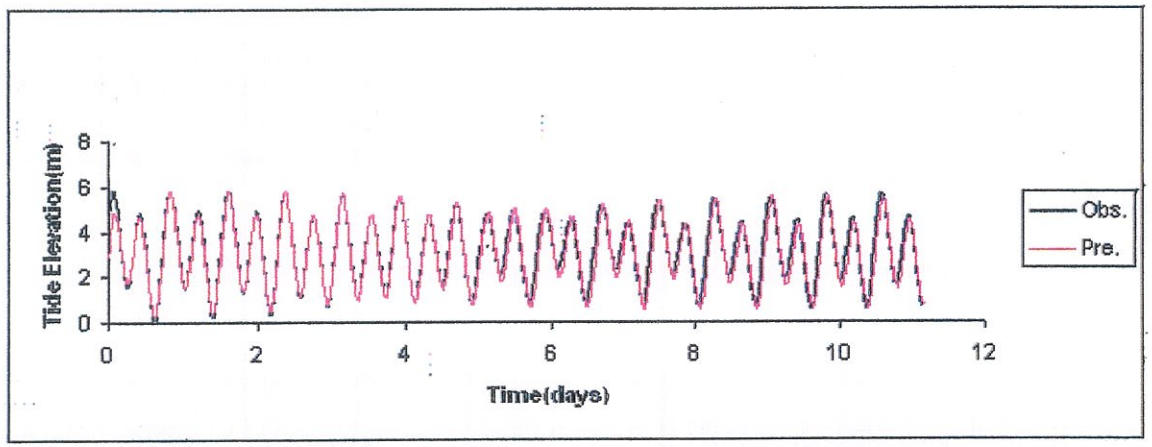


Figure 6.5.5 : Comparison of predicted and measured tides at Berth-E (Jan 2006)

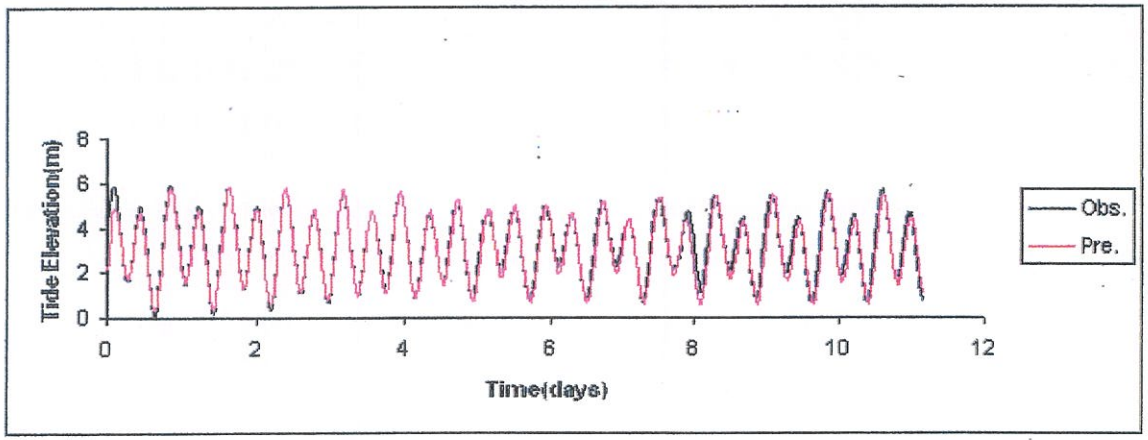
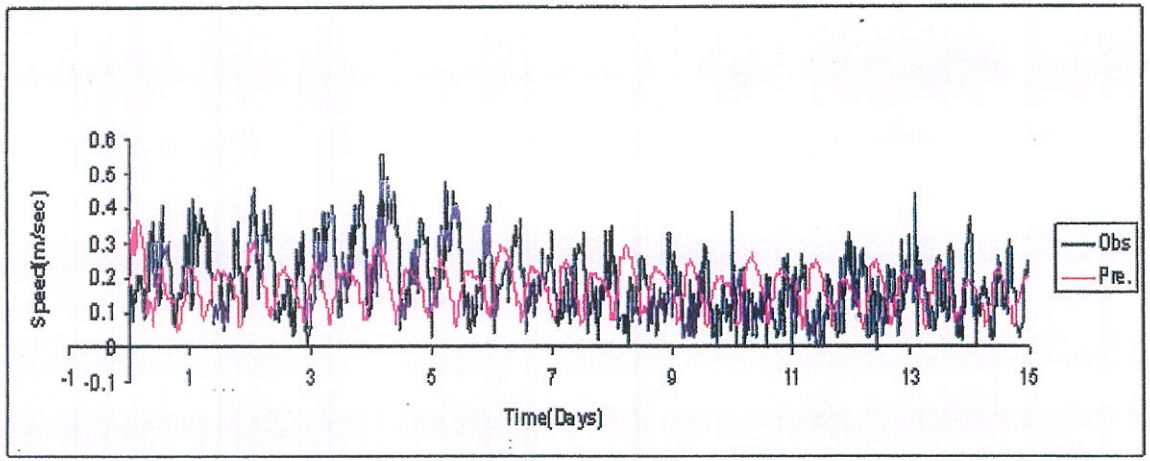
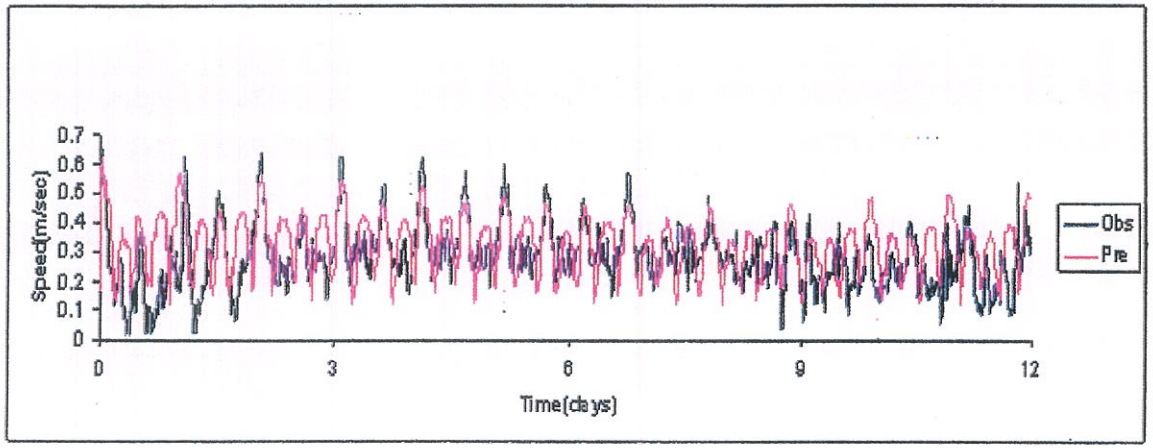


Figure 6.5.6 : Comparison of predicted and measured tides at Berth-F (Jan 2006)



(a)



(b)

Figure 6.5.7 : Comparison of observed and predicted currents at (a)Berth-E and (b)Berth-F

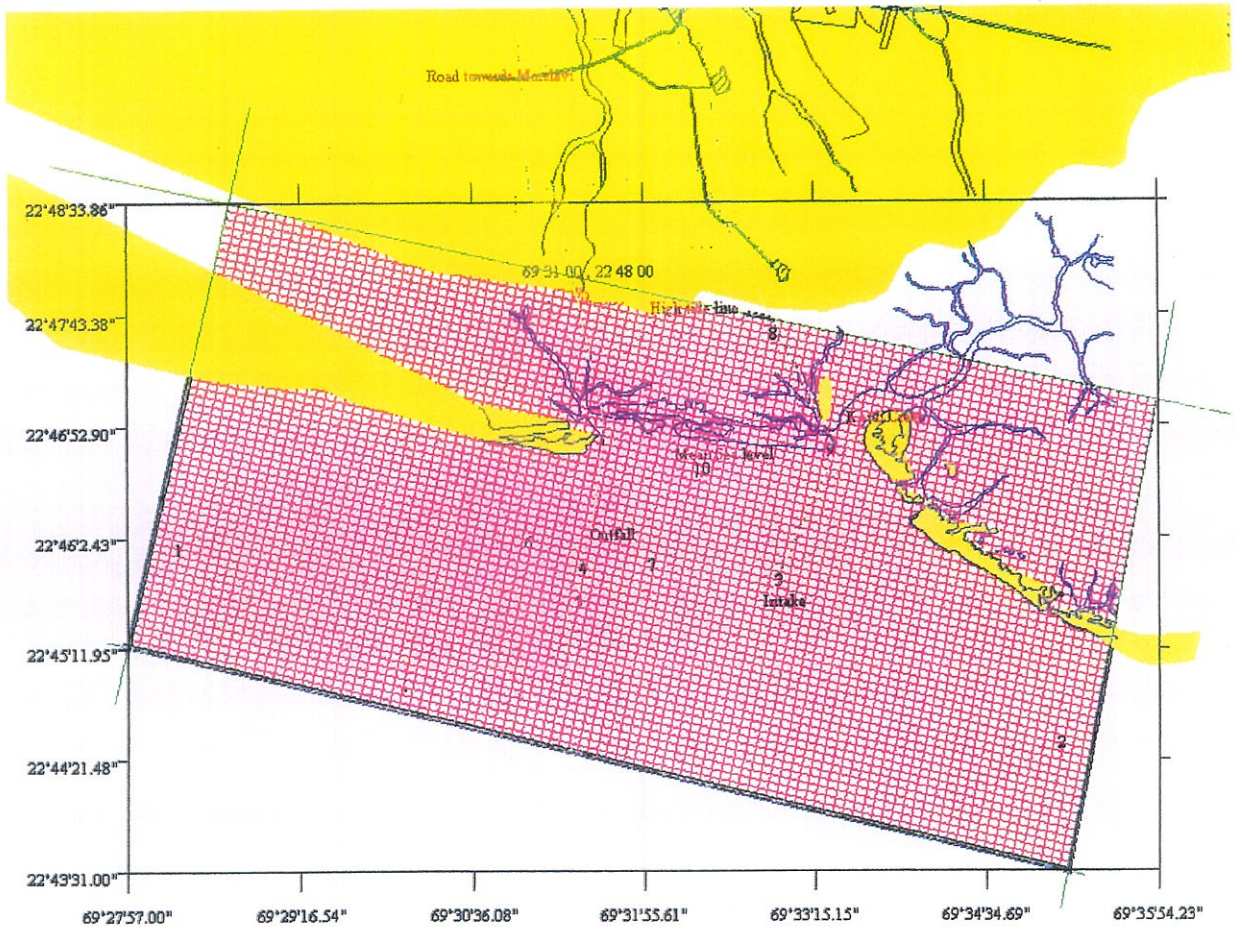


Figure 7.1.2 : Interpolated bathymetry depths smaller domain.

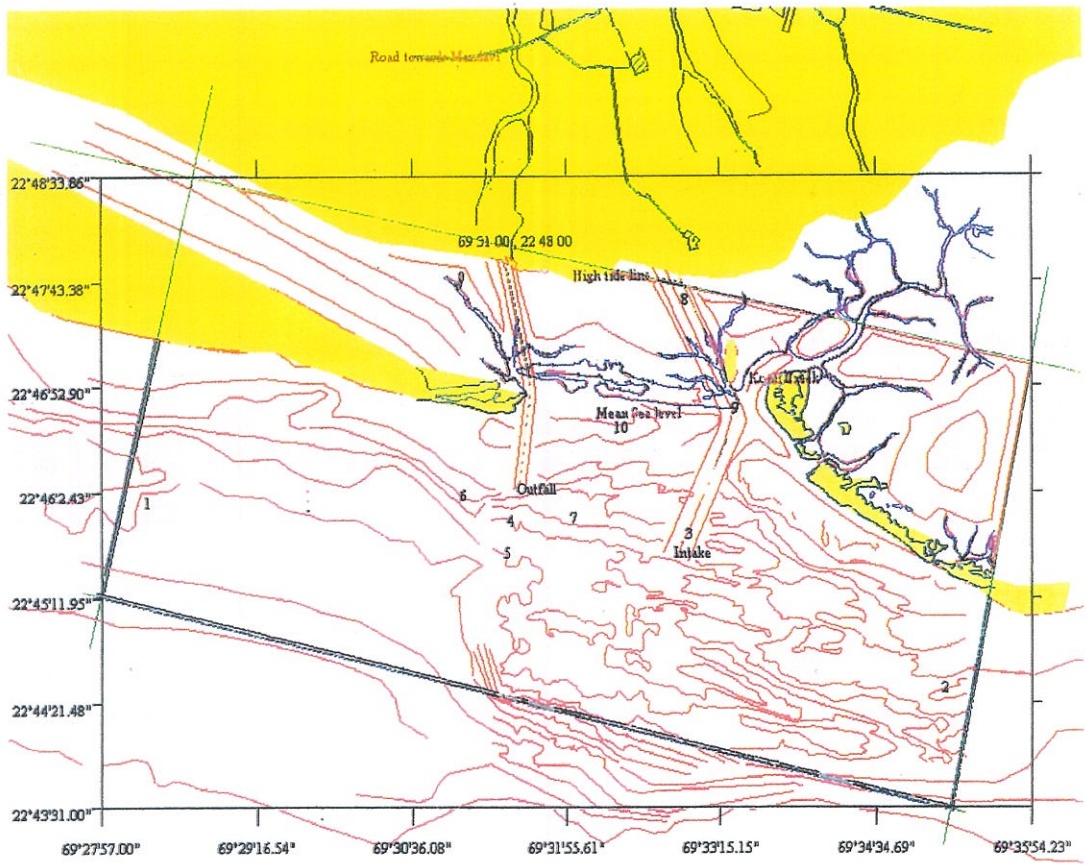


Figure 7.1.1 : Study domain smaller

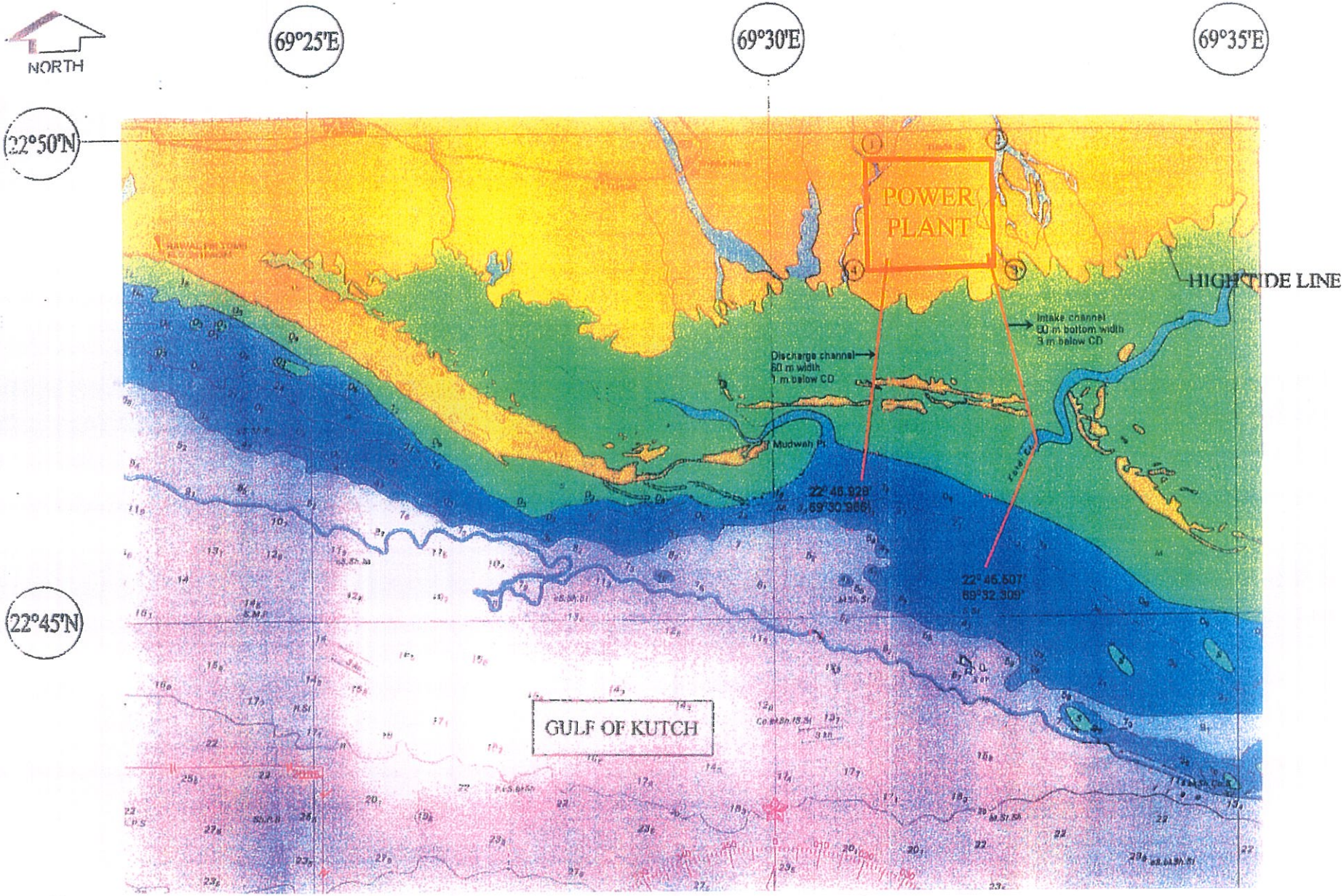


Figure 7.2.1: Proposed seawater intake and effluent release options

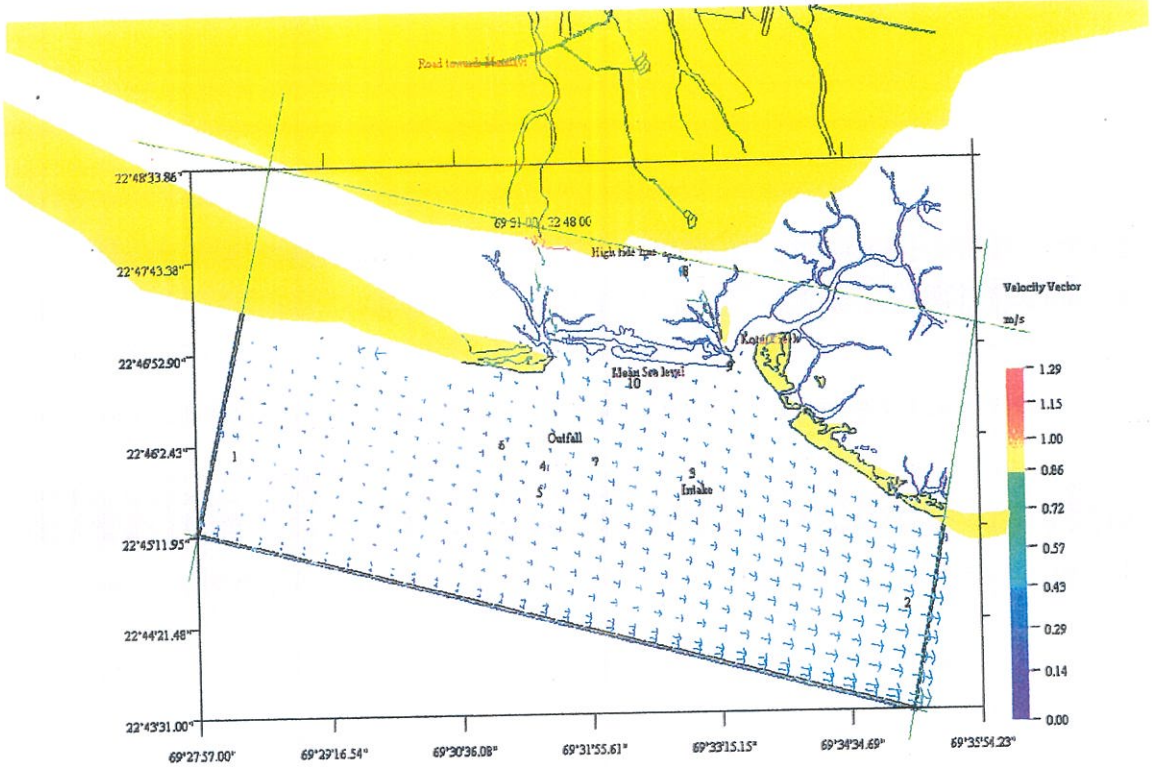


Figure 7.2.2 : Current vectors at mid flood during spring.

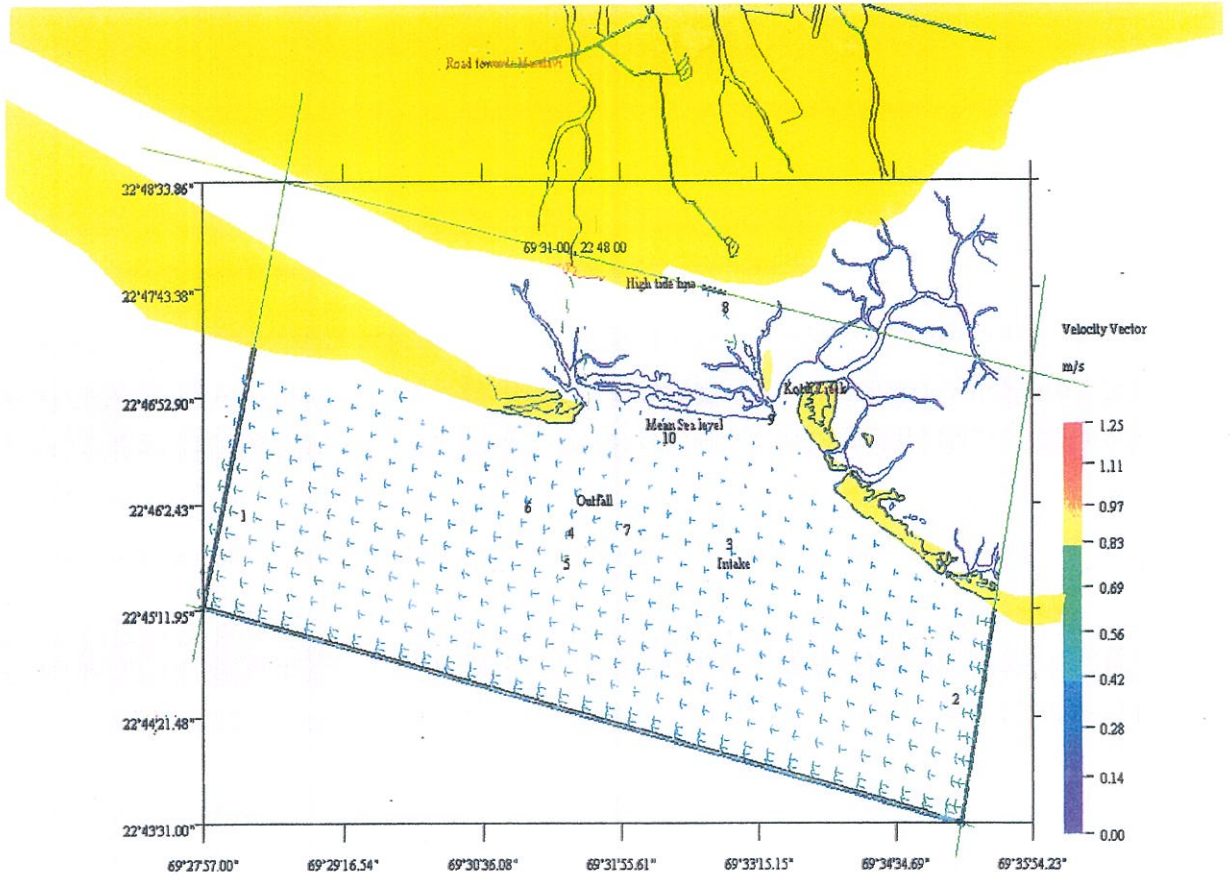


Figure 7.2.4 : Current vectors at mid ebb during spring.

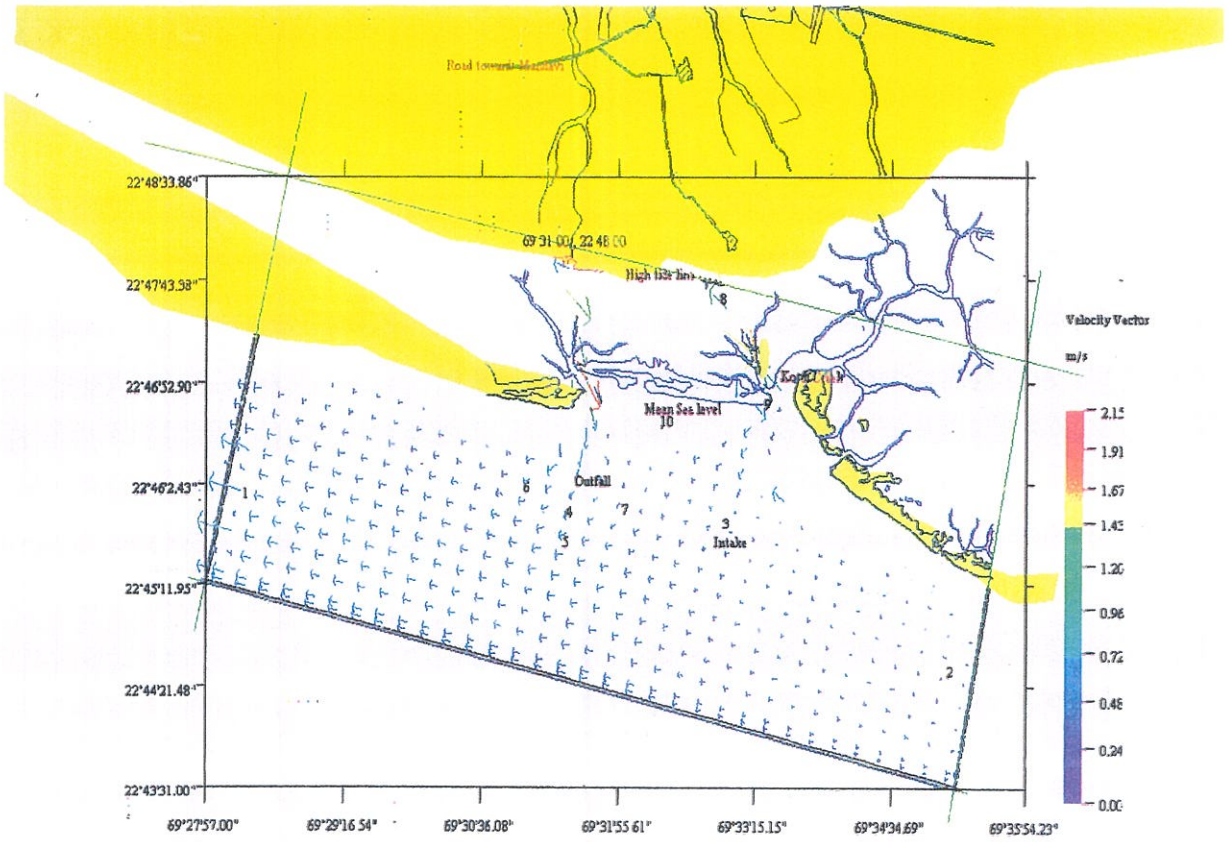


Figure 7.2.5 : Current vectors at low water during spring

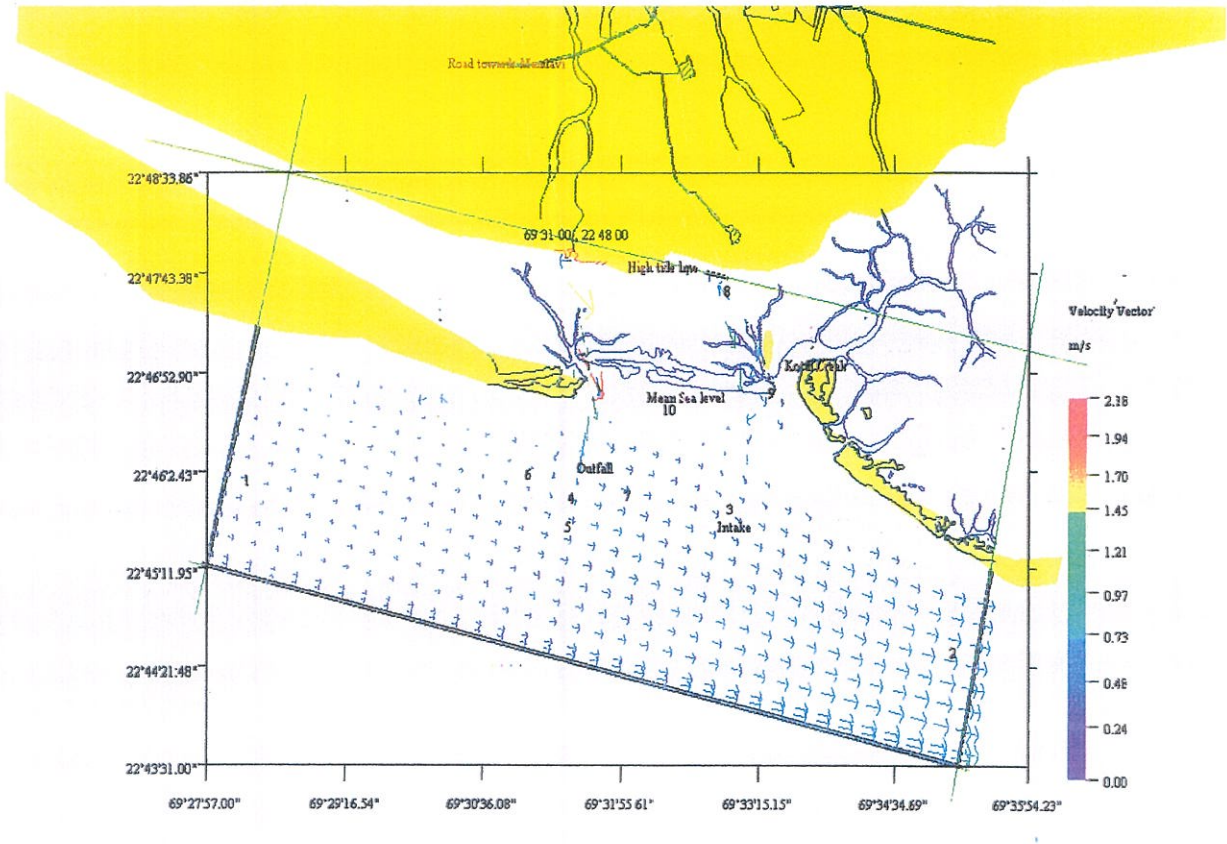


Figure 7.2.6 : Current vectors at mid flood during neap.

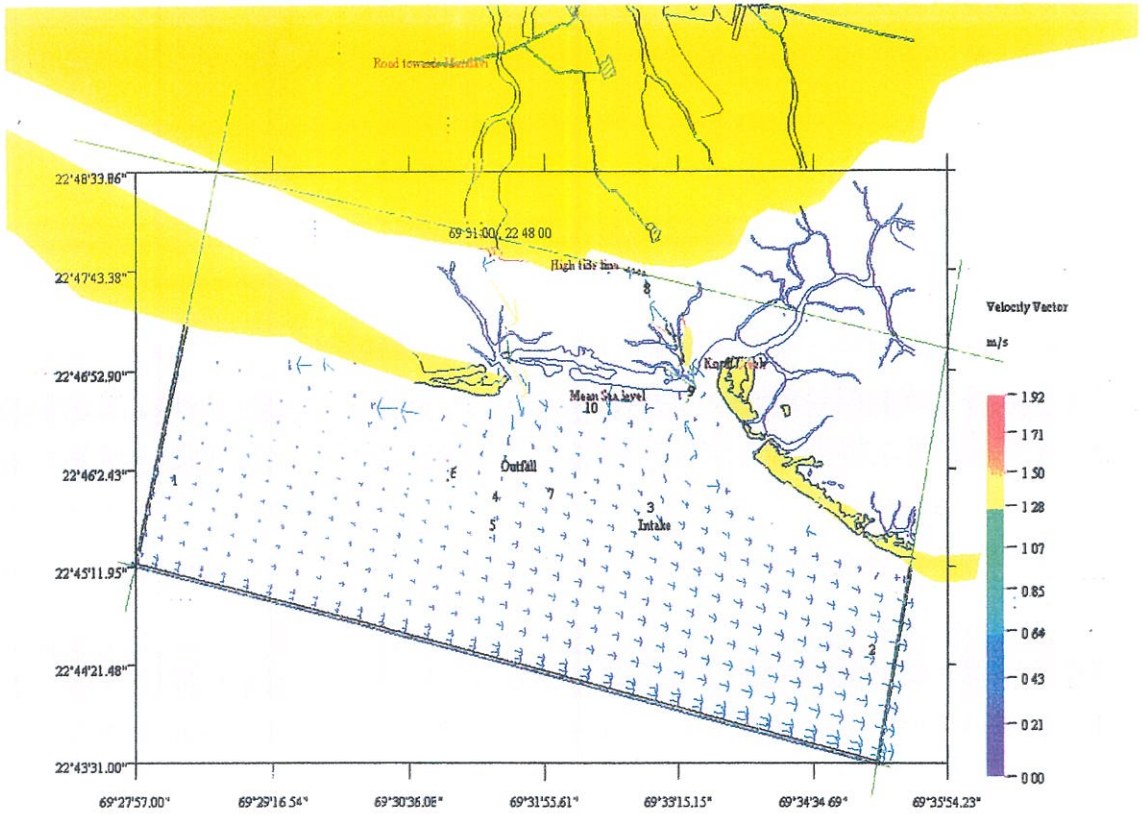


Figure 7.2.7 : Current vectors at high water during neap

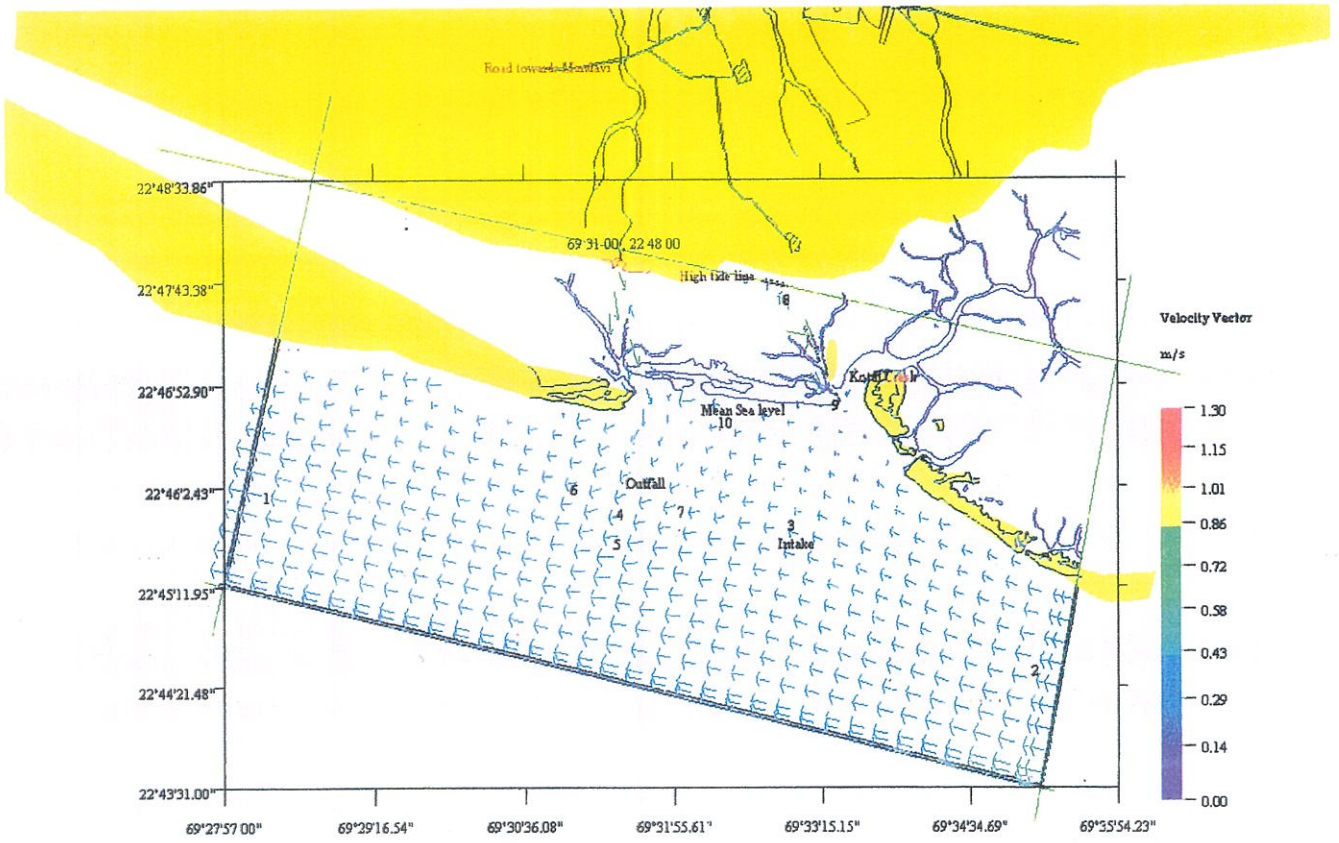


Figure 7.2.8 : Current vectors at mid ebb during neap.

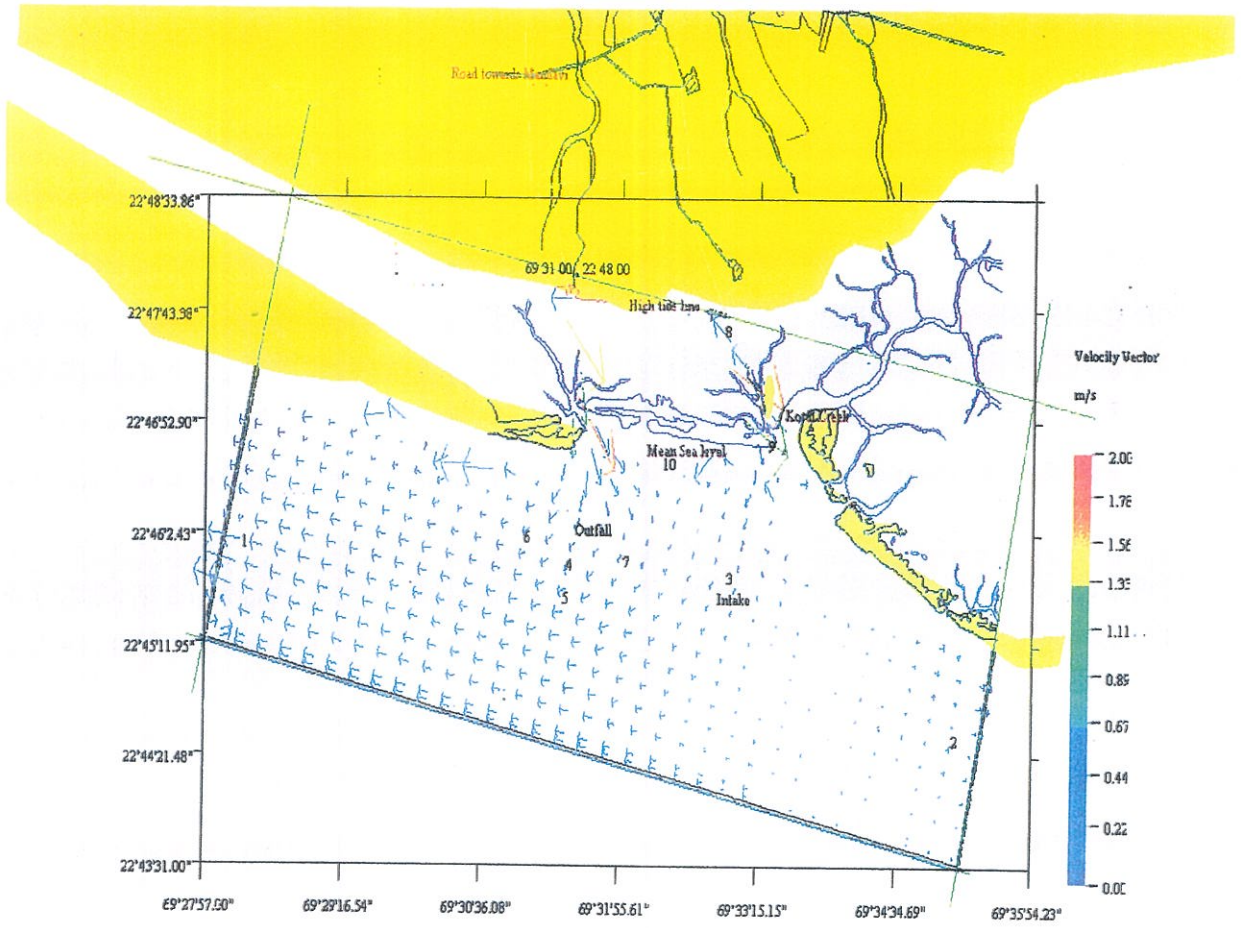


Figure 7.2.9 : Current vectors at low water during neap.

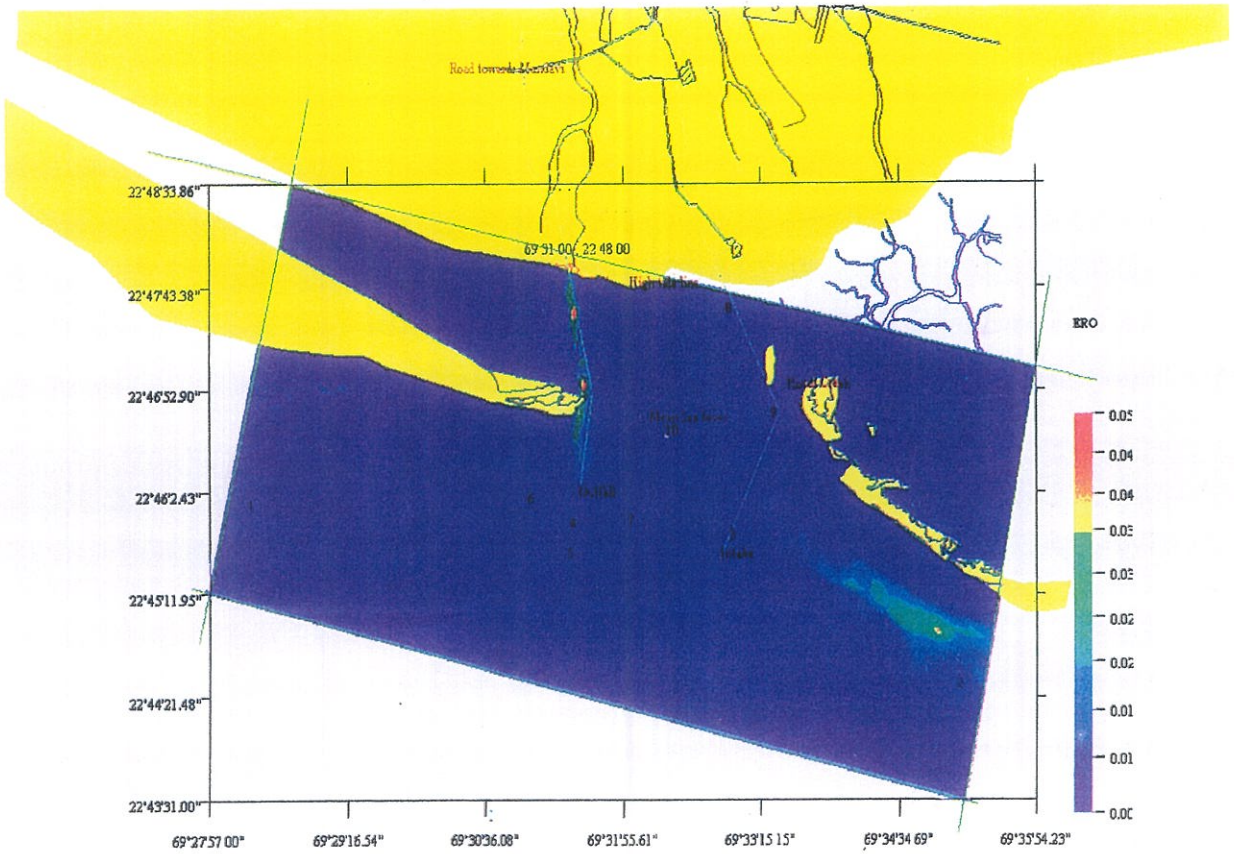


Figure 7.3.1 : Predicted erosion in the model domain after 10 days run.

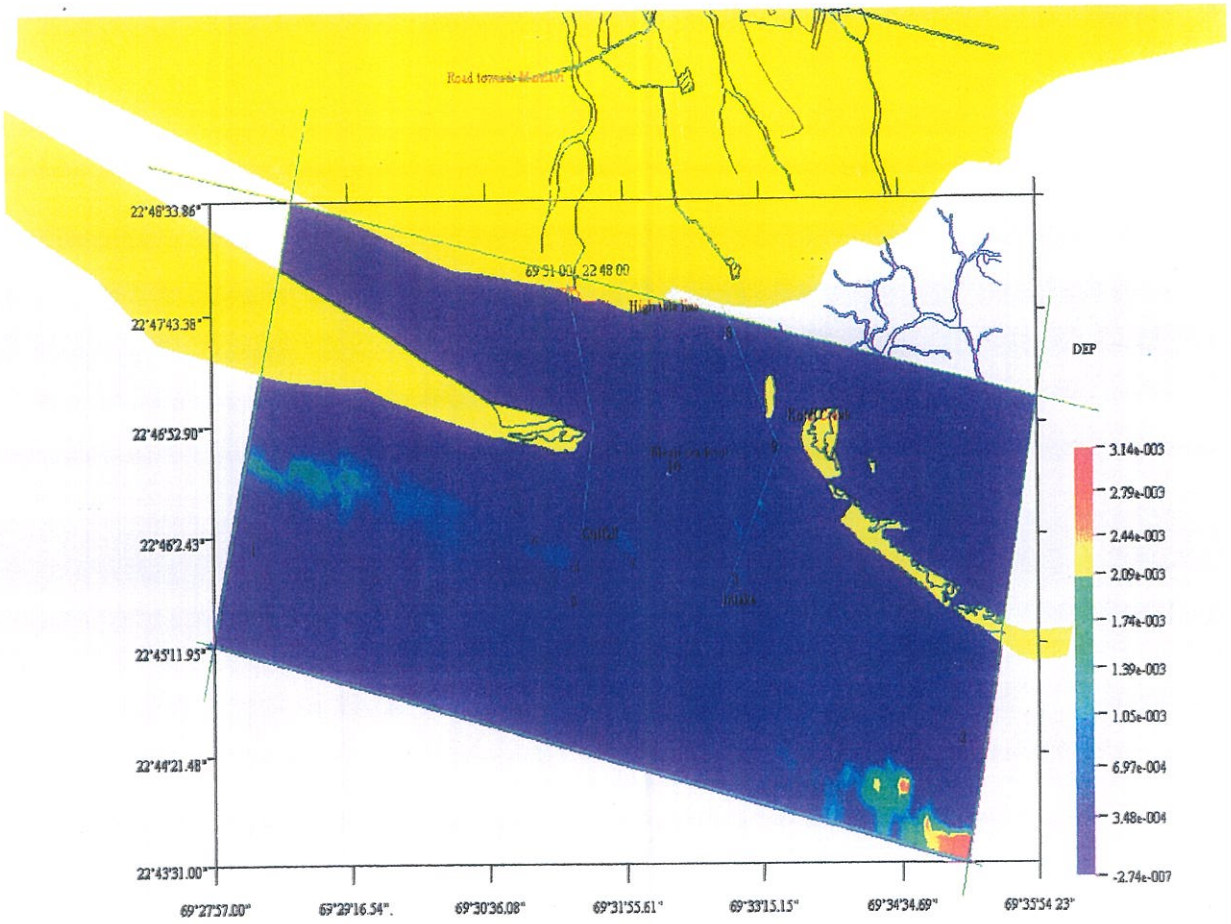


Figure 7.3.2 : Predicted deposition in the model domain after 10 days run.

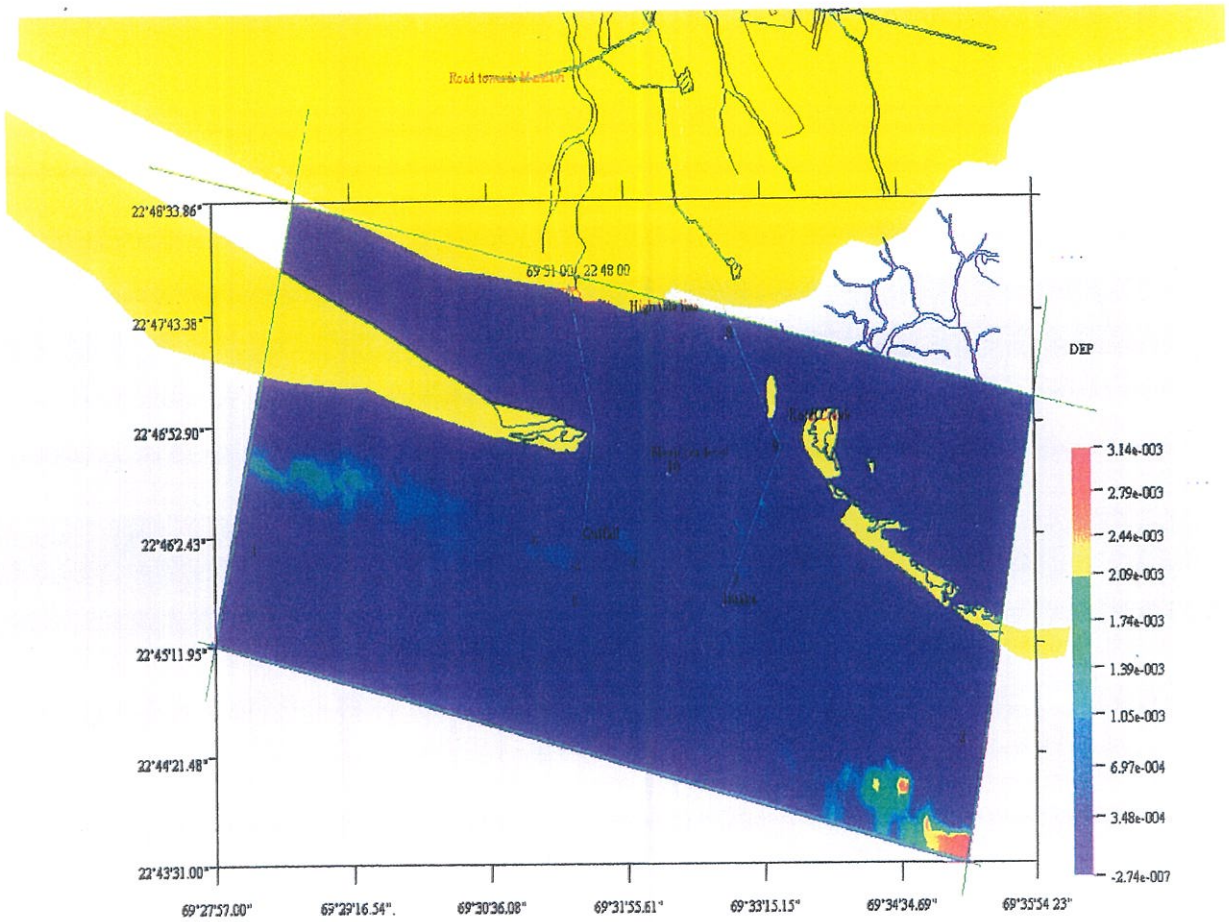


Figure 7.3.2 : Predicted deposition in the model domain after 10 days run.

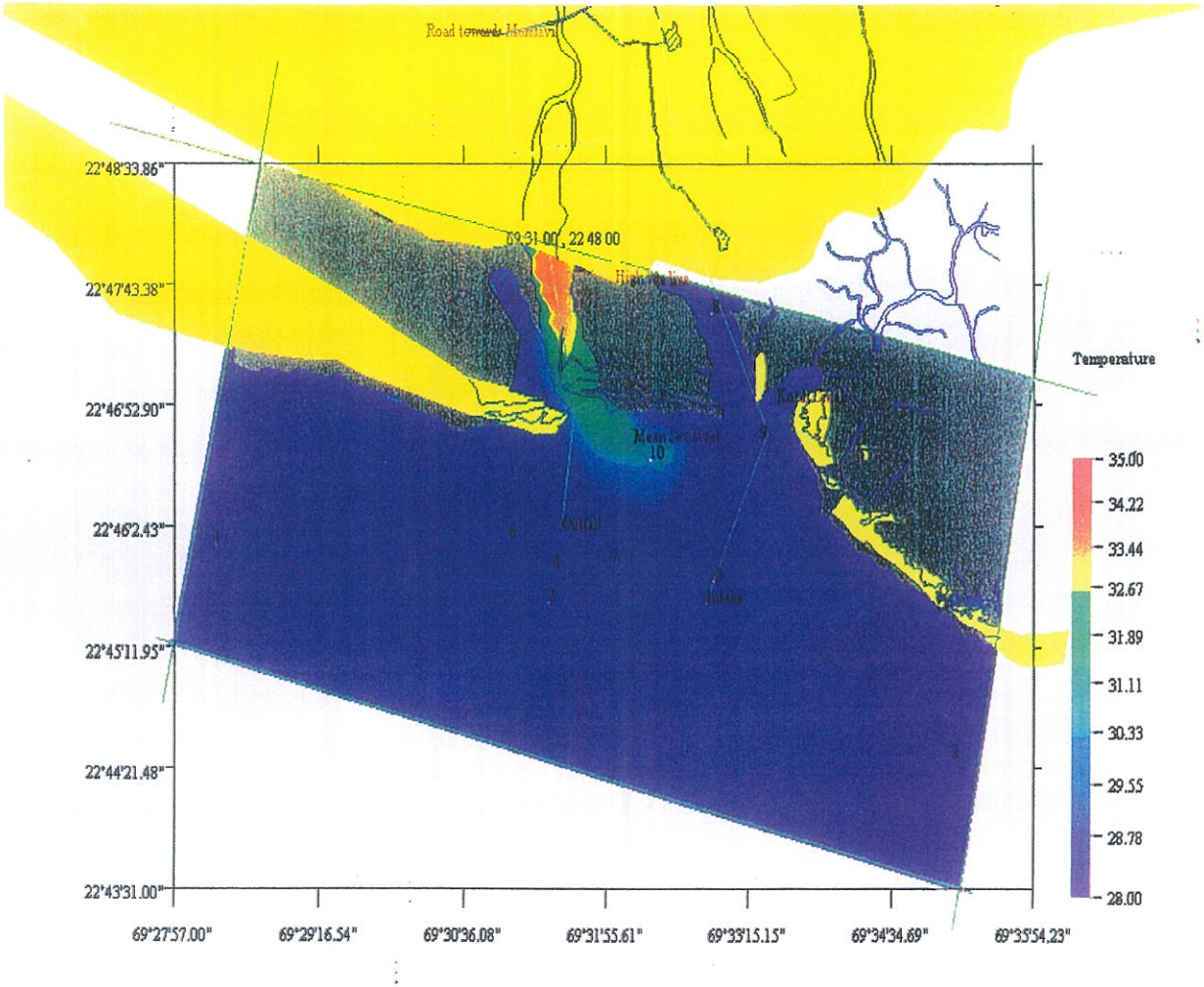


Figure 7.4.1 : Predicted temperature field at mid flood during spring for case 1.

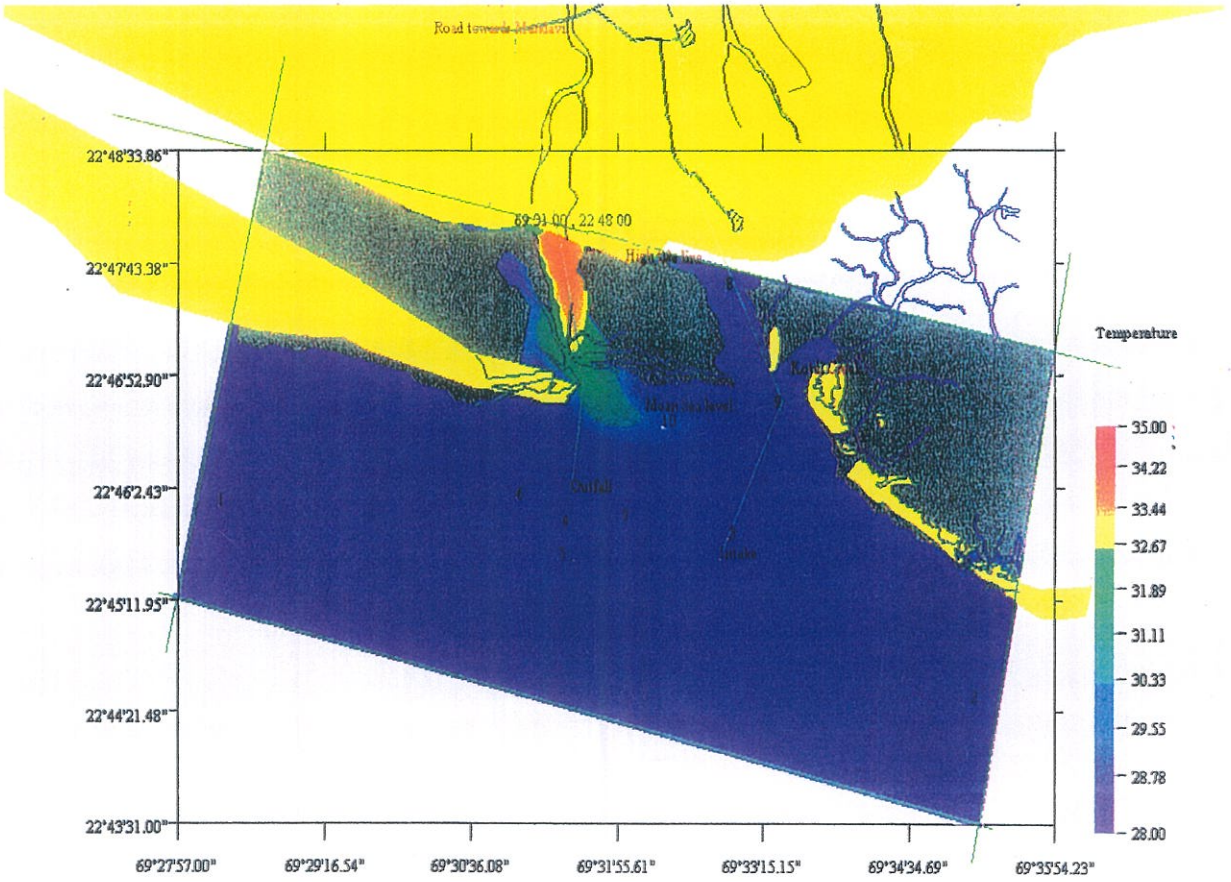


Figure 7.4.2 : Predicted temperature field at high water during spring for case 1.

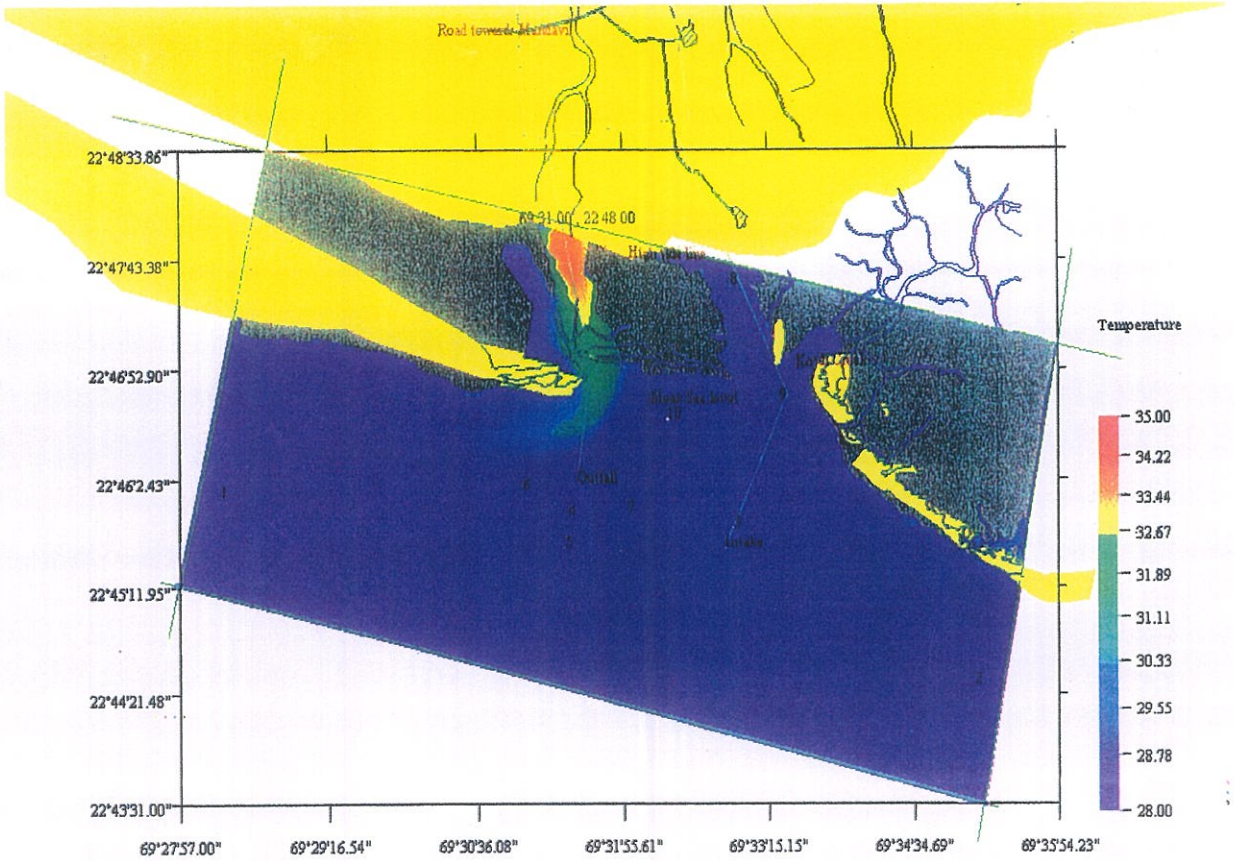


Figure 7.4.3 : Predicted temperature field at mid ebb during spring for case 1.

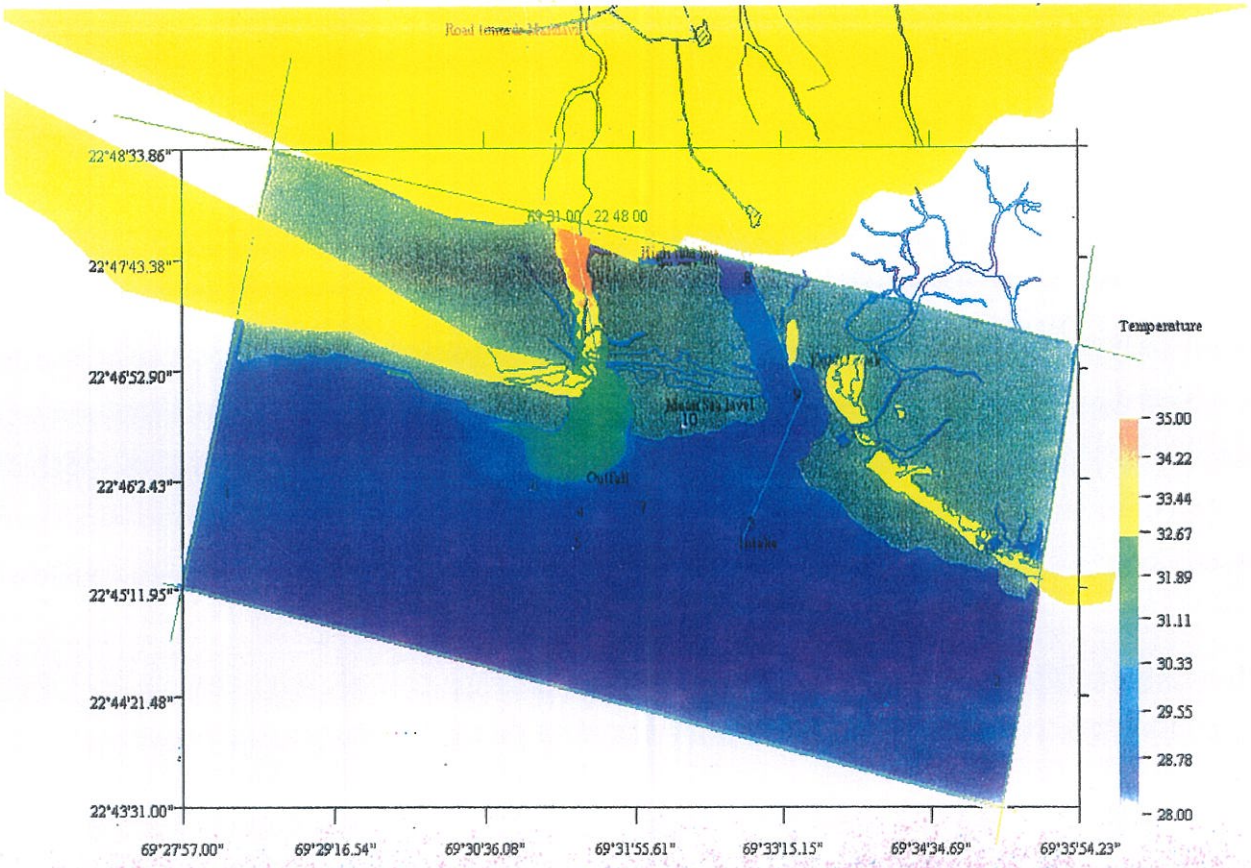


Figure 7.4.4 : Predicted temperature field at low water during spring for case 1.

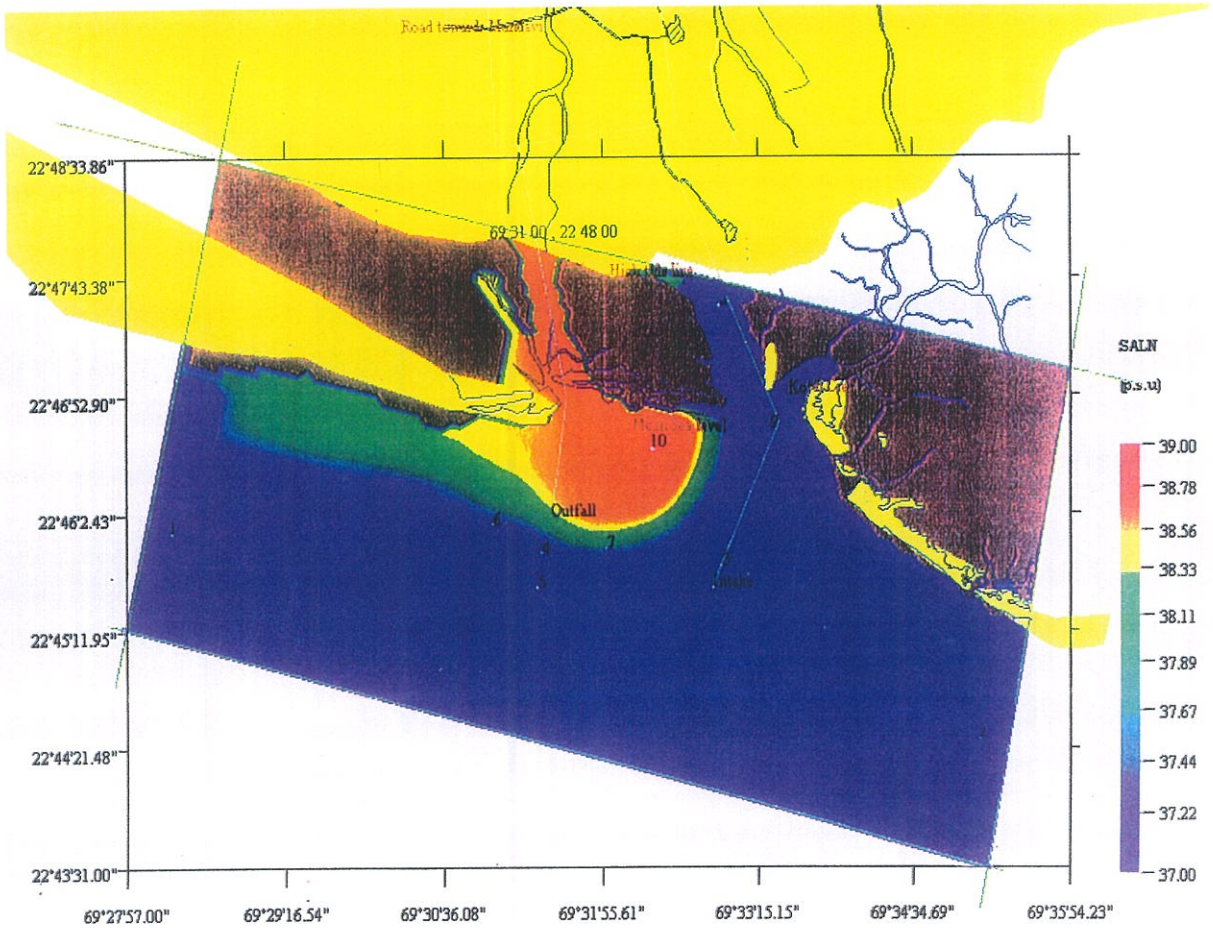


Figure 7.4.5: Predicted salinity field at mid flood during spring for case 1.

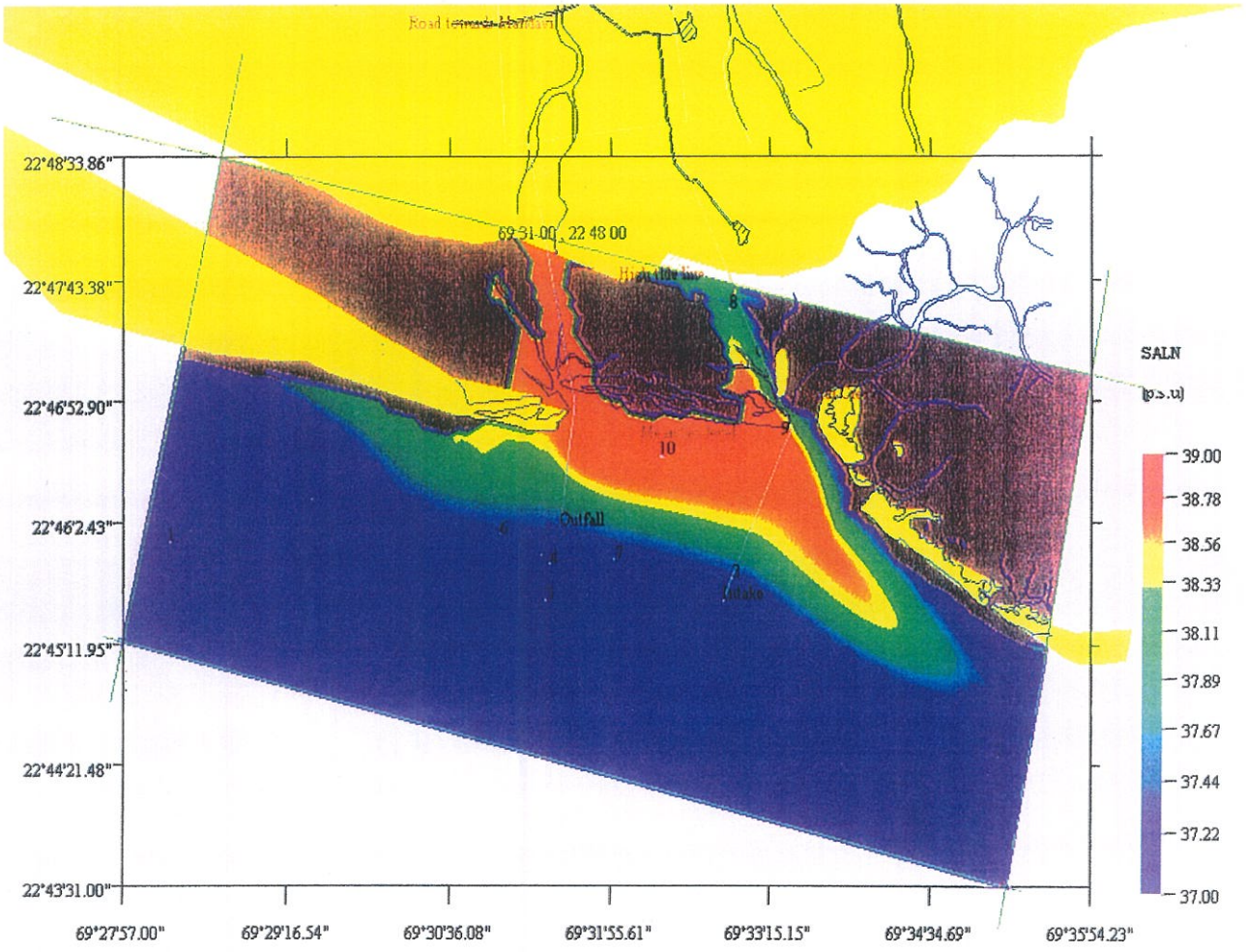


Figure 7.4.6: Predicted salinity field at high water during spring for case 1.

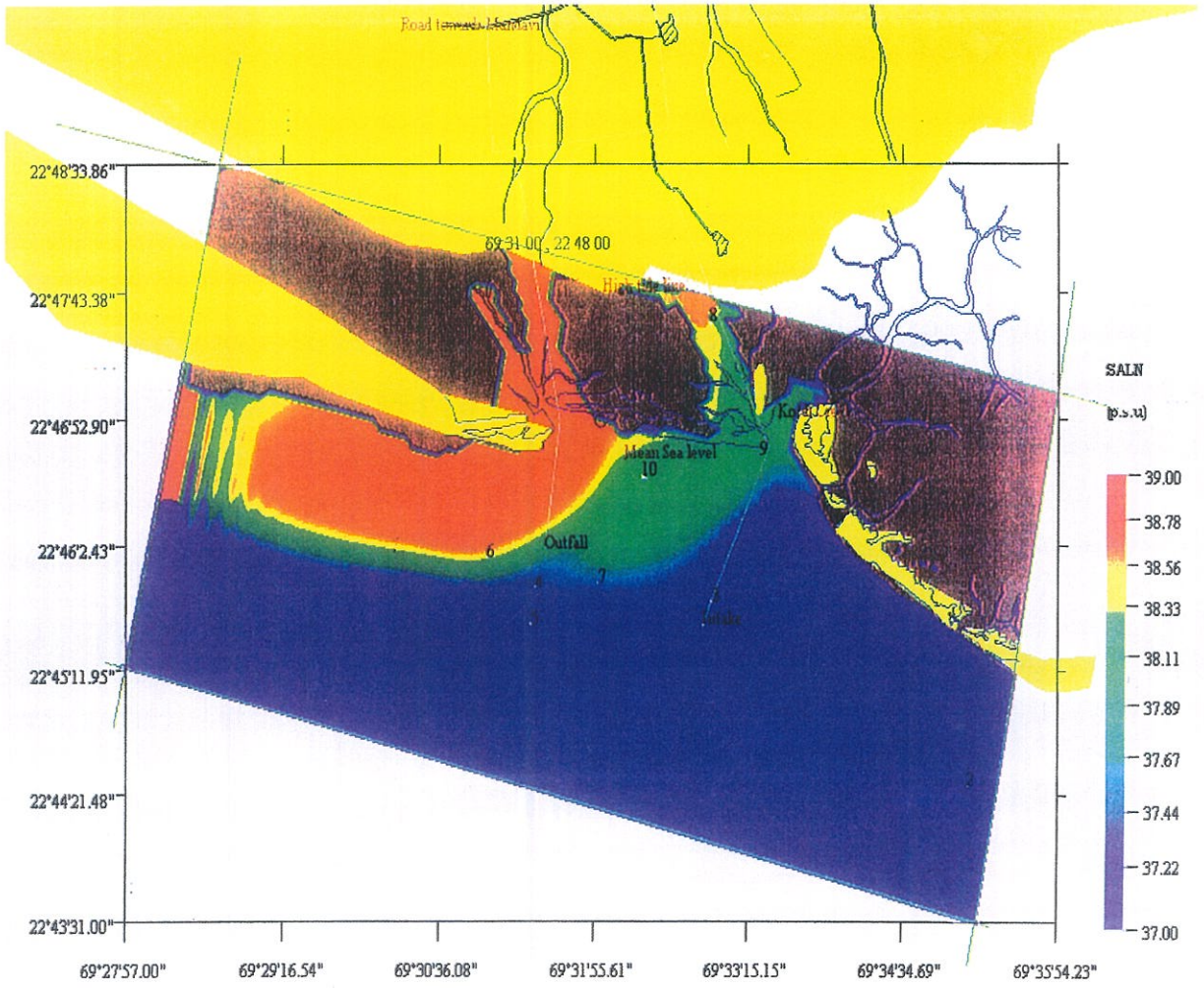


Figure 7.4.7: Predicted salinity field at mid ebb during spring for case 1.

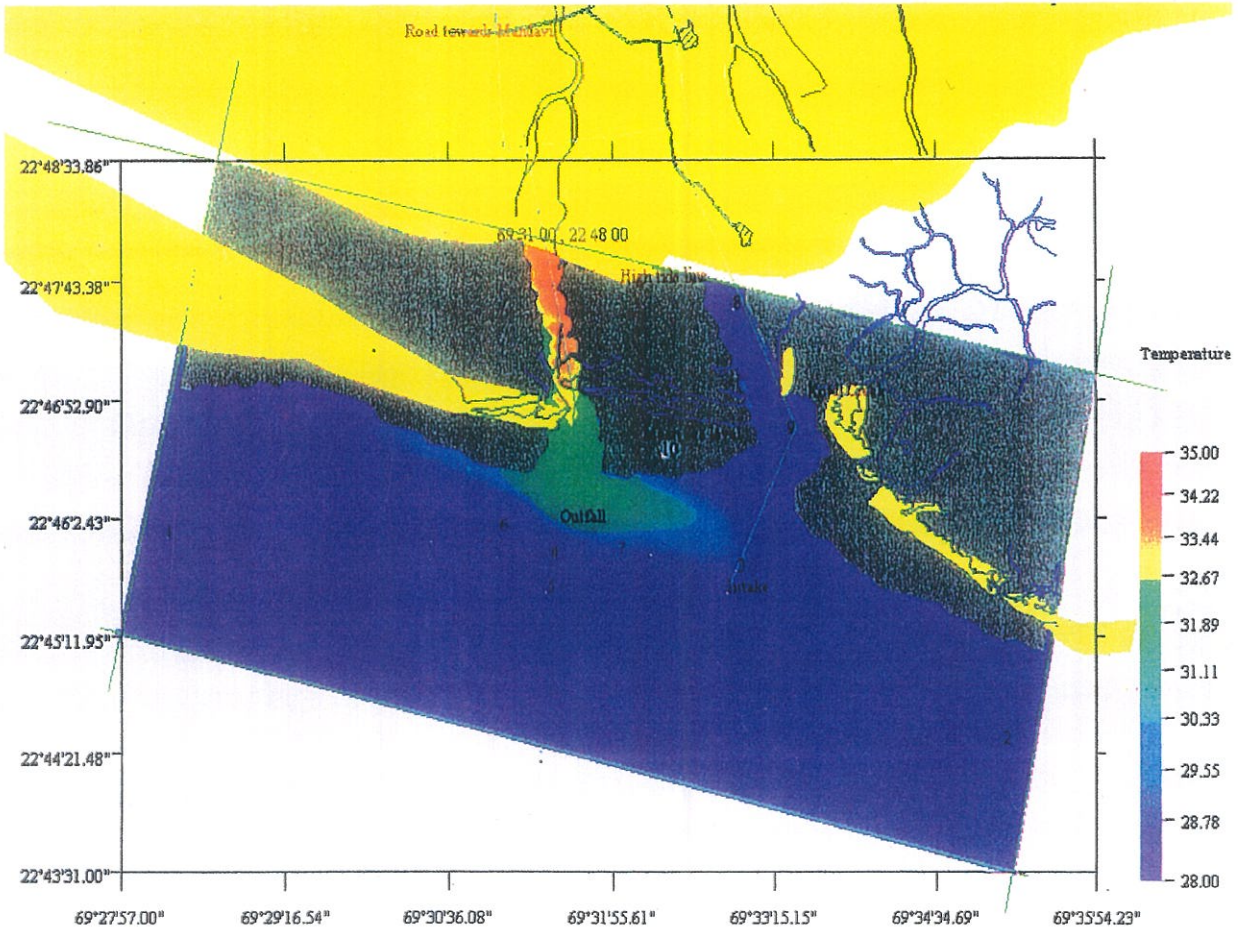


Figure 7.4.9 : Predicted temperature field at mid flood during neap for case 1.

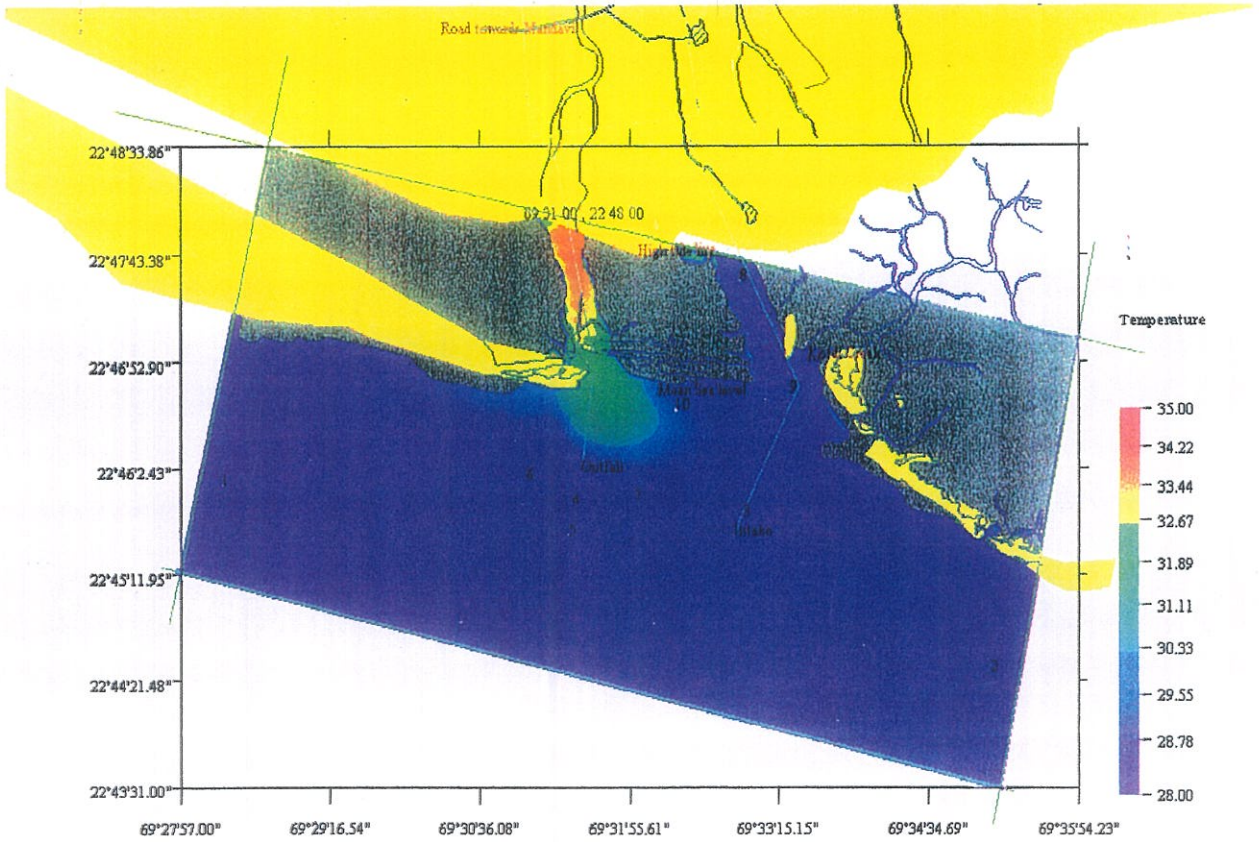


Figure 7.4.10 : Predicted temperature field at high water during neap for case 1.

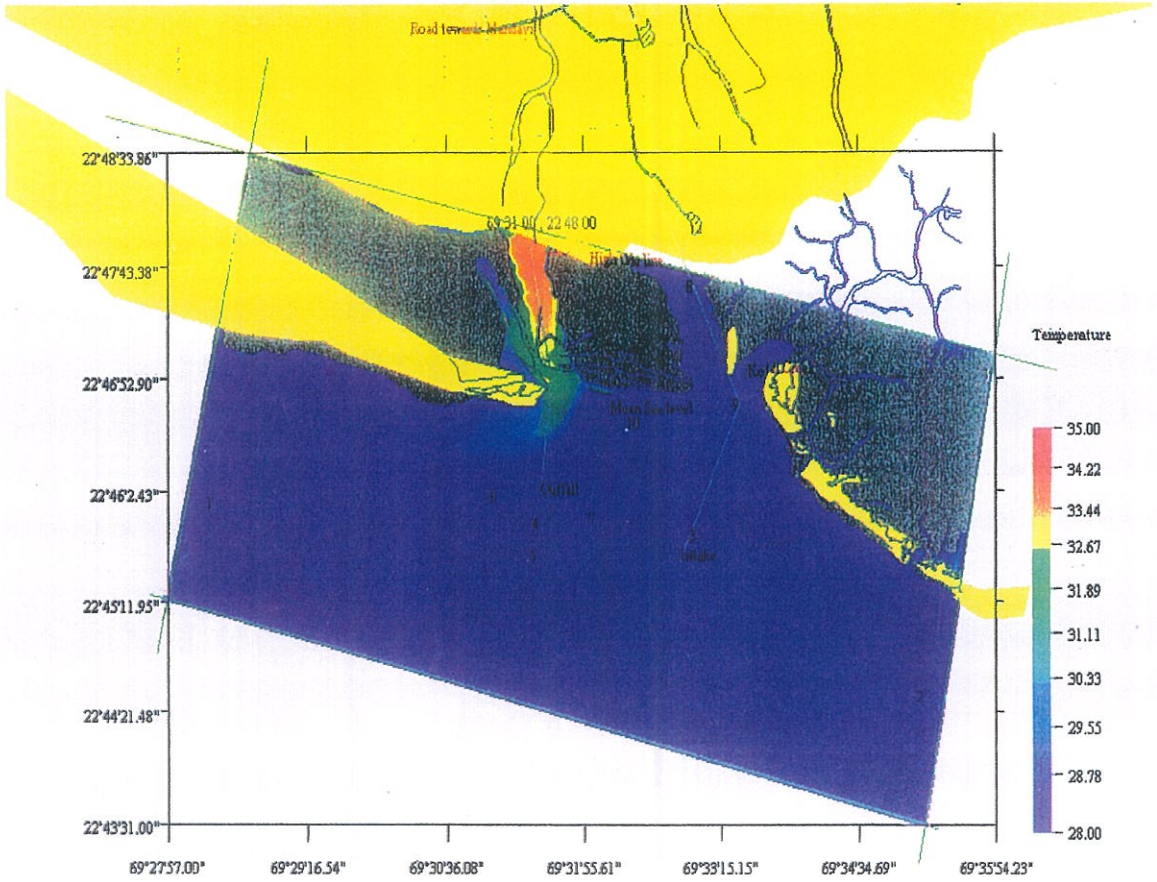


Figure 7.4.11 : Predicted temperature field at mid ebb during neap for case 1.

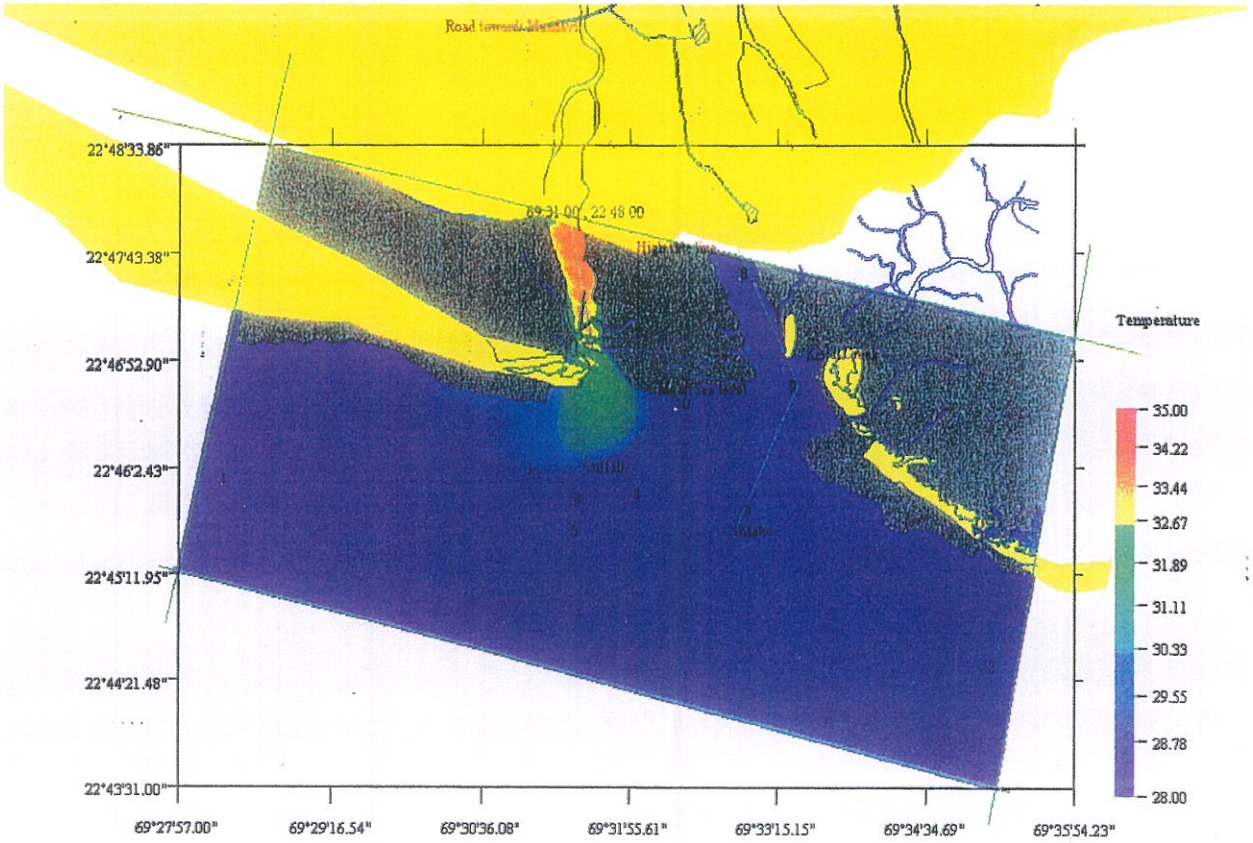


Figure 7.4.12 : Predicted temperature field at low water during neap for case 1.

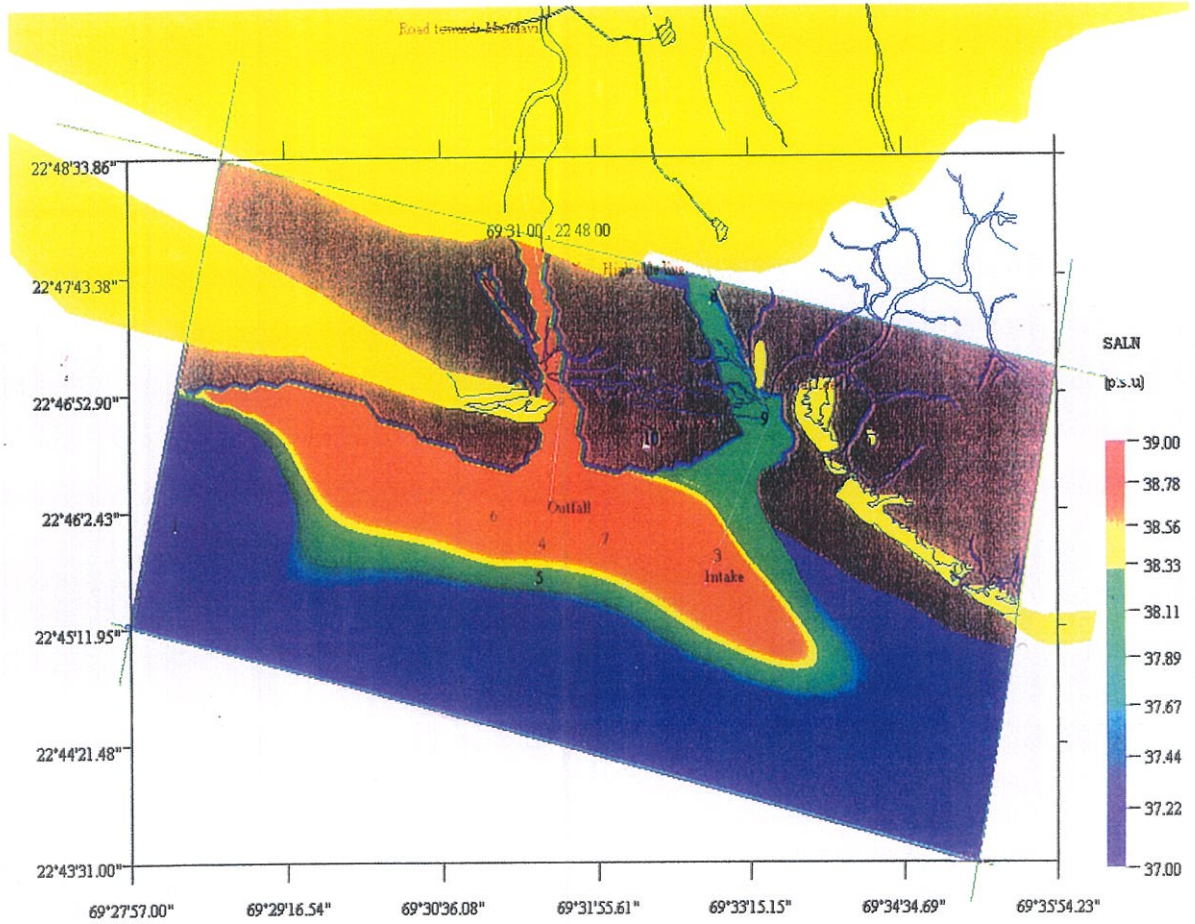


Figure 7.4.13 : Predicted salinity field at mid flood during neap for case 1.

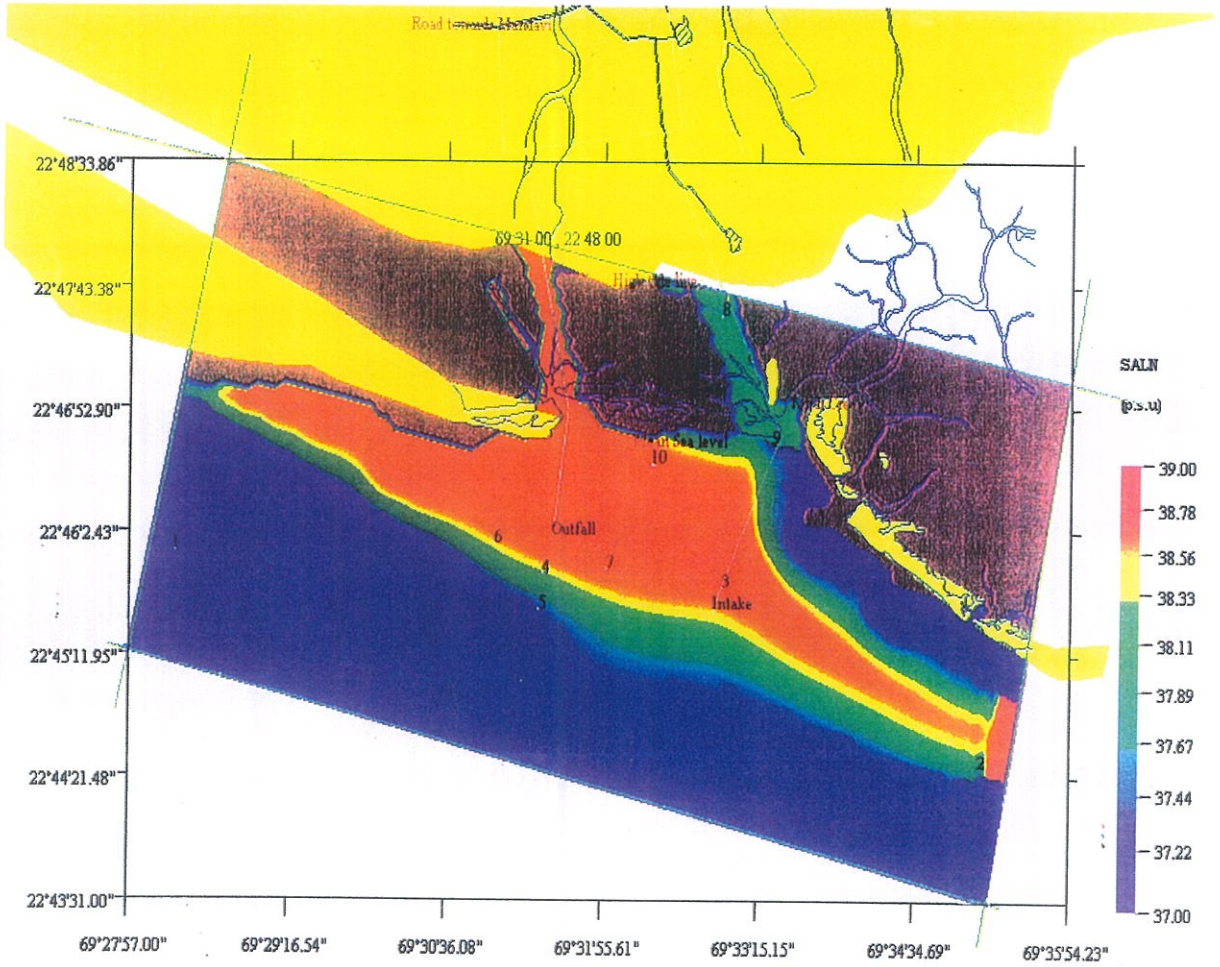


Figure 7.4.14 : Predicted salinity field at high water during neap for case 1.

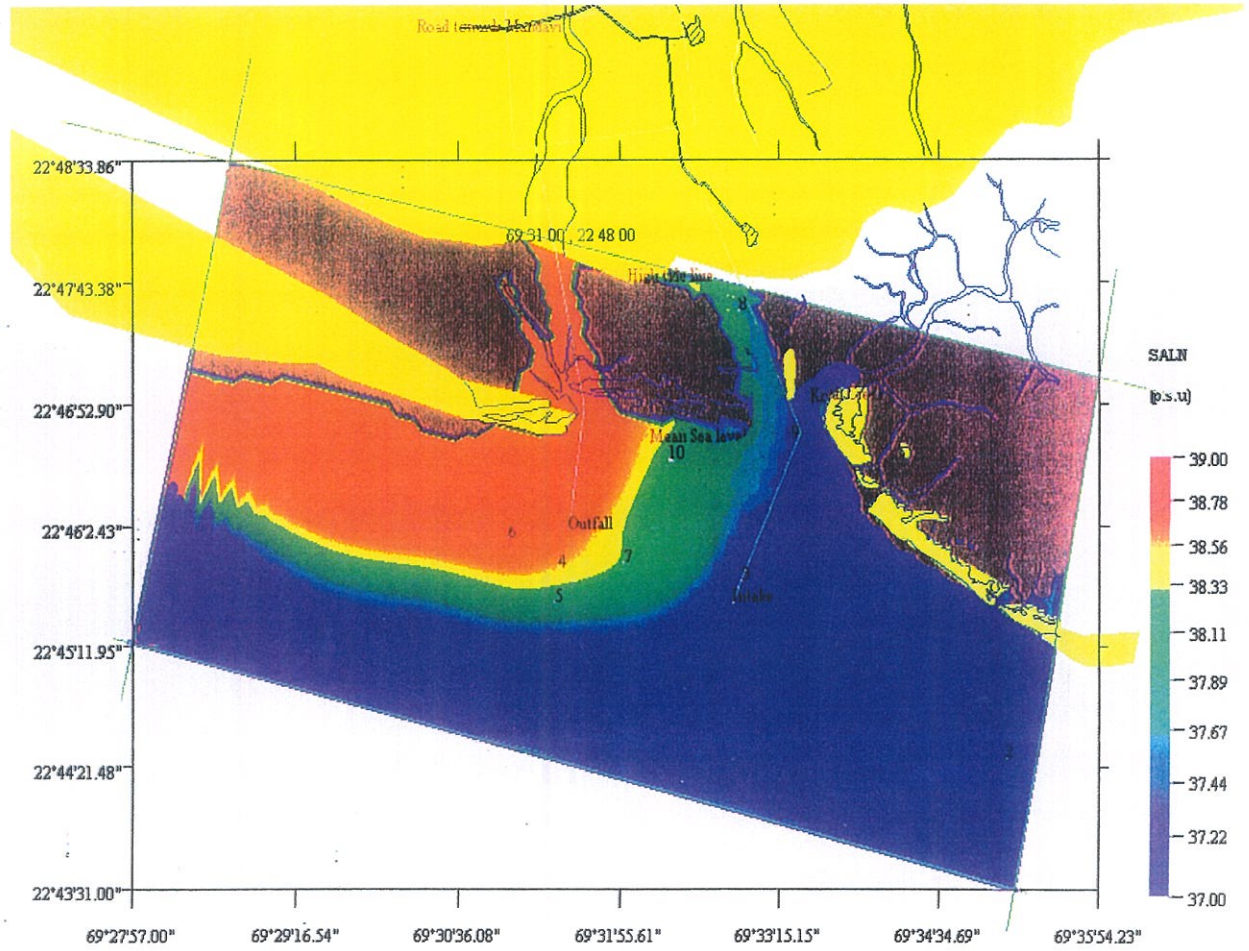


Figure 7.4.15 : Predicted salinity field at mid ebb during neap for case 1.

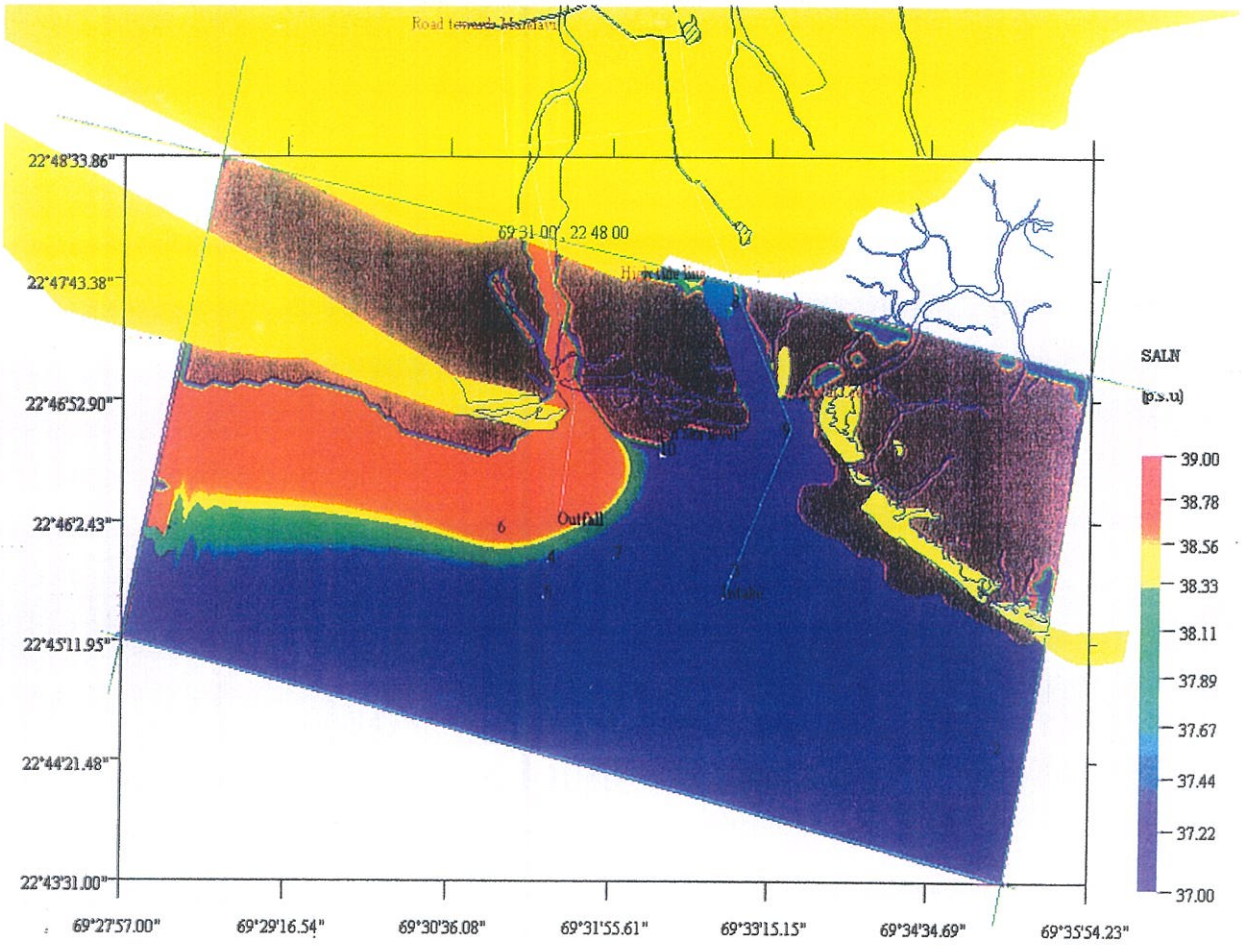


Figure 7.4.16 : Predicted salinity field at low water during neap for case 1.

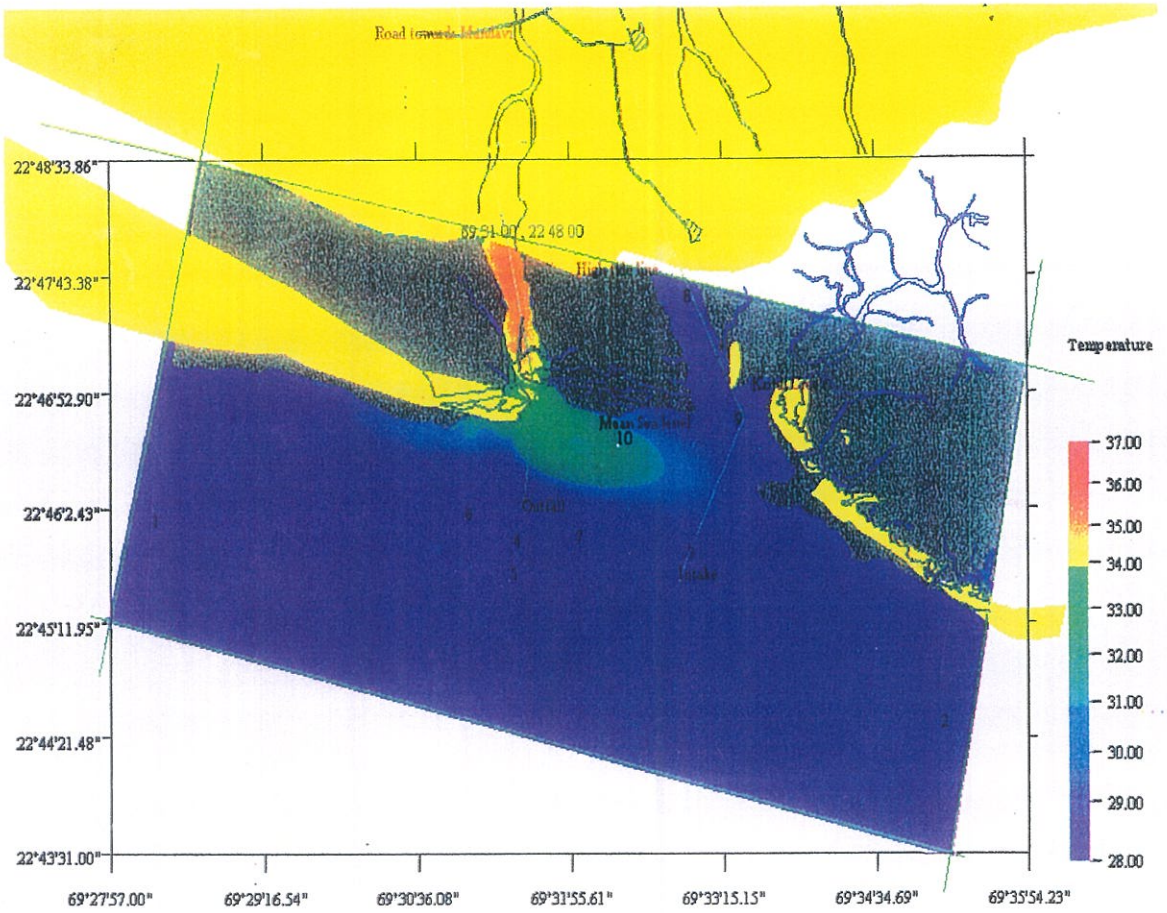


Figure 7.4.17 : Predicted temperature field for case 1 after 10 days run..

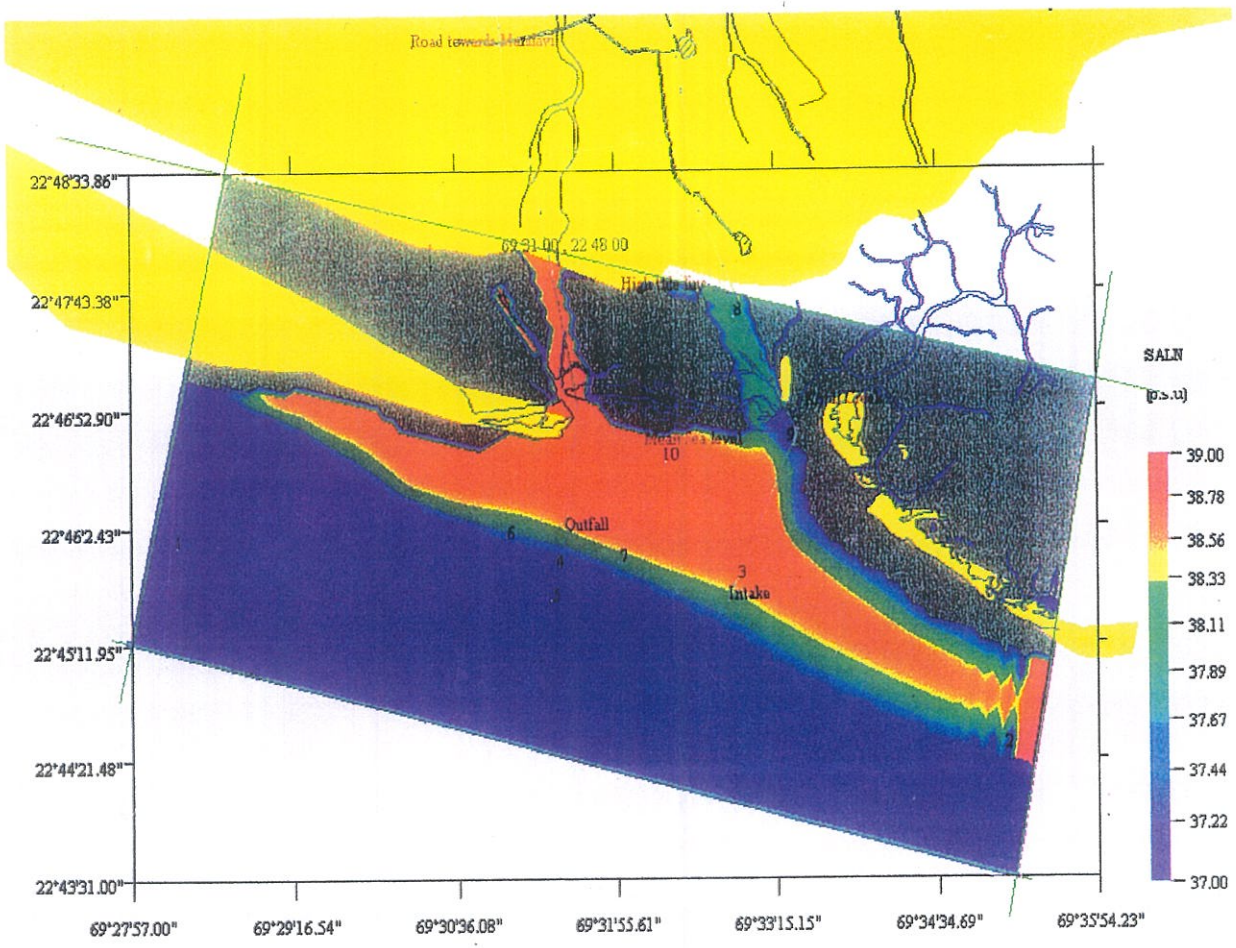


Figure 7.4.18 : Predicted salinity field for case 1 after 10 days run..

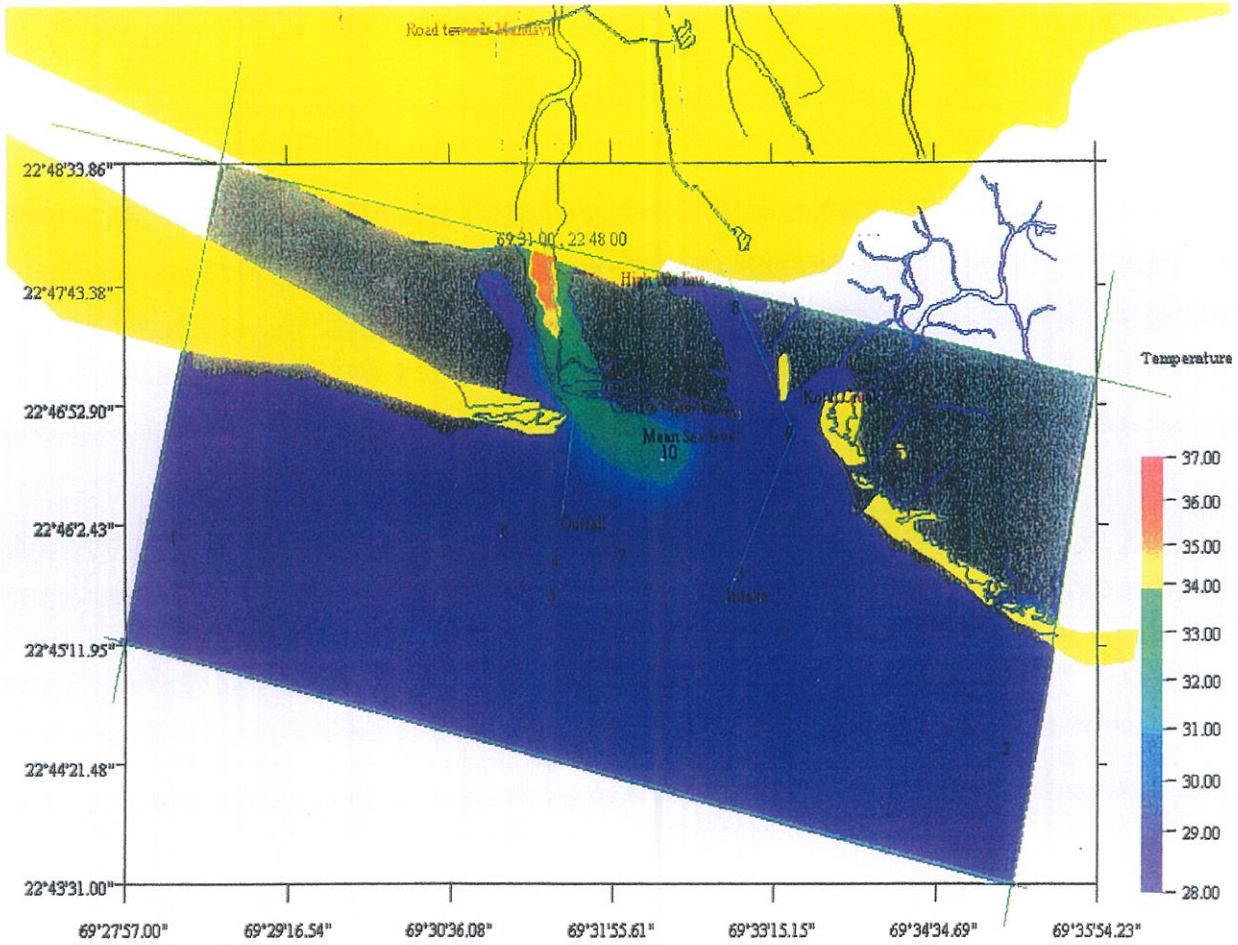


Figure 7.4.19: Predicted temperature field at mid flood during spring for case 2.

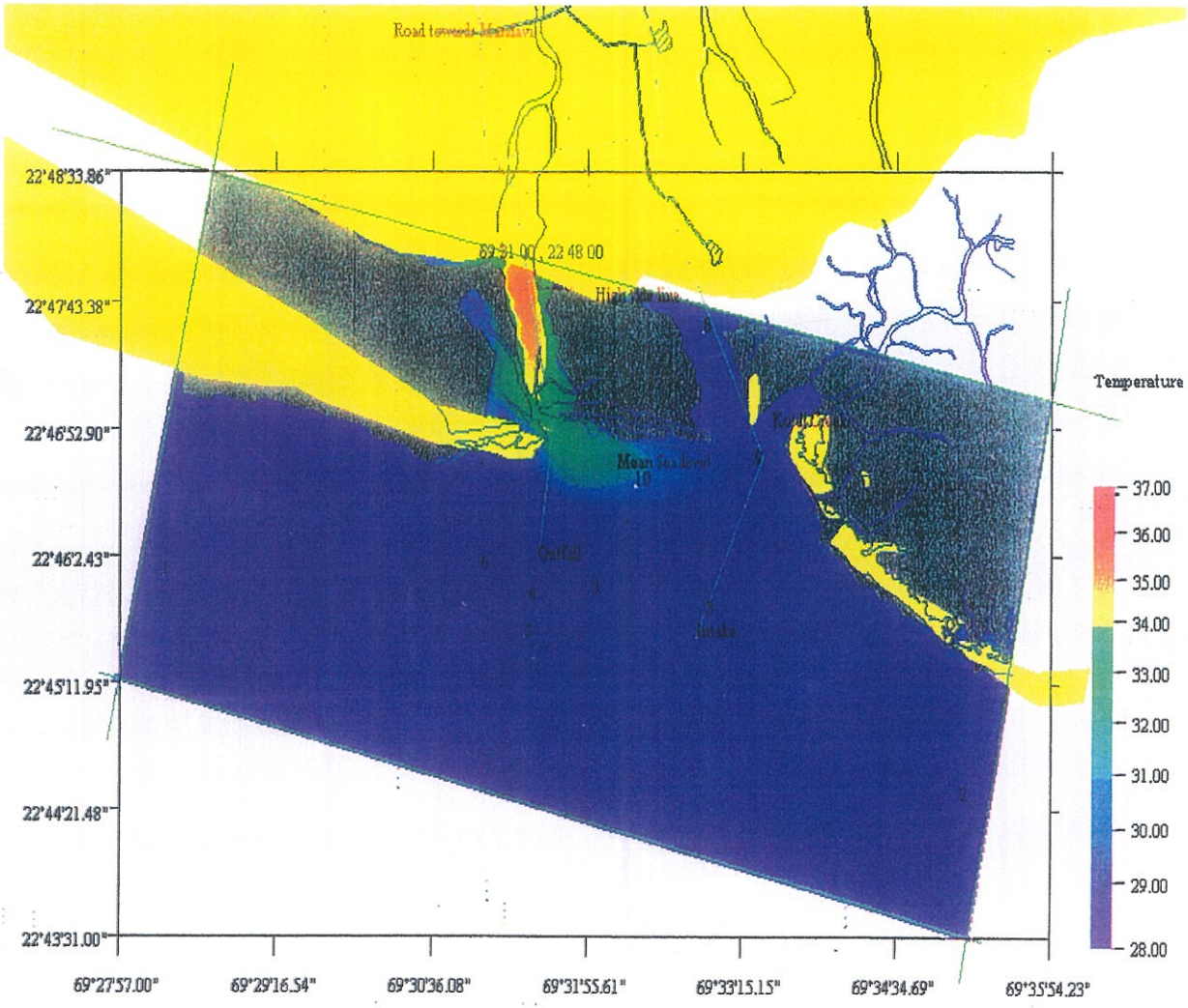


Figure 7.4.20: Predicted temperature field at high water during spring for case 2.

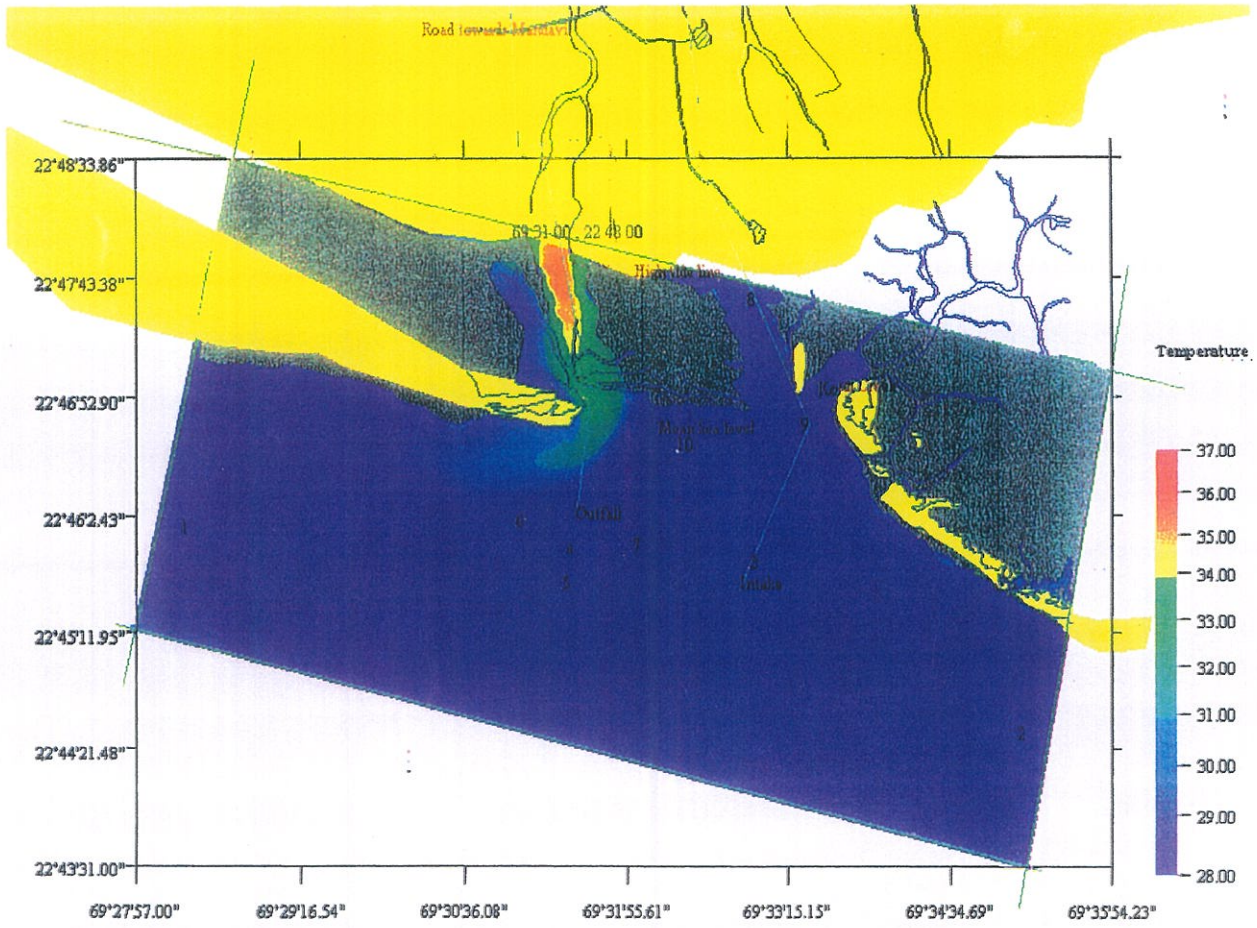


Figure 7.4.21: Predicted temperature field at mid ebb during spring for case 2.

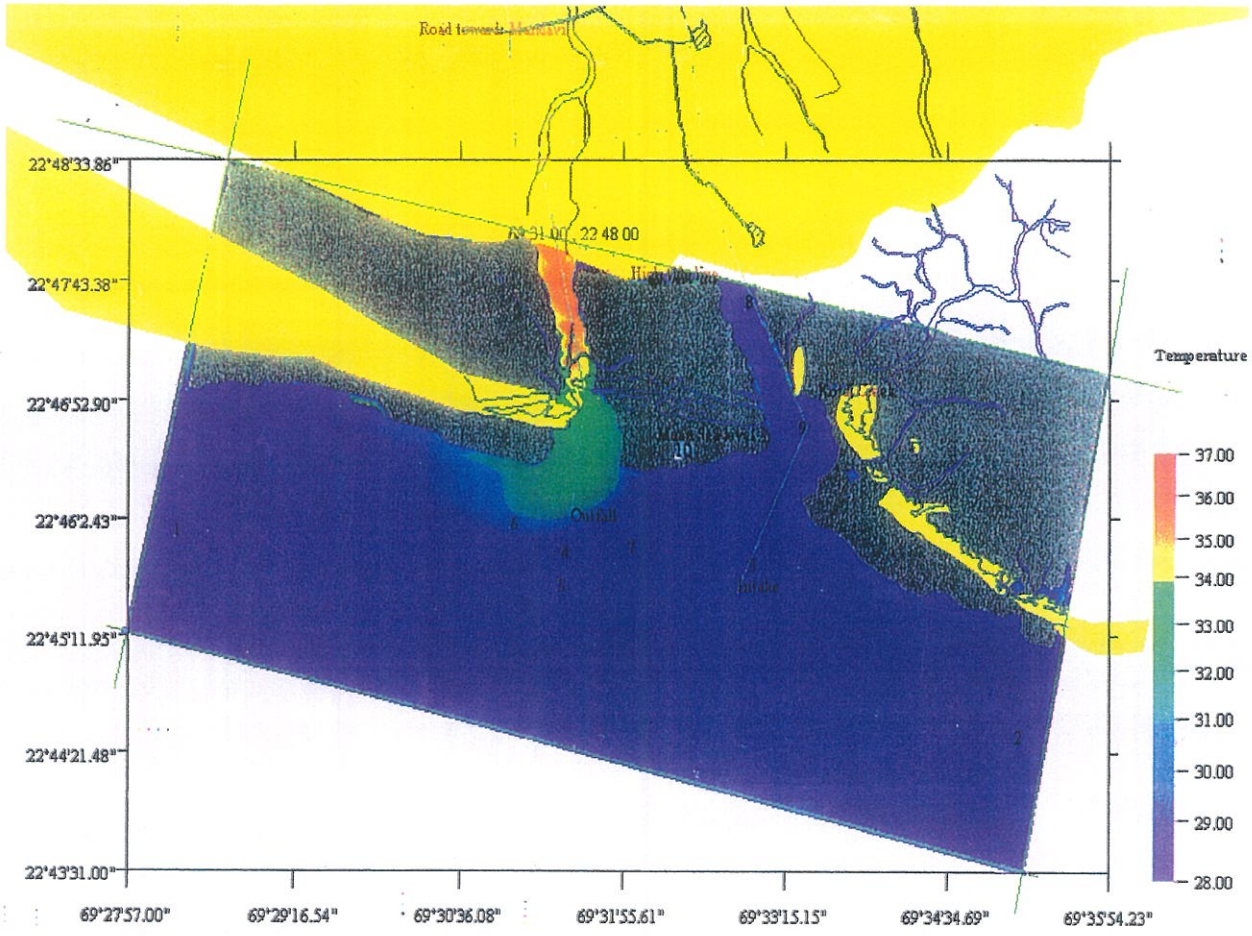


Figure 7.4.22: Predicted temperature field at low water during spring for case 2.

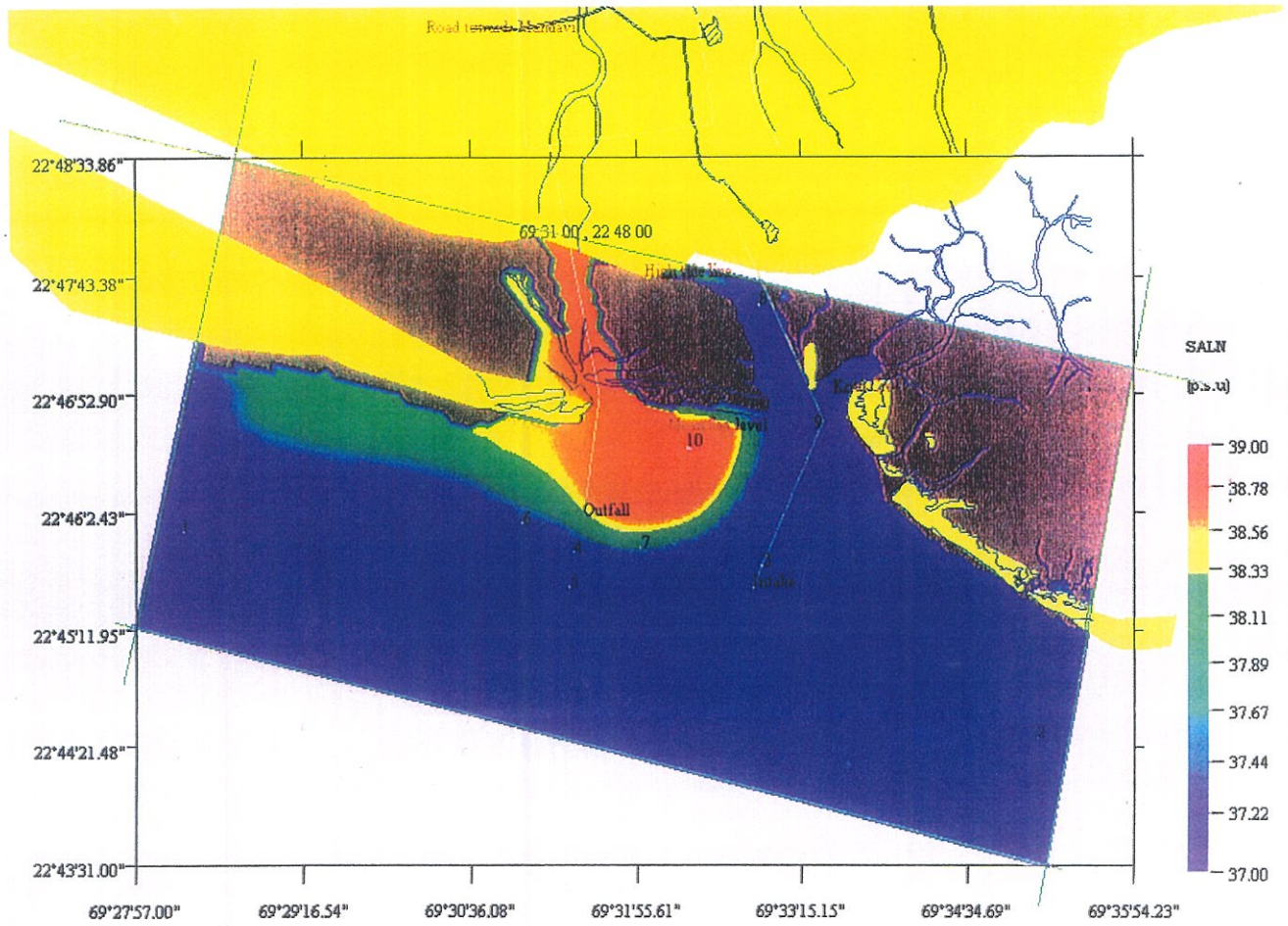


Figure 7.4.23 : Predicted salinity field at mid flood during spring for case 2.

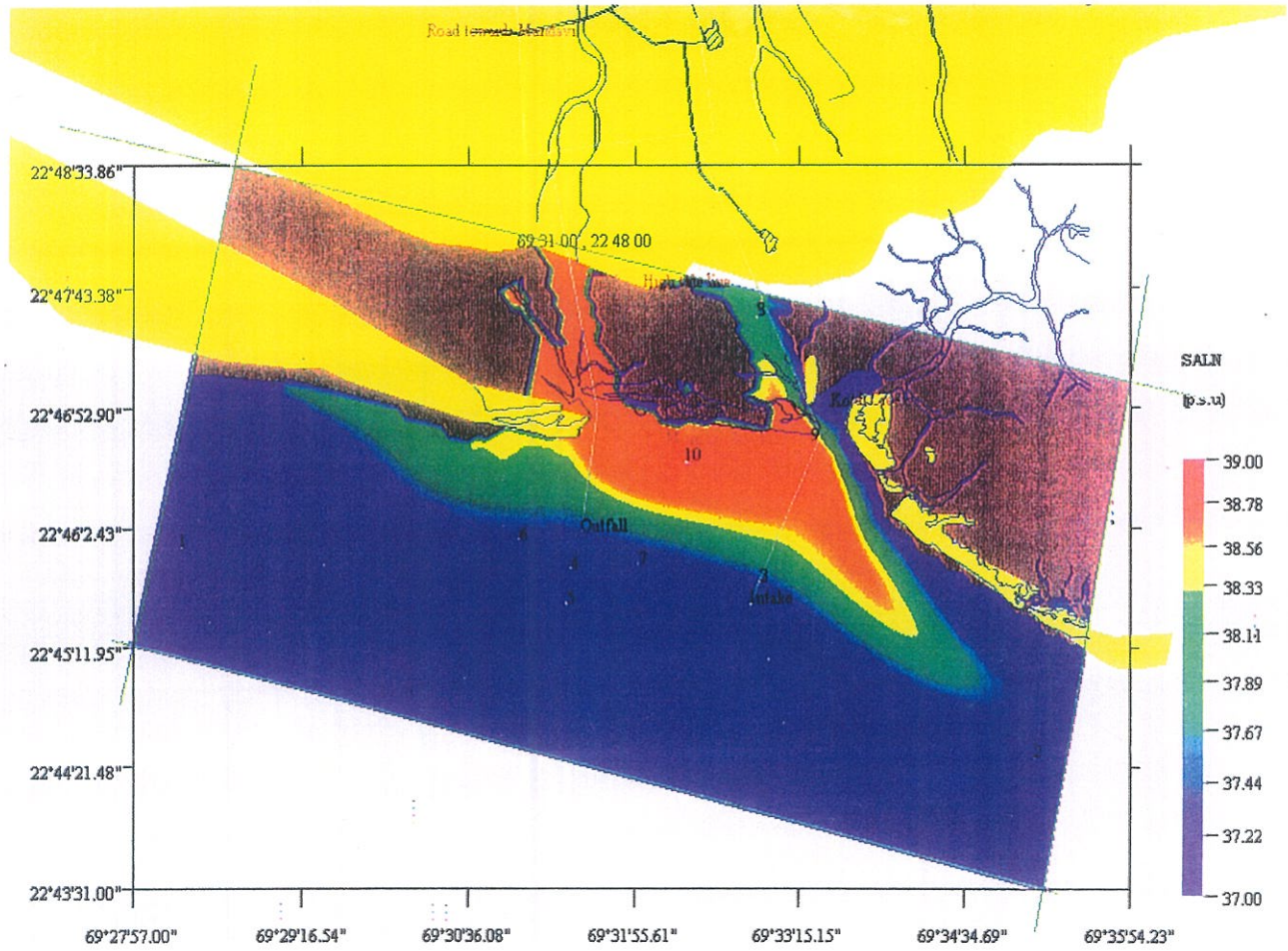


Figure 7.4.24: Predicted salinity field at high water during spring for case 2.

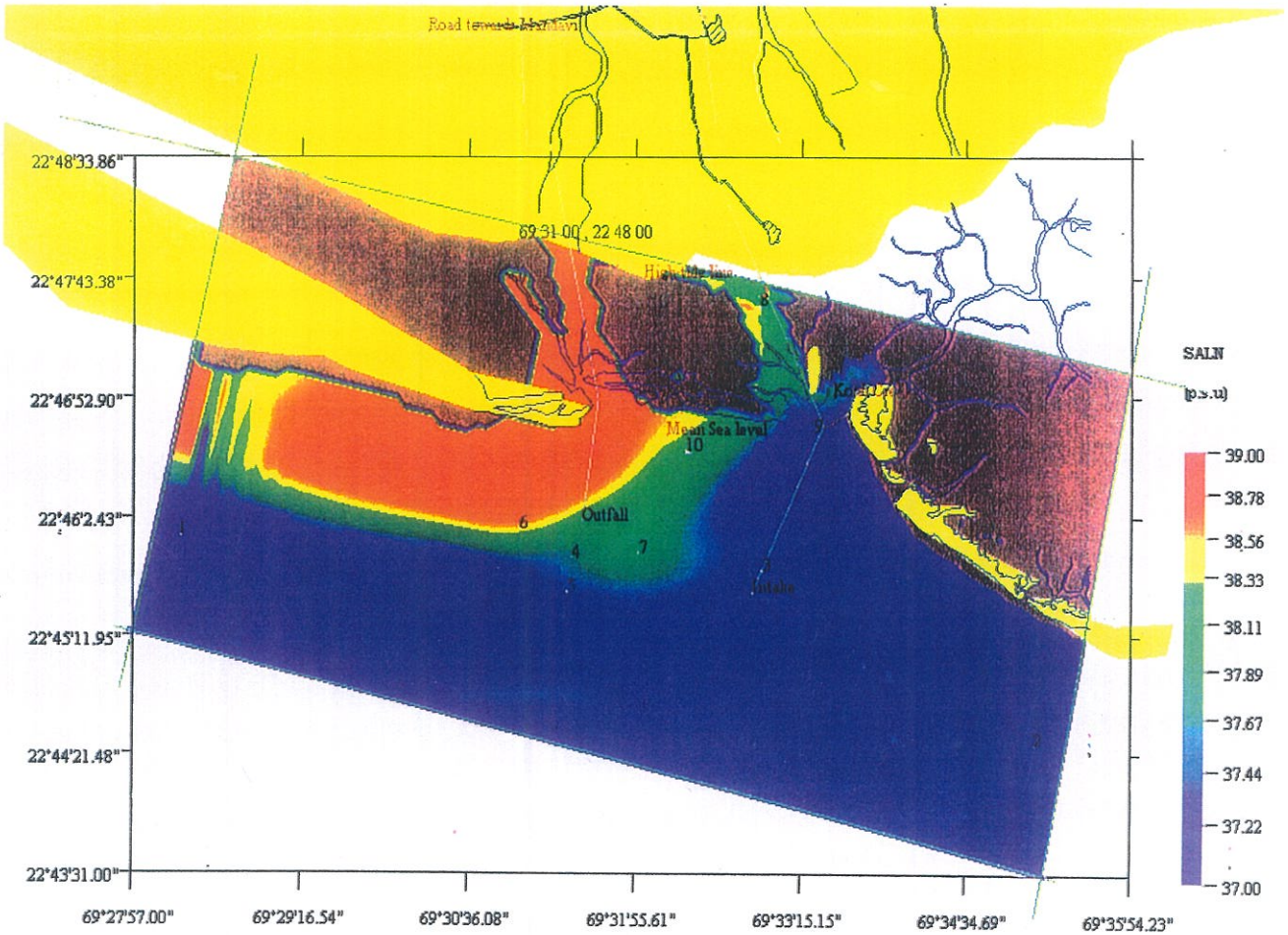


Figure 7.4.25 : Predicted salinity field at mid ebb during spring for case 2.

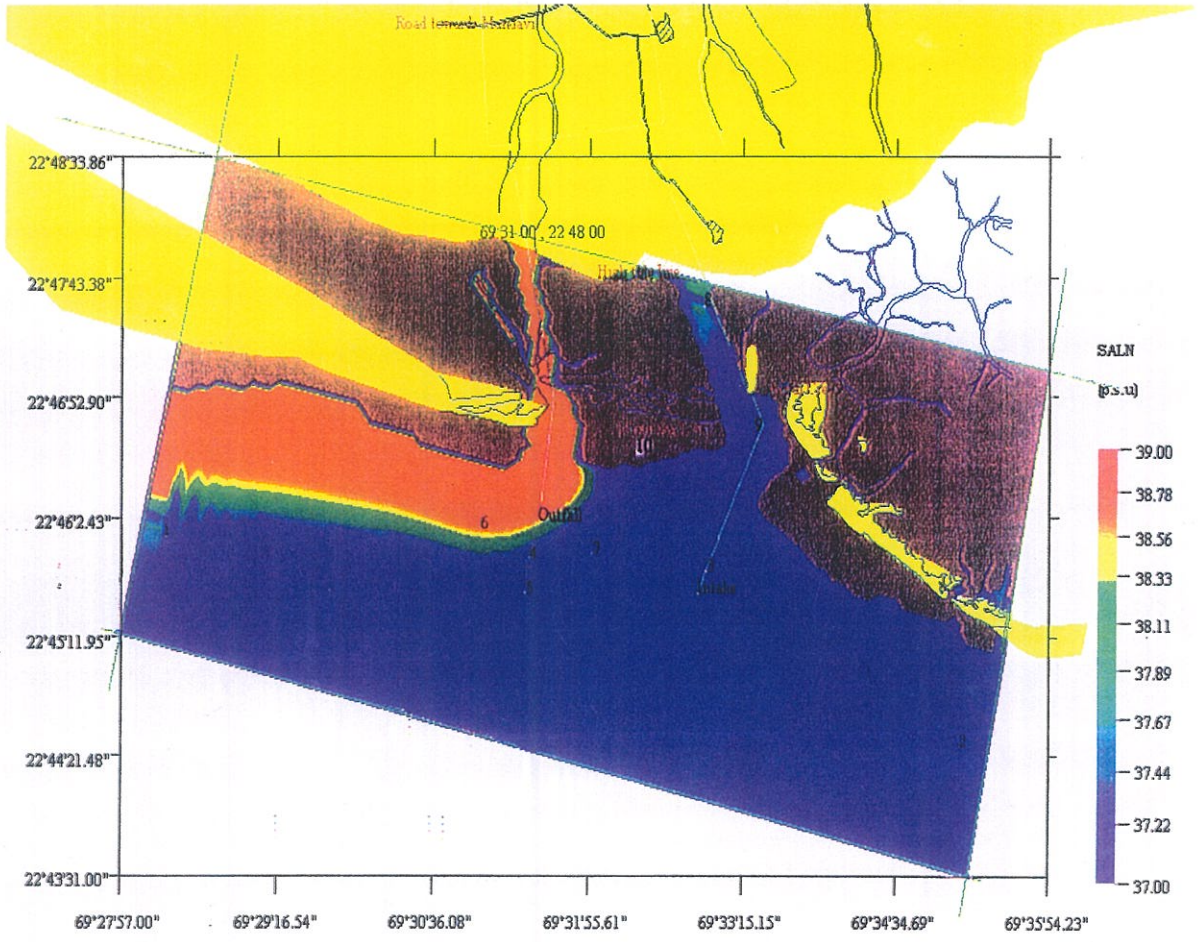


Figure 7.4.26 : Predicted salinity field at low water during spring for case 2.

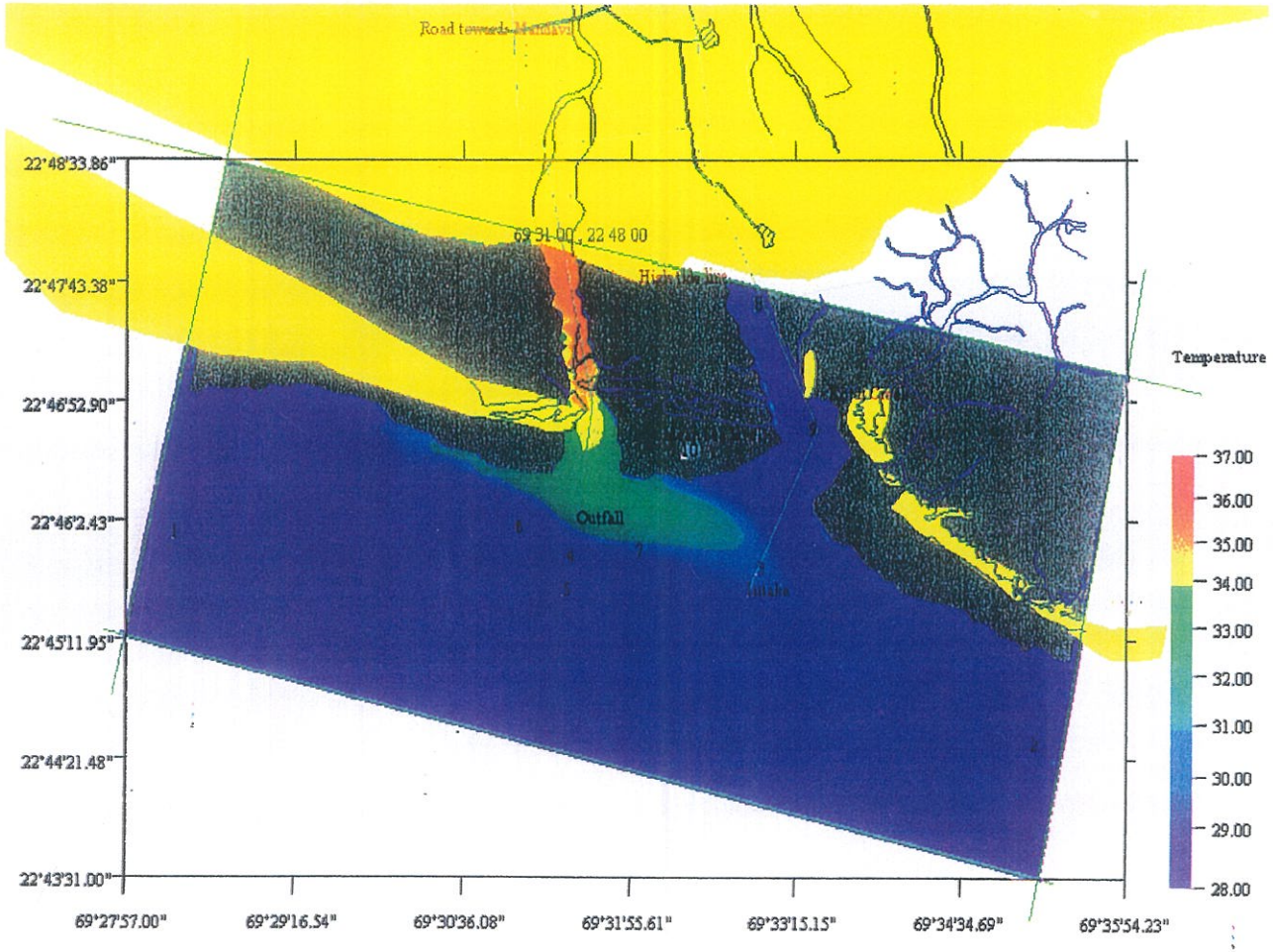


Figure 7.4.27: Predicted temperature field at mid flood during neap for case 2.

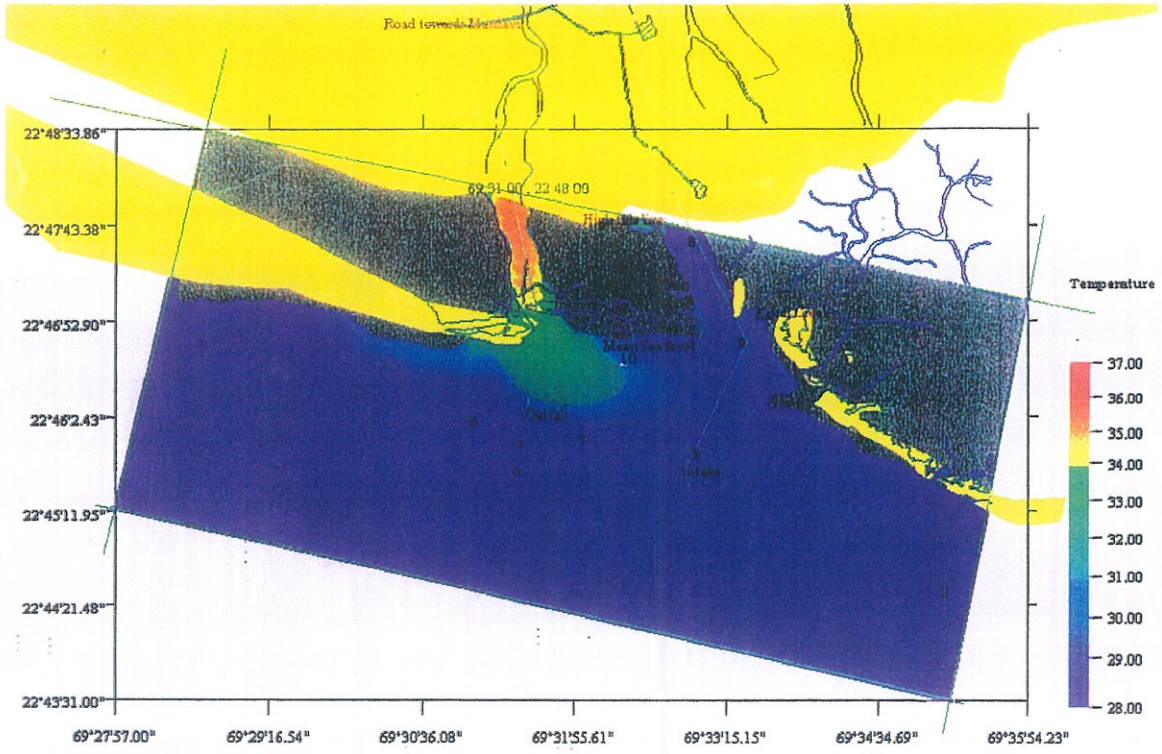


Figure 7.4.28 : Predicted temperature field at High water during neap for case 2.

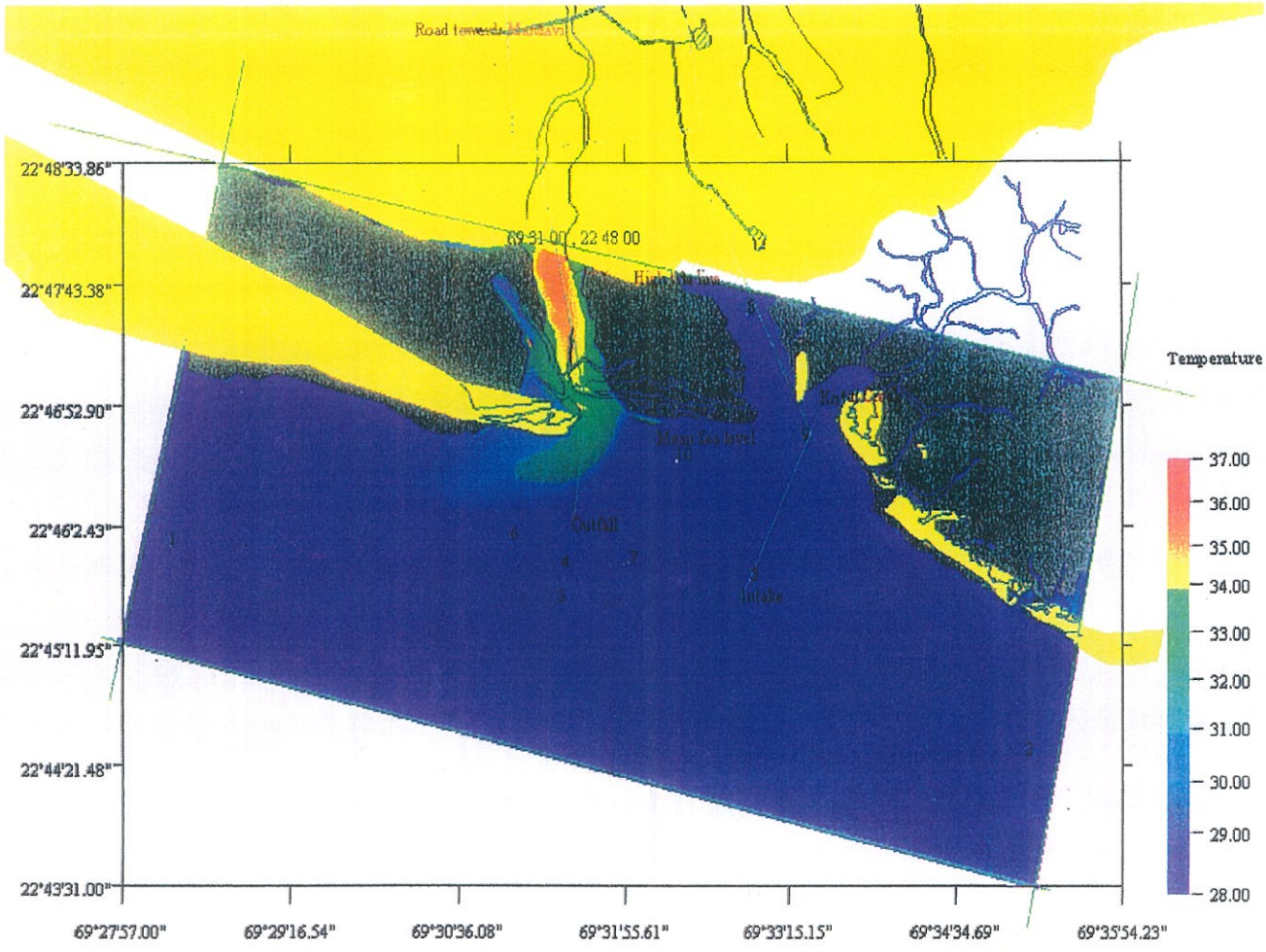


Figure 7.4.29 : Predicted temperature field at mid ebb during neap for case 2.

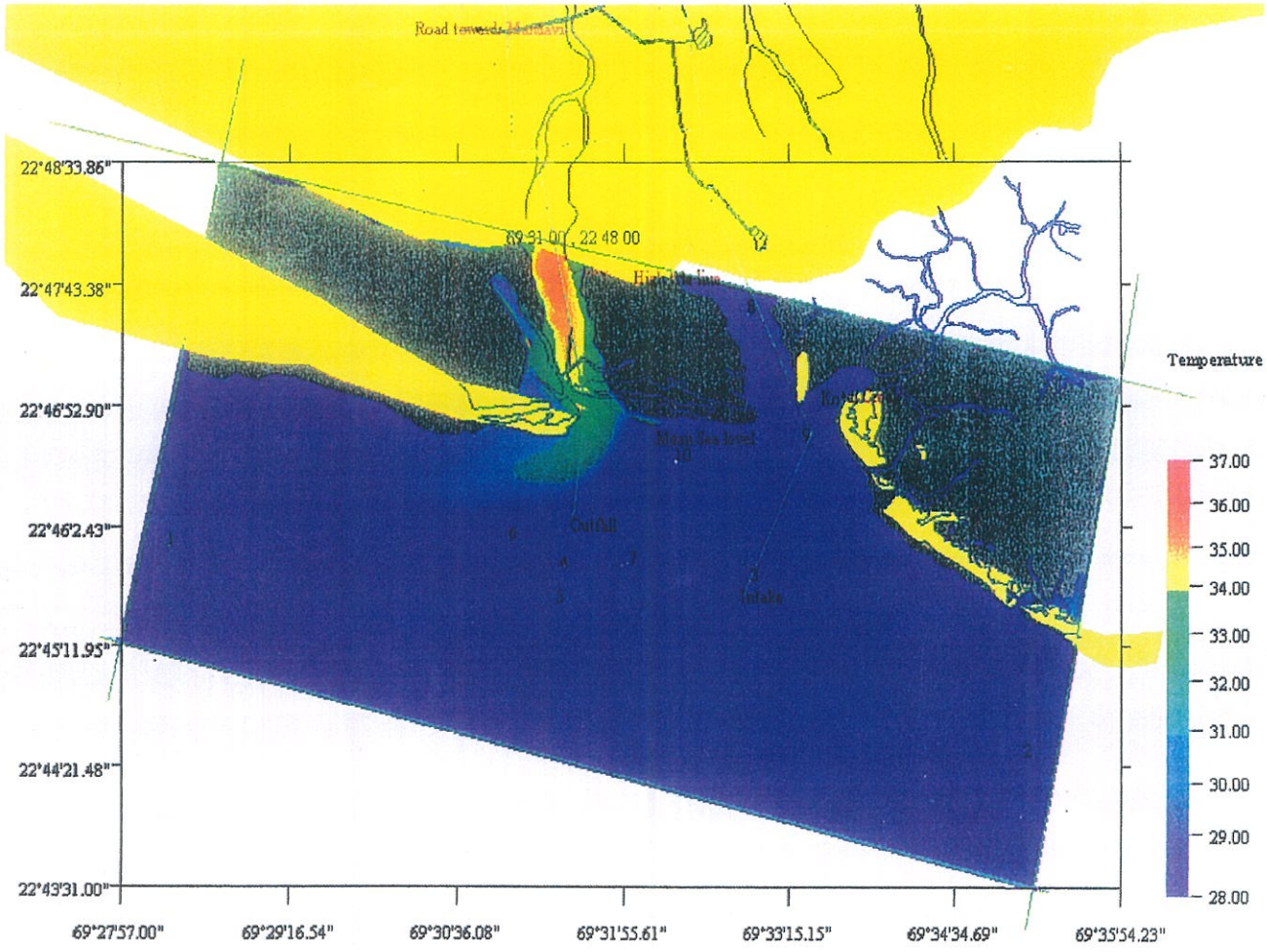


Figure 7.4.29 : Predicted temperature field at mid ebb during neap for case 2.

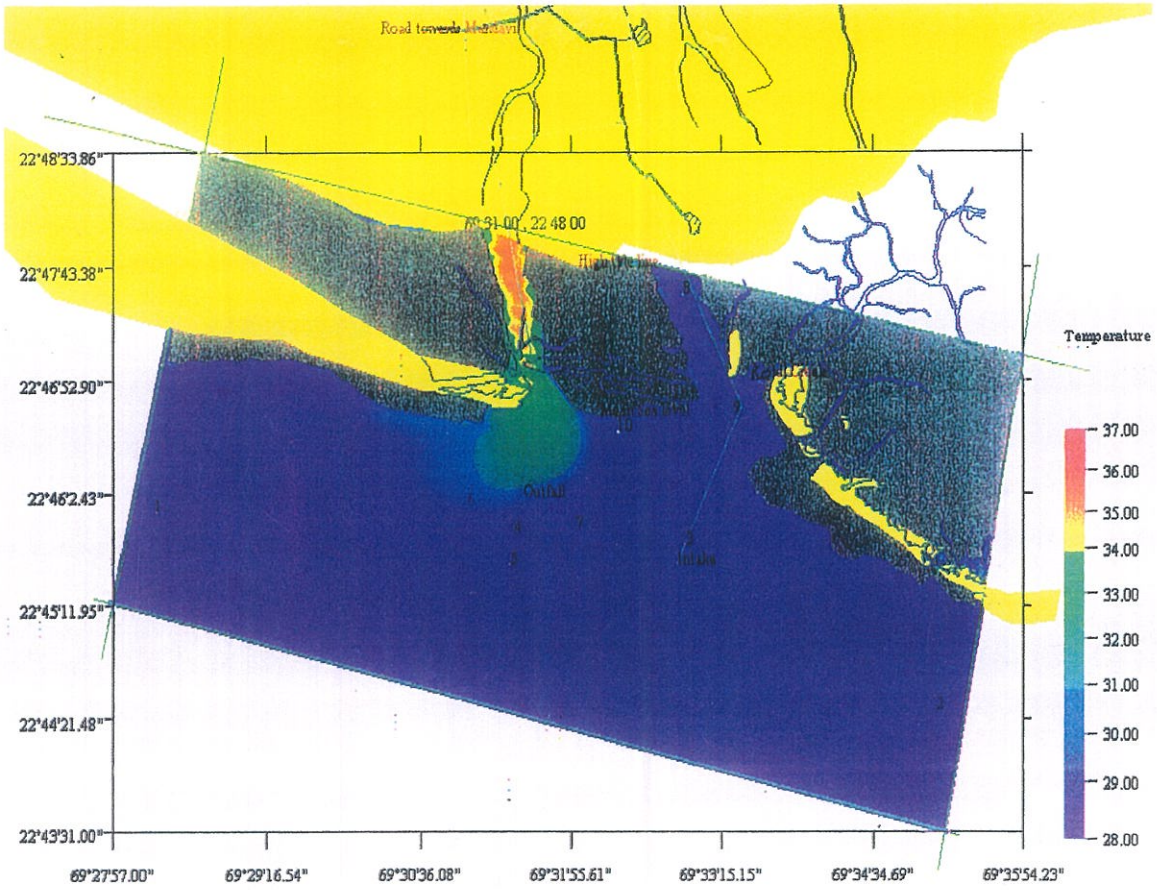


Figure 7.4.30 : Predicted temperature field at low water during neap for case 2.

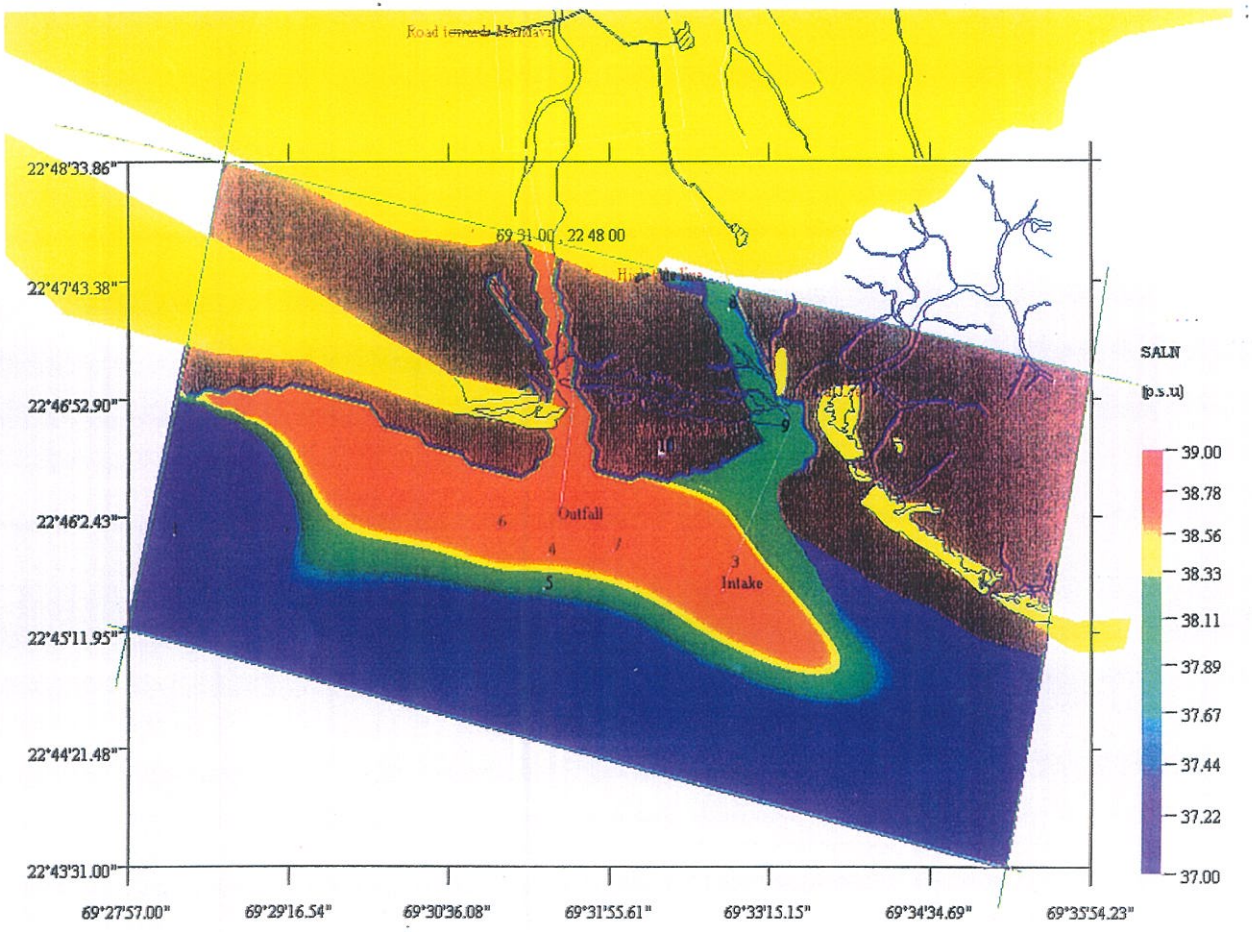


Figure 7.4.31 : Predicted salinity field at mid flood during neap for case 2.

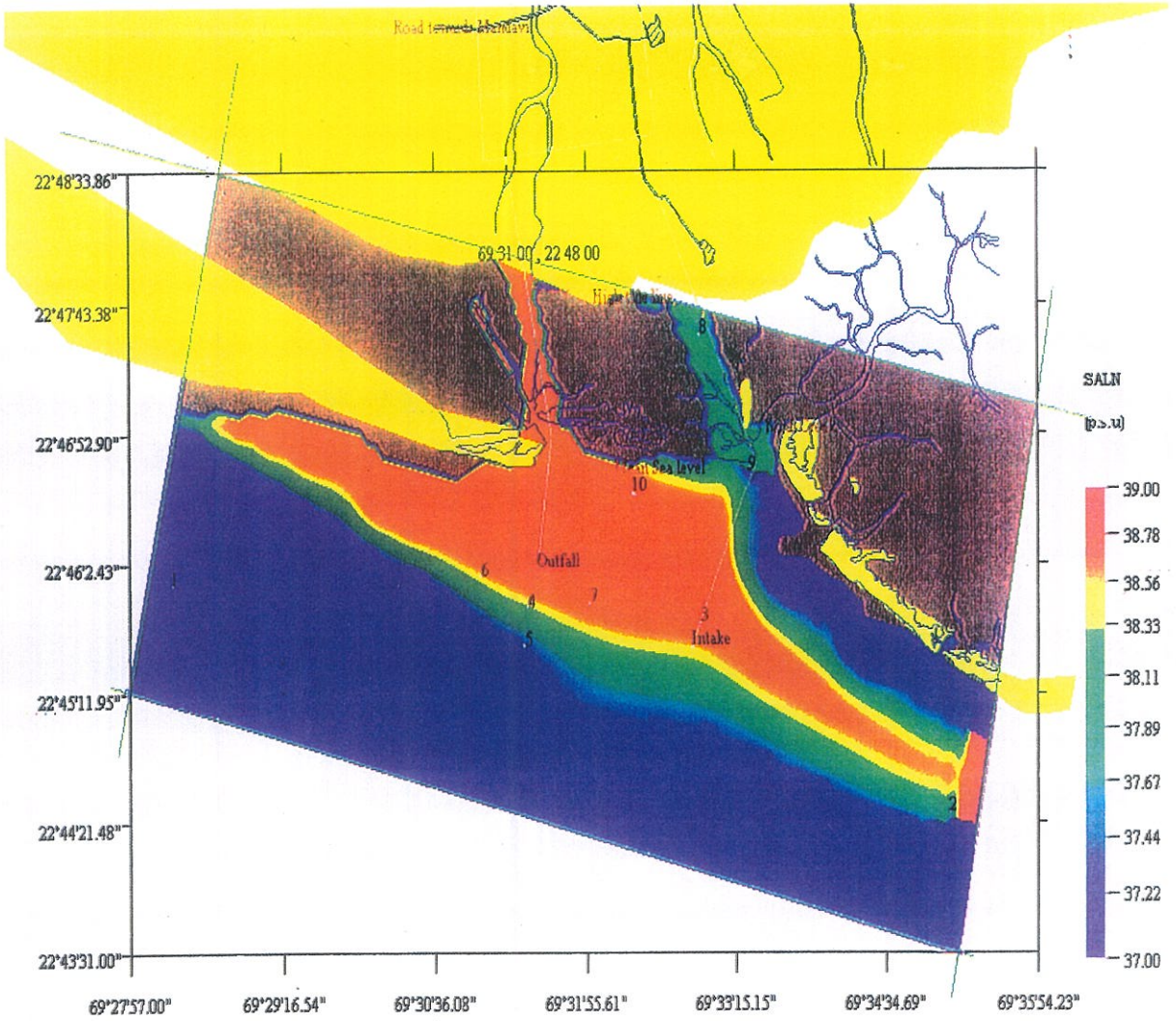


Figure 7.4.32 : Predicted salinity field at high water during neap for case 2.

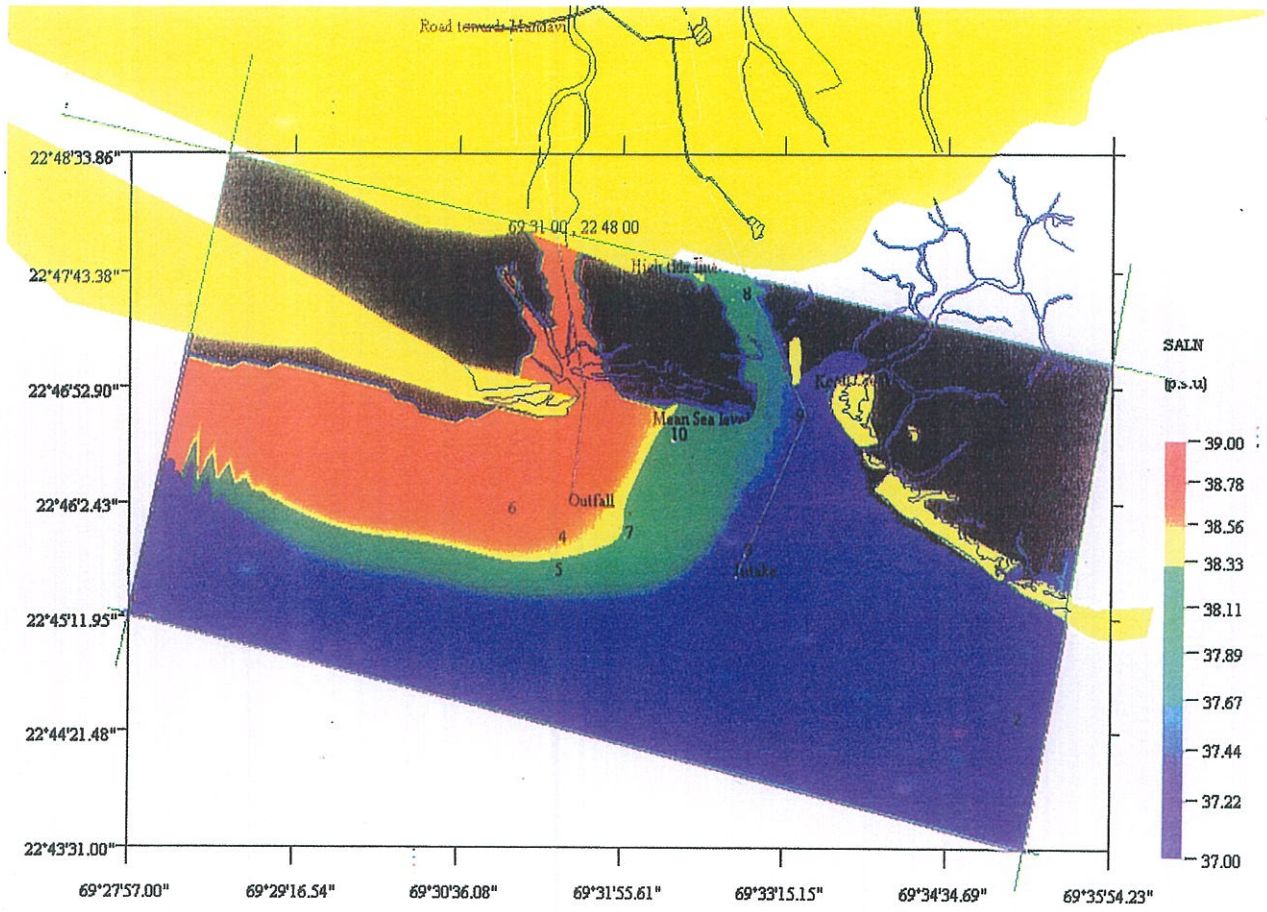


Figure 7.4.33 : Predicted salinity field at mid ebb during neap for case 2

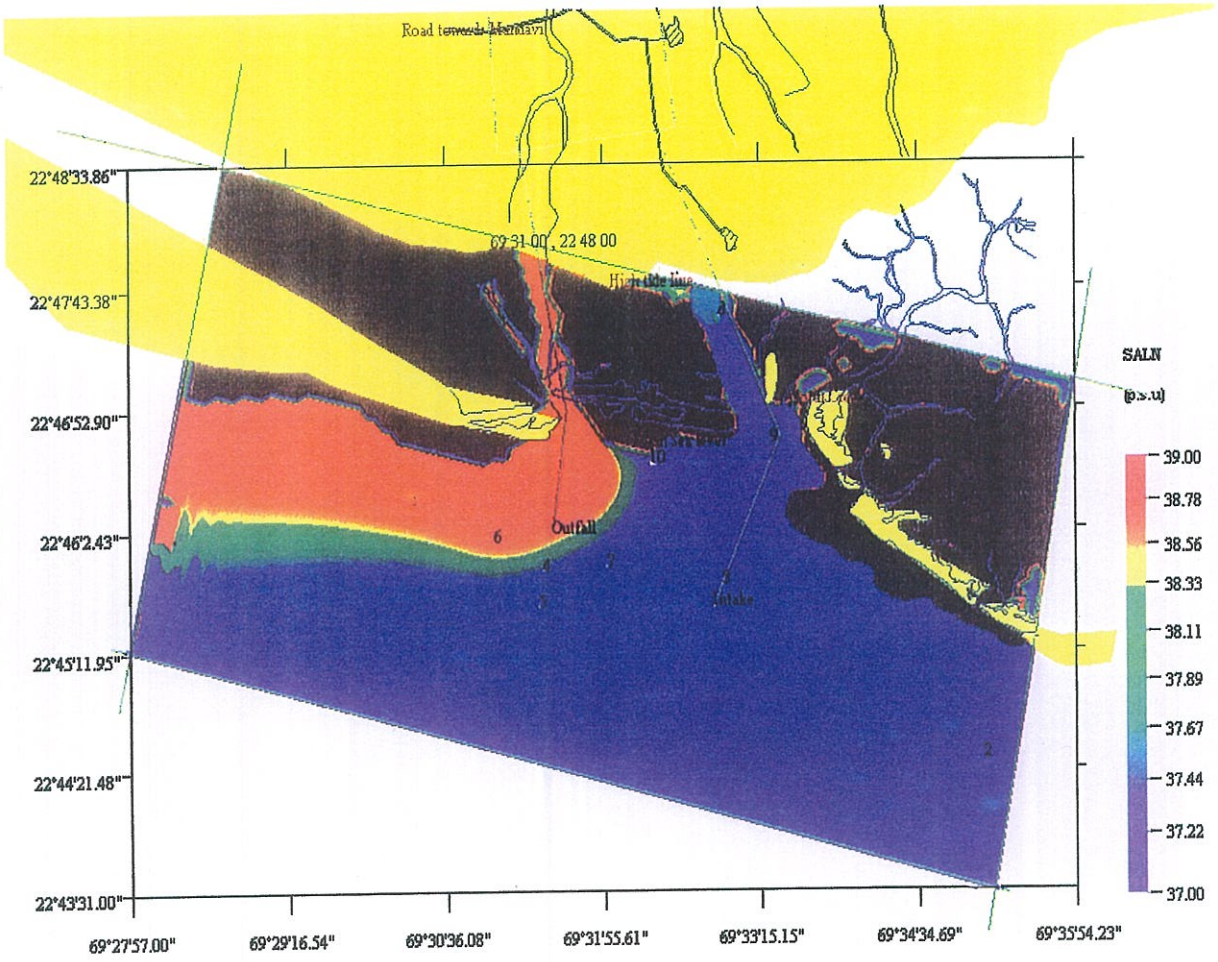


Figure 7.4.34 : Predicted salinity field at low water during neap for case 2.

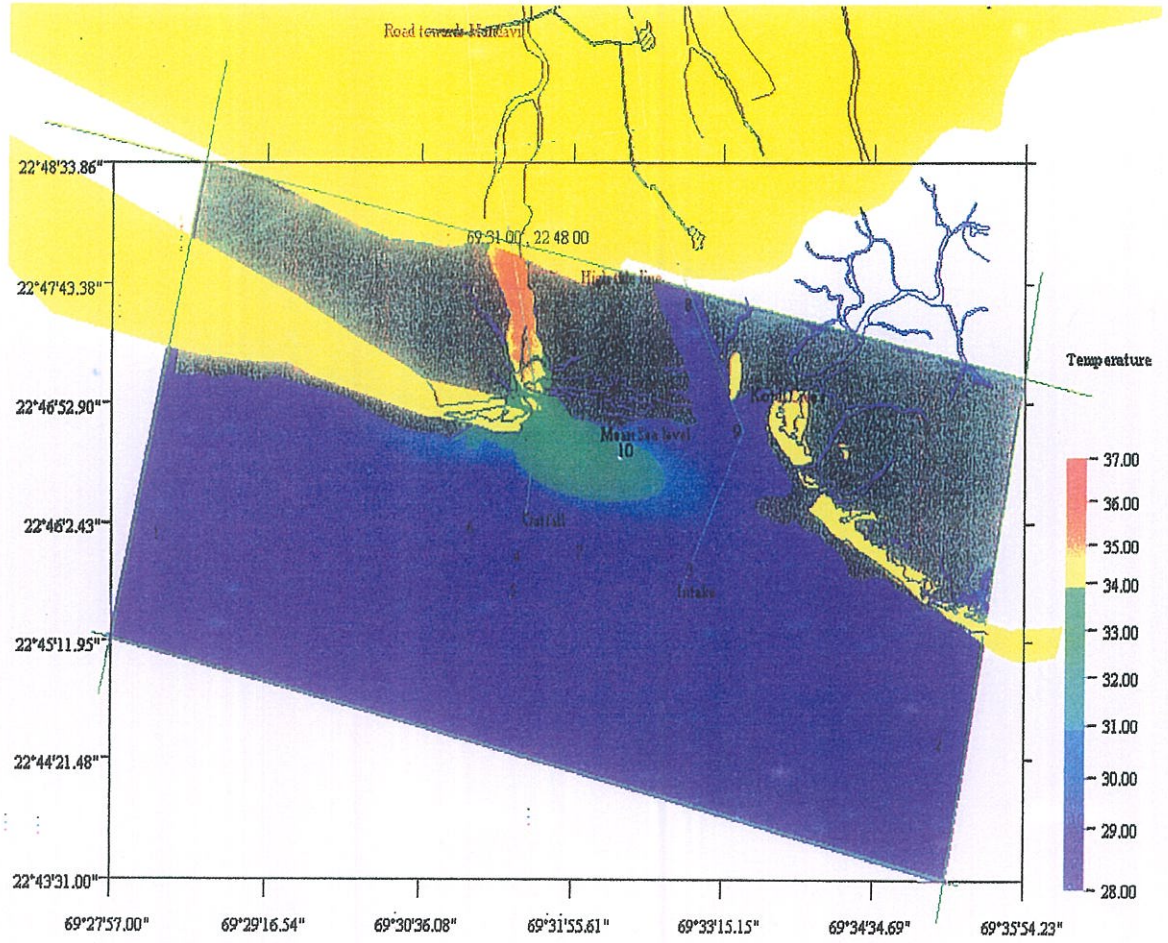


Figure 7.4.35 : Predicted temperature field for case 2 after 10 days run.

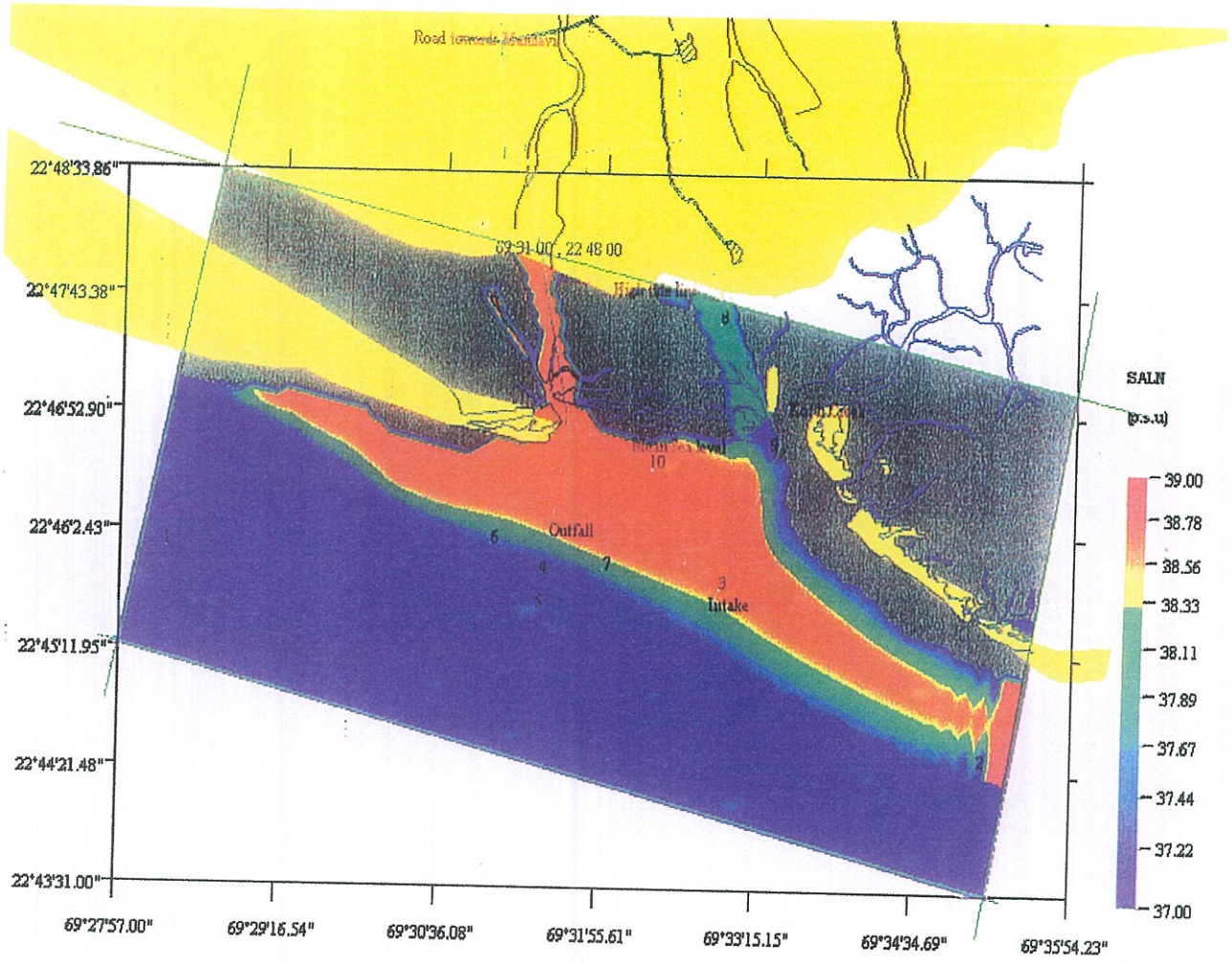


Figure 7.4.36 : Predicted salinity field for case 2 after 10 days run.

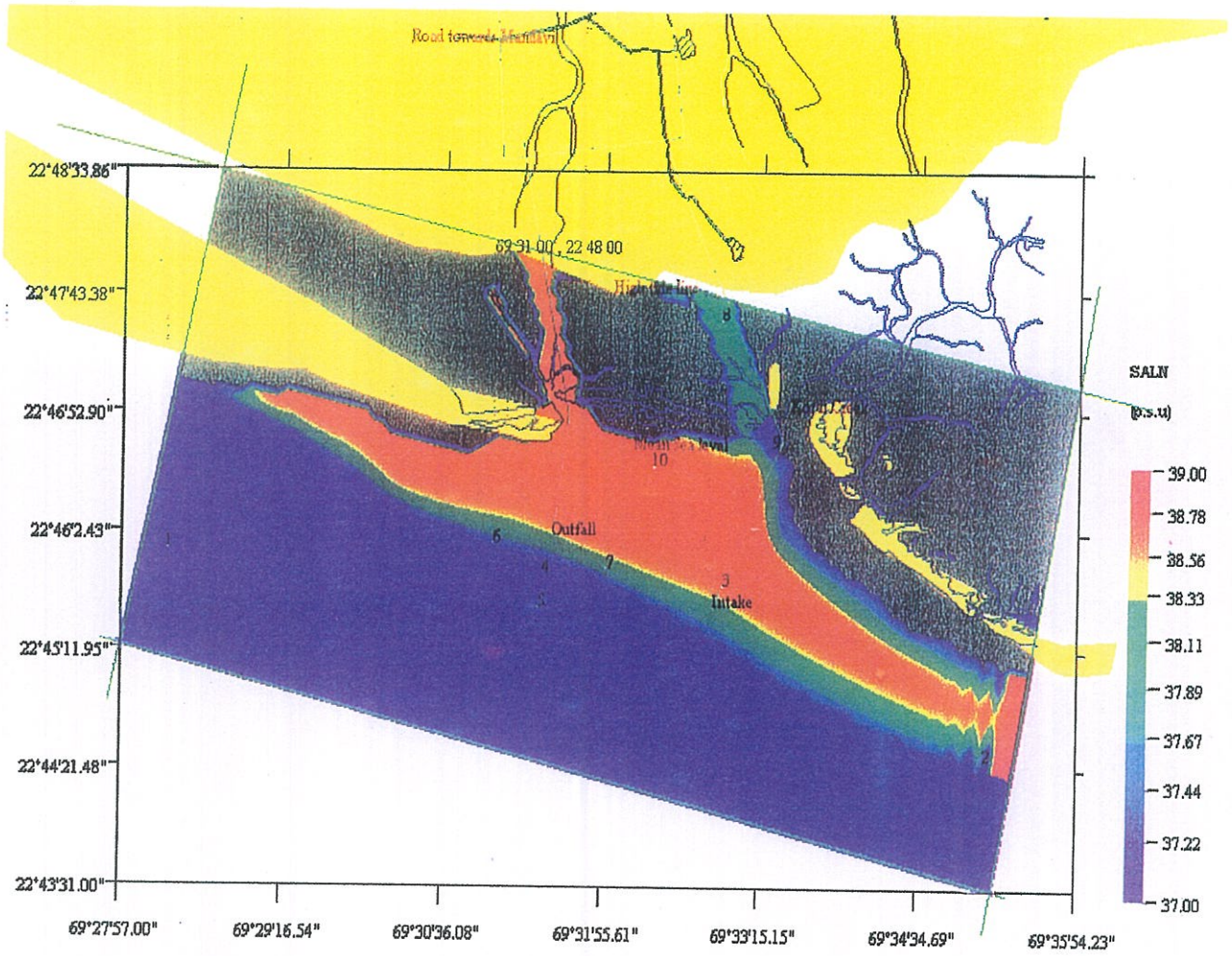


Figure 7.4.36 : Predicted salinity field for case 2 after 10 days run.

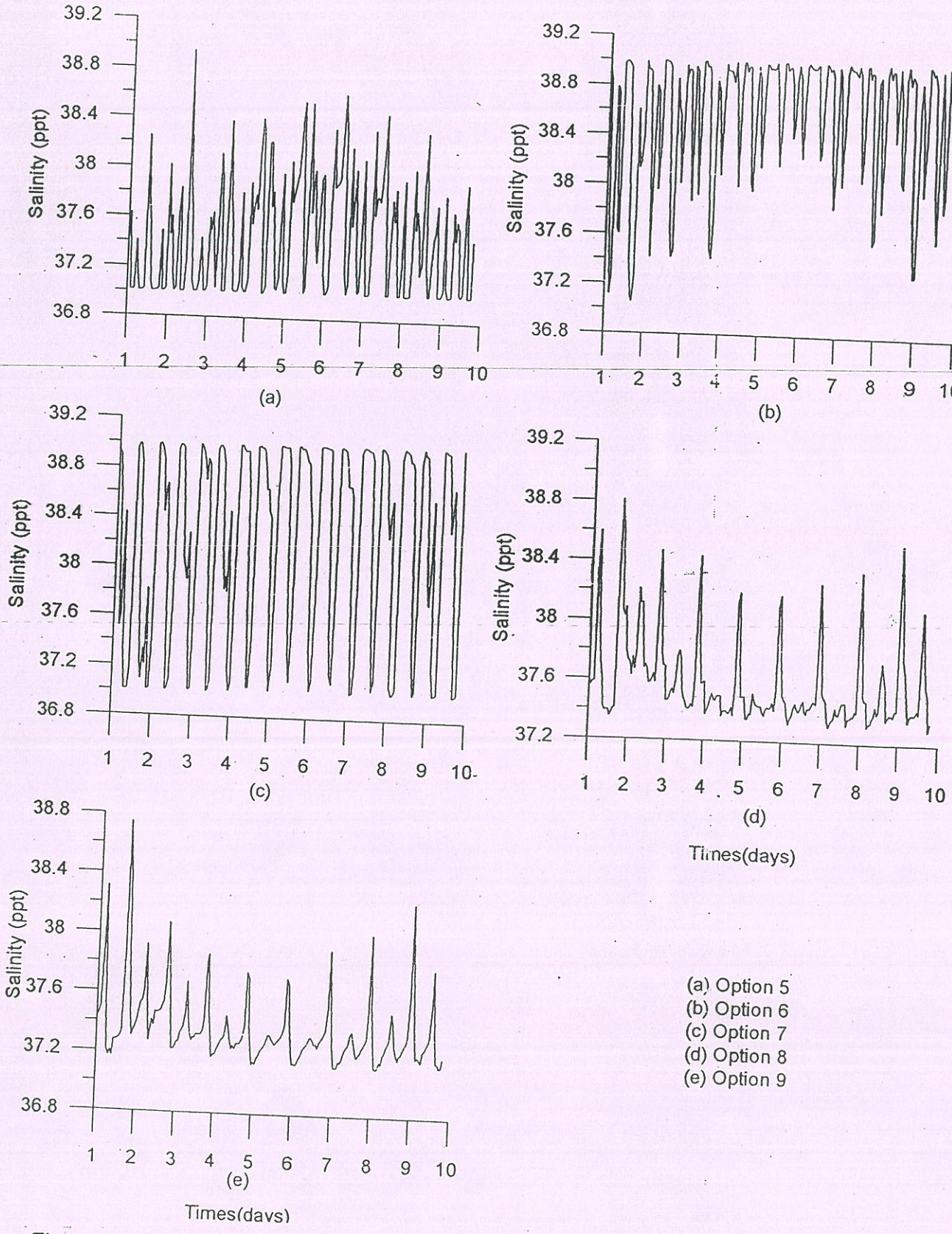


Figure 7.4.40 : Salinity variations over the run period at different observation points for case2

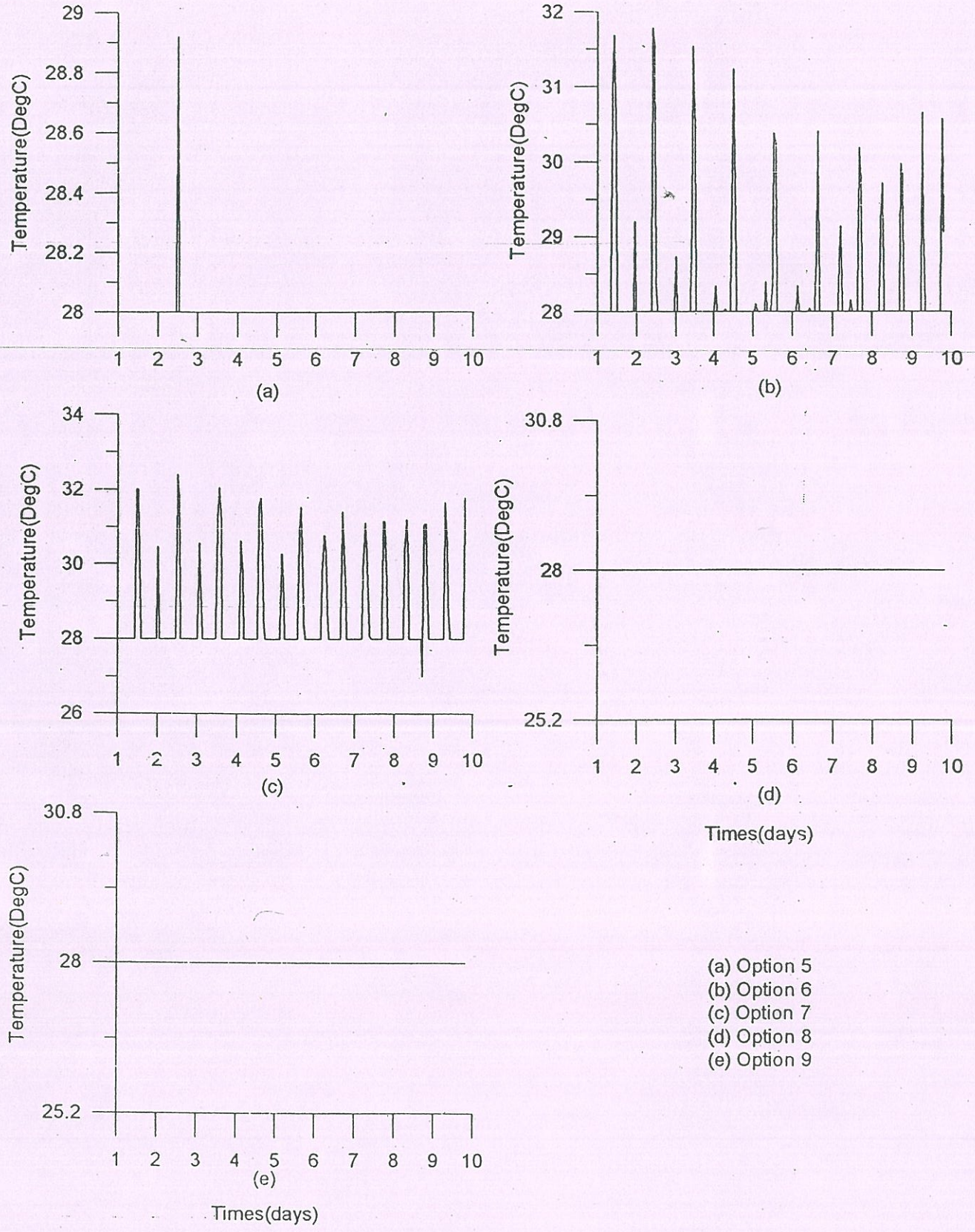


Figure 7.4.37 : Temperature variations over the run period at different observation points for case 1

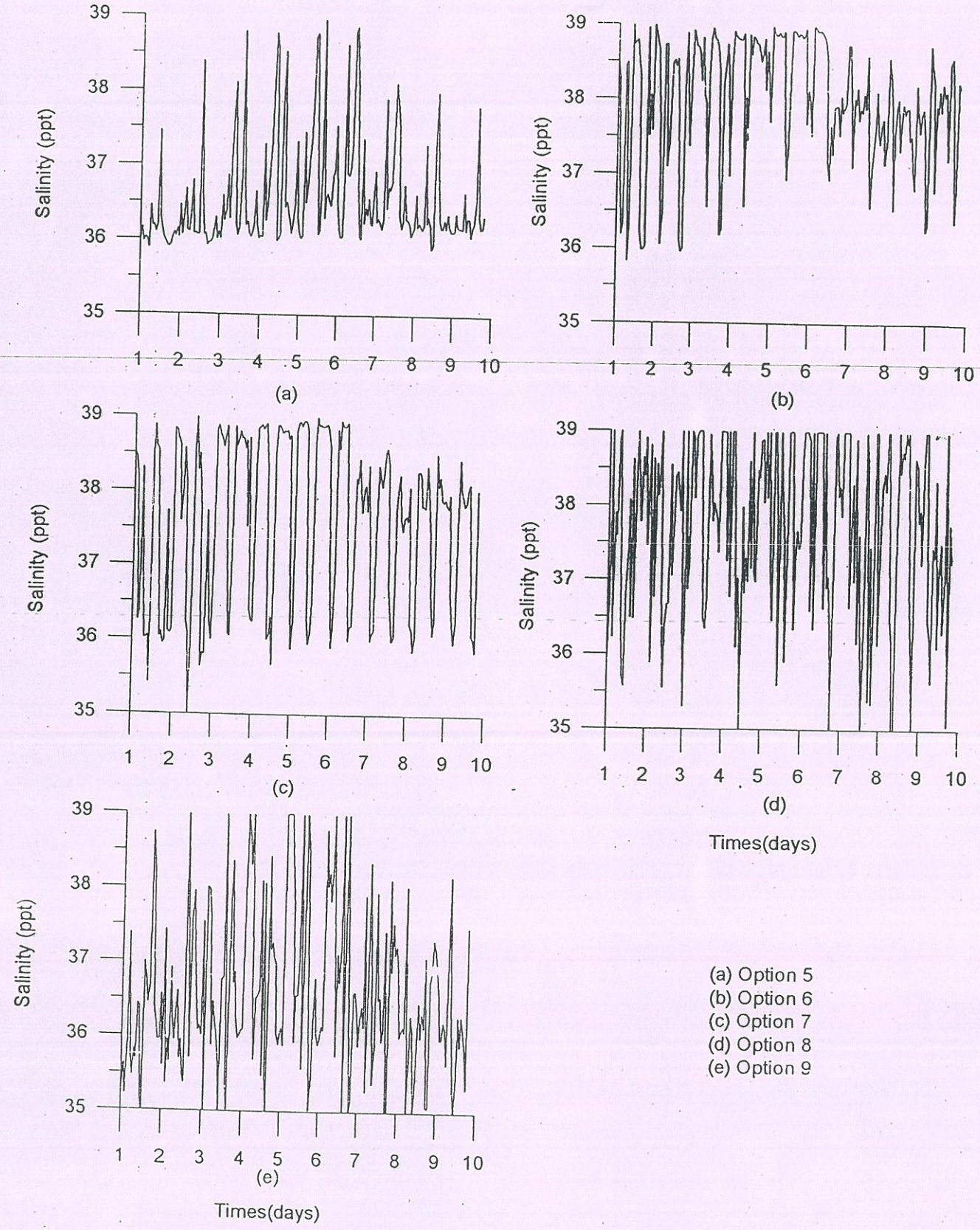


Figure 7.4.38 : Salinity variations over the run period at different observation points for case1

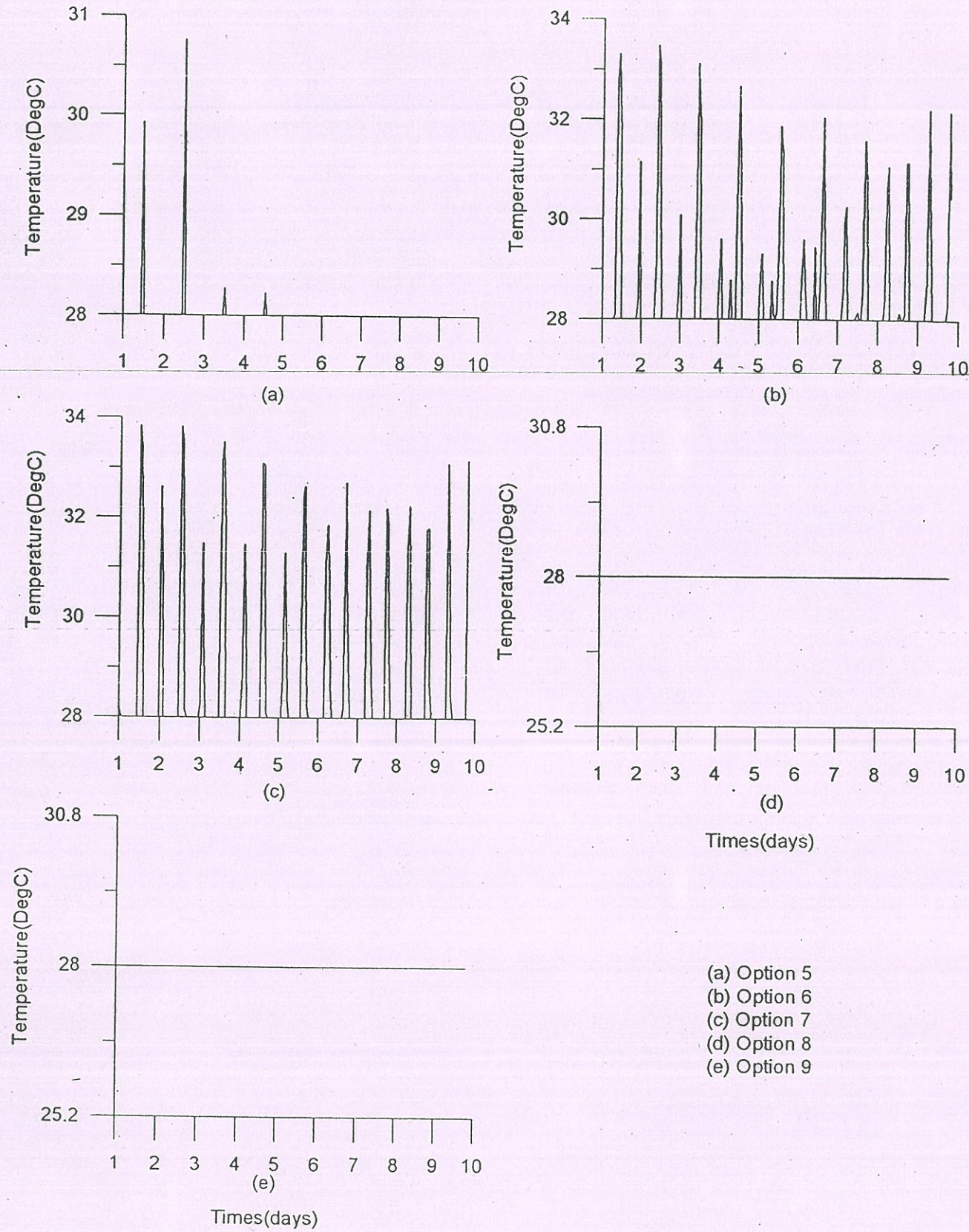


Figure 7.4.39 : Temperature variations over the run period at different observation points for case 2