சென்னைக் குடிநீர் வாரியம்

CHENNAI METRO WATER

EIA REPORT

For

Proposed 150 MLD Sea Water Reverse Osmosis Desalination Plant at Nemmeli Along ECR, Chennai, Tamilnadu, India

AECOM

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EXECUTIVE SUMMARY

BACKGROUND

Chennai Metropolitan Water Supply & Sewerage Board (CMWSSB) is presently operating one 100 MLD R.O. desalination plant at Nemmeli, south of Chennai. It has now proposed to set up additional seawater desalination plant of 400 MLD & 150 MLD.

PROJECT DESCRIPTION

For the Phase III plant to be developed in future, the seawater of 18958.33 m^3/hour will be drawn from the sea and about 12708.33 m^3/hour of brine reject will be released into the sea. The seawater intake head will be located at a distance of about 1050 m from the shoreline at 10 m depth. The outfall diffuser will be located at 650 m distance from the shoreline at 7.5 m water depth. The diffuser will have the multiple ports of 10 nos. x 500 mm diameter. This project involves construction of the following activities:

- *Laying of seawater intake pipeline*
- *Laying of outfall pipeline*
- *Construction of seawater intake head*
- *Construction of outfall diffuser*
- *Construction of seawater sump with pump house.*

This report deals with the investigations carried out, prediction of possible impact on the environment arising out of the provision of the above facilities and the proposed mitigation measures adopting the standards and norms prescribed by the Government and other authorities. The objective is to provide a facility having minimum environment impact in terms of temperature, salinity, and chlorine dosage, which are the vital parameters having influence on marine life. The sequence of task modules associated with the development pertaining to marine environment, are discussed in this report in detail and this section highlights the main aspects in a nutshell.

BASELINE DATA

To start with, baseline data of the existing environment needs to be established so as to determine the impact of additional facilities that are to be created, on the existing environment. For this purpose, the marine environment of the project region covering the open sea at 10 km radius has been studied as per the norms stipulated by MOEF. The baseline data required for chemical and biological parameters were collected in open sea in July 2013. The parameters studied pertain to:

i) *Physical parameters: Meteorological and oceanographic parameters such as wind, storms, waves, tides, currents, salinity and temperature, littoral drift, bathymetry, seismic survey, side scan survey, Advection - Diffusion modelling etc.*

ii) *Water quality parameters: Temperature, pH, TDS, Salinity, Dissolved Oxygen, BOD, COD, Ammonia-N, Nitrite-N, Nitrate-N, Total nitrogen, Inorganic phosphate, Total phosphorus, Turbidity, Total suspended solids, Cadmium, Lead, Mercury, Total Chromium, Phenolic Compounds, Total Petroleum Hydrocarbons, and Oil and grease.*

iii) *Sediment quality parameters: Sediment structure, Total Nitrogen, Total Phosphorous, Total organic carbon, Calcium carbonate, Cadmium, Lead, Mercury, Total Chromium and Total Petroleum Hydrocarbons.*

iv) *Biological parameters: Primary productivity, phytoplankton, zooplankton, macro benthos and their respective biomass and diversity, mangroves and seaweeds, flora and fauna, fisheries etc.*

The results of detailed analysis carried out are shown in Tables and Plates which are attached with the report. Only the important and vital parameters are discussed in this section to provide an overall insight into various sections included in the report.

i) Physical parameters

Wind: *The wind speed varies between 7 to 11 knots throughout the year and during April, May, June and December the wind speed varies around 10-11 knots and during the remaining months wind speeds varies between 7 and 9 knots. During April to September, the morning wind mostly prevailed from SW and W, and during November to February, it mostly prevailed from NW.*

Storm: *In total 58 storms had crossed within 300 km off the project region and occurrence of storms in this region are more frequent in October and in November.*

Tide: *MHWS-1.15 m, MLWS-0.14 m, MSL-0.65 m.*

Current: *During the measurement period, the maximum current speed recorded was 0.33 m/s. The current direction was shifting with tides showing the variation within the sector of 330° – 90°.*

Waves: *The significant wave height varies between 0.5 m and 1.0 m during February to April and it varies between 1 and 3.0 m during May to September and it varies between 1 and 2 m during rest of the year. The zero crossing period of the waves varied between 5 and 8 s.*

Salinity: *It varies between 32 to 34.5 ppt throughout the year.*

Temperature: *It varies between 27 and 30°C throughout the year.*

Littoral drift: *The sediment transport rates were high in May and December and it was low in March. The littoral drift was towards north from April to October and towards south during the remaining months of the year.*

Bathymetry: *At offshore, the seabed shows a steep gradient of 1:70 till 7 m depth, and the water depth is 4 m at 225 m, 5 m at 340 m, 7 m at 520 m, 8 m at 66 m, 9 m at 83 m, 10 m at 1040 m, 11 m at 1360 m, 12 m at 1890 m, 13 m at 2160 m, 14 m at 2460 m, 15 m at 2720 m and 16 m at 2950 m.*

Seismic survey: *The shallow seismic study reveals that the sub-seabed consists of sedimentary layer such as sand and clay up to few meters below seabed. The submerged and buried rocks are also noticed within the study region.*

Side scan survey: *The analyzed records reveal that the seabed is generally covered by sandy clay, clayey sand, coarse sand with scattered rocky outcrops.*

Ambient Air Quality : Predominant winds from W, WSW and E directions were observed during study period. Present major source of air pollution in the region is due to road traffic emission, domestic activities and rural conditions. The PM10 and PM2.5 are observed to vary from 32.7 to 52.5 μg/m3 and 11.0 to 19.5 μg/m3 respectively. The SO2 and NOx are observed to vary from 7.5 to 10.8 μg/m3 and 9.7 to 14.8 μg/m3 respectively. The CO values are observed to vary from 365 to 536 μg/m3 . The results of the monitored data indicate that the ambient air quality of the region in general is in conformity with respect to norms of the National Ambient Air Quality (NAAQ) Standards of Central Pollution Control Board (CPCB), with present level of activities and also it infers that the air quality levels in the study area are of fairly good quality.

Soil Characteristics :The soil samples were tested at 8 locations covering various land uses. It was observed that the soil in the study area is predominantly of sandy clay type. The pH of the soil samples ranged from 7.8 to 8.1. The Electrical Conductance of the soil samples varied from 144 to 280 µmhos/cm. The phosphorus values ranged between 28.2 kg/ha – 78.0 kg/ha. The nitrogen values ranged between 38.0 kg/ha – 65.0 kg/ha. The potassium values ranged between 0.06 kg/ha -0.20 kg/ha.

Noise Level Survey: The noise monitoring has been conducted at 8 locations in the study area. The Day Night Noise Level (Ldn) near plant site was observed as 45.7 dB(A). The noise levels in general found within the acceptable levels as per standards prescribed by Central Pollution Control Board (CPCB).

Landuse Studies: The land use pattern within 10 km radius around the proposed project area has been studied by analyzing the available primary census data. The study area falls in Chengalpattu taluk in Kancheepuram district of Tamil Nadu. The study area of 10 km zone around project area covers about 21 villages within. Altogether, the study area covers about 5663 ha of cultivated land, which works out to about 46.78 % of the total study area. The irrigated and un-irrigated land is about 25.09 % and 21.69 % of the study area respectively. Cultivable waste land and area not available for cultivation are about 14.70 % and 25.79 % respectively. Forest land is about 12.73% of the total study area.

Socio-Economic Details : The information on socio-economic aspects of the study area has been compiled from secondary sources, which mainly include census data of 2011. As per the 2011 census, the study area consists of a total population of 73245 persons residing in 17961 households. The configuration of male and female indicates that the males constitute about 50.51 % and females 49.49 % of the total population. About 34.19 % of the population in the study area belongs to Scheduled Castes (SC) and 1.04 % to Scheduled Tribes (ST). The study area experiences a literacy rate of 72.65% and has 38.83% of the total population as working population.

ii) Water Quality

pH: *This is the most important parameter having impact on rearing of fishes and aquatic life. During the study period, it was noticed that the pH varied between 8.19 and 8.22 at all the 10 locations.*

TDS: *TDS values varied from 34.97 to 35.27 g/l at all 10 locations.*

Salinity: *The estimated salinity of the collected water samples varied between 34.55 to 34.79 ppt at all 10 locations.*

DO: *The range of DO was observed at 4.51 to 6.74 mg/l. These are considered within normal range as anything below 2 mg/l will alone cause respiratory impacts on marine fauna.*

BOD: *BOD varies from 1.09 to 4.55 mg/l. The BOD values indicate that the oxidisable organic matter brought to nearshore is effectively assimilated in coastal water and the narrow range of variation in BOD indicates that the water column is well mixed in the project area.*

COD: *The COD values varied from 12.6 to 79.0 mg/l at all 10 locations.*

Nitrite-Nitrogen: *Nitrite is an important element, which occurs in seawater as an intermediate compound in the microbial reduction of nitrate or in the oxidation of ammonia. Nitrite concentration ranged from 0.11 to 1.96 µmol/l at all 10 stations.*

Nitrate-Nitrogen: *Nitrate is considered to be the micronutrient, which controls primary production in the euphotic surface layer. Nitrate concentration ranged from 1.17 to 4.32 µmol/l.*

Total nitrogen: *Total nitrogen ranged from 6.20 to 18.60 µmol/l.*

Turbidity: *This is the measure to understand the level of suspended particulate matter load which controls the photosynthesis in the water column. It varies from 0.8 to 90.2 NTU*

The turbidity of nearshore waters in the surface region was found to be within the normal ranges, whereas in the bottom it was high, possibly due to presence of underwater currents.

Ammonia-Nitrogen: *The values of ammonia - Nitrogen are in normal range and indicate a healthy environment as detailed in tables attached with the report.*

Phosphate (PO4-P): *Phosphate concentration ranged from 0.20 to 1.78 µmol/l.*

Total phosphorous: *Total phosphorous ranged from 0.52 to 1.92 µmol/l.*

TSS: *Total Suspended Solids varies from 16 to 84 mg/l. The results are similar to turbidity values and appear to be within normal range.*

Metal: *Very important from the point of view of their possible adverse effects on marine biota. Cadmium concentration in the study area was < 0.01 mg/l*

Mercury concentration remained <0.002 mg/l in open sea area as revealed during the study period.

Lead concentration was < 0.02 mg/l in the open sea.

Chromium concentration was very low i.e., <0.05 mg/l in the open sea.

Phenol was found below detectable level (BDL) < 0.1 mg/l in the open sea.

Petroleum hydrocarbons were found below detectable level 0.1 µg/l in the open sea.

Oil and grease in the study area was found to be <2.0 mg/l in the open sea.

iii) Sediment Characteristics

Sediment: *Predominantly, it was medium and fine sand. Other characteristics:*

TOC	0.37 to 1.55%.
Total Nitrogen	0.14 to 0.23 mg/g
Total phosphorus	0.15 to 0.22 mg/g
Calcium carbonate	25.35 to 42.90%
Lead	3.43 to 32.50 mg/kg
Cadmium	0.42 to 1.14mg/kg
Mercury	<2.0 mg/kg
Chromium	12.05 to 78.71 mg/kg
Phenol	<0.1 mg/kg
Total petroleum hydrocarbons	<0.5 mg/kg

Oil and grease	*<2.0 mg/kg*

These are low values indicating clean sediments devoid of any contamination.

iv) Biological parameters

Primary productivity:	*323 to 780 mgC/m^3/day* *Area is highly productive.*
Floral diversity	*Varies from 21 to 29 species. Most dominant species are: Bacilleriophyceae (Diatoms) formed the major group followed by Dinophyceae (Dianoflagellates) and Cyanophyceae (blue green algae). Phytoplankton population analyzed at various stations showed that their numerical abundance varied from 68 to 103 nos./ml. As many as 55 species of phytoplankton (net and unit samples put together) represented by 3 diverse groups namely, diatoms (43 species consisting of 34 centrales and 9 pennales), dinophyceans (11) and chlorophyceae (1). There were relatively fewer (46) species in the unit samples*
Zooplankton	*Fluctuates from 38 to 44 species. Zooplankton mostly consists of Coryceas danae (13.5% to 8.7%), Paracalanus parvus (7.2% to 2.0%), Oithona brevicornis (6.8% to 0.6%), Coryceas catus (6.8% to 1.8%) and Copepod stages (5.6% to 1.9%).*
Benthos	*Benthic faunal population in an environment depends on the nature of the substratum and the organic matter content of the substratum.* *Sediment characteristics is of coarse to medium sand, the numerical abundance of benthic fauna varied between 80 and 170 nos/m^2 mainly consisting of amphipods, polychaetes, bivalves and mysids.* *Intertidal benthos: Numerical abundance varied between 30 to75 nos/m^2. Generally, in a project area without pollution/stress/disturbance, the Shannon diversity values and Margalef richeness indices are higher in the range of 2.5 to 3.5, whereas it is low in the project area-which can be attributed to nature of sediment-which is sand in the area.*
Microbiology	*The study indicated that there is no microbiological pollution. Bacterial densities were higher in the sediment samples than those in the water samples which can be attributed to rich organic content in sediment and lesser residence time of microorganism in the water than the sediments.*
Mangroves	*Study area is devoid of presence of mangroves.*
Fishery	*Based on the information collected on fisheries data, it can be concluded that the area is highly productive and has very good potential fishing grounds.*

A. General conclusions of biological parameters

The present study has revealed the following:

- *The diversity values of phytoplankton and zooplankton are in the range of 3.1 to 4 indicating that the region is moderately polluted and its status can be classified as 'Moderate'.*
- *Continuous post monitoring of the environment would indicate the possible changes in the ecological status.*

- *The diversity index of sand is low because of the sandy nature of the seabed and the low organic content,*
- *Region is known to support good fishery indicating a healthy status of environment in general.*

B. Environmental parameters and modelling study

i) Environmental impact study

Having established the baseline data on the above basis, the next important task is to assess the impact arising out of i) the quality aspects of return water let into the sea on marine life and ii) construction of the marine facilities required for the seawater intake and outfall.

ii) Modelling technique

The main objective of the study is to ensure that the rejected water does not unduly alter the marine ecosystem by way of changes in salinity levels, chlorine effects and above all temperature variation exceeding the admissible levels. These are studied by simulating the situation in numerical models developed by various institutions, the most popular one being CORMIX model and MIKE 21.

The boundary conditions are:

Quantity	*12708.33 m^3/hour*
Ambient temperature of the receiving body:	*28 deg C,*
Salinity level of reject water;	*71 ppt i.e. 33 ppt > ambient value (38 ppt).*

The study has conclusively shown that a diffuser outfall located at 650 m distance into the sea at 7.5 m depth, with 10 ports of 500 mm dia. each, projecting above the bed by 1.5 m with orientation of 30 deg horizontal is adequate to ensure proper mixing and dilution which will not induct any major alteration to the existing marine ecosystem and consequently on marine life. The study on CORMIX model shows the mixing zone will extend for 65 m to achieve 22 times and extending further till 200 m distance to achieve to dilution of 27 times from the disposal location.

iii) Identification of Impacts

Generally, construction of approach trestle, seawater intake and the warm water outfall may have some marginal magnitude of impact on seawater, marine ecology, land use and community at large on some occasions. The brine in the initial mixing zone would cause migration of fish communities. Fishes also may undergo a kind of shock and physical damages and may become prey to predators. Further, prolonged exposure of aquatic organism to chlorine at concentration as low as 0.01 mg/l (or even less to especially sensitive species) can be toxic.

iv) Prediction of impacts

Activities which need prediction of impacts are:

- *Construction of seawater intake trestle jetty,*
- *Construction of Seawater intake head*
- *Construction of return water outfall*
- *Trenching for outfall pipeline and*
- *Discharge of brine reject with chlorine*

v) Impact Assessment

The baseline data collected from the project region and the review of available information indicate that the water quality parameters are within the acceptable limits for coastal regions. The quality of brine discharged into the sea is confined to stipulated standards of the Government authorities. The impact causing activities such as piling, intake head, laying of pipelines etc. are purely temporary and they are all light weight structure and the civil works can be completed within a short period of time. The benefits that will accrue to the society in terms of additional power becoming available to industrial needs will outweigh the impacts.

vi) Mitigation measures

The mitigation measures suggested in the report will, among others, include:

- *Design of light weight structure avoiding heavy duty construction equipment and adopting good engineering practice and latest construction techniques*
- *Use of trash bars and screens in the intake head to avoid migration of fishes*
- *Short construction period*
- *Use of guard ponds to minimize the temperature before discharging into sea*
- *Design of appropriate number of ports, diameter, orientation of ports and protection of the installation against damage by floating and lighted buoys.*
- *Controlled dredging for trenching*

vii) Marine Environmental Management Plan (MEMP)

The MEMP has been prepared with the guidelines on proper locations of marine facilities, appropriate design, control and flow of intake and outfall, preservation of marine ecology and social life of the people in the region.

viii) Post Project monitoring

Monitoring programme will be a continuous activity during the construction phase as well as operational phase of the facility in coordination with the power plant. This activity has to be properly organized with qualified and experienced team. Automation in measuring the quantity of discharged water is possible and will be implements.

1. INTRODUCTION

1.1. General

Chennai Metropolitan Water Supply & Sewerage Board (CMWSSB) is operating a 100 MLD R.O. desalination plant at Nemmeli, south of Chennai in order to meet the acute drinking water supply of the southern part of the Chennai city. Now CMWSSB has proposed to augment the drinking water supply by setting up additional seawater desalination plant of 400 MLD capacity as Phase II. There is a future plan to set up a desalination plant of 150 MLD capacity as Phase III. The project location is shown in Fig. 1 and the satellite imagery is shown in Fig. 2. AECOM, Gurgaon has been nominated as Consultant for setting up the desalination plant.

The marine facilities for the Phase III desalination plant will consist of: i) laying of seawater intake pipeline on the seabed but buried below seabed to a distance of 1050 m into the sea till 10 m water depth, ii) laying of outfall pipeline on the seabed but buried below the seabed to a distance of 650 m into the sea till 7.5 m water depth, iii) construction of seawater intake head, iv) construction of outfall diffuser and

AECOM has awarded various oceanographic investigations to Indomer Coastal Hydraulics (P) Ltd., Chennai. Indomer has carried out studies in four parts viz., Part I: Seabed investigations, Part II: Marine EIA study, Part III: Advection Dispersion modelling study. Separate reports have been submitted under each part.

This report covers Part II - Marine EIA study comprising of baseline data collection on water quality, seabed sediment quality and biological parameters incorporated with modelling study on mixing and seabed investigations on the pipeline corridor. The demarcation of LTL/HTL/CRZ along the project shoreline was carried out for the existing operational plant; hence the same has been taken, as the proposed plant is within the premises of the existing operational 100 MLD. Attached is the map of the same, from the existing plant.

Coastal Regulation Zone

The Central Government has declared the following areas as Coastal Regulation Zones (CRZ),

i. The land between the High Tide Line (HTL) to 500 metres on the landward side along the sea front;

ii. Land associated with tidal influenced water bodies such as tidal creeks;

iii. The land area falling between the hazard line as defined by the Ministry of Environment and Forestry (MoEF), and 500 metres from HTL on the landward side;

iv. The land area between the HTL and the Low Tide Line (LTL), which is referred to as the intertidal zone;

v. The water and the bed area between the LTL to the territorial water limit, 12 nautical miles offshore.

Central Government has prohibited certain activities within the CRZ, and has declared certain activities permissible with clearance from the MoEF. Desalination plants are permissible activities with permission from the MoEF, refer Section 4 (ii) (h) of the Coastal Regulation Zone Notification.

CRZ-I, II, III and IV areas are defined in the notification. CRZ zones III and IV are relevant at Perur:

✓CRZ-III: Are areas that are relatively undisturbed.

✓CRZ-IV: Is the water area from the Low Tide Line to twelve nautical miles on the seaward side.

Within CRZ-III there are two designated zones, a "No Development Zone" and the "200 m to 500 m zone". Within both these zones, "Foreshore activities for desalination plants and associated facilities" are permitted activities, refer Section III, CRZ-III, A (iii)(h), and CRZ-III, B (v). In CRZ-IV areas, the activities impugning on the sea and tidal influenced water bodies are regulated. The construction of intake and outfall conduits, and intake and outfall structures, are regulated in this area.

All calendar dates are referred in Indian style as dd.mm.yy. (eg. 05.07.14 for 5th July 2014). The WGS84 spheroid with UTM coordinates in Zone 44 is followed for the surveys and for the presentation in this report.

1.2. Plant description

The seawater Reverse Osmosis Desalination Plant is planned for 150 MLD under this Phase III plan. The phase III plant will be located at Perur (Nemmeli village) at a latitude of 12° 42' 05.83" N and longitude of 80° 13' 35.82" E adjacent to the existing 100 MLD Seawater Desalination plant at Nemmeli, Kancheepuram. The nearest railway station is Othivakkam which is at a distance of 28 km from the site and the nearest airport is located at Chennai at a distance of 31 km.

The prime purpose of desalination system is to remove most of the dissolved solids from filtered seawater to make it potable for the south Chennai citizens. The seawater will be drawn from the adjacent Bay of Bengal and will be carried to the sump located inside the desalination plant. The brine reject coming out from the desalination plant will be routed by pipeline to back into the sea. Desalination Plant will have a pre treatment plant, filtration plant, reverse osmosis chambers including high pressure pump, energy recovery system and pumps for discharging the outfall.

Chemicals such as Sodium hexa meta phosphate (SHMP) and Sodium bi-sulphite (SBS) will be dosed prior to SWRO (Sea Water Reverse Osmosis) micro filters so as to optimize the water parameters before feeding to SWRO membranes.

In the SWRO unit the water is boosted upto the desired pressure by high pressure pumps and is supplied to the unit, where majority of total dissolved solids are arrested by the membranes and rejected along with the water.

The backwash and sludge generated at periodic intervals from various treatment units would be discharged into the sea along with brine.

1.3. Project Location

The plant location for phase III development is shown in Fig. 3. The site is located at eastern side of East Coast Road (ECR) at 12° 42' 05.83" N, 80°13' 35.82" E. The phase III 150 MLD Sea Water Reverse Osmosis (SWRO) Plant will be located at Perur near Nemmeli village, Kancheepuram District approximately 40 km south of Chennai city.

The plant site is mainly barren land, which is in the process of being acquired for the Project. East side of the site towards the sea face is fully planted with Casuarina Plantations, whereas ECR road is bordering the west side of the proposed side.

1.4. Project region

Morphology: The coastline is comprised of long and straight sandy beach exposed to open sea with elevated backshore and dune vegetations as shown in Plate 1. The coastal region is backed up with wide sand dunes upto 500 m distance inland. ECR is running immediately adjoining this shore. The strip of coastal stretch between ECR and sea is more urbanized developed with tourist resorts, hotels, cottages, farm houses and intermittent pockets of fishing hamlets. The stretches under the possession of Government remain as a plain and barren land with thorny bushes and at places protected with Casuarina farms. The nearshore remains relatively steeper due to the action of high waves during monsoon season. The seabed at nearshore primarily comprises of sand and silty clay with the spread of submerged rocky patches.

The plant situated inland will have an effluent land fall point at shore near New Kalpakkam). The coastline in this region consists of long open beaches with Casuarina plantations. The beach predominantly consists of fine sand to medium sand.

The coastline between Thiruvanmiyur and Madras port shows accretional trend due to the construction of breakwaters at Chennai port. The widest part of the beach, having horizontal spread of 600 m is seen at Marina beach. Between Thiruvanmiyur and Uthandi, beach is stable and not much subjected to human activities. This stretch showed urbanized development with an average width of 100 m foreshore and sand dunes reaching a height of 2 m. From Uthandi to Mahabalipuram towards the south, rocky outcrops are prominent in the nearshore waters. The stretch between Covelong and Mahabalipuram, is widely used for recreation. Due to the construction of semi-circular breakwater around the Mahabalipuram Shore temple, the shoreline over a stretch of 3 km towards the north is exposed to erosion. Many beach resorts are situated in this region. At 1 km north of the Mahabalipuram temple, the beach is narrow with only 50 m width with steep foreshore.

The oceanographic parameters suggest that the nearshore waters between Madras and Mahabalipuram is rich in biological resources. It was further supported from the fish catch data that the area under investigation is potentially rich in fish production.

<u>Oceanography:</u> The oceanography of this region is influenced by 3 climatic conditions viz., southwest monsoon (June – September), northeast monsoon (Mid October to Mid March) and fair weather period (Mid March to May). The coast is more influenced by the northeast monsoon than other two seasons. Wave action prevails high during northeast monsoon and cyclonic period. The coastal current within 5 km distance from the shore is greatly influenced by wind and tides. The nearshore remains more dynamic and turbulent due to persistent action of seasonal wind, high waves and coastal currents. The distribution of temperature and salinity indicates that the nearshore water is well mixed without stratification. The influence of littoral drift is significant and the annual net drift takes place in northerly direction.

1.5. Ecology & Economy

The fishery potential of the region is relatively good. The nearshore supports certain type of demersal fisheries with moderate bottom animal community. Tourism and beach resorts are developing in this region. The Metro water is operating 100 MLD desalination plant nearby.

2. DETAILS OF MARINE FACILITIES

The marine facilities for the phase III plant is shown in Annexure-VII. The phase III marine facilities will consist of laying of seawater intake pipeline on the seabed with intake head, laying of outfall pipeline on the seafloor with outfall diffuser and construction of seawater sump with pump house on the land.

2.1. Basis for selection of marine facilities

For the desalination plant, it is essential to draw the water from the sea and release brine outfall into the sea at the appropriate locations. The locations of the seawater intake and outfall are decided based on the nearshore topography, geological composition of the seabed, the dynamics of the ocean including waves and currents, the mixing characteristics of the nearshore water, the restriction imposed on the recirculation of discharged water into the intake. The various parameters relevant to all these aspects were studied during the data collection and mathematical modeling and accordingly, the appropriate locations are identified.

In the present case, the intake has been located at 1050 m distance offshore in order to draw clean seawater without the interference of the outfall. The outfall diffuser located at 650 m distance from the shoreline. Since the nearshore currents in this region are predominantly directed towards north, it is preferred to locate the outfall on the northern side, so that the plume spread will be mostly oriented towards north and there will not be any re-circuit to the intake. The various concepts and the relevant calculations are shown in detail in forthcoming chapters. The summary of the various facilities are described below.

2.2. Seawater intake

The seawater will be drawn by laying a submarine pipeline. The details are given below:

Land Fall Point (LFP) Location	Geographical Co-ordinates		UTM	
	Latitude, N	Longitude, E	X (m)	Y (m)
LFP – Intake	12°42'06.72"	80°13'34.40"	416011	1404283
Intake head Depth = 10 m	12°41'41"	80°14'01.06"	416864	1403490

Intake volume: The seawater requirement for the RO (Reverse Osmosis) plant will be 10833 m3/hour (260 MLD) initially during the present stage (100 MLD Operational) and it will be 18958.33 m3/hour (455 MLD) finally after phase III development.

Intake description: The both seawater intake head will be located at a distance about 1050 m from the shoreline at 10 m CD (Chart Datum) water depth. The water from the intake head will be drawn by gravity flow through the submarine pipeline buried 1 m below the seafloor.

Sump with pump house: There will be a seawater collection sump with pump house into the land.

2.3. Marine outfall

Brine outfall quality: The salinity of the return water released into the sea will be 71 ppt, which will have the salinity difference of 33 ppt higher than the seawater ambient salinity of 38 ppt. A chlorine dosage of 3 ppm will be given to the drawn seawater and the return water discharged into the sea will have the concentration of around 0.2 ppm. The water quality of the return water disposed into the sea will conform to the standards stipulated by Tamilnadu Pollution Control Board. There will not be any change in other water quality parameters compared to the ambient values.

Brine outfall volume: The brine discharge into the sea will be 6667 m^3/hour (160 MLD) initially during the present stage and it will be 12708.33 m^3/hour (305 MLD) after phase III development.

Outfall location: The outfall diffuser will be located at 650 m distance from the shoreline at the water depth of 7.5 m CD. The outfall will have a multiple port diffuser arrangement system.

Location	Geographical Co-ordinates	UTM

	Latitude, N	Longitude, E	X (m)	Y (m)
LFP - Outfall	12°42'07.29"	80°13'34.25"	416023	1404305
Outfall diffuser Depth = 7 m	12°41'53.07"	80°13'52.10"	416572	1403881

3. SCREENING AND SCOPING

The project region primarily comprises of dry and barren land without much inhabitation. The phase III expansion of desalination plant will improve the drinking water supply to the southern part of Chennai city. The project related activities are concerned with the marine environment and thus a marine EIA study will be essential in order to identify the impacts, mitigation and to draw an Environmental Management Plan.

4. BASELINE DATA

The marine environment of the project region at open sea has been studied for the evaluation of baseline information as per the norms stipulated by the Ministry of Environment and Forests, Govt. of India. The baseline data were collected during July 2013. The chemical and biological samples were collected at ten locations in the open sea covering 10 km radius. In addition, water samples were also collected from six more locations around the intake and outfall locations proposed under phase III for detailed analysis. The details of the sampling locations are presented in Table 1 and also shown in Fig. 4. The details of the studies carried out in the coastal region on physical, chemical and biological aspects are presented below.

Physical parameters

Wind
Storm
Waves
Tides
Currents
Salinity and Temperature,
Littoral Drift
Computer modelling on mixing and
Bathymetry, shallow seismic and side scan surveys

Water quality parameters

Temperature
pH
TDS
Salinity
Dissolved Oxygen
BOD
COD
Ammonia-N
Nitrite-N
Nitrate-N,
Total nitrogen
Inorganic phosphate
Total phosphorus
Turbidity
Total suspended solids
Cadmium
Lead
Mercury
Total Chromium
Phenolic Compounds
Total Petroleum Hydrocarbons
Oil and grease

Sediment quality parameters

Sediment structure
Total Nitrogen
Total Phosphorous
Total organic carbon
Calcium carbonate
Cadmium
Lead
Mercury
Total Chromium and
Total Petroleum Hydrocarbons.

Biological parameters

Primary Productivity
Phytoplankton, its biomass and diversity
Zooplankton, its biomass and diversity
Macro benthos, its biomass and diversity
Microbial population in water and sediments
Mangroves
Biological status of floral and faunal communities and Fisheries.

Environmental study

Assessment of fishery resources in the area,
Assessment of coastal and marine ecosystem,
Assessment of impact on laying of intake/outfall pipelines,
Assessment of impact on construction of seawater intake head,
Assessment of impact on construction of outfall diffuser,
Assessment on the impact of the discharge of brine,
Recommendation on mitigation measures and
Preparation of Environment Management Plan.

4.1. Plan of work

The data collection was carried out during July 2013 in order to prepare the Marine EIA report.

4.2. Methods of data collection and analysis

4.2.1. Physical

Wind: To understand the wind pattern prevailing in the project region, the data on daily variation of wind speed and direction at 0830 hours and 1730 hours available for Chennai region were compiled from the *Bay of Bengal Pilot (1978).*

***Storm*:** The information on cyclonic storm is essential for the environmental assessment. Occasional occurrence of severe cyclonic storm is found to occur in this region. Based on the IMD data on the Tracks of Storms and Depressions in the Bay of Bengal and the Arabian Sea, (1979), and the Addendum (1996) published by IMD, the details on the storms occurred between 1877 and 1990 were compiled.

Waves: The ship reported visual observations documented in Indian Daily Weather Reports (IDWR) published by the India Meteorological Department, Pune, compiled over the period from 1968 to 1986 were used for the base line data. The data reported for the region between the latitude 10°N - 15°N, and longitude 80°E - 85°E were considered for the present project (Chandramohan, et.al., 1990).

***Tides*:** Tide measurement was carried at Fishing harbor using Aanderaa WTR9 Wave and Tide Recorder for a period of 19 days from 27.07.2013 to 15.08.2013. The tide data were recorded at 30 min interval. The Tides are measured at site. The details of measurements are:

Location	Geographical Co-ordinates		UTM - Zone 44		Duration	
	Latitude, N	Longitude, E	X (m)	Y (m)	From	To
Stn. T1	13°07'33"	80°17'53"	0423938	1451168	27.07.13	15.08.13

Aanderaa WTR9 Wave and Tide Recorder: It is manufactured by Aanderaa Instruments, Norway. It has a pressure sensor, which is based on a high precision quartz crystal oscillator. The pressure is measured every 0.5 seconds and 1024 samples are taken (512 seconds) and stored in internal RAM for wave analysis. The parameters/ channels are transmitted as Aanderaa standard PDC-4 from the electronic control board to the removable and reusable solid state Data Storage Unit (DSU). The instrument is housed in a pressure case and has the arrangement for shallow and deep water moorings. A mode switch with a test and serial communication setting, a depth-setting switch and a recording interval switch is built into this board. The quartz pressure sensor is also attached to the board by a shock-absorbing bracket. A specially designed bottom mounting frame was used for installing the instrument on the seabed. The sensor is of quartz pressure type based on a pressure-controlled oscillator having frequency of 30 – 45 kHz. It has a range of 0-690 kPa, with an accuracy of 210 Pa and a resolution of 7 Pa. By use of the Deck Unit 3127 interface, the output raw data signals can be read by a PC through the same terminal and converted into engineering units.

Currents: Variations of current speed and direction were measured at one location off the project region using Aanderaa Seaguard SW RCM current meter (Stn. C1). The measurements were carried out in 15 minutes interval from 10.08.13 to 25.08.13. The measurement location is shown in Fig. 5. The details of measurement location, depth and duration are:

Location	Geographical Co-ordinates		UTM - Zone 44		Distanc offshore (km)	Water depth (m)	Duration	
	Latitude N	Longitude, E	X (m)	Y (m)			From	To
Stn.C1	12°37'30"	80°12'31"	04140	1395	1.5	8.5	10.08.	25.0

Aanderaa Seaguard RCM SW Current Meter: The SEAGUARD RCM manufactured by Aanderaa Data Instruments (AADI), Norway, comes standard with the ZPulse™ multi frequency Doppler current sensor. The new current sensor comprises acoustic pulses of several frequency components to lower the statistical variance in the Doppler shift estimate. The advantage of this is reduced statistical error with fewer pings, providing increased sampling speed and lower power consumption. The new Doppler Current Sensor also incorporates a robust fully electronic compass and a tilt sensor.

The Seaguard architecture is based on a general data logger unit and a set of autonomous smart sensors. The data logger and the smart sensors are interfaced by means of a reliable CAN bus interface (AiCaP), using XML for plug and play capabilities. The autonomous sensor topology also gives the sensor designer flexibility and opportunities where each sensor type may be optimized with regard to its operation; each sensor may now provide several parameters without increasing the total system load. Data storage takes place on a Secure Digital (SD) card. The current capacity for this card type is up to 4GB, which is more than adequate for most applications.

Littoral Drift: Based on the ship reported wave data, the longshore sediment transport rate at the study region was estimated using the following equation (Shore Protection Manual, CERC, US Army, 1975).

$$Q = 1290(\frac{\rho g^2}{64\pi})T(H_0 K_r)^2 \sin 2\alpha_b$$

Where,

Q	=	longshore sediment transport rate in m^3/year,
ρ	=	mass density of the sea water in kg/m^3,
g	=	acceleration due to gravity,
H_o	=	deepwater wave height in m,
T	=	wave period in seconds,
K_r	=	refraction coefficient, and
α_b	=	wave breaking angle.

4.2.2. Water quality

Water samples were collected at 10 locations in open sea and also collected six more locations (A1 to A6), as indicated in Table 1. and Fig. 4. Samples were collected at surface, mid depth and bottom. Van Dorn water sampler was used for collection.

Samples for Dissolved Oxygen was collected in DO bottles (125 ml capacity) soon after the sampler was retrieved. One end of the nozzle tube was inserted into the sample bottle bottom and filled till 100 ml and the water was allowed to overflow from the bottle to ensure that no bubble is trapped or carried out in the bottle. To the brimful DO bottles 1 ml of Winkler A (manganese chloride) and 1 ml Winkler B (alkaline KI) were added. The stopper is then inserted and the bottle is shaken vigorously for about 1 minute to bring each molecule of dissolved oxygen in contact with manganese (II) hydroxide. After fixation of oxygen, the precipitate was allowed to settle. The DO bottles were kept in dark and transported to the laboratory for analysis. Samples for Biochemical Oxygen Demand (BOD) was also collected in the similar fashion as described for DO in 300 ml glass BOD bottles. All the samples were transported to the laboratory in portable ice box. The samples were incubated at 27°C for 3 days. After incubation, the samples were fixed with Winkler A and Winkler B and later the BOD was analyzed in the laboratory.

Water samples for salinity, total suspended solids, turbidity, nutrients, trace metals and phenolic compounds were collected from the sampling locations using clean polyethylene bottles and were transported to the laboratory by keeping them in a portable ice box. Water samples for total petroleum hydrocarbons were collected separately in 5 litre glass bottles. The sample for Phenol estimation was collected in a pre cleaned 1 litre plastic container.

Method of analysis

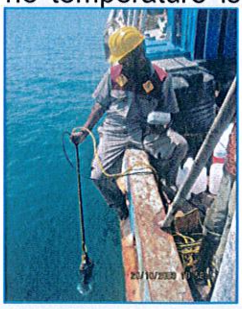
YSI 6600 V2 Multiparameter Water Quality Sondes: For the current project we have also used one of the latest equipment, YSI Multiparameter Water Quality measurement and data collection system. The main advantage of this system is its ability to collect data on several parameters continuously and simultaneously while the instrument is deployed into the water column from the surface. This type of measurement would help us to see the presence of any stratification in the water column and if needed, measurements at a given location can be undertaken even for a number of days. This instrument is also accompanied

by a hand held monitor for real time recording on board the survey vessel. The unit which we have used measured the following parameters:

- Depth
- Temperature
- Salinity
- Total Dissolved Solids
- pH
- ROX Optical Dissolved Oxygen
- DO Saturation

Method of analysis

Temperature: The sondes utilize a thermistor of sintered metallic oxide that changes predictably in resistance with temperature variation. The algorithm for conversion of resistance to temperature is built into the sonde software, and accurate temperature reading in degrees Celsius, or Fahrenheit is provided automatically. The measurable temperature range is -5 to 50 °C with an accuracy of ± 0.15 °C. The temperature is measured with a resolution of 0.01°C.



pH: The sonde employ a field replaceable pH electrode for the determination of hydrogen ion concentration. The probe is a combination electrode consisting of a proton selective glass reservoir filled with buffer at approximately pH 7 and a Ag/AgCl reference electrode that utilize electrolyte that is gelled. A silver wire coated with AgCl is immersed in the buffer reservoir. Protons (H^+ ions) on both sides of the glass (media and buffer reservoir) selectively interact with the glass, setting up a potential gradient across the membrane. Since the hydrogen ion concentration in the internal buffer solution is invariant, this potential difference, determined relative to the Ag/AgCl reference electrode, is proportional to the pH of the media. The sonde was calibrated using standard pH buffer. The measurable pH range is 0 to 14 units with an accuracy of ± 0.2 units. The pH is measured with a resolution of 0.01 units.

Salinity: Salinity is determined automatically from the sonde based on conductivity and temperature readings according to algorithms found in *Standard Methods for the Examination of water and wastewater* (1989). The measurable Salinity range is 0 to 70 ppt with an accuracy of ± 1.0% of reading or 0.1ppt. The Salinity is measured with a resolution of 0.01 ppt.

Total Dissolved Solids: The electrical conductivity of environmental water is due to the presence of dissolved ionic species. Thus, the magnitude of the conductivity (or specific conductance) value can be used as a rough estimate of amount (in g/L) of these ionic compounds which are present. The 6-series software provides a conversion from specific conductance to total dissolved solids (TDS) by the use of a simple multiplier. However, this multiplier is highly dependent on the nature of the ionic species present.

Dissolved Oxygen (DO): Dissolved Oxygen sensors from a variety of manufacturers are based on the well-documented principle that dissolved oxygen quenches both the intensity and the lifetime of the luminescence associated with carefully-chosen chemical dyes. The sensor operates by shining a blue light of the proper wavelength on this luminescent dye which is immobilized in a matrix and formed into disk about 0.5 inches in diameter. This dye-containing disk will be evident on inspection of the sensor face. The blue light causes the immobilized dye to luminance and the lifetime of this dye luminescence is measured via a photodiode in the probe. The measurable Dissolved Oxygen range is 0 to 50 mg/l with an accuracy of $\pm$ 0.01 mg/l. The Dissolved Oxygen is measured with a resolution of 0.01 mg/l.

Biochemical Oxygen Demand (BOD): BOD was determined by the same procedure (Winkler method) as that for DO, after 3 days of incubation at 27°C in a BOD incubator. The difference in the amount of oxygen on the 1^{st} and 3^{rd} day give the measure of Biochemical Oxygen Demand.

Chemical Oxygen Demand (COD): Chemical oxygen demand (COD) determines the oxygen required for chemical oxidation of organic matter with the help of strong chemical oxidant. The organic matter gets oxidized completely by potassium dichromate ($K_2Cr_2O_7$) in the presence of H_2SO_4 to produce CO_2 plus H_2O. The excess $K_2Cr_2O_7$ remaining after the reaction was titrated with ferrous ammonium sulphate [$Fe(NH_4)_2(SO_4)_2 . 6H_2O$] using ferroin as indicator. The volume of dichromate consumed gives the oxygen required for oxidation of the organic matter.

Turbidity: Turbidity was measured by the Nephelometric method after calibrating the Nephelometer using known dilutions of standard prepared from hydrazine sulfate and hexamethylene tetramine in distilled water.

Nitrite-Nitrogen (NO_2-N): The nitrite was estimated by following method of Parsons et al. (1984). The nitrite from known volume of sea water (25 ml) was allowed to react with sulfanilamide in an acid solution. The resulting diazo compound was allowed to react with

N-(1-naphthyl)-ethylenediamine to form a coloured azo dye which was spectrophotometrically measured at 543 nm.

Nitrate-Nitrogen (NO_3-N): It was determined using the method given by Parson *et al.* (1984). Nitrate in the sea water was quantitatively reduced to nitrite by running the sample through a column containing cadmium filings coated with metallic copper. The nitrite produced is diazotised with sulfanilamide and coupled with N-(1-naphthyl)-ethylenediamine to form a pink coloured azo dye, which was measured spectrophotometrically at 543 nm. Nitrate values were corrected for nitrite in the sample.

Total Nitrogen: This nutrient was estimated by following method suggested by Grasshoff *et al.* (1983). Total nitrogen represents all forms of dissolved inorganic and organic compounds of nitrogen in seawater. Organically bound nitrogen is oxidized to nitrate during alkaline persulphate digestion. The nitrate content of the sample is determined after reduction to nitrite running the sample through a column containing cadmium filings coated with metallic copper. The nitrite produced is diazotised with sulfanilamide and coupled with N-(1-naphthyl)-ethylenediamine to form a pink coloured azo dye, which was measured spectrophotometrically at 543 nm.

Inorganic Phosphate (PO_4-P): It was determined by following the procedure of Parsons *et al.* (1984). In this method the seawater sample was allowed to react with a composite reagent containing molybdic acid, ascorbic acid and trivalent antimony. The resulting phosphomolybdate complex is reduced to give a blue colour solution, which was measured using in spectrophotometer at 880 nm.

Total phosphorous: This nutrient was estimated by following method suggested by Grasshoff *et al.* (1983). Total phosphorous represents all forms of dissolved inorganic and organic species of phosphorous. Organically bound phosphorous is completely decomposed to phosphate by a strong oxidizing agent (alkaline persulphate). Inorganic forms of phosphorous in lower oxidation state are also oxidized to phosphate. The pH is between 4 and 5. These conditions are obtained by a boric acid-sodium hydroxide system. Phosphate in sea water is allowed to react with ammonium molybdate in acid medium, forming a phosphomolybdate complex, which is reduced by ascorbic acid, in presence of antimony ions (to accelerate the reaction), to a blue coloured complex containing 1:1 atomic ration of phosphorous to antimony. The absorption of the complex is measured at 880 nm.

Ammonia-Nitrogen (NH_3-N): This nutrient was estimated by following method suggested by Grasshoff *et al.* (1983). Ammonia from the seawater sample reacts in moderately alkaline solution with hypochlorite to monochloramine, which in the presence of phenol, trisodium citrate buffer and excess hypochlorite and gives indophenol blue. The reaction temperature of 37 - 40° C was used for the estimation of ammonia-nitrogen. The concentration was measured spectrophotometrically at 640 nm to obtain NH_3-N.

Total Suspended Solids (TSS): The TSS of seawater samples was determined by filtering a known volume (500 ml) of seawater sample through pre-weighed 4.5 cm Whatman GF/C glass microfibre filter paper. Filtration was carried out under controlled vacuum source. The filter papers were then dried (40°C) till a constant weight was obtained. The difference between the final and initial weight of the filter paper resulted in the estimation of TSS from the water samples.

Phenols: Phenols in seawater (500 ml) was converted to yellow coloured antipyrine complex by adding 4 –amino antipyrine. The complex was extracted in chloroform (25 ml) and the absorption was measured at 460 nm using phenols as a standard. The method followed was according to IS: 3025 (P-43) 1992 (RA 2003).

Total Petroleum Hydrocarbons (PHC): The fraction of the PHC was estimated using a Gas chromatography with Flame Ionization Detector (GC/FID) following the method of TNRCC, 1055. The various fractions analyzed were: Decane, Docosane, Dodecane, Eicosane, Hexacosane, Hexadecane, Octacosane, Octadecane, Tetracosane and Tetradecane.

Cadmium, Lead and Chromium: Known volume of sample was acidified to pH 2.0 using HCL. APDC (Ammonium Pyrrolidine Dithiocarbamate) was added and sample shaken well for complete mixing. Known volume of MIBK (Methyl Isobutyl Ketone) was added to the sample followed by thorough mixing. Metals' forming a yellow ring over the sample was separated and this extract was kept for further analysis of trace metals (Cd, Pb, Cr) using AAS (Model- HITACHI-Z-7000, Polarized Zeeman Atomic Absorption Spectrophotometer, Graphite Furnace, Tube type covet). Protocol followed was according to IS: 3025 (P-41) 1992 (RA 2003), IS: 3025 (P-47) 1994 (RA 2003) and IS 3025 (P-52) 2003.

Mercury: Seawater samples for the determination of mercury was transferred from Niskin sampler to acid washed bottles and acidified to a pH below 2 by adding 0.1 N hydrochloric acid which was previously tested for traces of mercury. Pre-concentration of mercury in seawater was achieved by complexing with dithiozone at pH below 2. The complex was extracted in carbon tetrachloride and back extracted in 5 M hydrochloric acid. The acid extract was shaken with sodium nitrite to decompose the dithizone and revert mercury to the aqueous phase. Excess of nitrite was reduced to hydroxylamine hydrochloride. Inorganic mercury compounds in the final solution was reduced to the elemental mercury with stannous chloride and measured by cold vapor Atomic Absorption Spectroscopy (Protocol according to IS: 3025 (P-48) 1994 (RA 2003)).

Oil and Grease: The total oil and grease content of the water samples were estimated according to the method outlined in IS 3025 (P-39) 1991 (RA 2003) and the results are expressed in mg/l.

4.2.3. Sediment characteristics

Method of collection

Seabed sediment samples were collected at 10 locations (stns. S1 to S10). Intertidal zone sediment samples were also collected at 3 locations for inter tidal benthos analysis (stns. IB1 to IB3). The sediment sampling locations are shown in Fig. 4. Seabed sediments were collected using van Veen grab, stored in two plastic bags. One fraction was fixed in buffer formaldehyde mixed with rose Bengal solution for sub-tidal benthos analysis and another fraction taken to the laboratory for seabed sediment quality parameters. Inter-tidal benthos samples were collected using a handheld shovel using a quadrant (0.25m^2). After collection, the scooped sample was sieved using a handheld sieve (500 micron) and organisms transferred to polythene bags, fixed, labeled and stored for further analyses at the laboratory. On reaching the laboratory the sediment samples were dried and sieved.

Method of analysis

Size distribution: The sediment samples were dried and sieved for fractions: 53 μ, 125 μ 212 μ, 300 μ, 425 μ, 500 μ, 600 μ, 1000 μ and 2000 μ. The fractions retained in each mesh size were weighed and analyzed.

Total Organic Carbon: TOC was determined by wet oxidation method. Potassium dichromate was added to the sample, followed by Sulfuric acid and after cooling distilled water was added. A drop of diphenylamine indicator and pellets of sodium fluoride was added, and sample was titrated against Ferrous ammonium sulfate.

Total nitrogen: Total nitrogen from the sediment sample was estimated by extracting the sediment with an extracting reagent ($CuSO_4$ and silver sulfate) and shaking the experimental flask for 15 minutes. Later $Ca(OH)_2$ and $MgCl_2$ was added and the contents filtered through Whatman 1 filter paper. A known volume (5 ml) of the filtrate was used for total nitrate estimation similar to the process used for water samples (reduction by passing through a cadmium column).

Total Phosphorus: Total Phosphorus of the sediments was estimated by initially digesting the sediment samples in sulfuric acid for 30 minutes to oxidize phosphorus to phosphate. After filtration, a known volume of the filtrate was allowed to react with ammonium molybdate and reduced using ascorbic acid to form a blue coloured complex which was measured at 880 nm using a spectrophotometer.

Calcium Carbonate: Calcium Carbonate from the sediment sample was estimated by treating a specimen of known dry weight (5 g) with dilute hydrochloric acid until all visible reactions are complete. Then the sediment is washed with distilled water and dried in oven at 40°C and weighed again. The initial dry weight and the final dry weight give the carbonate content present in the seabed sediment

Cadmium, Lead and Chromium: Sediment sub-samples were collected and sealed in plastic bags and frozen till the analyses were carried out at the shore laboratory. These were thawed and dried in oven at 40° C. The dried sediment was then finely ground and digested with hydrofluoric acid in a pre cleaned acid washed Teflon beaker. During this process the silica volatized as silicon tetrafluoride. This was followed by treatment with nitric and perchloric acid to destroy the organic matter. The residue after the evaporation of acids was dissolved in dilute hydrochloric acid. The metals were determined on a graphite furnace Atomic Absorption Spectrophotometer, calibrated with suitable standards digested similarly and measured at recommended wavelengths.

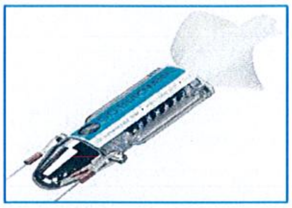
Mercury: Sediment samples were oven-dried at 40°C and crushed to fine powder. About 0.5 gm aliquot of the sample was transferred into 300 ml BOD bottles (in duplicate). 5 ml of Milli Q water and 5 ml Aqua Regia were added and mixed with the sample. The samples were heated for 2 minutes in a water bath at 90°C. On cooling 20 ml of Milli Q water and 15 ml of $KMnO_4$ solutions were added to each. After thorough mixing, the samples were again heated in the water bath for 30 minutes at 90°C. On cooling 6 ml of sodium chloride- Hydroxylamine hydrochloride reagent was added to each bottle to reduce the excess permanganate and the final volume was made up to 75 ml. Blanks and standards were also digested similarly. Mercury compounds in the final solution were reduced to elemental mercury with 5 ml of 20% stannous chloride and measured by cold vapor Atomic Absorption Spectrophotometer at 253.7 nm.

Oil and Grease: The total oil and grease content of the sediment samples were estimated according to the method outlined in APHA 22nd edition 2012, 5520-E and the results are expressed as mg/kg.

4.2.4. Biological parameters

Primary Productivity: Primary Production was estimated at 10 locations i.e. stns. S1 to S10 (Fig. 4). From the water sampler, the samples were immediately transferred to 125 ml Dissolved Oxygen (DO) bottles (two light bottles and one dark bottle). One light bottle containing sample was fixed with Winkler A and Winkler B for analysis of initial oxygen content. The other light bottle and dark bottle with sample were kept in a bucket containing same water sample for 6 hours to allow photosynthesis and respiration. After 6 hours the samples were fixed with Winkler A and Winkler B, and later the DO was analyzed in the laboratory. The increase in dissolved oxygen of water as a result of photosynthesis was measured in the light bottle; simultaneously the decrease in oxygen content in the dark bottle was measured to estimate the respiration alone in the same sample of water. From the two DO values the amount of organic carbon synthesized during photosynthesis was calculated.

Flowmeter: Digital flowmeter (model - 2030R) duly calibrated by the company was used for collection of phyto and zooplankton in the current project. The flow meter consists of an impeller and a counter. The impeller is directly connected to the counter which records each revolution of the impeller. The flow meter has to be attached to the mouth region of the plankton net. With the help of the flow meter we can measure and calculate the volume of water filtered to obtain the plankton biomass in a unit area.

Phytoplankton: Phytoplankton samples were collected at 10 locations i.e. S1 to S10 (Fig. 4). Phytoplankton net (60 micron) was towed 0.5 m below the water surface for 5 minutes and the collected samples were immediately preserved in Lugol's iodine solution for identification purpose only. Besides, phytoplankton was also collected from surface waters using 1 lit. clean polyethylene bottles for population estimation and preserved with Lugol's iodine. Total sedimentation time was 72 hours. After sedimentation of phytoplanktons, the supernatant solution was siphoned out to concentrate the volume to about 100-150ml. During the siphoning process, due care was taken to prevent entry of phytoplankton by attaching an appropriate net (mesh size-55micron) at the inlet of the siphoning tube. Moreover, instead of taking the supernatant in one lot out, about 200 to 300 ml of the supernatant was removed after every 24 hrs, so that disturbance is kept at minimum during the siphoning process. From the above concentrated aliquot, after homogenizing, 1ml was taken on a Sedge-wick Rafter cell for counting and analyses under a binocular research microscope (Nikon, Eclipse 50i with 400 X magnification). Identification of phytoplankton was carried out using phytoplankton identification manuals (UNESCO, 1978; Subrahmanyam (1946), Parson et al., 1984, Santhanam et al. (1987) and Tomas (1997) and Subba Rao, 2002).

Zooplankton: Zooplankton samples were collected at 10 locations i.e. stns. S1 to S10 (Fig. 4). Zooplankton net (300 micron) was towed 0.5 m below water surface for 5 minutes and the collected samples were immediately preserved in 5% buffer formaldehyde. The biomass values of zooplankton were calculated from the displacement volume method. Based on the zooplankton volume, fractions were taken for analysis using plankton counting chamber for quantitative, qualitative analysis and species diversity. Organisms were identified up to genus level under a binocular microscope using standard identification key and counting chamber.

Macro Benthos: Seabed sediment samples for macro benthos were collected using Van Veen grab sampler at 10 locations, (Fig.4). The intertidal benthos samples were collected at 3 locations along the beach (stns. IB1, IB2 and IB3) as shown in Fig.4. The benthic organisms were separated by sieving through 500 micron mesh and preserved using buffer formaldehyde with Rose Bengal. The samples were sorted and identified up to groups/Genera level using stereo zoom microscope. The wet weight was taken to calculate the biomass of benthic organisms.

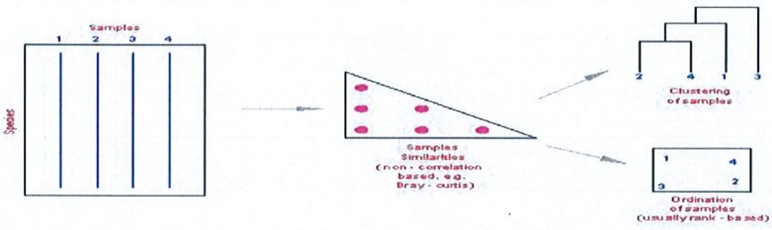
Microbiology: The microbiological samples were collected from 10 locations, i.e. stns. S1 to S10 (Fig. 4). Samples were collected in sterilized bottles and transported for analysis. Spread plate method was used to culture the microorganisms. The agar media used for analysis were: Nutrient agar, MacConkey agar, M-FC agar, Thiosulphate Citrate Bile Sucrose agar, Xylose Lysine Deoxycholate agar, M-Enterococcus agar and Cetrimide agar. Plates were incubated at 37° C for 48 hrs. After incubation, the colonies were counted and identified based on their color characteristics.

Fisheries: The information on fisheries and their potential were collected from the local fishing villages and from Department of fisheries, Government of Tamilnadu.

Coastal vegetation and Seaweeds: The nearshore plants like sand dune plants and seaweeds were collected and herbarium was prepared for further identification in the laboratory.

Statistical Analyses: All statistical calculations and graphs were generated using computer software package PRIMER V.6.1.9 (Plymouth Routines In Multivariate Ecological Research) obtained from Primer –E Ltd., Plymouth, UK (see www.primer-e.com). It's scope is the analysis of data arising in community ecology and environmental science which is multivariate in character (many species, multiple environmental variables).Sample data were compiled into square matrix (species x samples) and square root transformed to counter act the weight of dominant species without severely diminishing their importance. The transformed species – by – sample was then converted into a triangular sample-by-sample similarity matrix by calculating the Bray–Curtis similarity index between all samples – pairs, based on joint species abundance, and presence and absence. Ecological data were then analyzed for similarity of population using agglomerative hierarchical cluster analysis based on the Bray – Curtis similarity index and an average linkage dendrogram were produced.

Further analysis used non-metric multi-dimensional scaling (MDS) which constructs a rank similarity – based sample configuration. On the two dimensional (2D) plots generated from MDS analysis, highly similar samples will appear closer together than samples with lower rank similarities, effectively constructing a two dimensional map of similar samples.



Stages in a multivariate analysis based on similarity coefficients

Diversity measures were calculated from the untransformed data for each sample. Indices calculated were: Margalef's species evenness coefficient (J'), the Shannon – Wiener diversity coefficient (H') and Simpson's diversity index (1- λ). The cumulative dominance plot was also constructed to compare the biodiversity between the samples.

4.2.5. Meteorology

The meteorological data recorded during the monitoring period is very useful for proper interpretation of the baseline information as well as for input prediction models for air quality dispersion. Historical data on meteorological parameters will also play an important role in identifying the general meteorological regime of the region.

The year may broadly be divided into four seasons:

- Winter season : December to February
- Pre-monsoon season : March to May
- Monsoon season : June to September
- Post-monsoon season : October to November

Methodology

The methodology adopted for monitoring surface observations is as per the standard norms laid down by Bureau of Indian Standards (IS : 8829) and India Meteorological Department (IMD). On-site monitoring was undertaken for various meteorological variables in order to generate the site-specific data. The generated data is then compared with the meteorological data generated by IMD.

Methodology of Data Generation

The automatic meteorological instrument was installed on top of a building near to the project site to record wind speed, direction, relative humidity and temperature. Cloud cover is recorded by visual observation. Rainfall is monitored by rain gauge. Hourly average, maximum, and minimum values of wind speed, direction, temperature, relative humidity and rainfall have been recorded continuously at this station during 1st August 2013 to 31th October 2013.

Sources of Information

Secondary information on meteorological conditions has been collected from the nearest IMD station at Chennai Airport.

India Meteorological Department has been monitoring surface observations at Chennai since 1891. Pressure, temperature, relative humidity, rainfall, wind speed and direction are measured twice a day viz., at 0830 and 1730 hr. The wind speed and direction data of IMD, Chennai has been obtained for the past available 10 years. The data for the remaining parameters has been collected for the last 10 years and processed.

4.3. Results

4.3.1. Physical

Wind: The month wise distribution of wind speed and direction are shown in Table 2. It is observed that during April, May, June and December wind speeds were around 10-11 knots and during the remaining months wind speeds were varying between 7 and 9 knots. During April to September, the morning wind mostly prevailed from SW and W, and during November to February, it mostly prevailed from NW. The wind patterns during morning hours and evening hours show the influence of land-sea breeze system in this region. During the days of depressions and cyclones, the wind speed commonly exceeds 50 kmph.

Storm: The tracks of cyclones which have crossed the coast near Chennai (within 150 km on either side) during 1877 to 1990 are presented in Table 3. It indicates that totally 58 storms had occurred within 300 km off the project region. The occurrence of storms in this region are more frequent in November (23) and in October (19). Among them about 37 number of storms had crossed the coast within 300 km distance during 1877 to 1990.

Tides: The various tide levels with respect to Chart Datum for Chennai as presented in *Indian Tide Table 2013* are shown below:

Mean High water Spring	:	1.15 m
Mean High Water Neap	:	0.84 m
Mean Sea Level	:	*0.65 m*
Mean Low Water Neap	:	0.43 m
Mean Low Water Spring	:	0.14 m

The measured tide levels reduced to chart datum for the period 27.07.2013 to 15.08.2013 are shown in Fig. 6. It showed a spring tidal range of 0.95 m and a neap tidal range of 0.33 m.

Currents: The variation of surface current speed and direction measured at 1500 m offshore (stn. C1) is shown in Fig. 7. The current speed reached upto 0.33 m/s and the current direction was shifting with tides showing the variation within the sector of 330° – 90°.

Waves: The data compiled based on the ship observed deep-water waves over the region between the latitude 10°N - 15°N, and longitude 80°E - 85°E is considered for the present project. It is observed that the significant wave heights varied between 0.5 and 1 m during February to April, 1 and 3.0 m during May to September and, between 1 and 2 m during rest of the year. The zero crossing period of the waves varied between 5 and 8 s. The project region is located on the region which is significantly influenced during the northeast monsoon. The wave climate remains rough from May to November. The occurrence of storms and depressions during northeast monsoon often increase the wave activity in this region.

Tsunami: The occurrence of a Tsunami along the Indian coast is an extremely rare event with a very low frequency of less than once in 500 years. One worst tsunami event was witnessed on 26^{th} December 2004 along the Tamil Nadu coast. From records of tide gauge data during the 2004 tsunami event, the run up due to tsunami at different stretches along the coast was observed to vary between 1 m and 3.5 m. The water level rise due to this Tsunami near the project region was around 2.0 m and the run-up crossed over the highways (ECR). Eye -witness accounts say that each high tsunami wave that approached the coast was like a solitary surging / tidal bore wave, and the rise in water level near the coast due to such surging wave existed for a short duration of nearly 30 minutes.

Ambient Air Quality

Predominant winds from W, WSW and E directions were observed during study period. Present major source of air pollution in the region is due to road traffic emission, domestic activities and rural conditions. To establish the baseline status of the ambient air quality in the study area, the air quality was monitored at 8 locations during the study period. The PM_{10} and $PM_{2.5}$ are observed to vary from 32.7 to 52.5 $\mu g/m^3$ and 11.0 to 19.5 $\mu g/m^3$ respectively. The SO_2 and NOx are observed to vary from 7.5 to 10.8 $\mu g/m^3$ and 9.7 to 14.8 $\mu g/m^3$ respectively. The CO values are observed to vary from 365 to 536 $\mu g/m^3$

The results of the monitored data indicate that the ambient air quality of the region in general is in conformity with respect to norms of the National Ambient Air Quality (NAAQ) Standards of Central Pollution Control Board (CPCB), with present level of activities and also it infers that the air quality levels in the study area are of fairly good quality.

Soil Characteristics

The soil samples were tested at 8 locations covering various land uses. It was observed that the soil in the study area is predominantly of sandy clay type. The pH of the soil samples ranged from 7.8 to 8.1. The Electrical Conductance of the soil samples varied from 144 to 280 µmhos/cm. The phosphorus values ranged between 28.2 kg/ha – 78.0 kg/ha. The nitrogen values ranged between 38.0 kg/ha – 65.0 kg/ha. The potassium values ranged between 0.06 kg/ha -0.20 kg/ha.

Noise Level Survey

The noise monitoring has been conducted at 8 locations in the study area. The Day Night Noise Level (Ldn) near plant site was observed as 45.7 dB(A). The noise levels in general found within the acceptable levels as per standards prescribed by Central Pollution Control Board (CPCB).

Landuse Studies

The land use pattern within 10 km radius around the proposed project area has been studied by analyzing the available primary census data. The study area falls in Chengalpattu taluk in Kancheepuram district of Tamil Nadu. The study area of 10 km zone around project area covers about 21 villages within. Altogether, the study area covers about 5663 ha of cultivated land, which works out to about 46.78 % of the total study area. The irrigated and un-irrigated land is about 25.09 % and 21.69 % of the study area respectively. Cultivable waste land and area not available for cultivation are about 14.70 % and 25.79 % respectively. Forest land is about 12.73% of the total study area.

Socio-Economic Details

The information on socio-economic aspects of the study area has been compiled from secondary sources, which mainly include census data of 2011. As per the 2011 census, the study area consists of a total population of 73245 persons residing in 17961 households. The configuration of male and female indicates that the males constitute about 50.51 % and females 49.49 % of the total population. About 34.19 % of the population in the study area belongs to Scheduled Castes (SC) and 1.04 % to Scheduled Tribes (ST). The study area experiences a literacy rate of 72.65% and has 38.83% of the total population as working population.

Salinity and temperature: The available literature (Wyrtki, 1971) on annual variation of surface salinity for this offshore region indicates that the salinity values ranged between 32 ppt and 34.5 ppt over different months of the year (Table 4). The vertical salinity gradient is not relevant in shallow coastal waters off the study region and no density stratification can be expected in this region.

The available literature (Rao, 1995) on annual variation for the offshore region indicates that the temperature varies between 27° C in December and 30° C in May (Table 4). During southwest monsoon period (June-September), no wide fluctuation in temperature was observed.

Littoral drift: The monthly volume of littoral drift at project region is shown in Table 5. The sediment transport rates were high (>1.98×10^5 m^3/month) in May and December. It was lowest (< 0.75×10^5 m^3/month) in March. The littoral drift was towards north from April to October and towards south during the remaining months of the year. The annual northerly transport is 0.98×10^6 m^3/year and the annual southern transport is 0.51×10^6 m^3/year.

Synthesis of Data on Climatic Conditions

Analysis of the Data Recorded at IMD-Chennai

1) Temperature

The winter season starts from December and continues till the end of February. January is the coldest month with the mean daily maximum temperature at 33.3°C with the mean daily minimum temperature at 17.0°C. Both the day and night temperatures increase rapidly during the onset of Pre-monsoon season. During Pre-monsoon the mean maximum temperature (May) is observed at 43.4°C with the mean minimum temperature at 21.6°C. The mean maximum temperature in the Monsoon season was observed to be 42.8°C whereas the mean minimum temperature was observed to be 21.2°C. By end of September with the onset of Northeast monsoon (October), day temperatures decrease slightly with the mean maximum temperature at 35.9°C with the mean minimum temperature at 22.4°C. The monthly variations of temperatures are presented in **Table-1.4.1**.

2) Relative Humidity

The air is generally very humid in the region especially during monsoon when the average relative humidity is observed around 67% with a maximum and minimum of 100% and 35% respectively. In the pre-monsoon period the relative humidity is 63%. During the pre-monsoon season the mean maximum humidity is observed at 100%, with the mean minimum humidity at 39% in the month of May and April respectively. During winter season the humidity is found to be in line with the values recorded during the Pre-monsoon season. The mean maximum humidity recorded during winter season, which is the driest part of year with an average of 66% relative humidity. The mean maximum relative humidity is observed to be 100% with mean minimum humidity at 38%. The monthly mean variations in relative humidity are presented in **Table-1.4.1**.

3) Atmospheric Pressure

The station level maximum and minimum atmospheric pressure levels are recorded during the winter and monsoon seasons. The maximum pressure observed is in the range of 1016.5 to 1003.5-mb, with the maximum pressure (1016.5-Mb) occurring during the winter season, in the month of January. The minimum pressure observed is in the range of 1013.6 to 999.9 Mb, with the minimum pressure (999.9-Mb) occurring during the pre-monsoon season in the month of June. The average pressure levels in all other months are found to be in the range of 1008.5 to 1010.6-mb. The monthly variations in the pressure levels are presented in **Table-1.4.1**.

4) Rainfall

It is observed that the north-east monsoon is more predominant than the south-west monsoon. The southwest monsoon generally sets in during the last week of May. About 30% of the rainfall is received during the southwest monsoon. The rainfall gradually increases after September (and reaches maximum rainfall is recorded in the month of November). The area experiences maximum rainfall (308.0 mm) in the month of November. The Northeast monsoon rain occurs between October to December and contributes to the rainfall by about 60% of the total rainfall. Monthly variations in the rainfall for past available 10 years are given in **Table-1.4.1**.

5) Cloud Cover

Generally light clouds are observed during winter mornings. During pre-monsoon and the post-monsoon evenings the skies are either clear or lightly clouded. But in post-monsoon mornings as well as monsoon morning heavy clouds are commonly observed. Whereas in the evening time the skies are light to moderately clouded through out the year.

6) Wind Speed/Direction

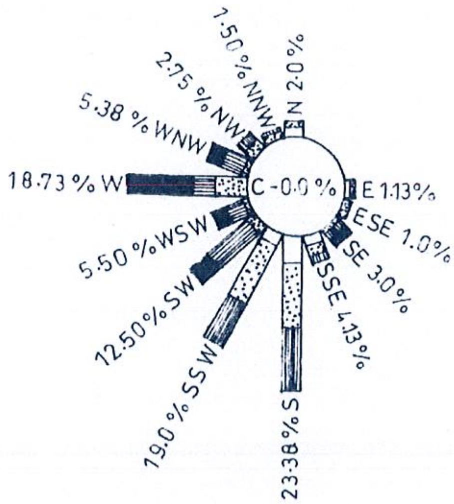
The windrose for the study period representing pre-monsoon, monsoon, post-monsoon and winter season along with annul windrose are shown in **Figure-1.4.1** and presented in **Table-1.4.2.**

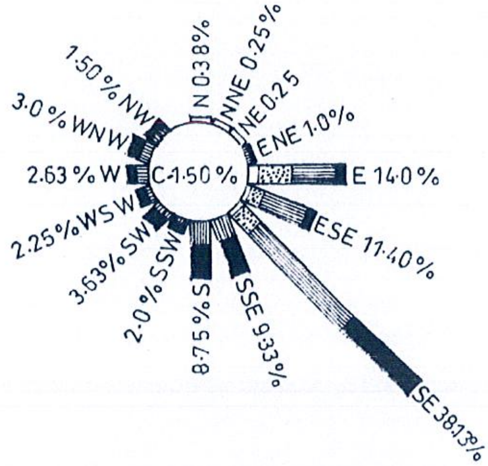
TABLE-1.4.1
CLIMATOLOGICAL DATA - IMD, CHENNAI (MINAMBAKAM)

Month	Temperature (^{0}C)			Relative Humidity (%)		Atmospheric Pressure (Mb)		Rainfall (mm)
	Max	Min	Avg.	0830	1730	0830	1730	
January	33.3	17.0	26.1	100	38	1016.5	1013.6	23.8
February	34.9	16.0	25.2	95	31	1012.2	1009.0	6.8
March	38.7	18.2	27.5	91	28	1010.6	1007.1	15.1
April	42.7	21.0	32.0	96	39	1008.4	1004.3	24.7
May	43.4	21.6	32.2	100	15	1004.5	1000.8	51.7
June	42.8	21.2	32.5	100	32	1003.5	999.9	52.6
July	39.5	22.3	31.0	95	35	1004.2	1000.7	83.5
August	39.0	22.0	31.0	98	32	1004.9	1001.1	124.3
September	37.8	21.5	29.5	97	35	1006.3	1002.4	118.0
October	35.9	22.4	28.7	98	46	1008.5	1005.3	267.0
November	34.4	18.0	27.0	99	42	1010.9	1003.1	308.0
December	31.7	17.8	25.0	100	34	1012.9	1010.0	139.1

TABLE-1.4.2
SUMMARY OF WIND PATTERN – IMD, CHENNAI

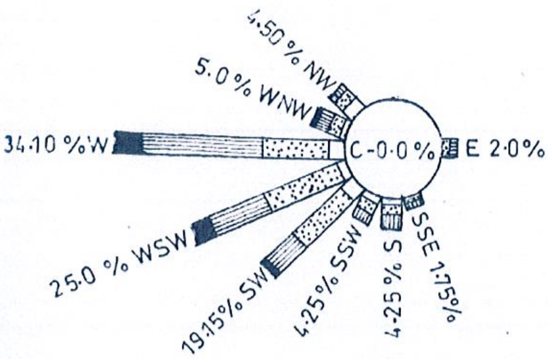
Season	First predominant winds		Second predominant winds		Calm condition in %	
	0830	1730	0830	1730	0830	1730
Pre-monsoon	S (29.0)	S (37.5)	SSW (17.5)	SSW (24.9)	10.3	1.7
Monsoon	SSW (17.3)	SSW (20.3)	SW (16.9)	S (18.1)	10.5	8.2
Post monsoon	NNE (17.0)	E (15.0)	N (15.5)	NE (14.0)	21.0	25.0
Winter	NE (16.7)	S (14.6)	NNE (14.0)	E (11.6)	31.0	16.7
Annual	SSW (12.9)	S (18.9)	SW (10.0)	SSW (14.2)	15.8	12.9

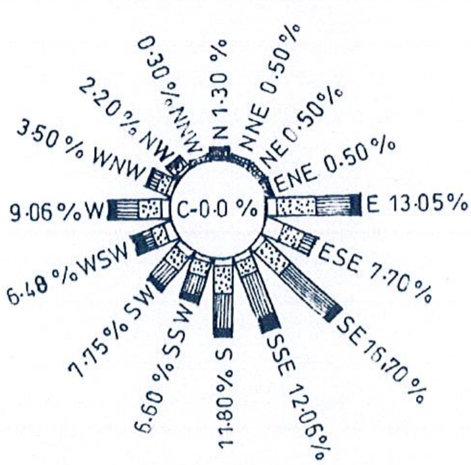


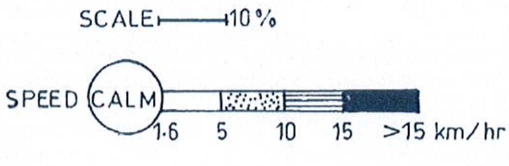


PRE MONSOON SEASON
(0830 hrs)

PRE MONSOON SEASON
(1730 hrs)







MONSOON SEASON
(0830 hrs)

MONSOON SEASON
(1730 hrs)

FIGURE-1.4.1 (A)
WINDROSE FOR PRE MONSOON & MONSOON SEASON-IMD, CHENNAI

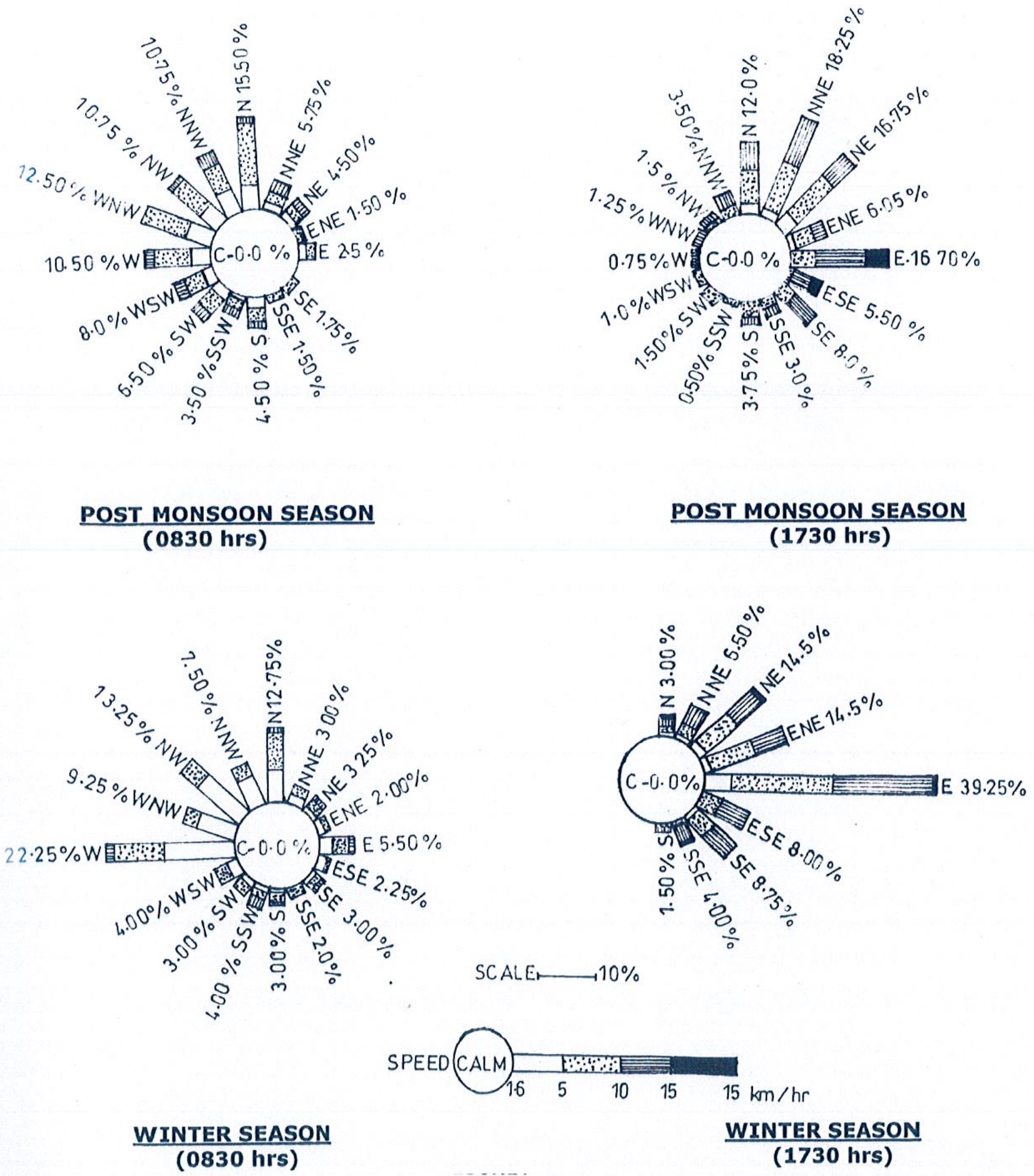
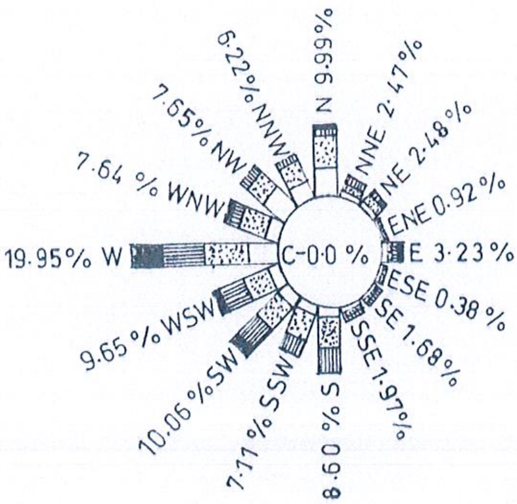
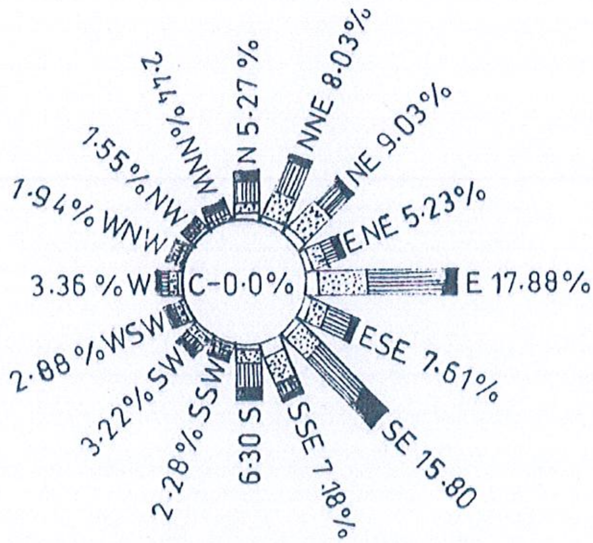


FIGURE-1.4.1 (B)
WINDROSE FOR POST MONSOON & WINTER SEASON-IMD, CHENNAI



08·30hrs



17·30 hrs

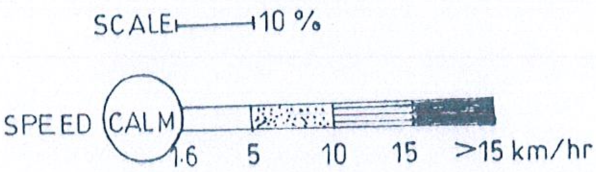


FIGURE-1.4.1 (C)
ANNUAL WINDROSE -IMD, CHENNAI

Analysis of Meteorological Data Recorded at Project Site

The meteorological data recorded at the project site during the study period (1st August, 2013 to 31st October, 2013) is presented in **Table-1.4.3.**

TABLE-1.4.3
SUMMARY OF THE METEOROLOGICAL DATA AT SITE

Month	Temperature (°C)		Humidity (%)		Total Rainfall (mm)
	Max	Min	Max	Min	
August 2013	37.5	23.7	100	28	73
September 2013	36.8	22.9	100	34	89
October 2013	36.3	22.6	100	21	121

1) **Temperature**

It was observed that the temperature at the proposed site during study period ranged from 22.9°C to 37.5°C. The monthly variations in the temperatures are presented in **Table-1.4.3.**

2) **Humidity**

During the period of observation, the humidity ranged from 21.0% to 100.0%. The monthly variations in the humidity are presented in **Table-1.4.3.**

3) **Rainfall**

A total of 283 mm of rainfall was observed during the study period. The maximum rainfall was recorded in the month of October in study period.

4) **Cloud Cover**

Mostly clear skies were observed except rainy days during the study period.

5) **Wind Speed and Direction**

The windrose for the study period representing winter season is shown in **Figure-1.4.2**. A review of the windrose diagram shows that predominant winds are mostly from West (14.4%) and WSW (10.3%) followed by E (8.1%) direction. Calm condition was recorded for 4.5%.

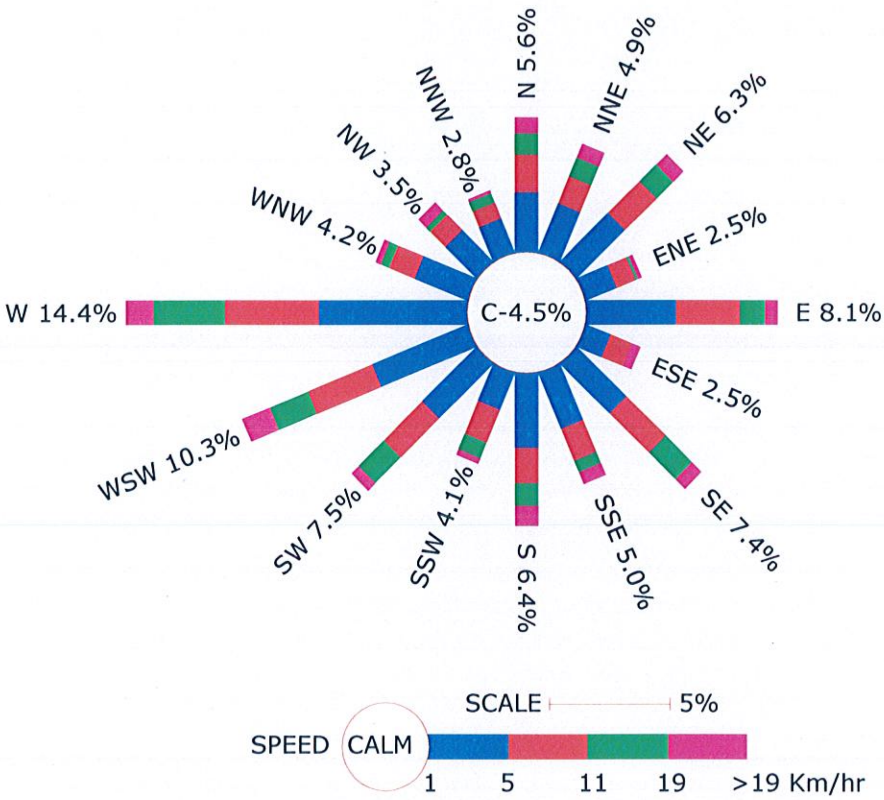


FIGURE-1.4.2
SITE SPECIFIC WINDROSE (AUGUST – OCTOBER 2013)

4.3.2. Water quality

The estimated water quality parameters on temperature, Total dissolved solids, salinity, dissolved oxygen, pH, nitrite-nitrogen, nitrate-nitrogen, total nitrogen, inorganic phosphate, total phosphorous, ammonia-nitrogen, total suspended solids, turbidity, biochemical oxygen demand and chemical oxygen demand are presented in Tables 6. The results of cadmium, lead, mercury, total chromium, oil and grease, phenols and total petroleum hydrocarbons are presented in Table 7.

Temperature: Steep gradients of sea water temperature across the depths bear direct impact on the productivity and animal colony of the region. The temperature varied from 26.58° C (station 10, bottom) to 28.82°C (station 3, surface) among all 10 locations.

Total Dissolved Solids: The electrical conductivity of environmental water is due to the presence of dissolved ionic species. The TDS values varied from 34.97 (station 8, surface) to 35.27 g/l (station 9, bottom) at all 10 locations.

Salinity: The estimated salinity of the collected water samples varied between 34.55 to 34.79 ppt at all 10 locations .The minimum (34.55 ppt) was recorded at S8 surface water while the maximum (34.79 ppt) was observed at S9 in bottom waters.

Dissolved Oxygen (DO): Of all the dissolved gases in water, oxygen is the most important one for the survival of aquatic biota. The amount of oxygen dissolved in the water column at a given time is the balance between consumption and replenishment. In an ideal ecosystem, these two processes should be at equilibrium to keep the water column saturated with DO. Generally, the coastal waters are always found to be saturated and this is so in the present study area also.

Dissolved oxygen content varied from 4.51 to 6.74 mg/l at all 10 locations. The minimum (4.51 mg/l) was recorded at S10 in bottom waters while the maximum (6.74 mg/l) was at S4 in surface water .The principal natural physical factors affecting the concentration of oxygen in the marine environment are temperature and salinity. DO concentrations decrease with increasing temperature and salinity. So it is possible to calculate the theoretical saturation of dissolved oxygen for a given combination of temperature and salinity. Then the observed values can be compared to see whether the system can sustain the biological demand. The dissolved oxygen saturation and a comparison of values with COMAPS (Coastal ocean monitoring and prediction system) data are also given in Table 8 respectively. These values indicate a normal condition which shows good productivity in the project region. Review of literature indicates that the levels below 2 mg/l are only known to cause respiratory impacts on marine fauna.

pH: Variations in pH due to chemical and other industrial discharges render a water column unsuitable for the rearing of fish and other aquatic life. pH is a very sensitive and most important parameter of an environmental study. Primary production, respiration and mineralization are able to alter the redox and pH of aqueous system due to the changes in oxygen and carbonate concentration. Identifying pH for acidic or alkaline disturbances enables one to locate zones of pollution and other quality conditions for the use of seawater.

During the present study, water pH varied between 8.19 and 8.22. The minimum (8.19) was recorded at stations 7 (surface), while the maximum (8.22) was recorded at S1, S3, S4 and S6, in surface, mid depth and bottom waters. More uptake of CO_2 by the photosynthetic organisms especially phytoplankton of the sea during the period could have increased the pH levels. The result shows that the pH values lie within the range of normal sea water.

Nutrients: Nutrients determine the potential fertility of an ecosystem and hence it is important to know their distribution and behavior in different geographical locations and seasons. The fishery potential of an area is in turn, dependent on the availability of primary nutrients like nitrogen and phosphorus. Enrichment of these nutrients by anthropogenic inputs in the coastal waters having limited ventilation may result in water becoming eutrophicated.

The major inorganic species of nitrogen in water are ammonia, nitrite and nitrate of which nitrite is very unstable and ammonia is bio-chemically oxidized to nitrate. Hence, the concentrations of nitrite and ammonia are often very low in natural waters. The utilization of nutrients such as nitrates and phosphates can be taken as a measure of the productivity of the area.

Inorganic phosphate and nitrogen compounds in the sea play a decisive role in the biological production. Normally they occur in low concentrations. Their distribution in the coastal waters is mostly influenced by land run off. Since nutrients form an important index to the primary productivity of an ecosystem, the study of its distribution is important from the point of view of its role in the biological productivity and also as an indicator of pollution. Values of various nutrient parameters analyzed at different stations are presented in Tables 6 and 13.

Nitrite-Nitrogen (NO_2-N): Nitrite is an important element, which occurs in seawater as an intermediate compound in the microbial reduction of nitrate or in the oxidation of ammonia. In addition, nitrite is excreted by phytoplankton especially, during plankton bloom.

Nitrite concentration ranged from 0.11 to 1.96 µmol/l at all 10 stations. The minimum (0.11 µmol/l) was recorded at S4 and S10 mid depth while the maximum (1.96 µmol/l) was noticed at S7 (bottom). The distribution in spatial and vertical direction shows more random.

Nitrate-Nitrogen (NO_3-N): Nitrate values are in general higher as compared to nitrite values. Nitrate is the final oxidation product of nitrogen compounds in seawater and is considered to be the only thermodynamically stable oxidation level of nitrogen in seawater. Nitrate is considered to be the micronutrient, which controls primary production in the euphotic surface layer. The concentration of nitrate is governed by several factors of which microbial oxidation of NH_3 and uptake by primary producers may be important in the present study area.

Nitrate concentration ranged from 1.17 to 4.32 µmol/l. The minimum (1.17 µmol/l) was recorded at S2 (surface) while the maximum (4.32 µmol/l) was noticed at S8 (bottom-). As in the case of nitrate the distribution is random.

Total nitrogen: Total nitrogen ranged from 6.20 to 18.60 µmol/l. The minimum (6.20 µmol/l) was recorded at S2 (mid depth) while the maximum (18.60 µmol/l) was recorded at S8 (bottom).

Ammonia-Nitrogen (NH_3-N): Unpolluted waters are generally devoid of ammonia and nitrite. However, coastal input by sewage and other nitrogenous organic matter and fertilizers can increase these nutrients to higher levels. In addition, ammonia in seawater can also come from various organisms as an excretory product due to the metabolic activity and the decomposition of organic matter by micro-organisms.

Ammonia concentration ranged from 0.09 to 0.27 µmol/l. The minimum (0.09 µmol/l) was recorded at station 2 (mid depth) and station 10 bottom water and maximum (0.27 µmol/l) was recorded at S6 (surface). The values are in normal range and indicate a healthy environment.

Inorganic Phosphate (PO_4-P): Inorganic phosphate is also an important nutrient like nitrogen compound in the primary production of the sea. The concentration of phosphate especially in the coastal waters is influenced by the land run off and domestic sewage.

Phosphate concentration ranged from 0.20 to 1.78 µmol/l. The minimum (0.20 µmol/l) was recorded at S4 and S7 (surface) while the maximum (1.78 µmol/l) was noticed at S1 (bottom).

Total phosphorous: Total phosphorous ranged from 0.52 to 1.92 µmol/l. The minimum (0.52 µmol/l) was recorded at S4 (surface) while the maximum (1.92 µmol/l) was noticed at S1 (bottom).

The water quality parameters observed at open sea do not show much variation and the water remains clean without any contamination or organic load.

Total Suspended Solids (TSS): Total Suspended Solids in seawater originate either from autochthonous (biological life) or allochthonus (derived from terrestrial matter) sources. It varied from 16 to 84 mg/l at all 10 stations. The minimum 16 mg/l was found at S4, S5 and S8 at surface and the maximum 84 mg/l at S1 bottom water.

Turbidity: Turbidity is another measure to understand the suspended particulate matter which controls the photosynthesis in the water column. The measured turbidity varied between 0.5 to 8.5 NTU at all 10 locations. The minimum (0.5 NTU) value was noticed at S6 in surface. The maximum (8.5 NTU) value was noticed at S1 in bottom. The turbidity of the nearshore waters in the surface region was found within normal ranges indicating the existence of unturbid and clean water whereas in the bottom waters the turbidity was high due to movement of underwater currents.

Biochemical Oxygen Demand (BOD): Rate of aerobic utilization of oxygen is a useful tool to evaluate the intensity of deterioration in an aquatic medium. The oxygen taken up for the breakup of organic matter leads to a reducing environment or in the event of release of excess nutrients, it may cause eutrophication.

For the present study the BOD values varied from 1.09 to 4.55 mg/l at all 10 locations. The minimum value was recorded at S8 in mid water and maximum was noticed at S10 in surface water. The low BOD values indicate that oxidisable organic matter brought to the nearshore waters is effectively assimilated in coastal water. The range of variation in BOD values indicate that the water column is well mixed in the project area.

Chemical Oxygen Demand (COD): Chemical oxygen demand (COD) determines the oxygen required for chemical oxidation of organic matter with the help of strong chemical oxidant. The organic matter gets oxidized completely by potassium dichromate ($K_2Cr_2O_7$) in the presence of H_2SO_4 to produce CO_2 plus H_2O. The excess $K_2Cr_2O_7$ remaining after the reaction was titrated with ferrous ammonium sulphate [$Fe(NH_4)_2(SO_4)_2 . 6H_2O$] using ferroin as indicator. The volume of dichromate consumed gives the oxygen required for oxidation of the organic matter.

The COD values varied from 12.6 to 79.0 mg/l at all 10 locations in the present study. The minimum (12.6 mg/l) value was recorded at S10 surface waters. The maximum value was (79.0 mg/l) recorded at S2 in middle water. In general the bottom values were higher than the subsurface and surface values.

Trace metal concentration: Concentrations of trace metals in water are often close to the background level due to their efficient removal from the water column through hydrolysis and adsorption by suspended particulate matter. Hence, sediments serve as an ultimate sink for several trace metals and their analyses can serve as a useful index of metal pollution.

Knowledge of the trace metal concentration in seawater is very important from the point of view of their possible adverse effects on marine biota. Oysters by their ability to concentrate some trace metals from the environment are considered to be useful indicators of metal pollution. Many of the trace metals are adsorbed to the particulate matter and are ultimately deposited at the bottom. Bottom sediments are considered to provide a reliable estimate of metal pollution status. The relationship between gross concentration of heavy metal in solution and its ability to cause toxic effects in an organism is a complex one, and is mostly decided by the speciation of metal and the condition of the organism. Whether or not, a trace metal can interact with the biota depends on its "bio-availability" in the medium. Presence of other toxicants or metals can reduce or increase the additive toxicity of each element. In addition to these factors, temperature, total dissolved solids, pH, salinity, turbidity and dissolved oxygen concentration also significantly affect metal-organism interactions.

The nominal presences of trace metals, which occur in seawater, are found to be necessary to promote growth of marine organisms. The concentration levels of Cadmium, Lead, Total Chromium, Mercury, Phenols and Total Petroleum hydrocarbon measured at 10 locations are presented in Table 7.

Cadmium (Cd): The bioavailability and toxicity of trace metals such as Cd, Cu, and Zn are related to the activity of the free metal ion rather than the total metal concentration. For Cd it is the $CdC1_2$ complex that predominates in seawater. Therefore, salinity is the overriding factor which can alter free Cd ion activity {Cd2+}, and hence, bioavailability and toxicity in marine systems.

The cadmium concentration of the study region was found below detectable level < 0.01 mg/l at all 10 locations.

Mercury (Hg): Mercury is considered as a non-essential and toxic element for living organisms. Mercury, amongst other heavy metals has attracted global concern due to its extensive use, toxicity, widespread distribution and the biomagnifications. A chemical whose concentration increases along a food chain is said to be biomagnified. The bio-concentrate of mercury in aquatic organisms such as oysters and mussels has been reported to be much greater than those contained in the environment in which they live. Mercury is considered as a non-essential and toxic element for living organisms.

During this period, the concentration of the study region was found below detectable level < 0.002 mg/l at all 10 locations.

Lead (Pb): Lead has been used by man for centuries and is amongst the most widely dispersed environmental contaminant. The considerably greater toxicity of organo-lead compounds compared to inorganic forms has led to studies whether; such compounds may be formed by natural process. Available literature suggests that alkylation of lead is purely a chemical process which may occur in organic-rich anoxic sediment.

The lead concentration for the sea water samples was estimated as lead strongly gets accumulated in fishes especially with shell fish. The lead concentration in the study region was found below detectable level < 0.02 mg/l at all 10 locations.

Chromium (Cr): In dissolved form chromium is present as either anionic trivalent $Cr(OH)_3$ or as hexavalent CrO_4^{2-}. The amount of dissolved Cr^{3+} ions is relatively low, because these form stable complexes. Oxidation ranks from Cr(II) to Cr(VI). In natural waters trivalent chromium is most abundant. Chromium is a dietary requirement for a number of organisms. This however only applies to trivalent chromium. Hexavalent chromium is very toxic to flora and fauna. Chromium water pollution is not regarded as one of the main and most severe environmental problems, although discharging chromium polluted untreated wastewater in rivers have caused environmental disasters in the past. Chromium (III) oxides are only slightly water soluble, therefore concentrations in natural waters are limited. Cr^{3+} ions are rarely present at pH values over 5, because hydrated chromium oxide ($Cr(OH)_3$) is hardly water soluble.

Chromium (VI) compounds are stable under aerobic conditions, but are reduced to chromium (III) compounds under anaerobic conditions. The reverse process is another possibility in an oxidizing environment. Chromium is largely bound to floating particles in water. The LC_{50} value for chromium in sea fish lies between 7 and 400 ppm, and for algae at 0.032-6.4 ppm.

The Chromium concentration in the study region was found below detectable level < 0.05 mg/l at all 10 locations.

Phenol: The main source of phenolic compounds in seawater is through plants. Additionally, they can also be released during humification processes occurring in soil. Higher concentrations occur in industrial wastewaters. Phenols can be toxic to marine organisms and can accumulate in certain cellular components. Chlorination of phenol-containing waters can lead to formation of chlorophenols with unpleasant odour and taste.

The concentration of phenol in the study area was found below detectable level (BDL) < 0.1 mg/l at all 10 locations.

Total Petroleum Hydrocarbons: The coastal waters are susceptible to oil pollution due to various maritime activities like fishing operation, spillage from oil tankers, port activities etc. In the study area, the dissolved and dispersed Petroleum hydrocarbons were found below detectable level 0.1 µg/l at all 10 locations.

Oil and grease: The coastal waters are susceptible to oil pollution due to various maritime activities like fishing operation, spillage from oil tankers, port activities etc. The concentration of oil and grease in the study area was found to be <2.0 mg/l in all the sampling stations.

4.3.3. Sediment characteristics

Sediment size distribution: The sand size distribution and nature of the sediments collected from the seabed at 10 locations are shown in Table 9. The seabed is predominantly composed of coarse to medium and fine sand.

The percentage composition of total organic carbon, calcium carbonate, concentration of total nitrogen and total phosphorus in sediment samples are given in Table 10.

Total Organic Carbon: Total organic carbon content ranged from 0.37 to 1.55% at all 10 locations. The minimum (0.37%) was recorded at S7 while the maximum (1.55%) was recorded at S4.

Calcium Carbonate: The carbonate content in the sediments varied from 25.35 to 42.90% at all 10 locations. The minimum was recorded at S10 while the maximum was recorded at S9.

Total Nitrogen: Total nitrogen concentration ranged from 0.14 to 0.23 mg/g. The minimum (0.14 mg/g) was recorded at S7 while the maximum (0.23 mg/g) was recorded at S4.

Total Phosphorus: Total phosphorus concentration ranged from 0.15 to 0.22 mg/g. The minimum (0.15 mg/g) was recorded at S7 and S9 while the maximum (0.22 mg/g) was recorded at S1.

The concentration of lead, cadmium, mercury, total chromium, oil & grease, phenol and total petroleum hydrocarbons in bottom sediments are presented in Table 11.

Lead (Pb): The lead concentration of the study area varied from 3.43 to 32.50 mg/kg at all 10 locations.

Cadmium (Cd): The concentration of cadmium in the study region varied from 0.42 to 1.14 mg/kg at all 10 locations.

Mercury (Hg): The concentration of mercury in the study area was found below detectable level <2.0 mg/kg at all 10 locations.

Total Chromium (Cr): The concentration of total chromium in the study area varied between 12.05 and 78.71 mg/kg at all 10 locations.

Phenol: The concentration of Phenol in the study region was found below detectable level <0.1 mg/kg at all 10 locations.

Total Petroleum hydrocarbons: Total petroleum hydrocarbons were found below detectable level <0.5 mg/kg at all 10 locations.

Oil & Grease: They were found to be below detectable level <2.0 mg/kg at all 10 stations.

The concentrations of heavy metals, phenols and petroleum hydrocarbons in the sediment samples showed extremely low values in the open sea. It indicates that there is no accumulation of pollutants and there is no contamination in sediment.

4.3.4. Biological parameters

Biological status of an area is an essential prerequisite for environmental impact assessment and can be evolved by selecting a few reliable parameters from a complex ecosystem. Whenever we consider assessment of the implications of environmental pollution, we must be aware of the fact that despite many changes it may cause in the physio-chemical properties of water body and seabed sediment, the ultimate consequences are inevitably of biological nature. The biological parameters considered in the present study are Primary production, phytoplankton biomass and population, zooplankton biomass and population, macro benthic biomass and population, and fishery of the region. The first four reflect the productivity of a water column at primary and secondary levels. Benthic organisms being sedentary animals associated with the seabed, provide information regarding the integrated effects of stress due to disturbances, if any, and hence are good indicators of early warning of potential damage.

Phytoplankton and primary productivity: Phytoplankton is the primary source of food in the marine environment. The concentration and numerical abundance of the phytoplankton indicate the fertility of a region. The plankton population depends primarily upon the nutrients present in the sea water and the sunlight for photosynthesis. This primary production is an importance source of food for the higher organisms in the marine environment. The measured primary productivity results are shown in Table 12. The results indicate that the area is highly productive and the values vary from 323 to 780 mgC/m^3/day. A comparative statement of primary production along the east coast of India is also given in Table 13. The numerical abundance of phytoplankton is shown in Table 14. Various phytoplankton groups were observed and their percentage compositions are shown in Table 15.

The floral diversity fluctuates from 21 to 29 species. Bacilleriophyceae (Diatoms) formed the major group followed by Dinophyceae (Dianoflagellates) and Cyanophyceae (blue green algae). Phytoplankton population analyzed at various stations showed that their numerical abundance varied from 68 to 103 nos./ml^{-1}. As many as 55 species of phytoplankton (net and unit samples put together) represented by 3 diverse groups namely, diatoms (43 species consisting of 34 centrales and 9 pennales), dinophyceans (11) and chlorophyceae (1). There were relatively fewer (46) species in the unit samples. Table. 14 contains a detailed account on species composition and distribution at different stations in the surface waters. Overall, bacillariophyceans remained the largest group (29 species). In general, *Biddulphia heteroceros, Biddulphia mobiiliensis, Ditylum brightwelli, Thalassiosira subtilis, Pleursigma normanii, Ceratium macroceros* and *Trichodesmium erythraeum* and to be found at all stations. Overall, centrales formed the bulk (55%) of the population followed by pennales (15%), dinophyceans (17%) and Cyanophyceans (13%). Highest phytoplankton population (103 nos./ml^{-1}) was observed at stn. S8 and the minimum (68 nos./ml^{-1}) were at stn. S1. The biomass varied between 31.36 to 58.61ml/100m^3 (Table 16). Average phytoplankton biomass value recorded in this region is 42.36ml/100m^{3}..

The same thing was also reflected in the population numbers. *Biddulphia heteroceros, Biddulphia mobiiliensis, Ditylum brightwelli, Thalassiosira subtilis, Pleurosigma normanii, Ceratium macroceros* nd *Trichodesmium erythraeum* were recorded in good numbers at all the stations. *Ceratium macroceros* and *Pleurosigma normanii* was the dominant species found at all station. *Trichodesmium erythraeum* was observed to be in good numbers at all stations expect at stn. S3 and S8.

Based on the Primer software, the Shannon-Wiener (H') diversity clearly showed the diverse nature of project area (4.216 – 4.738). The similarity in species composition and abundance among stations varied from 43.24 to 75.58% with an average similarity percentage of 61.24%. The dominance plot for all the stations showed sigma shaped curves indicating healthy condition of the environment.

Zooplankton: The zooplankton diversity fluctuated from 38 to 44 species. Various zooplankton groups and their percentage composition observed at various stations are shown in Table 17. The zooplankton data indicated a high standing stock in the area of observation. Zooplankton population analysis at various stations showed that their numerical abundance varied from 309283 to 720187 nos./100 m^3 (Table 18). Highest Zooplankton population was observed at S6 and the minimum was observed at S5. The percentage occurrence of various groups varied from place to place.

The zooplankton biomass at various stations varied from 10.31 to 37.50 ml/100 m^3 (Table 17). The most zooplankton species contributing to the population are given (Table 18). Zooplankton mostly consists of *Coryceas danae* (13.5% to 8.7%), *Paracalanus parvus* (7.2% to 2.0%), *Oithona brevicornis* (6.8% to 0.6%), *Coryceas catus* (6.8% to 1.8%) and Copepod stages (5.6% to 1.9%).

The Shannon-Wiener (H') diversity clearly showed the rich diversity of the project area (4.957-5.144). The similarity in species composition and abundance among stations varied from 73.55 – 90.76% with an average similarity percentage of 84.29%. The dominance plot for all the stations showed sigma shaped curves indicating healthy condition of the environment.

Benthos: Benthic faunal population in an environment depends on the nature of the substratum and the organic matter content.

Subtidal benthos: The sediment characteristics of the study area showed gravel, coarse and medium sand. The numerical abundance of the benthic fauna was moderate and varied from 80 to 170 nos./m^2 (Table 19). The faunal population was mainly dominated by Polychaete worms, followed by Nematodes, Amphipods, Gastropods and Bivalves.

Intertidal benthos: The intertidal faunal population is shown in (Table 19). In the samples collected from this region (IB1, IB2 and IB3) Amhipods were found to be equally dominant followed by polychaetes and cumaceans. The numerical abundance of the inter tidal benthic fauna was low and varied from 30 to 75 nos./m^2.

In general the subtidal benthic population was about 7 to 8 times more than intertidal benthic population. Polycaetes was the dominant group found at the subtidal region with *Perineries* sp. recording the highest number followed by *Eunice* sp. *Owenia* sp. and *Cossura* sp. were found in equal numbers and occupied the third place. The next in abundance was *Nephtys* sp., followed by *Scolelepis* sp. and *Polydora* sp. Polychaetes were collected from almost all the ten subtidal benthic region stations with the maximum number at station 2 followed in equal number from station 3 and station 5. Minimum number of polychaetes were recorded at station 9.

Crustaceans dominated by amphipods were the second abundant group in the subtidal and intertidal benthic population followed by molluscan, nematode and cumacean groups. However, nematodes and molluscan groups were completely absent at the intertidal region. It is interesting to note that all the molluscan forms recorded at the subtidal region were mostly from station 7 to station 10 and were completely absent at station 1 to station 6. On the other hand two third of the polychaetes recorded at the sub-tidal region were all from station 1 to station 6. Overall, the highest number of organisms at the subtidal was region recorded at station 3 and the minimum at station 9. At the intertidal region IB3 recorded the most number of organisms followed by IB1 and IB2. It is concluded that the subtidal area of this region is more diverse and moderately populated than the intertidal region.

Inference: The Shannon-Wiener diversity was low in the project area *(0.918 to 2.873). Similarly the Margalef richness (d) values were also low (0.263 - 1.438). However the evenness was similar in all stations. Generally in a healthy environment, Shannon diversity and Margalef richness indices are higher and in the range of 2.5 – 3.5. Values less than these are normally attributed to some sort of stress or disturbance. However in the project area there is no evidence of such stress or pollution. The only explanation that can be offered to the observed low values is the nature of sediment (dominated by sand) and the low organic carbon content. These factors obviously contributed to low number of species. The similarity in species composition and abundance among stations widely varied from 0 to 78.23% with an average similarity percentage of 36.37%. The dominance plot for all the stations showed steep rise curves possibly because of low number of organisms as there is no apparent disturbance or pollution in the environment.

Phytoplankton diversity indices calculated for stations 1-10

Station	S	N	d	J'	H'(loge2)	1-Lambda'
S1	23	68	5.214	0.9445	4.272	0.9482
S2	25	84	5.417	0.9676	4.493	0.9624
S3	21	73	4.662	0.96	4.216	0.9524
S4	23	87	4.926	0.9503	4.299	0.9511
S5	24	87	5.150	0.9523	4.366	0.9511
S6	23	94	4.842	0.9390	4.248	0.9460
S7	26	98	5.453	0.9538	4.483	0.9546
S8	29	103	6.041	0.9753	4.738	0.9684
S9	28	102	5.838	0.9600	4.615	0.9608
S10	27	99	5.658	0.9699	4.612	0.9641

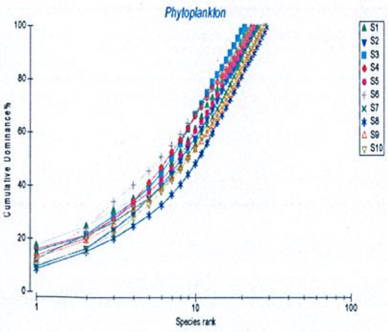
Zooplankton diversity indices calculated for stations 1-10

Station	S	N	D	J'	H'(loge2)	1-Lambda'
S1	44	379232	3.347	0.930	5.082	0.9596
S2	42	333113	3.224	0.954	5.144	0.9667
S3	40	379246	3.036	0.948	5.049	0.9637
S4	42	402305	3.177	0.933	5.036	0.9615
S5	41	309283	3.164	0.925	4.957	0.956
S6	42	720187	3.040	0.920	4.964	0.9558
S7	41	589039	3.011	0.937	5.024	0.9620
S8	38	346190	2.901	0.958	5.029	0.9647
S9	43	355505	3.286	0.927	5.033	0.9581
S10	41	373930	3.117	0.949	5.087	0.9648

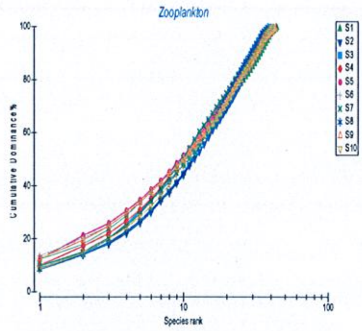
Benthic community diversity indices calculated for stations 1-10 & IB1 to IB3

Station	S	N	d	J'	H'(log2)	1-Lambda'
S1	6	130	1.027	0.970	2.507	0.8229
S2	5	140	0.809	0.913	2.121	0.7503
S3	7	170	1.168	0.947	2.660	0.8354
S4	6	90	1.111	0.968	2.503	0.8240
S5	5	110	0.851	0.878	2.040	0.7173
S6	5	80	0.913	0.969	2.250	0.7911
S7	6	100	1.086	0.975	2.522	0.8283
S8	8	130	1.438	0.957	2.873	0.8587
S9	5	80	0.913	0.928	2.156	0.7595
S10	7	100	1.303	0.969	2.722	0.8485
IB1	2	45	0.263	0.918	0.918	0.4545
IB2	2	30	0.294	1.000	1.000	0.5172
IB3	4	75	0.695	0.9610	1.922	0.7297

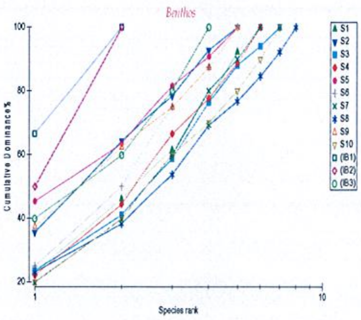
S-Total number species (richness); N- total number of individuals; d- Margalef's richness index; J'- Pielou's evenness index; H'- Shannon-Wiener diversity index; 1- Lambda'- Simpons's diversity index.



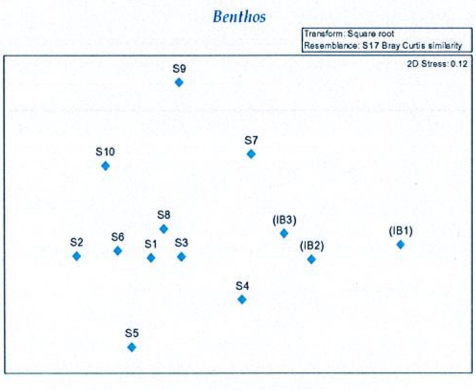
Dominance curve for Phytoplankton



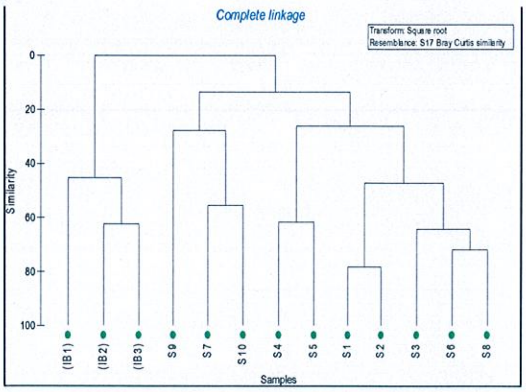
Dominance curve for Zooplankton



Dominance curve for Benthos



MDS plot for Benthic animals recorded in various stations



Dendrogram of Benthic species recorded in various stations

Bray – Curtis similarity for Phytoplankton collection from different stations

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1										
S2	72.0									
S3	61.5	60.4								
S4	62.1	63.7	68.2							
S5	57.5	52.1	53.7	60.8						
S6	45.6	50.8	48.8	51.0	43.2					
S7	58.0	54.5	59.3	64.6	54.3	58.8				
S8	59.1	60.7	63.3	70.8	60.9	57.0	75.5			
S9	66.8	63.5	64.2	69.8	73.6	50.0	73.5	69.3		
S1	63.5	66.5	66.7	67.3	57.1	51.0	70.1	68.4	64.4	

Bray – Curtis similarity for Zooplankton collection from different stations

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
S1										
S2	89.9									
S3	87.8	90.7								
S4	85.3	87.9	87.1							
S5	84.1	86.1	84.3	82.8						
S6	80.7	80.1	82.8	82.8	73.5					
S7	82.2	79.1	80.0	78.6	79.6	82.5				
S8	82.0	85.1	84.1	85.0	80.1	77.6	77.9			
S9	88.6	88.2	87.7	86.8	85.3	80.5	82.3	86.9		
S10	89.5	88.4	88.7	89.7	86.0	81.2	82.7	88.8	89.6	

Bray – Curtis similarity for Benthos collection from different stations

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	IB1	IB2	IB3
S1													
S2	78.2												
S3	67.9	47.2											
S4	42.8	26.1	54.0										
S5	43.3	50.6	49.9	61.7									
S6	70.1	67.5	64.2	29.6	51.3								
S7	34.5	17.9	41.9	51.3	13.5	28.78							
S8	62.4	48.9	69.4	39.6	40.0	71.88	34.0						
S9	26.9	28.1	23.8	29.8	15.1	32.29	49.4	37.2					
S1	40.2	46.9	36.2	25.8	31.5	41.42	55.5	48.4	27.8				
IB1	21.0	0.00	18.0	24.0	0.00	0.00	23.0	15.4	0.00	0.00			
IB2	21.9	0.00	37.5	50.5	25.7	23.01	44.0	35.8	0.00	18.7	45.3		
IB3	41.9	18.1	52.2	41.7	19.6	34.34	55.7	41.9	17.3	32.6	58.5	62.3	

Microbiology: Microorganism distribution in the marine and brackish environment plays an important role in the decomposition of organic matter and mineralization. Since the last two decades, water quality analysis was given more importance in marine pollution monitoring programmes. These pathogenic bacteria invade into marine environment through human and animal excreta, river runoff, land runoff, sewage with organic and inorganic contents, agricultural waste and industrial waste. Hence, the spatial and temporal distribution of the Total fecal coli forms as well as pathogenic bacteria in water and sediment is essential to assess the sanitary. The regular monitoring in the coastal environment is an integral and essential part in predicting the microbial population of coastal waters.

Bacterial counts in the surface water and in sediment samples at all stations were analyzed, and are presented in Tables 20 and 21 respectively. In the water samples, population density enumerated from the all stations varied from 0.01 to 4.91 × 10^3 CFU ml^{-1} with the minimum (0.01 ×10^3 CFU ml^{-1}) at S1 & S3 and the maximum (4.91 × 10^3 CFU ml^{-1}) at S10. In the sediment samples, population density enumerated from the all stations varied from 0.03 to 5.75 $\times10^4$ CFU g^{-1} with the minimum (0.03 $\times10^4$ CFU g^{-1}) at S1 and S10. The maximum 5.75 $\times10^4$ CFU g^{-1}) at S1.

The bacterial colonies were identified up to generic level. Organisms isolated were normally expected in all coastal waters, under moderate human influence. The total count in the water sample at the surface closer to the coastal areas was found to be higher due to terrestrial run off and towards the open sea the count was found to be lesser. *Pseudomonas aerugenosa* and *Shigella* like organisms were found to be present in very low numbers. Other counts indicated lesser populations. This result implies that in this region there is no indication of any microbiological pollution.

Bacterial densities were higher in the sediment samples than the water samples. This could be ascribed to the fact that the coastal and shelf sediments play a significant role in the demineralization of organic matter which supports the growth of microbes. Higher bacterial population in sediments than water is generally due to the rich organic content of the former and the lesser residence time of microorganism in the water than the sediments. The pathogenic organism such as (TVC) *Escherichia coli, Vibrio* like organisms, *Shigella, Proteus klebsiella, Vibrio cholera* and *Vibrio parahaemolyticus,* Total coli forms have been recorded in the study area. The counts indicated lesser population which shows that the environment is healthy and pollution free.

In general the coastal waters are influenced by *Escherichia coli, Salmonella* sp., *Klebsiela* sp., *Enterobacter* sp., *Bacillus* sp., and *Staphyloccous* sp., and *Vibrio* like organisms. Estuaries and creeks are influenced by *E.coli*, *Salmonella* sp., *Shigella* sp., *Vibrio cholera, Vibrio parahaemolyticus, Pseudomonas* sp., and other pathogens like Total Coli forms and Total Viable Counts.

Mangroves: Mangroves are salt-tolerant forest ecosystems found mainly in tropical and sub-tropical inter-tidal regions of the world. They are trees or shrubs that have the common trait of growing in shallow and muddy salt water or brackish waters, especially along quiet shorelines and in estuaries. Mangroves are not common on sandy beaches and rocky shores. A muddy substratum of varying depth and consistency is necessary for their normal growth. The survey conducted in the project area does not indicate any mangrove species.

Turtles: Sea turtles are the key species in marine ecosystem function and helps in sustaining the biodiversity. Five species of sea turtles occur along the coast of India, including Olive Ridley (Lepidochelys olivacea). Out of this five reported species, four species nests along Indian coast. Olive Ridley is the most common and well known for 'arribadas' or annual mass nesting along Indian coast. Tamil Nadu and Andhra Pradesh coasts are considered as the migratory pathways of Olive Ridleys for approaching mass nesting beaches in Odisha.

Tamil Nadu, located at southeast coast of India, has a coastline of 950 km. Interestingly, all five species of the sea turtles have been reported. Olive Ridley nests sporadically along northern Tamil Nadu coast and high nesting was observed along Nagapattinam and Chennai coasts. The other turtle nesting areas are the coasts between Tranquebar and Pazhayaru, Mahabalipuram and Chennai and Point Calimere and Nagapattinam. In the Kanyakumari to Trichendur stretch, the earlier reports indicate that the core nesting area existed between Manapad and Periyathalai. The turtle nesting was reported during December to February.




In Tamil Nadu, 36 Olive Ridley nests were recorded during January to March 2004 in the stretch of Mahabalipuram - Pondicherry coastline (100 km). The Chennai beach has been monitored by the Students' Sea Turtle Conservation Network (SSTCN) since 1988. A total of 50 nests were collected for their hatchery during January - April 2004, and 62 nests during 2005.

Observations on the nesting of Olive Ridley turtles is carried out on a regular basis across two beach stretches by the SSTCN team. The observations are made along the 14 km stretch from Neelankarai to Besant Nagar. As part of the conservation initiatives, the SSTCN team move turtle eggs from their natural nests into hatcheries situated at Besant Nagar and Marina beach where they are protected from the natural predators and human disturbances. The hatchlings that emerge are released safely into sea. During their survey, 121 nests were identified in both the beach stretches (76 nests were sighted in Marina beach (7 km); and 45 nests were found between the Besant Nagar and Neelankarai beach area (7 km)). Maximum numbers of nests were observed during February 2012 along both the stretches

Observations by WWF-India Personnel

Nesting survey was carried out fortnightly in the stretch between Neelankarai and Uthandi by WWF-India personnel. The survey was conducted from January to March 2012. A total of 6 Olive Ridley nests were recorded during the survey.

A beach stretch of 50 km from Mahabalipuram to Pondicherry was monitored by WWF-India personnel and a resource person. The nesting survey was carried out on a fortnightly basis and nesting information was recorded.

During the survey conducted by Indomer from February to March 2012, 44 nests of Olive ridley turtles were observed. The maximum number of nests was observed during 2nd week of February and March 2012 and some areas recorded higher nesting activity, ranging between 12 and 17 nests.

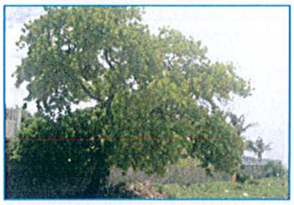
Coastal sand Dunes: Vast tracts of India's coast consist of beaches and coastal sand dunes. These natural formations are among the most effective natural defense against storms, cyclones and tsunamis. Fishing communities rely on their presence and most of the coastal tourism industry advertises them as major attractions. What is often not realized is that these are dynamic and complex habitats, many of which are under threat. Coastal sand dunes depend on a constant supply of sand, which is often is obstructed by activities such as construction of sea walls and wind breaks along the coast or damming of rivers and choking off their natural supply of sediment to the coast. Conservation of dunes thus involves both their stabilization as well as ensuring a constant supply of sand.

Coastal sand dunes perform a unique ecological function as a buffering mechanism for coastal erosion and deposition and protection against wave action, wind and tides. They also provide a large range of goods and services to coastal communities. These include sites for boat landing, sales of fish, drying and repairing of nets and motors as well as ground water recharge. Additional uses of coastal sand dune vegetation are fodder, food and medicinal plants. They also serve as a store house of sediments and nutrients and source of beach nourishment, protection from storm surges, hurricanes and erosion. They provide habitats for plants, bird nesting, sea turtle and mammals. Sand dune helps in the arrest of blowing sand and deflect wind upwards assist in the retention of fresh water and obstruct the ingress of saline marine water into the hinterland. Prevent loose sand from advancing inland on the coastal zone. The survey conducted in the project area absence of sand dunes.

Coastal Vegetation: The project area is widely dominated with *Casuarina litorea* trees and sparsely populated with veelikkaruvai (*Prosopis juliflora), Ipomea pes caprae, Pandanus odoratissimus, Catharanus roseus, Thespesia populnea, Cocus nucifera, Borassus flabellifer, Azadirachta indica, Pedalium* sp., *Calotropis gigantea* and *Spinifex littoreus.* In addition, dead shells of gastropod and bivalve molluscs are largely found washed on the shore line. The shore plants were collected and herbaria were prepared for further identification and confirmation in the laboratory. On the coastal front, farm houses, resorts and tourist spots are fast developing due to the internationally famous tourist spot at Mamallapuram.

Prosopis juliflora

Ipomea pes-caprae.



Thespesia populnea

Calotropis gigantea

Pandanus odoratissimus

Catharanthus roseus

Cocos nucifera

Borassus flabellifer

Spinifex littoreus

Azadirachta indica

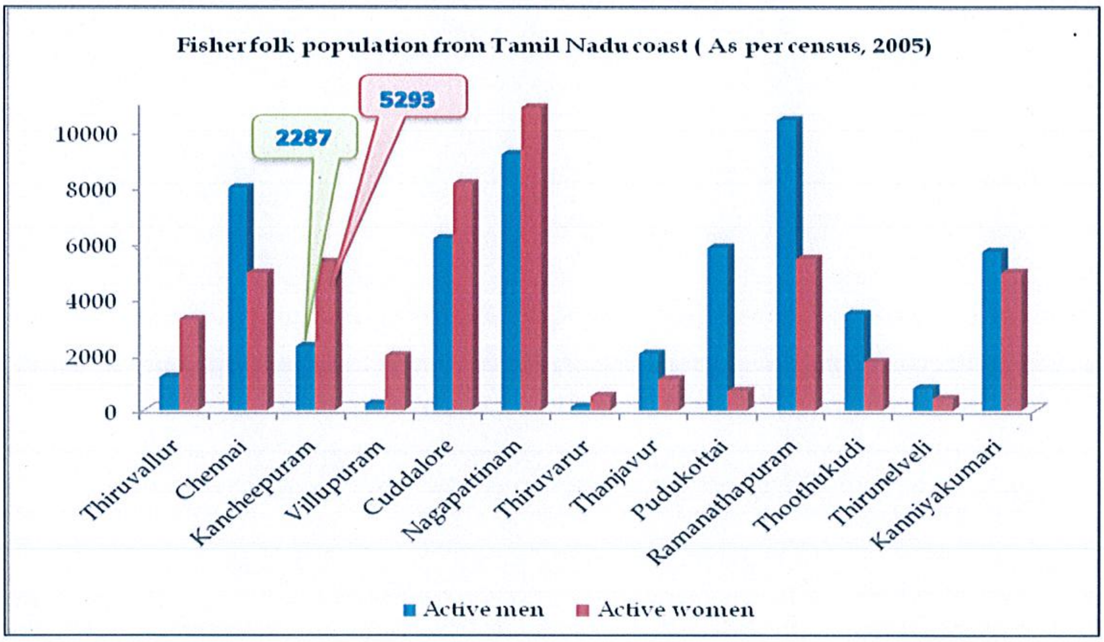
Pedalium sp.

Casuarina litorea

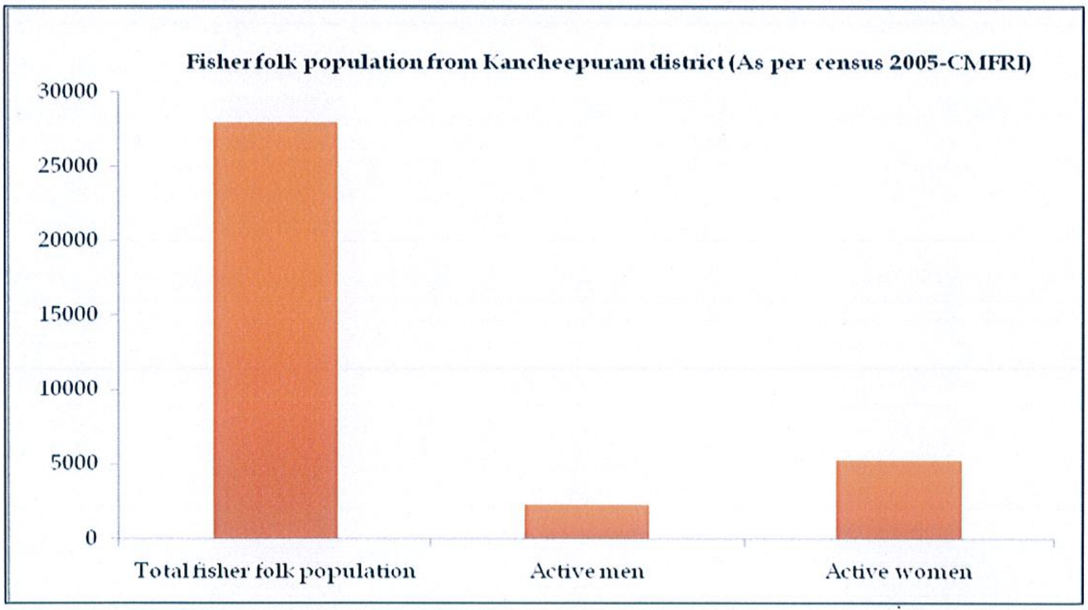
Fishery: Tamil Nadu has got a coastline of 1076 km and the continental shelf area covers 41,400 sq.km extending up to 40-60 km. This coastline is the third longest in India after A&N islands and Gujarat. The coast line of Tamil Nadu covers 14 out of 32 districts and starts from Chennai in the north to Kanyakumari in the south. According to the survey conducted by the CMFRI (2005), there are 7,90,408 fishermen and fisherwomen along the coast and only 1,04,509 are active in the fishing industry.

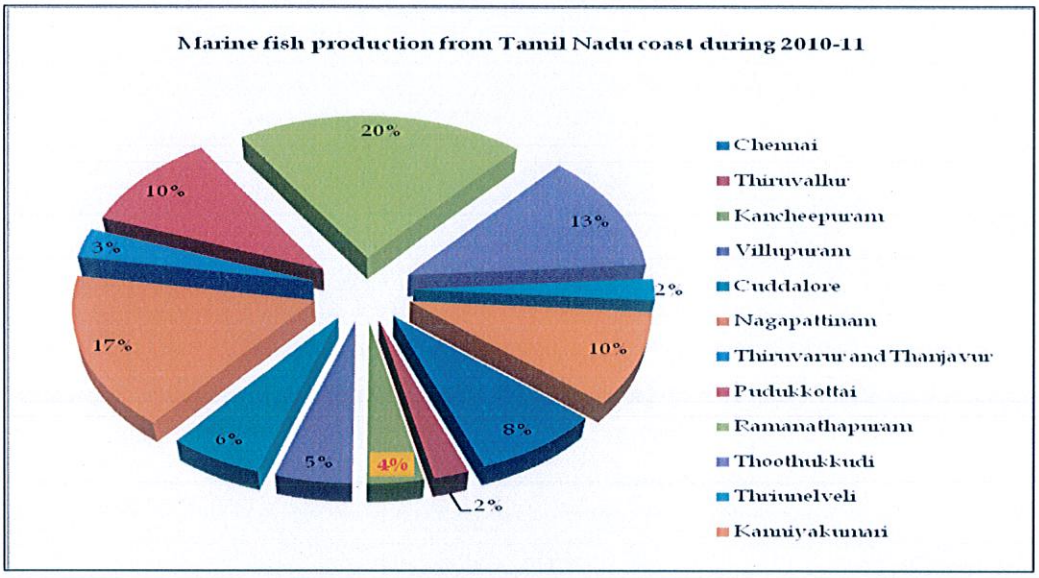
The Kancheepuram district under which the present site comes, has 87 km. of coast line and the fourth longest in the state with 44 fishing villages. There are 2 major and 37 minor fish landing centers.

The total fisher folk population in the district is 27,962 with an active fishermen (2,287) and fisherwomen (5,293) totaling 7,580 (Table 22) as given below.



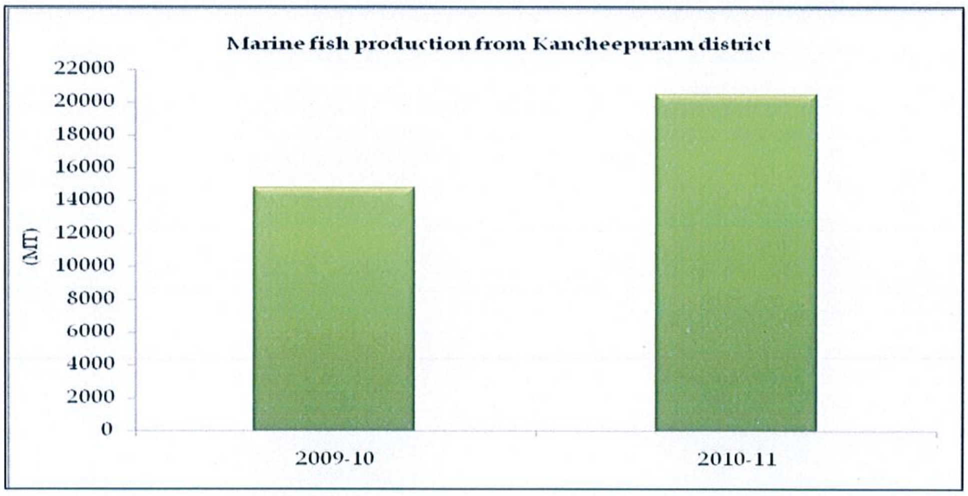
The fishery of the region is assessed based on the data obtained from the Department of Fisheries, Govt. of Tamil Nadu. The marine fish landings for the entire Tamil Nadu coast for the year 2010 - 2011 are presented below.

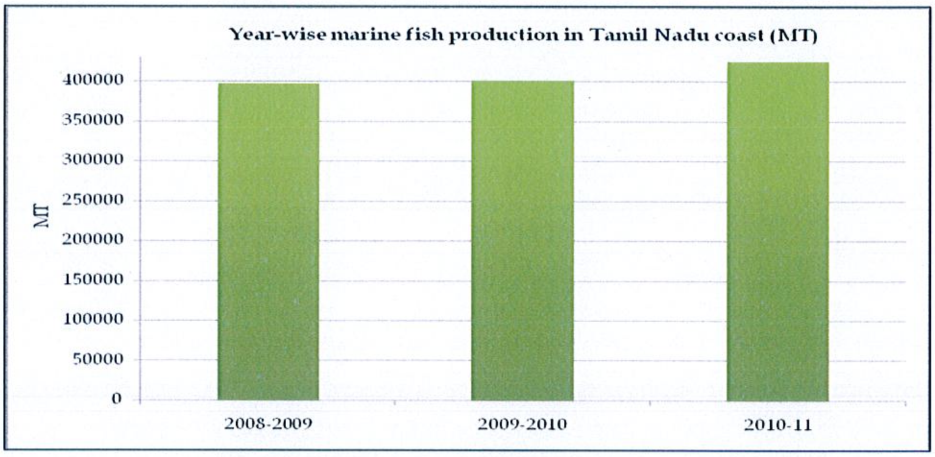




Kancheepuram district contribute as much as 4% to that of total marine fish catch of Tamil Nadu. The available data indicate that the yearly fish landings of the Kancheepuram area are not constant and they fluctuate widely.

An increasing trend in the marine fish catch during the post Tsunami period (2009 – 2011) has been observed in the Kancheepuram district as indicated in the figure below.

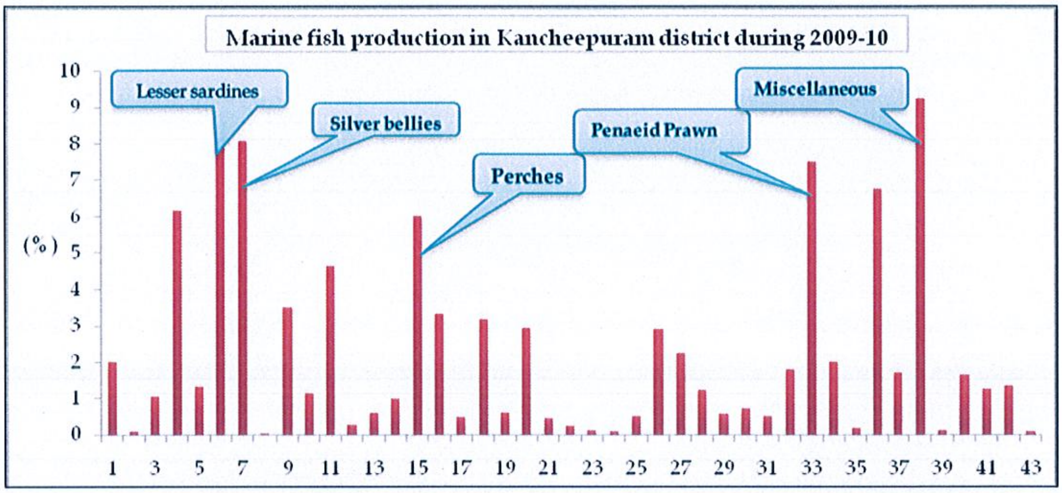


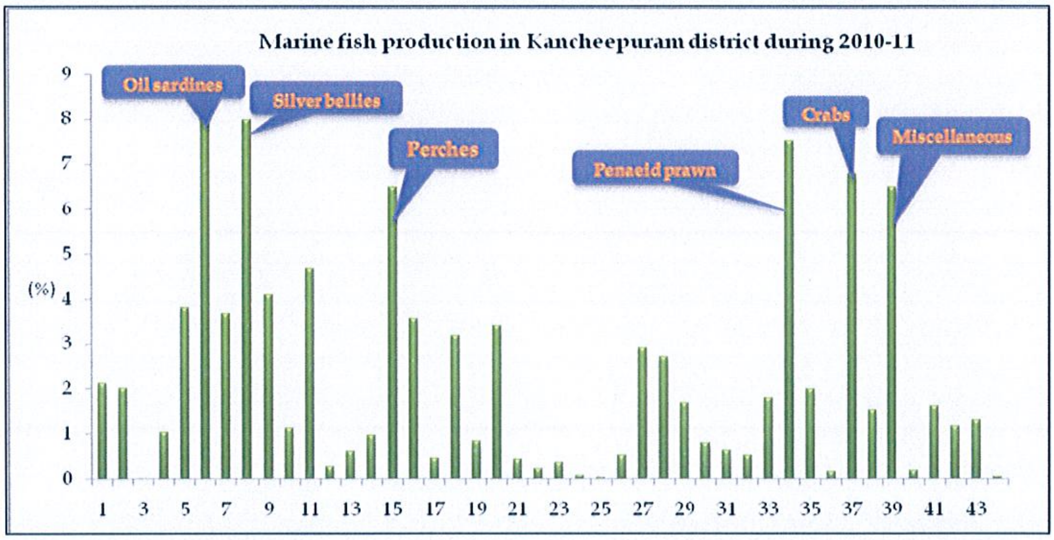


Total fish production during the last three years were 3,97,117.22 MT (2008-09), 4,01,128.37MT (2009-10) and 4,24,833.84 MT (2010-11).

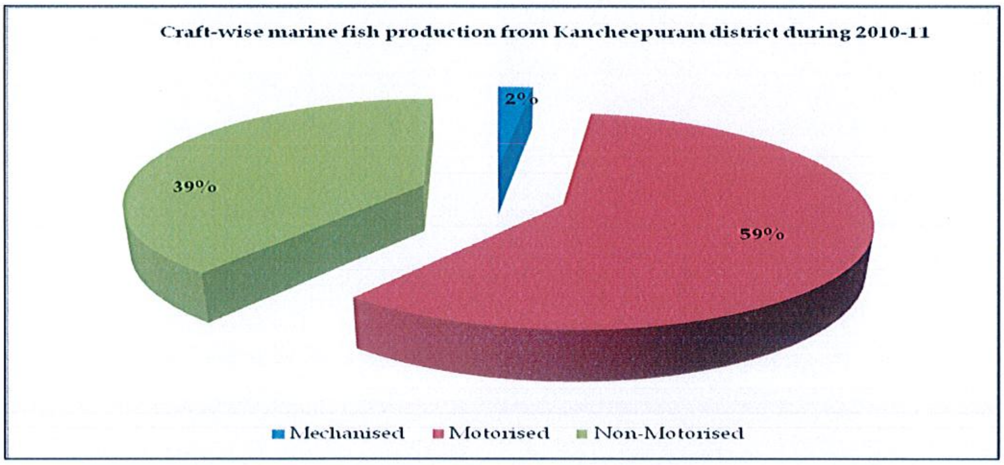
A variety of fishing crafts, like mechanized boats, wooden vallams and FRP Vallams, are used in this region. The total number of such crafts are 4011. However, mechanised boats (8), Wooden vallams (1722) and FRP Vallams (2281) are the most commonly used fishing crafts in this region (Table 23). Among the fishing gears, gill nets, trawl nets, hook nets and bag nets are primarily used for fishing by these communities (Table 24). However gill nets are the most popular among the fishing communities.

In general, the dominant fishes species of the Kancheepuram region are *Dussumieria acuta* (Mothakendi), oil Sardines (Paichalai), lesser Sardines (Keerimeen – Chalai), Anchovies (Nethili), Silver bellies (Kare), Savalai (*Lepturacanthus* sp.), Calawah (*Epinephelus* sp.), Catfish (Keleru), Carangoides (Parah), *Scomberomorus* sp. (Vanjiaram), Mackerels (Kanangeluthi), Changarah, Thullunkendai (*Nemipterus* sp.), Cuttle fish (*Sepia* sp.), Squids (*Loligo* sp.), Crab (*Portunus sanguinolentus, P. Pelagicus*) and Prawns (*Penaeus indicus, P. monodon*). Marine fish production from Kancheepuram district (2009 – 2011) is presented in (Table 25). The available data indicate that the yearly fish landings fluctuate and are not constant. While the total landing was 14,822.87 MT in 2009-2010, it was 20,476.53 MT during 2010-11.





The total marine fish catch in the district from all crafts accounted for 15,822.95 MT during 2010-11, with the following break – up; Mechanized boats (354.48 MT), Non-mechanized boats (6187.39 MT) and Motorized boats (9281.08 MT- Table 26) and their percentage catch is given below.

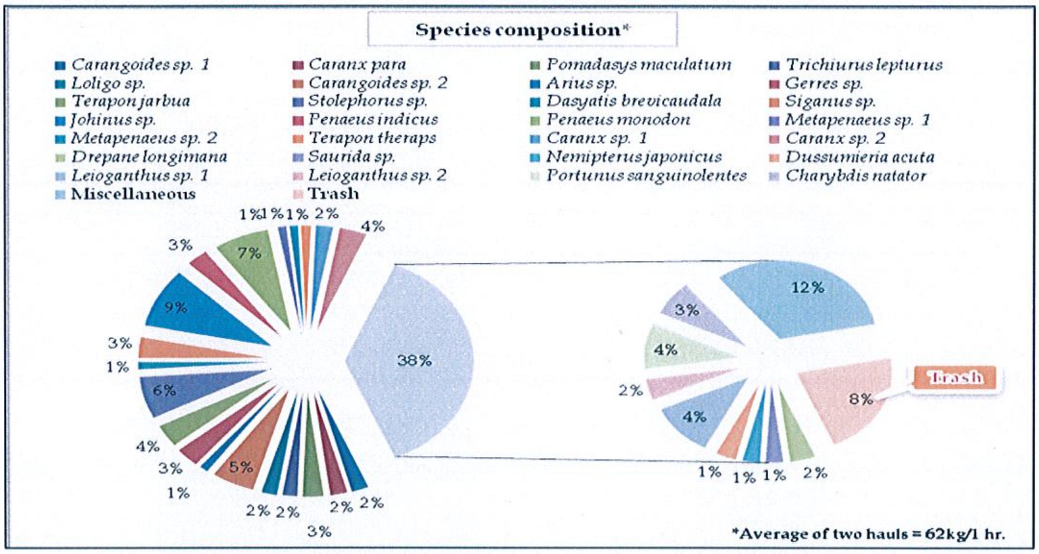


The biological productivity of this region in the open sea is largely influenced by the seasonal coastal circulation. Phytoplankton and zooplankton population is relatively high as seen by the biomass and primary production values. The coastal waters are highly dynamic and show good mixing which minimizes any likely impact of discharges in the region. The fishery is well represented by various groups of pelagic and demersal species. Based on the observations and results obtained, from the study area, it is concluded that the near shore environment is biologically normal and free from pollution.

Experimental trawl surveys: In order to assess the fishery potential of the region, it is necessary to conduct exploratory and experimental fishing. Accordingly, experimental trawl fishing was conducted using a commercial mechanized stern trawler of 46 ft. in length. The area covered is adjacent to the project site and all the trawls were done at 10-25 m depth. Two types of bottom trawls, shrimp trawl with 34 m head-rope with cod end mesh size of 10mm and fish trawl with 40 m head-rope with a cod end mesh size of 20 mm are available. In the present study, we used shrimp trawl nets for the experimental trawling.

Totally two hauls (shrimp trawl nets) were carried out on 27.07.13 during day time. The duration of each haul was approximately 1 hr 30 min and the towing speed varied between 2.5 and 3.5 knots. The catch of each haul was sorted out into various groups/species and weighed. Fish samples including prawns and crabs collected from the trawl survey were also examined for the maturity stages. Using the experimental trawl survey data, both biomass and density of fish stocks, were calculated following swept area method (Sparre *et.al.* 1989). This method assumes that the mean catch in weight per unit area is an index of stock abundance. The area swept by the trawl is: Area = DW (km^2) where D is the distance covered by the trawl during one haul and W is the width of the path swept by the trawl. The Biomass (B) for the given area was estimated following the formula: B=S (mean CPUE/Q) where S is the stratum area, CPUE is the catch per unit effort, and Q is the catch ability coefficient, which is normally taken as 0.5. Then the density of fish stock is calculated: Biomass/Area.

The location of hauls and other details are given in Table 27. The catch rate ranged from 64kg/hr. to 60kg/hr with a mean value of 62kg/hr. The estimated total biomass of the water body area is 157 km^2 (Volume of area πr^2; 22/7 x 10 km X 10 km) and the rest of the area (157km^2) is terrestrial. Based on the experimental trawl survey from the water body, the biomass was calculated to be 19.47 tonnes with an estimated population density of 124kg/km^2. The haul wise composition of catch is given in Table 28. A set of photographs on trawling operations and groups of fishes collected are given in the following pages.



In general, the fish catch was moderate with major portion of both hauls dominated by species belonging to the family Carangidae and Leioganthidae. Among the catch, members of the Family: Carangidae (*Carangoides* sp.1, *Carangoides* sp.2, *Caranx para*, *Caranx* sp.1 and *Caranx* sp. 2) constituted the major portion (15%) followed by other family Leioganthidae. Species like *Leiognathus* sp.1 and *Leiognathus* sp. 2 constituted 6%. Rest of the catch was dominated by miscellaneous groups constituting (12%) representing fish species such as *Rhabdosargus* sp., *Pampus chinensis*, *Plotosus anguillaris*, *Narcine brunnea*, *Narcine* sp., *Ophisthopterus tardoore*, *Aesopia cornuta*, *Aesopia* sp., *Ambassis* sp., *Scomberomorus* sp., *Sphyraena* sp., *Gerres filamentosus*, *Platycephalus* sp., *Nemipterus* sp., *Alectis* sp., *Upeneus* sp., *Alepes* sp., *Lactarius lactarius*, *Cynoglossus* sp., *Pseudorhombus* sp., *Psettodes* sp., *Himantura uarnak* and cephalopod like *Sepiella* sp. etc., Other major family, Sciaenidae was represented by species like *Johnius* sp. formed (9%) of the catch. The rest of the catch comprised by other commercially important species like *Stolephorus* sp. (6%), *Terapon jarbua* (4%), *Siganus* sp. (3%), *Gerres* sp. (3%), *Pomadasys maculatum* sp. (3%), *Trichiurus lepturus* (2%) and *Drepane longimana* (2%). In addition other important species like *Arius* sp. (1%), *Dasyatis brevicaudala* (1%), *Terapon theraps* (1%), *Saurida* sp. (1%), *Nemipterus japonicas* (1%) and *Dussumieria acuta* (1%). were present as shown in figure given below. This was followed by crustacean species like *Penaeus monodon* (7%), *P. indicus* (3%), *Metapenaeus* sp.1 (1%) and *Metapenaeus* sp. 2 (1%) crabs like *Portunus sanguinolentus* (4%), *Charybdis natator* (3%) and cephalopod species such as *Loligo* sp. (2%) were present in the catch. The catch grouped as trash fish constituting (8%) is represented by *Squilla* sp., sea snakes, Gastropods, Bivalves, non edible crabs, small sized *Leiognathus* and Echinoderms. The sea snakes caught in the catch were very large and many.

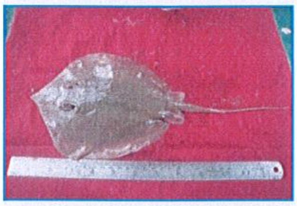

Shooting of trawl net


Trawl net operation


Opening haul


Assorted fish catch

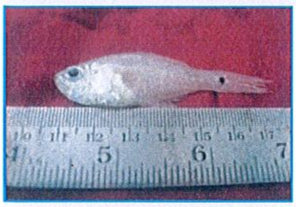

Shorting fish catch


Dasyatis brevicaudala


Himantura uarnak

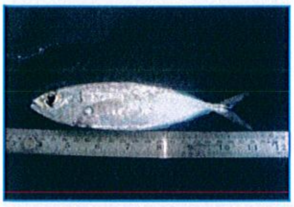

Narcine sp.


Narcine brunnea


Ambassis sp.


Caranx para


Caranx sp.1

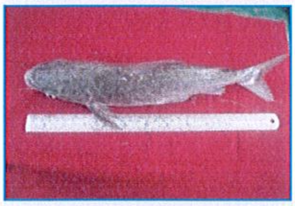


Caranx sp.2

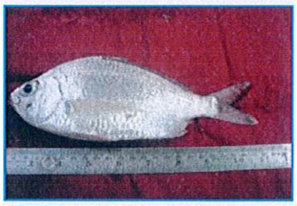
Trichiurus lapturus

Pampus chinensis

Plotosus anguillaris

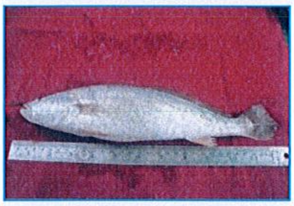


Arius sp.

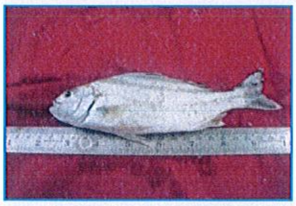


Gerres sp.

Gerres filamentosus

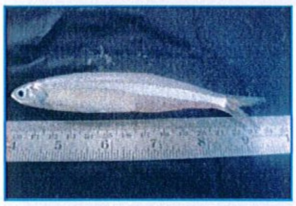


Johnius sp.



Terapon jarbua

Terapon theraps

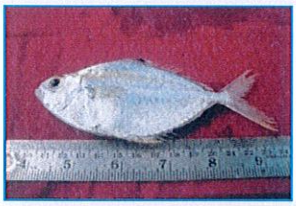


Stolophorus sp.

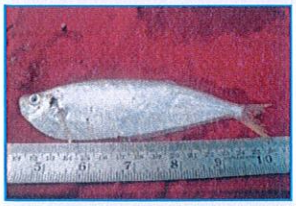
Siganus sp.

Johnius sp.

Leiognathus sp.



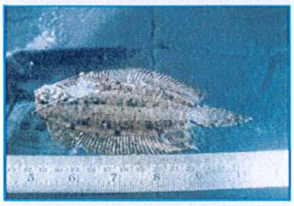
Leiognathus sp.



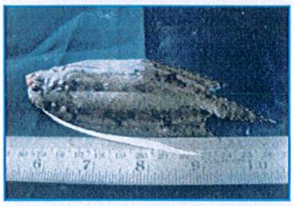
Opisthopterus tardoore

Aesopia cornuta

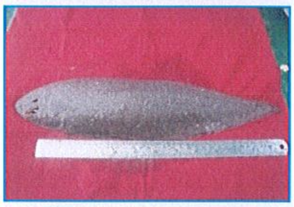
Aesopia sp.



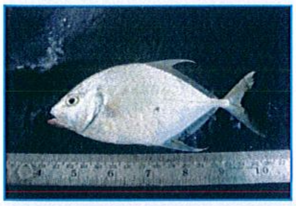
Pseudorhambus sp.

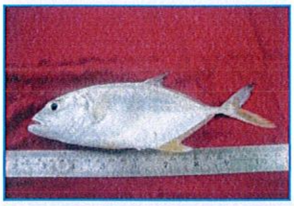


Psettodes sp.

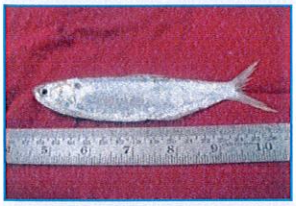


Cynoglossus sp.


Carangoides sp. 1

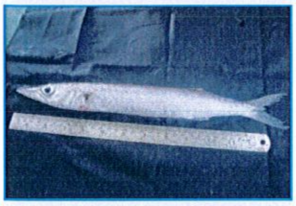

Carangoides sp. 2

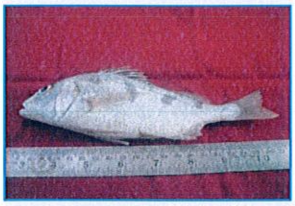

Drepane longimana

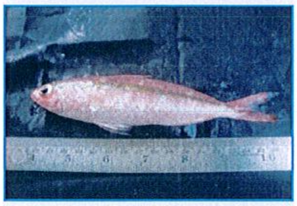

Opisthopterus tardoore

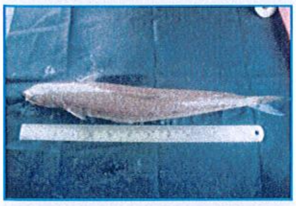

Lactarius lactarius

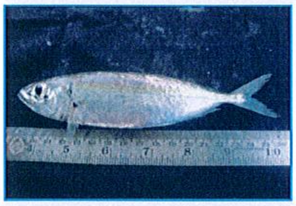

Scomberomorus sp.


Sphyraena sp.


Pomadasys maculatum

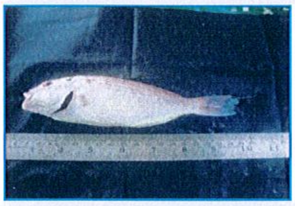

Unidentified

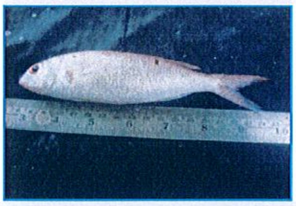

Saurida sp.

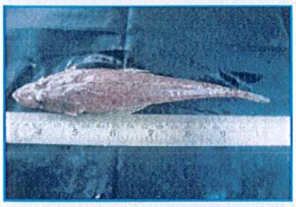


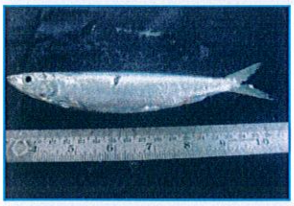

Alepes sp.

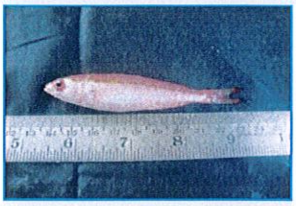

Alectis sp.

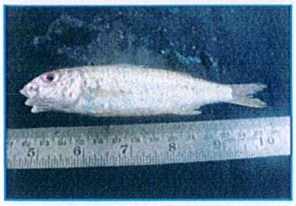

Nemipterus japonicus


Nemipterus sp.


Platycephalus sp.


Dussumieria acuta

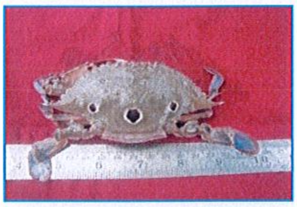

Unidentified


Upenus sp.


Rhabdosargus sp.

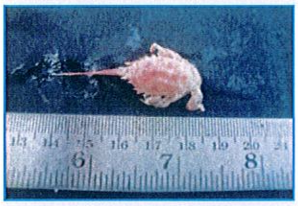

Lagocephalus intermis

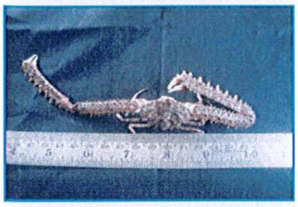

Triacanthus biaculeatus


Portunus sanguinolentus


Charybdis nataor


Calappa lophos


Albunea symnista




Penaeus indicus


Penaeus monodon


Metapenaeus sp.1


Metapenaeus sp.2


Panulirus polyphagus


Thenus sp.


Octopus sp.


Loligo sp.


Sepiella sp.


Sepia sp.


Ficus sp.


Lophitoma sp.

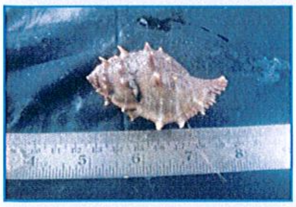

Babylonia spirata


Turritella attenuata


Conus sp.


Conus sp.


Olivancellaria sp.


Bursa rana


Murex virgineus


Architectonica sp.

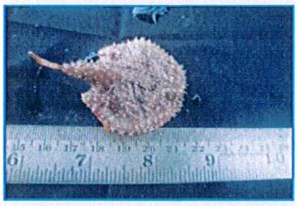

Fusinus sp.

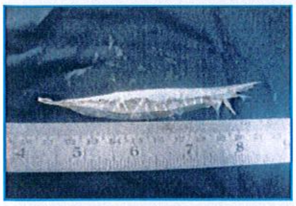

Pleuroploca sp.


Circe sp.


Meretrix sp.


Amusium pleuronectus




Peristeidion sp.


Astropecten sp.


Clypeaster sp.


Squilla sp.


Weighing fish catch


Leiognathus sp.


Shirmp


Stolephorus sp.


Crab

measures, whenever necessary. The biodiversity or community structures of flora and fauna of the region react to changes in the environment which ultimately affect the productivity of that region. There are several statistical methods and indices to explain these changes and based on the values people classify the ecological status. One such general method is the classification of Shannon -Weiner diversity Index as given below.

Productivity Status	Species Diversity (Shannon - H')	Explanation
Bad	0.0 – 1.5	Very highly polluted
Poor	1.6 – 3.0	Highly polluted
Moderate	3.1 – 4.0	Moderately polluted
Good	4.1 - 4. 9	Transitional zone (i.e. pristine to polluted)
High	5.0 and above	Normal/Pristine (i.e. can be a reference site)

In the present study, the diversity values (H') for phytoplankton and zooplankton were found to be >5.0 indicating that the region may be classified as "high" which is an indication of normal or pristine zone. Continuous post monitoring of the environment would be necessary to indicate the possible changes in the ecological status. As pointed out earlier, the diversity values were high in this region due to of the sandy nature of the bottom and low organic matter content. However, there could be a direct impact of anthropogenic activities in the region, and these values could be taken for comparison to assess the ecological status subsequently. Based on the statistics available from the Tami Nadu State Fisheries Department, it is evident that the fishery of this region is very good.

5. SEABED INVESTIGATIONS

The seabed investigations consisting of bathymetry survey, shallow seismic survey and side scan sonar survey were carried out in the nearshore of the proposed intake and outfall region. These surveys were carried out to cover 2.5 km distance along the coast and 3 km distance into the sea. The surveys were carried out during July - August 2013.

5.1. Bathymetry

The bathymetry chart of the project region prepared in 1:15000 scale is presented in Annexure-II. The nearshore till 7 m depth remained steep with the gradient of 1:70. The region between 7 m and 15 m water depth showed the gradient of 1: 250. The water depth of 16 m appears at a distance of about 3 km from the shore. It has been noticed that the depths near the existing outfall and intake locations have become deeper due to the existence of construction debris, dredging activities, burying of pipelines etc. The offshore beyond 11 m water depth is found to be slightly shallower on the southern side compared to the northern side. The variation of water depth with distance from the shore close to the Phase II development is shown below.

Depth w.r.t. CD (m)	Distance from shore (m)
4	225
5	340
6	440
7	520
8	660
9	835
10	1040
11	1360
12	1890
13	2160
14	2480
15	2720
16	2950

5.2. Shallow seismic survey

Characteristics of sub-seabed

The interpreted isopach map based on seismic data is generated in 1:15000 scale and presented in Annexure-III.

The shallow seismic study reveals that the sub-seabed consists of sedimentary layer such as sand and clay up to few meters below seabed. The submerged and buried rocks are also noticed within the study region.

Submerged Rocks: The seismic records are showing higher amplitude signals at few places which are indicating the rocks submerged above the seabed. The isopach contours less than 1 m are showing the rocky out crops that are located randomly at different elevations.

The submerged rocks are identified on the southern region (nearshore) at a distance of about 850 m from the shore. The nearshore rock spreads o quite large spatial extents on the seabed extent. The offshore seismic records also reveal the presence of the submerged rocky patches beyond 2000 m from the shore. At the northern side, rocks are not seen till 1500 m from the shore. Beyond that, patches of linear rocks are located randomly.

Buried Rocks: The gradual increase in sediment thickness close to the rocky-outcrop indicates the extension of buried rock beneath the seabed. The buried rocks are extending beneath near the submerged rocky patches at various directions. As the limitation of acoustic basement depends on the mask of seismic multiples, the dipping angles and depth of extension of buried rocks are not described further deep.

Sedimentation: Generally, the sediment thickness (till acoustic basement) within the survey boundary varies up to 9 m.

Southern side: The sediment thickness appears slightly lesser than the northern side and varies up to 5 m at the nearshore. The sediment thickness increases towards offshore till the distance of about 2 km from the shore. Further, the isopach values decrease due to the presence of submerged and buried rocks. The sediment thickness of 9 m appears on the southern side at a distance of about 1 km from the shore.

Northern side: At the northern side, the sediment thickness is varying between 3 m and 7 m till the distance of about 1.5 km from the shore. Beyond that, it decreases due to the existence of linear NE-SW rocky patches. The offshore sub-seabed is found to be composed by sand and clay varying the thickness between 7 m to 9 m.

5.3. Side scan sonar survey

The seabed map prepared in 1:15000 scale is presented in Annexure-IV. The analyzed records reveal that the seabed is generally covered by sandy clay, clayey sand, coarse sand with scattered rocky outcrops.

Spread of submerged rocks: The higher amplitude acoustic signals on the sonogram shows the presence of about 20 rocky outcrops on the seabed. The rock-outcrops are scattered on the seafloor at various random locations with different elevations above the seafloor. At some of the places the rock-heads are carpeted by the seashells and coarse sand.

Southern side: Four submerged rocky patches of various spatial extents are seen on the nearshore region till the distance of about 1300 m from the shore. Beyond that, the rocks are not visible from side scan records till 2000 m from the shore. Further, six patches of submerged rocks are demarcated till the end of the survey limit.

Northern side: The nearshore is observed by the absence of rock-outcrops till 1.5 km from the shore. Beyond that, the seabed shows the patches of linear rocky outcrops in NE-SW direction. It has been noticed that the stretch of linear rock is about 1 km long in NE-SW direction. It exists at 2 km offshore.

Existence of pipelines: The intake and outfall pipelines of Phase-I which are partially buried have been observed on the seafloor. The construction debris and trenches are also noticed in the side scan records along the pipeline corridor.

Seabed covered by sediments: The rest of the seabed apart from rock-heads is carpeted by mainly sandy clay and clayey sand. The patches of coarse sand with different grain sizes are noticed to be distributed on the seafloor. The presence of seashells is also illuminating the side scans sonogram at few locations.

6. DISPERSION MODEL

The main objective of the study is to ensure that releasing the brine would not alter the existing marine ecosystem in terms of the water quality and biological characteristics deviating from the prescribed standards. The total volume of AECOM brine to be discharged into the sea after phase III will be 12708.33 m^3/hour ≈3.53 m^3/s).

The distance of outfall diffuser from the bank, water depth, wind, river water density gradient, current speed and direction etc. are some of the primary factors determine the extent of dilution. The dilution of effluent released in the marine environment takes place in 2 stages, viz., i) initial dilution due to jet mixing, and ii) secondary dispersion due to turbulence. The extent of initial dilution is controlled by the engineering design of the diffuser. For a proposed design of the diffuser port the behaviour of the jet plume is designed using CORMIX model. Once the return water rises to the water surface as the water moves away from the outfall location the subsequent dilution takes place by larger scale turbulence in the horizontal direction. This second stage is controlled by the prevailing currents and turbulence that exist in the coastal region. Such secondary dispersion is estimated using DHI-MIKE 21 model.

6.1. CORMIX model and mixing in near field

For a proposed design of the diffuser port the behaviour of the return water jet plume is designed and estimated using **CORMIX** model. The second stage is controlled by the prevailing currents and turbulence that exist in the coastal region. Such secondary dispersion is estimated using **DHI-MIKE 21 - AD** model.

The volume of discharge into the sea in each of the seven outfalls is assumed as 12708.33 m^3/hour (3.53 m^3/s). The outfall diffuser will have the multi ports of 10 nos. x 500 mm diameter. All the ports will be oriented 30° to the horizontal. The water depth at the disposal location will be 7.5 m and the diffuser height will be 1.5 m above the seafloor. The various input parameters for the CORMIX models are given below.

Volume of discharge	=	12708.33 m^3/hour (3.53 m^3/s)
No. of Ports	=	10 nos. x 500 mm dia.
Inclination of ports	=	30° to horizontal

CORMIX SESSION REPORT:

CORMIX MIXING ZONE EXPERT SYSTEM
CORMIX Version 8.0GTH
DYDRO : Version-5.0.0.0 April,2012

SITE NAME/LABEL	: NEMMELI
DESIGN CASE	: Metro water
FILE NAME	: C:\Users\PCM\Desktop\Nemmeli phase 3.prd
Using subsystem BCORMIX2	: Multiport Diffuser Brine Discharges
Start of session	: 1st December, 2014--17:28:40

AMBIENT PARAMETERS:

Cross-section		= unbounded
Average depth	HA	= 7.0 m
Depth at discharge	HD	= 7.5 m
Ambient velocity	UA	= 0.15 m/s
Wind velocity	UW	= 2 m/s
Stratification Type	STRCND	= U
Surface density	RHOAS	= 1023.34 kg/m^3
Bottom density	RHOAB	= 1023.34 kg/m^3

DISCHARGE PARAMETERS	:	Submerged Multiport Diffuser Discharge
Diffuser type	DITYPE	= unidirectional perpendicular
Diffuser length	LD	= 30 m
Nearest bank		= left
Diffuser endpoints	YB1	= 620 m; YB2 = 650 m
Number of openings	NOPEN	= 10
Number of Risers	NRISER	= 10
Spacing between risers/openings	SPAC	= 3.33 m
Port/Nozzle diameter	D0	= 0.5 m
Equivalent slot width	B0	= 0.0654 m
Total area of openings	TA0	= 1.9635 m^2
Discharge velocity	U0	= 1.79 m/s
Total discharge flowrate	Q0	= 3.53 m^3/s
Discharge port height	H0	= 1.5 m
Nozzle arrangement	BETYPE	= unidirectional without fanning
Vertical discharge angle	THETA	= 30 deg
Discharge density	RHO0	= 1050 kg/m^3
Density difference	DRHO	= -26.6600 kg/m^3
Discharge concentration	C0	= 31000 mg/l

NON-DIMENSIONAL PARAMETERS:

Port/nozzle Froude number	FRD0	= 4.6

D-CORMIX PREDICTION FILE:

FLOW CLASSIFICATION

X-Y-Z COORDINATE SYSTEM:

ORIGIN is located at the SURFACE and at the diffuser mid-point

X - Axis points downstream
S - Hydrodynamic average dilution

X	S
0.0	1.0
1.5	5.5
3.0	7.0
4.5	8.5
6.0	9.5
7.5	10.5
9.0	11.5
10.5.	12.5
12.0	13.2
13.5	13.9
15.0	14.5
65.0	22.0
110.0	24.0
160.0	26.0
200.0	27.0

Cumulative travel time = 1min

Discussion on Initial dilution

The study on CORMIX model shows the mixing zone will extend for 65 m to achieve 22 times and extending further till 200 m distance to achieve to dilution of 27 times from the disposal location. Thereafter the initial dilution, the secondary dispersion take place due to convection currents and undergoes further dilution. The secondary dispersion characteristics are studied in detail using MIKE 21 model.

6.2. Secondary Dispersion – MIKE 21 model

The tide and wind induced flow field over the project area is determined using the MIKE 21 hydrodynamic module (HD) and the return water diffusion using the Advection-Dispersion module (AD).

The relevant equations and method of solutions are given in detail in the report - "Mathematical modeling study for Phase III seawater desalination plant at Nemmeli, Chennai".

Details of Intake: The existing seawater intake laid for Phase I draws 260 MLD ≈ 10833 m^3/hour of seawater. For the Phase III considered in this report the seawater intake will draw 455 MLD ≈ 18958.33 m^3/hour of seawater in future.

Details of Outfall: The existing outfall laid for Phase I discharges 160 MLD ≈ 6667 m^3/hour of return water. For the Phase III considered in this report the outfall will discharge 305 MLD ≈ 12708.33 m^3/hour of brine reject in future.

Salinity of return water: The brine reject will have a salinity of 71 ppt which is 33 ppt higher than the ambient seawater salinity (38 ppt). There will be no change in other water quality parameters compared to the ambient values.

Modelling scenarios: In the present case, for the discharge of Phase II development, the model study has been conducted for the two scenarios as detailed below.

Case 1: Phase I (Existing) + Phase III (future)
Case 2: Phase I (Existing) + Phase II (proposed) + Phase III (future)

6.3. Simulations

In each simulation the flow field and the mixing pattern were obtained for a period of one lunar month (i.e. 28 days). The total number of simulations carried out is six as detailed below.

Number of simulations = I1 x I 2 x I 3 = 6

Where,

Number of dispersing substance	I 1 = 1
Number of seasons	I 2 = 3
Number of scenarios	I 3 = 2

The instantaneous flow and mixing patterns corresponding to flood and ebb phases during spring and neap tide periods are presented in the report.

6.4. Results

Fair weather

The flow simulation and the corresponding secondary dispersion of the return water for fair weather with no wind condition (representing conservative mixing scenario) are presented.

Spring tide

Flow field: The tide induced flow fields under no wind condition during the *flood and ebb phases on a spring tidal day* close to the project region are presented in Fig. 8.1. The magnitude of currents over a major portion of the project region was around 0.12 m/s with the direction of flow towards north during the flood phase and towards south during the ebb phase.

Dispersion due to Phase I and Phase III outfalls: The mixing pattern of the brine reject in the nearshore water discharged 600 m and 750 m offshore in Phase I and Phase III respectively is shown in Fig. 8.2. The brine discharged in the nearshore waters undergoes dilution around the outfall point such that the difference in salinity of 2 ppt was observed to occur at 80 m and 100 m from phase I and phase III outfalls respectively in the shore parallel direction. The modelling results reveal that the there is no merging between the outfalls.

Dispersion due to Phase I, Phase II and Phase III outfalls: The mixing pattern of the brine reject in the nearshore water discharged from phase I, phase II and phase III is shown in Fig. 8.3. The brine discharged in the nearshore waters undergoes dilution around the outfall point such that the difference in salinity of 2 ppt was observed to occur at 80 m, 250 m and 100 m from phase I, phase II and phase III outfalls respectively in the shore parallel direction. The modelling results reveal that the there is no merging between the outfalls.

Neap tide

Flow field: The tide induced flow field under no wind condition during the *flood and ebb phases on a neap tidal day* close to the project region is presented in Fig. 8.4. The magnitude of currents over a major portion of the project region was around 0.10 m/s with the direction of flow towards north during the flood phase and towards south during the ebb phase.

Dispersion due to Phase I and Phase III outfalls: The mixing pattern of the brine reject in the nearshore water discharged at 600 m and 750 m offshore in Phase I and Phase III respectively is shown in Fig. 8.5. The brine discharged in the nearshore water undergoes dilution around the outfall point such that the difference in salinity of 2 ppt was observed to occur at 90 m and 120 m from phase I and phase III outfalls respectively in the shore parallel direction. The modelling results reveal that the there is no merging between the outfalls.

Dispersion due to Phase I, Phase II and Phase III outfalls: The mixing pattern of the brine reject in the nearshore water discharged from phase I, phase II and phase III is shown in Fig. 8.6. The brine discharged in the nearshore waters undergoes dilution around the outfall point such that the difference in salinity of 2 ppt was observed to occur at 80 m, 300 m and 120 m from phase I, phase II and phase III outfalls respectively in the shore parallel direction. The modelling results reveal that the there is no merging between the outfalls.

Southwest monsoon

Spring tide

Flow field: The flow field due to tide and southwest monsoon wind during the *flood and ebb phase on a spring tidal day* for close to the project region is shown in Fig. 8.7. The magnitude of currents over major portion of the project region remains around 0.25 m/s with the direction of flow towards north.

Dispersion due to Phase I and Phase III outfalls: The mixing pattern of the brine reject in the nearshore water discharged at 600 m and 750 m offshore in Phase I and Phase III respectively is shown in Fig. 8.8. The brine discharged in the nearshore water undergoes dilution around the outfall point such that the difference in salinity of 1 ppt was observed to occur at 50 m and 90 m from phase I and phase III outfalls respectively in the shore parallel direction. The modelling results reveal that the there is no merging between the outfalls.

Dispersion due to Phase I, Phase II and Phase III outfalls: The mixing pattern of the brine reject in the nearshore water discharged from phase I, phase II and phase III is shown in Fig. 8.9. The brine discharged in the nearshore waters undergoes dilution around the outfall point such that the difference in salinity of 1 ppt was observed to occur at 50 m, 500 m and 90 m from phase I, phase II and phase III outfalls respectively in the shore parallel direction. The modelling result reveals that the there is no merging between the outfalls.

Neap tide

Flow field: The flow field due to tide and southwest monsoon wind during the *flood and ebb phase on a neap tidal day* close to the project region is presented in Fig. 8.10. The magnitude of currents over major portion of the project region remains around 0.20 m/s with the direction of flow towards north.

Dispersion due to Phase I and Phase III outfalls: The mixing pattern of the brine reject in the nearshore water discharged 600 m and 750 m offshore in Phase I and Phase III respectively is shown in Fig. 8.11. The brine discharged in the nearshore waters undergoes dilution around the outfall point such that the salinity of 1 ppt above the ambient condition was observed to occur within 60 m and 100 m from phase I and phase III outfalls respectively in the shore parallel direction. The modelling results reveals the there is no merging between the outfalls.

Dispersion due to Phase I, Phase II and Phase III outfalls: The mixing pattern of the brine reject in the nearshore water discharged from phase I, phase II and phase III is shown in Fig. 8.12. The brine discharged in the nearshore waters undergoes dilution around the outfall point such that the difference in salinity of 1 ppt was observed to occur at 60 m, 550 m and 100 m from phase I, phase II and phase III outfalls respectively in the shore parallel direction. The modelling results reveal that the there is no merging between the outfalls.

Northeast monsoon

Spring tide

Flow field: The flow field due to tide and northeast monsoon wind during the *flood and ebb phase on a spring tidal day* close to the project region is presented in Fig. 8.13. The magnitude of currents over major portion of the project region remains around 0.19 m/s with the direction of flow towards south.

Dispersion due to Phase I and Phase III outfalls: The mixing pattern of the brine reject in the nearshore water discharged 600 m and 750 m offshore in Phase I and Phase III respectively is shown in Fig. 8.14. The brine discharged in the nearshore waters undergoes dilution around the outfall point such that the difference in salinity of 1 ppt was observed to occur at 50 m and 70 m from phase I and phase III outfalls respectively in the shore parallel direction. The modelling results reveal that the there is no merging between the outfalls.

Dispersion due to Phase I, Phase II and Phase III outfalls: The mixing pattern of the brine reject in the nearshore water discharged from phase I, phase II and phase III is shown in Fig. 8.15. The brine discharged in the nearshore waters undergoes dilution around the outfall point such that the difference in salinity of 1 ppt above was observed to occur at 50 m, 180 m and 70 m from phase I, phase II and phase III outfalls respectively in the shore parallel direction. The modelling results reveal that the there is no merging between the outfalls.

Neap tide

Flow field: The flow field due to tide and southwest monsoon wind during the *flood and ebb phase on a neap tidal day* close to the project region is presented in Fig. 8.16. The magnitude of currents over major portion of the project region remains around 0.17 m/s with the direction of flow towards south.

Dispersion due to Phase I and Phase III outfalls: The mixing pattern of the brine reject in the nearshore water discharged 600 m and 750 m offshore in Phase I and Phase III respectively is shown in Fig. 8.17. The brine discharged in the nearshore waters undergoes dilution around the outfall point such that the difference in salinity of 1 ppt was observed to occur at 50 m and 80 m from phase I and phase III outfalls respectively in the shore parallel direction. The modelling results reveal that the there is no merging between the outfalls.

Dispersion due to Phase I, Phase II and Phase III outfalls: The mixing pattern of the brine reject in the nearshore water discharged from phase I, phase II and phase III is shown in Fig. 8.18. The brine discharged in the nearshore waters undergoes dilution around the outfall point such that the difference in salinity of 1 ppt was observed to occur at 50 m, 210 m and 80 m from phase I, phase II and phase III outfalls respectively in the shore parallel direction. The modelling results reveal that the there is no merging between the outfalls.

6.5. Discussion and Conclusion

The existing seawater intake laid for Phase I draws 260 MLD ≈ 10833 m^3/hour of seawater. For the Phase II, i.e., the proposed seawater intake will draw 1147 MLD ≈ 47791.66 m^3/hour of seawater. There is a proposal to establish Phase III unit in future, which will have a separate intake system to draw the seawater of 455 MLD ≈ 18958.33 m^3/hour and it is included in this report.

The existing outfall laid for Phase I discharges 160 MLD ≈ 6667 m^3/hour of return water. For the Phase II, i.e., the proposed outfall will discharge 747 MLD ≈ 31125 m^3/hour of brine reject. There is a proposal to establish Phase III unit in future, which is expected to discharge 305 MLD ≈12708.33 m^3/hour through a separate outfall. This expected discharge included in this report.

The brine reject will have the salinity of 71 ppt which will be 33 ppt higher than the ambient seawater salinity (38 ppt). There will be no change in other water quality parameters compared to the ambient values.

The MIKE 21 flow simulation study showed that the tide induced flow in the project region during fair weather is of the order of 0.12 m/s. The increase in turbulence due to stronger currents (> 0.25 m/s) induced by monsoon winds and rough seas would enhance the mixing during the southwest and northeast monsoons. The currents during the southwest monsoon are observed to be stronger (> 0.25 m/s) than the remaining period of the year, leading to higher rate of mixing.

Based on the Mike 21 Modelling studies, it is indicated that the brine undergoes dilution to a difference in salinity of 2 ppt above the ambient condition. The plumes of 2 ppt salinity difference spread from different outfalls do not merge with each other and they get diluted with their respective mixing zone. On the other hand the difference in salinity of 1 ppt is found to merge with other outfalls. However during the monsoon, the dilution is very high and there is no merging of plumes at all over at < 1ppt.

The study also shows that the brine reject discharged into the shoreline do not reach the shore and there will be no shoreline connection and no contaminations of the water near the coast.

Further it is noticed that there is no recirculation of discharged water into the intake.

7. SCHEME FOR SEAWATER INTAKE & RETURN WATER OUTFALL

Seawater intake: The volume of seawater to be drawn is 18958.33 m^3/hour. It has been proposed to lay a submarine pipeline with intake head and a gravity flow to a land based sump with pump house. The intake head will be located at 1050 m distance offshore at a water depth of 10 m CD. The pipeline will be buried 1 m below the seafloor with reference to the top of the pipeline. The landward end of the intake pipeline has to be connected with the intake sump at (-) 7 m CD on the landward side. There will be trash bars and vertical screens in the sump to avoid the entry of marine organisms.

Outfall: The volume of return water will be 12708.33 m^3/hour. The return water will be carried by a submarine pipeline with multiple port diffusers at the offshore end. The outfall diffuser will be located at 650 m distance offshore at a water depth of approximately 7.5 m CD. The entire stretch of the pipeline will be buried 1-1.5 m below the seafloor with reference to the top of the pipeline. The outfall will have a multiple port diffuser arrangement system consisting of 10 nos. x 500 mm dia. ports. In addition 2 nos. x 500 mm dia. ports will be provided as standby.

8. DESCRIPTION OF ENVIRONMENT

The schematic presentation of the coastal zone proposed for seawater intake is shown in Plate 1. The morphology of this region is influenced by the 3 climatic conditions, viz., southwest monsoon (June – September), northeast monsoon (Mid October to Mid March) and fair weather period (Mid March to May). The coast is more influenced by the northeast monsoon period followed by southwest monsoon period.

Wave action prevails high during southwest monsoon and cyclonic period in northeast monsoon. The coastal currents within 5 km distance from the shore are greatly influenced by wind. The nearshore remains more dynamic and turbulent due to persistent action of seasonal wind, high waves and coastal currents. The distribution of temperature and salinity indicates that the near shore water is well mixed without stratification. Presently the coastline remains with elevated dunes and wide backshore. The influence of littoral drift is significant and the annual net drift takes place in northerly direction.

Examination of water quality of this region indicated that they are homogeneous across the depth and do not differ in vertical and spatial directions. Absence of marked vertical gradients of the physical parameters indicates that the coastal waters are well mixed. Various results on the chemical and biological parameters indicate that the water is well oxygenated, nutrient rich and biologically productive at primary and secondary levels. The sub-tidal benthic fauna is moderately rich in diversity and numbers compared to the inter tidal benthic fauna.

The marine flora and fauna also indicate the existence of diverse population. The area is rich in fishery both pelagic and demersal. The study on various oceanographic parameters and the information on adjacent region indicate that the coastal water is clean and highly productive.

9. IMPACT ASSESSMENT

9.1. Identification of impacts

The schematic scenario of various activities in the project region is shown in Plate 2. The construction of seawater intake head and brine discharge will have marginal magnitude of impact on:

- Seawater,
- Marine ecology,
- Land use and
- Community

The magnitude of adverse impact appears to be very minimum. Nevertheless, the proposed project would bring positive impact on land use, people, their living and the economical development of the state.

The impacts due to different activities are analyzed. The construction of a seawater intake head and marine outfall for the release of brine reject into the sea will have impact on the marine environment.

Pipelines for both intake and outfall will be buried in such a way that the top of the pipeline will be 1-1.5 m below the seafloor. However it should be more than the scouring depth, say approximately 4 m below storm profile of the seafloor across the surf zone. As the intake point is located in the sea, the problem of entrapment of marine organisms and entrainment of zooplankton and fish eggs and larvae would occur. The impacts due to the construction of outfall diffuser are also analyzed. The discharge of brine would initially cause fall in seawater quality, especially on the ambient salinity. The discharge may affect the primary producers in the vicinity and thereby the productivity of the area. As benthic populations are essentially sessile, they will be the affected more. Fishes in the vicinity will avoid the discharge area and migrate from this region.

The effect of sudden change in salinity will present in a complex manner. Most fishes including shellfishes can tolerate mild increase than the normal range for a period of minutes to hours; however more extended periods may be fatal. Fishes may undergo shock and physical damages, and become prey to predators.

The residual chlorine present in the return water will affect the animal community living in the area. Prolonged exposure of aquatic organism to chlorine at concentration as low as 0.01 mg/l (or even less to especially sensitive species) can be toxic. The coastal installation like pump house and other infrastructure facilities may cause limited air and noise pollution on land. The magnitude of adverse impact for the indicated volume of intake and outfall appears to be low. Any negative impacts on historic/cultural heritage and social economic activities appear to be absent. The expected impacts on climate and soil condition are negligible. Nevertheless, the proposed project would bring positive impact on land use, people, their living and the economical development of the state.

9.2. Prediction of impacts

While the identification of the impacts provides the status of anticipated impact on the environment, the prediction of impact will give the extent to which these conditions can alter or improve the environment. Based on the prediction, mitigation measures can be evaluated to minimize the impact on the environment. The prediction of impacts is enumerated for:

i) Trenching for burial of intake and outfall pipelines,
ii) Construction of seawater intake head,
iii) Construction of outfall diffuser,
iv) Discharge of brine reject,
v) Impact on mangroves,
vi) Impact on turtles,
vii) Impact on fisheries and fishermen, and
viii) Impact due to tsunami and storm surge
ix) Impact on neighbourhood
x) Impact on shoreline

i) Trenching for burial of intake and outfall pipelines

It is proposed to lay submarine pipelines for both the intake and the outfall. The intake head has been proposed to be located at 1050 m distance offshore at 10 m water depth. Similarly the outfall has also been planned at 650 m distance offshore at 7 m water depth. The outfall diffuser will be erected at 600 m distance north of the intake in order to avoid the recirculation. The trench after laying the pipelines will be filled back with native sand. To meet the requirement of the proposed size of the trench, a moderate dredging activity along the entire stretch of the pipeline will have to be carried out. It is estimated that approximately 80,000 m^3 of sediment will be dredged temporarily. The identified effects due to dredging include entrainment and removal of organisms, increased turbidity near the dredging location, organic matter enrichment, fish injury associated with exposure to suspended sediments and decreased dissolved oxygen and fish behavioural effects due to the effects of noise.

Turbidity: Increased turbidity would affect the filter feeding organisms, such as shellfish, through clogging and damaging feeding and breathing equipment (gills). Similarly, young fish will be damaged if suspended sediments become trapped in their gills. Increased fatalities of young fish have been observed in heavily turbid water. Adult fish are likely to move away from or avoid areas of high suspended solids resulting from dredging activities. Increase in turbidity results in decrease of light penetration in water column which would further affect the density of phytoplankton which are the major primary producers in the coastal waters. Various studies show that, in general, the effects of suspended sediments and turbidity are confined to shortterm for less than a week on completion of dredging and limited to a region of less than a kilometer from the dredging location.

Removal of Benthic animals: During all dredging operations, the extraction of bottom sediments simultaneously leads to the removal the benthic animals living on the seabed and in the sediments. With the exception of some deep burrowing animals or mobile surface animals that may survive a dredging event through avoidance, dredging may initially result in the complete removal of animals from the excavation site. The rate of recovery of benthic communities following dredging in various habitats varied from few weeks to several years. Recovery rates are generally more rapid in highly disturbed sediments that are dominated by opportunistic species compared to stable sand habitats that are dominated by long-lived components with complex biological interactions controlling community structure.

Organic matter and nutrients: The release of organic rich sediments during dredging can result in the localized removal of oxygen from the surrounding water. Depending on the location and timing of the dredging, this may lead to the suffocation of marine animals and plants within the localized area or may deter migratory fish or mammals from passing through. However the removal of oxygen from water is only temporary, as tidal exchange would quickly replenish the oxygen supply. Therefore, in most cases where dredging is taking place in open coastal waters, the removal of oxygen has little effect on marine life. *In present project, the dredged channels will be filled with the dredged material after the pipelines are laid which would help to minimize the impact on the hydrodynamic regime and geomorphology.*

ii) Construction of seawater intake head

Improper design of intake head may cause vortex formation on the upper surface of the sea and also cause danger for the boats moving around the vicinity. The presence of intake head may alter or distort the existing current pattern.

Since the early 1970's, seawater intakes have been identified as having a potential adverse impact on aquatic organisms due to impingement/entrapment and entrainment. The cooling water intake structure extends from the point at which water is withdrawn from the surface water source up to, and including, the intake pumps. Entrainment means the incorporation of all early life stages of fish and shellfish with intake water flow entering and passing through a seawater intake structure and into sea water processing system. Impingement means the entrapment of all life stages of fish and shellfish on the outer part of an intake structure or against a screening device during withdrawal of intake water. The larval forms which enter the seawater system are likely to be killed completely and causes recognizable loss to the fishery, depending on the species available at the site. While impingement is also known to affect the fishery to a limited extent, it involves mostly young (juvenile) organisms, in the immediate vicinity of the intake structure. The intake velocity and volume are known to be the major contributory factors for the impingement. The amount of physical damage incurred by fishes at seawater intakes is variable with species, life history stage and size of the fish. The mortality resulting from impingement is highest for small fishes. The extent of physical damage to which a fish is subjected is directly related to the duration of impingement, the technique of handling impinged fishes and the intake water velocities.

Non-scientific design of intake mouth, screens and trash bars will cause such impingement of marine organisms and entrainment of zooplankton and fish larvae. Further, the improper location of intake head might pose danger to the boats and fishermen moving in the vicinity. The pump house may induce the noise pollution.

iii) Construction of outfall diffuser

The presence of outfall diffuser may locally restrict the use of drifting nets. The installation of diffuser in sea and the jet plume discharge of discharge water would locally alter the flow pattern within the initial mixing zone. Improper design of outfall diffuser may reduce the mixing and increase the distance of mixing zone. The presence of discharge ports above the seafloor will prohibit use of gill nets and drift nets. Any ambiguity in the engineering design of the outfall diffuser can cause interference with currents and may become potential danger for the boats moving in the vicinity.

iv) Discharge of Brine Reject

The brine discharge into the sea would initially raise the salinity of the seawater in the mixing zone. Effect of salinity changes present in a complex manner depending upon the corresponding changes in temperature and dissolved oxygen content. Most fishes including shellfishes can tolerate salinity outside their normal range for a period of minutes to hours; however the more extended periods may cause impact on fish life. Many shellfishes (Clams, Oysters etc) will be unable to move freely, but they can take protective action by temporarily closing their shells when exposed to abnormal salinities. Several instances of major losses of bivalves have been reported in other parts of the world as a result of larger variations of salinity.

Primary Producers: The phytoplankton is the primary producer that needs optimum salinity conditions for their growth and survival. An increase of salinity in the environment will lead to the death and decay of these primary producers. Therefore, it is advisable that the return brine may be discharged at a location where maximum dilution takes place within a short time of discharge so that the detrimental effect can be kept to a minimum.

Macrophytes: Macrophytes are multicellular plants which are attached to submerged rocks on the seabed in the shallow water region. They are sensitive to salinity changes in the environment.

Zooplankton: Zooplanktons, which are pelagic, move with the water current can be exposed to higher saline conditions resulting in varying degrees of stress due to changes in the osmoregulatory function. The residual chlorine present in the return water would also affect the population.

Benthic animal community: As the benthic community is sedentary in nature they will be affected by environmental changes more than the other communities. Like other animal population, they are also sensitive to the drastic changes in saline conditions, which may affect their body physiology. The noticeable effects are alteration of community structure resulting in the reduction of species.

Inter tidal fauna: The intertidal fauna are resistant to environmental changes to a limited extent, but large variations will affect their metabolism.

Fishes and shellfishes: Besides the effects of salinity changes, the dissolved oxygen content also affect the fish and shellfish lives. Most fish including shellfish can tolerate salinities outside their normal range for a period of minutes to hours, however, extended periods may cause impact in fish life. Many shellfish (Clams, Oyster etc) are unable to move freely, but they can take protective action by temporarily closing their shells when exposed to abnormal salinities. Several instances of major losses of bivalves have been reported as a result of larger variations of salinity.

Residual chlorine: The residual chlorine if present in the return water will affect the marine life living in the area. Prolonged exposure of aquatic organism to chlorine at concentration as low as 0.01 mg/l (or even less to very sensitive species) can be toxic. Besides high saline content affecting the salinity of the seawater, the residual chlorine in return water will also have impact on marine life. The intensity of impact depends on how soon the high saline water and residual chlorine concentration get diluted in the environment.

The freely available chlorine at any point of time should be kept within 0.5 mg/l. Residual chlorine present in the brine reject can have synergistic effects on the flora and fauna of the receiving water. Therefore, the standards stipulated by the Pollution Control Boards should strictly be adhered to in discharging the residual chlorine in the return water.

v) Impact on Fisheries and Fishermen

Kancheepuram district has a coastline of 87 km and is the fourth longest in the state with 44 fishing villages. There are 2 major and 37 minor fish landing centers. The active fisher folk population in the district is 7580 of which 2287 are male and 5293 are female.

The fishing village Perur and Nemmeli is located in the vicinity of the project region. Their fishing is mostly confined to Mahabalipuram region and at offshore. The laying of submarine outfall will have limited bearing on the day to day fishing activities. Entire stretch of the intake and outfall pipelines will be buried below the seafloor. Only the outfall diffuser and seawater intake head will be sitting on the seafloor and projecting above the seafloor. These locations will be marked with a marker buoy with lighted beacon so that the fishermen can avoid fishing in this zone. This will not cause any significant impact to the fishing community. In general, the dominant fishes species of the Kancheepuram region are *Dussumieria acuta* (Mothakendi), oil Sardines (Paichalai), lesser Sardines (Keerimeen – Chalai), Anchovies (Nethili), Silver bellies (Kare), Savalai (*Lepturacanthus* sp.), Calawah (*Epinephelus* sp.), Catfish (Keleru), Carangoides (Parah), *Scomberomorus* sp. (Vanjiaram), Mackerels (Kanangeluthi), Changarah, Thullunkendai (*Nemipterus* sp.), Cuttle fish (*Sepia* sp.), Squids (*Loligo* sp.), Crab (*Portunus sanguinolentus, P. Pelagicus*) and Prawns (*Penaeus indicus, P. monodon*).

There is no seasonal fluctuation in the fish catch, so no particular trend in the fish catch is followed. The coastal waters are highly dynamic and show good mixing which minimizes any likely impact of discharges in the region. The fishery is well represented by various groups of pelagic and demersal species. The proposed intake and outfall pipeline will be buried below the seafloor with reference to the top of the pipeline. There will be trash bars and vertical screens in the intake sump to avoid the entry of fishes and fish larvae. There will be disturbance to the species during the construction stage and later on the original equilibrium will be retained. Further be noted that fishing activity takes place minimum 5 km into the sea to 25 kms into the ocean, whereas the intake and outfall are restricted within 1.1 km offshore, thus having no impact on the activity. No fishing activities take place in near cost in the said region thus having no impact due the proposed plant. Also the outfall point is located at 650 m from the shore hence the discharge of return water into the sea is not expected to cause any threat to the tourists as the brine reject undergoes maximum dilution within 100 m.

vi) Impact on Mangroves

The survey conducted in the project area indicates that the project region is an open coastal stretch with sandy beaches and is devoid of Mangroves. Hence the construction of intake and outfall does not have the question of affecting mangroves.

vii) Impact on Turtles

In Tamil Nadu, 36 Olive Ridley nests were recorded during January to March 2004 in the stretch of Mahabalipuram - Pondicherry coastline (100 km). A total of 50 nests were collected for their hatchery during January - April 2004, and 62 nests during 2005 by the SSTCN.

During the survey conducted by Indomer from February to March 2012 44 nests of Olive Ridley turtles were observed. The maximum number of nests was observed during 2nd week of February and March 2012 and some areas recorded higher nesting activity, ranging between 12 and 17 nests.

viii) Impact due to tsunami and storm surge

Cyclone: The occurrence of depression and cyclones are common over the project region and keeps the wave climate relatively higher. The coastal currents are greatly influenced by tides directed perpendicular to the coast. Since the pipelines are laid subsea, there will not be any impact on the marine facilities.

Tsunami: The occurrence of a Tsunami along the Indian coast is an extremely rare event with a very low frequency of less than once in 500 years. No reliable historical records of occurrence of Tsunami events and their impact along the Indian coast are available because of its exceedingly rare nature. One worst Tsunami occurred on 26.12.04 along the Tamilnadu coast and the destruction was more near the project region. The project region is located on the notified area of Tsunami impact, as the offshore tectonic plates are alive in Andaman Island. The presence of sand dunes (> 3 m) on the coast may to some extent dissipate the strength of tsunami but cannot totally protect from tsunami run up.

Storm surge: The project location is located wherein the cyclones would generally cross during the northeast monsoon season. The storm surge of 1.3 m height has been predicted for a cyclonic wind speed of 180 kmph for this region. However the project area is elevated and the impact may not be severe.

ix) Impact on neighbourhood

The nearest tourist destination is Mahabalipuram and the strip of coastal stretch between ECR and sea is more urbanized developed with tourist resorts, hotels, cottages, farm houses and intermittent pockets of fishing hamlets. The proposed location of the outfall is located in the relatively remote part of the coastline wherein only two fishing villages are located. The outfall point is located at 650 m from the shore hence the discharge of return water into the sea is not expected to cause any threat to the tourists as the brine reject undergoes maximum dilution within 100 m.

x) Impact on shoreline

The project coastal front is subjected to high littoral drift. In case of the present project, the intake and outfall systems are designed by submarine pipelines which will be buried below the seabed. There will not be any projection above the seabed which can cause interference for the littoral drift. It will continue to allow the littoral drift to move smoothly across the surf zone. Since the littoral drift is not affected by the intake and outfall pipelines, there will not be any change in the neighbouring shoreline.

9.3. Impact assessment

The baseline data collected from the project region and the review of the available information indicate that the water quality parameters are within the acceptable limits for the coastal waters. The coastal waters are well mixed, remain clean and free from any pollution. The quality of return water discharged into the sea is confined to the stipulated standards of the Tamilnadu State Pollution Control Board.

The seawater intake and the marine outfall will result in marginal impacts on marine community viz., coastal fisheries. But such impacts are confined to a limited duration of the period of construction. The analysis on quality of seawater drawn and the quantity of discharge indicate that impact due to such activity is limited to 100 m radius. The discharge at open sea does not cause any impact to the environment.

Despite various initial impacts on the environment, the benefits due to this project outweigh such initial adverse impacts since the project would prove extremely beneficial for the State and the people living in the project region.

9.4 WASTE MANAGEMENT

1. Screenings

Screenings will be flushed from the screens into wire baskets and the wash water from the screens will be returned upstream of the screens, and the screenings will be disposed of to a municipal landfill.

2. Pre – Treatment Waste Water

Waste Water will be generated in the pre-treatment system by the following treatment units.

- Lamella settlers – settled sludge
- DAF float
- UF backwash

All the discharges will be directed to the ocean via the outfall.

3. Other wastes

a) Membrane CIP wastewater

The membrane CIP wastewater after neutralization will be directed to the ocean via the outfall, for the same a neutralization tank has been provided in the design.

b) Limewater Clarifier Waste

The waste from the limewater clarifier will be dewatered and trucked from the site as a solid. The total provision for the same has been in the potabilization area.

c) Domestic Waste Sewage

Domestic sewage waste will be treated independently from all liquid other wastes. A dedicated sewage treatment package plant will be used to treat this waste to a standard suitable for re-use for irrigation or similar. For the same, an STP is proposed within the plant premises.

d) Spent Membrane

The contractor is to check the possibility of recycling or incineration, as agreed during the appraisal mission. A disposal on a credited inert landfill is only the very last acceptable option after the other options have been explored. These will need to be rinsed with fresh water (or permeate) prior to disposal. The used RO membranes shall be recycle/disposal compliant with Indian laws and regulations. The way of recycling/disposal will be reported regularly to CMWSSB

10. MITIGATION

Though the proposed activities on construction of installation of seawater intake head and installation of outfall diffuser lead to certain adverse impacts initially on marine environment, there is sufficient scope for mitigations measures.

Trenching for burial intake and outfall pipelines

In order to minimize destruction on sub-tidal benthic community, the dredging may be carried out in controlled manner confined to only pipeline corridor. The turbidity induced during the dredging can be minimized using controlled dredging techniques using appropriate cutter suction dredger. The net enclosures with booms may be placed around the dredging area in order to control the spread of the turbid plume. Regular monitoring on the heavy metals in the water column may be carried out during dredging in order to watch any rise in concentration due to dredging. The dredged materials can be used as back fill after laying the pipeline in the trench.

Construction of seawater intake head

The intake head has to be designed in order to avoid vortex formation. The intake head shall be designed in cylindrical form to avoid interference of currents with a velocity less than 0.15 m/sec. It should not cause any hazard to the boats and fishermen sailing in the vicinity. The intake should have appropriate screens and trash bars with small openings to minimize the entry of small marine organisms, fish larvae and fishes (entrapment and impingement). A marker buoy has to be placed close to the intake head as per the norms of Directorate General of Lighthouses and Lightships. This will also help boats to avoid collision while enroute. The route of pipelines laid on the seafloor has to be furnished to Naval Hydrographic Office, Dehradun in order to mark on the Naval Hydrographic Charts as a warning for navigation.

Construction of outfall diffuser

The outfall can be designed with multiple ports, which can enhance the jet mixing of the brine with the seawater. In this case, it has been designed with 10 nos. x 500 mm diameter of ports. This will ensure faster dilution of brine to ambient levels of salinity within short distance and there will not be any impact on marine organisms including fish catch in the nearby zone. The outfall diffuser should not have any sharp projection and should not pose any risk for the boats and fishermen moving around this region. The part of the outfall pipelines before the diffuser port may suitably be placed and buried to avoid hindrance for fishing and the movement of the boat. The diffuser ports should be placed appropriately above the seabed and also below the sea surface, so that they do not cause obstruction to the movements of boats and crafts. A marker buoy has to be placed close to the outfall as per the norms of Directorate General of Lighthouses and Lightships. This will also help boats to avoid collision while enroute. The route of pipelines laid on the seafloor has to be furnished to Naval Hydrographic Office, Dehradun in order to mark on the Naval Hydrographic Charts as a warning for navigation.

Breakage of pipeline

Pipeline can be damaged due to natural hazards like storm, earthquake, extreme waves, scouring on the foreshore and tsunami. It can also get damaged due to manmade causes like fishing, trawling and intentional damage. In case of any damage leading to breakage caused on the outfall pipeline, the brine water will gush out at shorter distance from the shoreline and would affect the marine environment. In such eventuality, the necessary mitigation measures like immediately attending the repair of pipeline has to be taken up. Necessary spares of pipeline segments with bends/Tees and divers with experience in salvation operation irrespective of sea condition have to be kept ready always within the plant.

Construction of intake sump and pump house

The intake sump and pump house should be constructed as per CRZ regulations.

Impacts and mitigations

The list of various impacts and the possible mitigations are summarized below.

Activity	Impact	Duration of Impact	Mitigation
Trenching for intake and outfall pipelines	Trenching will disturb the sea bed resulting in loss of seagrass beds and associated benthic communities. Increased turbidity affecting the photosynthetic process of the water column. Suspended particles will affect the filter feeders and adult fish will migrate from the site of impact. Boat movements and fishing activity will be restricted.	Temporary Temporary Temporary Temporary	Use of good engineering tools like cutter suction dredger for trenching to be used. Controlled method of dredging with latest technology which will limit the plume generation. To minimize the spread of suspended particles, silt screens may be deployed. Complete the operation within shortest duration.
Laying of submarine pipelines	Boat movements and fishing activity will be restricted	Temporary	Laying operation may be done in shortest duration within a week. Barricading the water along the shoreline has to be avoided. Install proper marker lights indicating if any obstructions.
Seawater intake head	Entrapment of fishes and other organisms. Entrainment of smaller organisms such as fish larvae.	Continuous	Installation of trash bars with < 10 cm opening, subsequently screens with < 3mm opening, region covered for 50 m radius with nylon mesh having 1 cm opening to avoid entry of fishes and fish larvae. The entry should be only sideways with a limiting velocity of < 15 cm/s.
Outfall diffuser	Increased salinity Chlorine concentration	Continuous	Faster dilution of moderately high salinity levels to ambient levels Chlorine concentration to be maintained below 0.2 ppm.
Coastal installation	-	-	All installations as per CRZ regulations

11. MARINE ENVIRONMENTAL MANAGEMENT PLAN

11.1. Introduction

The marine facilities for the proposed desalination plant will consist of: i) laying of seawater intake pipeline on the seabed but buried below seabed to a distance of 1050 m into the sea till 10 m water depth, ii) laying of outfall pipeline on the seabed but buried below the seabed to a distance of 650 m into the sea till 7.5 m water depth, iii) construction of seawater intake head, iv) construction of outfall diffuser

The salinity of the return water released into the sea will be 71 ppt, which will have the salinity difference of 33 ppt higher than the seawater ambient salinity of 38 ppt. The proposed activities will have the impacts on the marine environment and it is necessary to draw an Environmental Management Plan. The Environmental Management Plan has been prepared with the guidelines on proper locations of the marine facilities, appropriate design, control and flow of intake and outfall, regulation of boats movements, preservation of near shore ecology and protection of social life.

Context and Scope

This Environmental Management Plan addresses the environmental issues associated with the project including potential effects to marine water quality, sediment quality, pelagic and benthic producer habitats and the ecosystem integrity. The Environmental Management Plan has been prepared with the guidelines on proper locations of the marine facilities, appropriate design, control and flow of intake and outfall, regulation of boats movements, preservation of nearshore ecology and protection of social life.

Objectives

The MoEF objectives relevant to Marine Management Plan include:

- To maintain or improve marine water and sediment quality in compliance with sediment and water quality guidelines documented.
- To maintain the integrity, ecological functions and environmental values associated with marine environment both coastal and offshore.

- To maintain the abundance, species diversity, geographic distribution and productivity of marine flora and fauna.
- To ensure that any impacts on locally significant marine communities are avoided, minimized and/or mitigated.
- To ensure that appropriate consideration is given to cumulative impacts so that the proposed activity does not cause considerable damage to the sustainability of the ecosystem.
- To protect Specially Protected (Threatened) Fauna in accordance with the provisions of the Wildlife Conservation Act.
- To monitor the impact of the proposed activity on the productivity of the region.

Potential impacts

The various impacts in any project development can be categorized as mitigable and non-mitigable and it is essential to list the impacts accordingly. Key activities or aspects of the proposal that may potentially affect habitat of flora and fauna and require application management controls include:

Site preparation includes welding of pipelines on shore, storing of marine spreads, pile driving equipments, sheet piling across the surfzone, construction of seawater intake head and marine outfall diffuser, pumping stations etc.

Operation of seawater intake on a continual basis will affect on the occurrence and distribution of marine fauna especially fishes. A detailed marine EIA report enumerating the project development on marine front has been prepared and presented in previous chapters.

11.2. Delineation of Impacts

The various impacts in any project development can be categorized as mitigable and non-mitigable and it is essential to list the impacts accordingly. The proposed activities in marine environment under this project will have impacts on: i) seawater, ii) marine ecology, iii) land use and iv) community.

In a broad sense, the construction of intake and outfall would affect the flow and in turn the sea bottom initially. While the construction of seawater intake head will not have any long term impact, the outfall with the diffuser will have marginal impact at nearshore. The construction of the facilities would affect the flow and in turn the sea bottom initially. It would further interfere with the movement of trawlers and fishing boats along its stretch. The presence of outfall diffuser would restrict the use of drifting nets.

The coastal installation of pump house and other infrastructure facilities would cause limited air and noise pollution on land. The impacts on historic/ cultural heritage and social-economic activities appear to be absent.

11.3. Identified Mitigation and compensation measures

Though the proposed activities on construction of seawater intake head and outfall diffuser lead to certain adverse impacts initially on marine environment, there is sufficient scope for mitigations measures.

a) Activity: Construction of seawater intake head

Mitigation: The seawater water intake head planned at open ocean should have a cylindrical shape with appropriate height. There should be enough clearance from the sea surface and the intake screens may be placed well below the water line to avoid any vortex formation. The location should not cause any hindrance to the divers working in the vicinity. The intake should have screens and trash bars with appropriate openings to minimize the entry of marine organisms, fish larvae and fishes. Marker beacon should be anchored close to intake head to warn the mariners and fisher men.

b) Activity: Construction of outfall diffuser

Mitigation: The outfall can be designed with multiple ports, in this case 10 nos. x 500 mm diameter ports, which can enhance the jet mixed brine. The outfall diffuser should not have any sharp projection and should not pose any danger for the boats and fishermen moving around this region. The diffuser ports should be placed on the seabed and the top of the ports should be well below the sea surface so that they do not cause obstruction to the movements of boats and crafts. A marker buoy placed close to the outfall would help boats to avoid collision while enroute.

c) **Activity: Trenching for burial of intake and outfall pipelines**

Mitigation: The outfall pipelines are to be placed on the seabed and buried beneath the seafloor, so that it will not cause hindrance for fishing and navigation. The pipelines on the seashore should be buried below the ground so that the movement of men and machinery will not be affected.

Compensation: Like in other cases, only fishermen are the stake holders on such activities and their need on social welfare can be partly taken care.

d) **Activity: Coastal installation**

Mitigation: All installations along the coast in connection with sump and pump house may be developed as per CRZ regulations.

Compensation: Proper access for the public to the shoreline has to be ensured.

12. POST PROJECT MONITORING

The post project monitoring is an equally important aspect in Environmental Management Plan. In order to verify the outcome on the implemented mitigation measures and also to alter the proposed mitigation, the post project monitoring becomes inevitable. Indomer can follow up its Environmental Assessment study and extend suitably on required parameters as detailed in this chapter.

12.1. Marine water and sediment quality monitoring

Water and sediment samples collected from at least 6 locations around the outfall will have to be analyzed for various physical, chemical and biological parameters (phytoplankton and zooplankton) with required frequency.

12.2. Monitoring of Marine Benthic fauna

The benthic population and community structure around the outfall have to be monitored periodically to assess any change. The collected data have to be statistically analyzed so that the diversity indices can be recorded. This will enable us to develop meaningful management plans in altering the discharge methods, if required.

12.3. Assessing the impact on fisheries

Continuous monitoring of the intake system for impingement and entrapment of marine organisms has to be carried out. The trash bars and screens meant to prevent impingement have to be regularly examined for the type of animal impinged and record the quantity of commercially valuable fish impinged on the screens. Similarly the intake water has to be examined at the pumping location for the entrapped organisms, especially fish eggs and larvae of commercially important species, so that a realistic assessment of possible fisheries loss could be made. This exercise is also necessary to understand the efficacy of the screens and other devices used to minimize the entrapment.

Summary of Monitoring, Review and Reporting

Purpose	Parameter	Frequency
Seawater & Sediment quality		
To monitor impacts on seawater and sediment quality	Measurements of levels of nutrients and heavy metals in water and sediment samples collected from sites at risk of pollution	Each season April (Fair Weather), July (SW monsoon) and November (NE monsoon)
Marine Benthic Fauna		
To determine the composition and distribution of major groups of fauna	Benthic faunal composition in the water outfall region.	Each season as indicated above
Intake		
To determine the incidence of entrapment and mortality of marine fauna	Screens on pump stations and effectiveness of management measure	Each season as indicated above
To determine the impact of entrainment within and external ponds/storage sump/well to assess the loss of fishery.	Record abundance of fauna within the pond/ storage sump/well	Each season as indicated above

Purpose	Parameter	Frequency
Seawater outfall		
To determine the effect of increased temp/salinity on the plankton.	Monitor abundance and distribution of both phytoplankton and zooplankton near the outfall.	Each season as indicated above
	Monitor abundance and distribution of benthic animal communities near the outfall.	Each season as indicated above

The results of monitoring can be reported to the relevant authority annually or as required which could include:

Ministry of Environment and Forests, New Delhi
State Department of Environment
State Department of Fisheries
State Pollution Control Board

Monitoring program has to be continued during the construction and operational phases of the project. It should be repeated at periodic intervals after the commencement of the project, when the project is fully operational. The monitoring has to be organized with qualified and experienced environmental team. Standard procedure shall be followed in sample collection and analysis.

PROJECT BENEFITS

The primary benefit of the proposed Desalination Plant is that it will assist in securing the supply of drinking water to the metropolitan population well into the future. It can continue to deliver high quality drinking water for consumption, even during periods of drought. It also provides an alternative source of water that will make our overall supply more diverse and less vulnerable to interruption.

The CMA is faced with recurring droughts and an existing shortage of water that will become more severe as populations continue to expand in the region. Since desalination represents the only climate independent water supply option, the proposed Desalination Plant offers considerable benefits in facilitating the ongoing development of metropolitan Chennai and the State in line with Tamil Nadu's Strategic Plan objectives.

In addition, the proposed development presents a number of State, regional and local benefits as follows:

State

- Provision of a climate-independent water source that will supplement Chennai's water supply and reduce the reliance on rainfall;
- Reduction in the State's reliance on the River and other traditional water resources, particularly during periods of severe drought;
- Enabling greater flexibility in water management through diversification of metropolitan Chennai's water sources;
- Enhancing confidence within the local community to both retain and increase investment in housing and business development; and
- It will encourage the investors to invest in Tamil Nadu thereby boost economy of the state.

Local

- The provision of a secure water supply for residents and industry within the Chennai metropolitan area which will assist in maintaining living standards and the amenity of the urban area;
- Primary and secondary employment opportunities during the construction and operation of the proposed Desalination Plant;
- Further impetus to industrial investment and growth across the southern suburbs and metropolitan Chennai more generally; and
- Ongoing opportunities for local community involvement in the operation of the proposed development.

REFERENCES

- Antony Fernando. S and Olivia J. Fernando, 2002. A field guide to the common invertebrates of the east coast of India. Pp. 258.
- Bay of Bengal Pilot, 1978, The Hydrographer of the Navy.
- Bhaskar, S., 1978. Note from the Gulf of Kutch. Hamadryad, 3: 9-10.
- Chandramohan, P., *et.al.,* 1990, Wave Atlas for the Indian Coast, NIO, Goa.
- FAO species identification sheets for Fishery purposes - Field Guide – Commercial Marine and Brackish water species of Pakistan. 1984. Published by FAO, Rome. P 200.
- Fishery Survey of India. 2009. Hand book for field Identification of fish species occurring in the Indian Seas Marine Fishery Resources. Ministry of Agriculture, Mumbai, P. 160.

- Tamil Nadu Fisheries Statistics, 2008-2011. Office of the Department of Fisheries, Government of Tamil Nadu, Teynampettai.
- Kasturirangan, L.R. 1963. A Key for the identification of the more common planktonic copepoda of Indian coastal waters, Council of Scientific & Industrial Research, New Delhi.p.87.
- Munro, Ian. S. R. 2000. The marine and freshwater fishes of Ceylon, Biotech Books, Delhi, pp. 349.
- Ramayan, V., R. Senthil kumar and M. Rajasegar. 2002 Finfish resources of Pichavaram Mangrove Ecosystem. CAS in Marine Biology, Annamalai University, P. 94.
- Rao, R.R., 1995, Atlas of Near-surface Thermohaline Fields of the tropical Indian Ocean from Levitus Climatology, NPOL, Cochin.c
- Singh, H.S., 2000. Mangroves in Gujarat: Current status and strategy or conservation. Gujarat Ecological Education and Research (GEER) Foundation, Gandhinagar.
- Shore Protection Manual, 1975, CERC, US Army, Washington, D.C.
- Sparre, P and Venema, C. Introduction to tropical fish stock assessment. FAO Fish Tech. Paper No. 306/2.
- Talwar, P.K. and R.K. Kacker. 1984. Commercial Sea fishes of India.
- Gopinathan, C.P. Training Manual on Phytoplankton Identification/Taxonomy
- Website of Ministry of Environment and Forest - www.enfor.nic.in
- Website of Central Pollution Control Board – www.cpcb.nic.in
- Website of Tamilnadu Pollution Control Board – www.tnpcb.gov.in
- Wyrtki, K, 1971, Oceanographic Atlas of the International Indian Ocean Expedition, National Science Foundation.