ENVIRONMENTAL IMPACT ASSESSMENT, ENVIRONMENTAL MANAGEMENT PLAN AND RISK ASSESSMENT FOR THE DEVELOPMENT OF BULK LIQUID BERTH FOR HANDLING LNG AT KARAIKAL PORT

For
KARAIKAL PORT PRIVATE LIMITED (KPPL)
KARAIKAL

SEPTEMBER 2015

QS SCES 047 SWISS CERTIFICATION
ISO 9001

INDOMER
Coastal Hydraulics (P) Ltd.
CHENNAI. INDIA.

ENVIRONMENTAL IMPACT ASSESSMENT, ENVIRONMENTAL MANAGEMENT PLAN AND RISK ASSESSMENT FOR THE DEVELOPMENT OF BULK LIQUID BERTH FOR HANDLING LNG AT KARAIKAL PORT

PROJECT CODE: 484061314

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KARAIKAL PORT PRIVATE LIMITED (KPPL)
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Client	:	Karaikal Port Private Limited, Karaikal.
Project Title	:	Environmental Impact Assessment, Environmental Management Plan and Risk Assessment for the development of bulk liquid berth for handling LNG at Karaikal Port.
Project Code	:	484061314
Abstract	:	Karaikal Port Private Limited is an all-weather Port developed by MARG Group on Build, Operate and Transfer format under Public Private Partnership in terms of the concession awarded by the Government of Puducherry. The Port is in operation since 2009 and it handled over 32 Million Tonnes of various cargoes including Liquid Petroleum. Presently KPPL is planning to set up a liquid cargo berth to handle LNG on the southern breakwater. This report presents the details of the EIA and EMP aspects and Risk Assessment and Disaster Management Plan of the development of Bulk liquid cargo berth for handling LNG adopting Floating Storage Regasification Unit (FSRU)/ Storage Unit (FSU).
Foreword	:	The materials presented in this report carry the copy right of Karaikal Port Private Limited and Indomer Coastal Hydraulics (P) Ltd. This report should not be altered or distorted or copied or presented in different manner by other organizations without the written concern from Karaikal Port Private Limited and Indomer Coastal Hydraulics (P) Ltd.
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					Annexures	:	3

Declaration by Experts contributing to the EIA

I, here by, certify that I was a part of the EIA team in the following capacity that developed the above EIA.

EIA Coordinator:

Name : Dr. P. Chandramohan

Signature & Date :

Period of involvement : 01.08.13 to 30.09.15

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Functional Area Experts

Sl.No.	Functional Areas	Name of the expert/s	Involvement (Period & Task)	Signature & Date
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Declaration by the Head of the Accredited Consultant Organization/authorized person

I, Dr.P.Chandramohan, hereby, confirm that the above mentioned experts prepared the EIA report entitled 'Marine Environmental Impact Assessment, Environmental Management Plan and Risk Asessment for development of bulk liquid berth for handling LNG at Karaikal Port, June 2015'. I also confirm that the consultant organization shall be fully accountable for any misleading information mentioned in this statement.

Signature:	
Name:	Dr.P. Chandramohan
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NABET Certificate No. & Issue Date:	S.I.No. 81 & 24.10.14

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AAQM	-	Ambient Air Quality Monitoring
AQSP	-	Air Quality Surveillance Program
BOG	-	Boil-Off Gas
CAAQM	-	Continuous Ambient Air Quality Monitoring
CRZ	-	Coastal Regulation Zone
CSR	-	Corporate Social Responsibility
CMD	-	Cubic Meter per Day
CPCB	-	Central Pollution Control Board
CD	-	Chart Datum
CPCL	-	Chennai Petroleum Corporation Limited
DGS	-	Director General Shipping
DMP	-	Disaster Management Plan
DPR	-	Detailed Project Report
EIA	-	Environmental Impact Assessment
EMP	-	Environmental Management Plan
EMS	-	Environmental Management System
EAC	-	Expert Appraisal Committee
EIS	-	Environmental Impact Statement
FSRU	-	Floating Storage and Regasification Unit
FPSO	-	Floating Production Storage and Offloading
FSU	-	Floating storage unit
FY	-	Financial Year
GW	-	Ground Water
GAIL	-	Gas Authority of India
HTL	-	High Tide Line
HW	-	Hazardous Waste
HSE	-	Health, Safety and Environment
IRS	-	Institute of Remote Sensing
IVDP	-	Integrated Village Development programme
ISO	-	International Organization for Standardization
KPPL	-	Karaikal Port Private Limited
KLD	-	Kilo Liters per day
LD	-	Liters per day
LD	-	Liters per day
LNG	-	Liquefied Natural Gas
LNGC	-	Liquefied Natural Gas Carrier
LU/LC	-	Land Use/Land Cover
LTL	-	Low Tide Line
MARPOL	-	Marine Pollution
MoEFCC	-	Ministry of Environment, Forest & Climate Change
MMSCMD	-	Million Standard Cubic Meter Per Day
MTPA	-	Million Tonnes Per Annum

MLD	-	Million Liters per day
MW	-	Mega Watt
MSSRF	-	MS Swaminathan Research Foundation
NAAQ	-	National Ambient Air Quality
NABET	-	National Accreditation Board for Education and Training
NNRIS	-	National Natural Resources Information System
NH	-	National Highway
OHSAS	-	Occupational Health and Safety Management Systems
ORV	-	Open Rack Vaporizers
OSV	-	Offshore Supply Vessels
PM	-	Particulate Matter
PP	-	Project Proponent
PPCC	-	Puducherry Pollution Control Committee
PPE	-	Personal Protective Equipment
PPN	-	Pillaiperumalnallur
PPMP	-	Post Project Monitoring Plan
PUC	-	Pollution under Control
QCI	-	Quality Council of India
QMS	-	Quality Management System
QRH	-	Quick Release Hooks
RA	-	Risk Assessment
R-LNG	-	Regasified LNG
RO	-	Reverse Osmosis
RCC	-	Reinforced Cement Concrete
SHG	-	Self Help Group
SW	-	Surface Water
SPM	-	Single Point Mooring
STV	-	Shell and Tube type Vaporizers
SCV	-	Submerged Combustion Vaporizers
SCR	-	Selective Catalytic Reduction
STP	-	Sewage Treatment Plant
SCZMA	-	State Coastal Zone Management Authority
TLS	-	Truck Loading System
ToR	-	Terms of Reference
TPA	-	Tonnes Per Annum
TSS	-	Total Suspended Solids
TDS	-	Total Dissolved Solids
USD	-	United States Dollar
WLS	-	Wagon Loading System

EXECUTIVE SUMMARY

Introduction

Karaikal Port Private Limited (KPPL) is an all-weather Port developed on Build, Operate and Transfer format under Public Private Partnership in terms of the concession awarded by the Government of Puducherry. The Port is in operation since 2009 and has handled over 32 Million Tonnes of various cargoes including Liquid Petroleum. The port provides a vital sea link for the rich hinterland and thus holding the key for accelerated growth of the entire region.

Project Location

Karaikal Port is located 9 km south of Karaikal town within the Union Territory of Puducherry. The coastal orientation near the port is nearly straight and oriented in N5°E direction. The inland formation exhibits low barren land with thorny bushes. The coastal stretch comprises very low and narrow beaches. The port location is abutted by Vettar River on the south side and Paravanar river on the north side. The tidal influence in both the rivers is restricted due to the formation of sand bar at the mouth and the absence of fresh water flow from upstream. During northeast monsoon, the rivers bring large quantity of fresh water discharge draining out from the neighbouring catchment basin and the mouths get open. Nagapattinam minor port is located at about 7 km south of Karaikal Port. CPCL Oil Terminal is located at about 500 m south of the southern breakwater. Chemplast Sanmar Chemical Terminal is located at about 500 m north of northern breakwater.

Liquified Natural Gas

KPPL is contributing to India's endeavour to graduate into use of less environmentally benign fuels, resulting in less number of environmental concerns such as smog, acid rain and green house gas emission.

- *Natural gas, the cleanest fossil fuel, is a highly efficient form of energy.*
- *Natural gas burns cleaner than the other fossil fuels such as coal and oil due to the highly efficient combustion process, which produces very few by-products that are released into the atmosphere as pollutants. Due to the clean burning process, natural gas does not leave residues like soot or ash when compared to coal.*
- *Natural gas produces 70% less carbon di-oxide emissions compared to other fossil fuels.*
- *Natural gas is non-toxic and is not poisonous to humans if inhaled in small volumes.*
- *Natural gas is a multi-user fuel. It is used inside the house for cooking, generating electric power, powering vehicles (by substituting for diesel and petrol), producing plastics, paints, fertilizers, refineries, dying in textiles, food processing, steam generation and many more uses.*

The proposed terminal at Karaikal (Puducherry) is best suited to supply the natural gas to the specific geographies (catchment area) based on economics.

Existing port facilities

At present the port is capable of handling 21.5 MTPA of various cargoes like Coal, General Cargoes, Containers, Crude oil, Edible oil, Project cargoes etc. The details of the facilities are:

- *Two breakwaters one on the north side and another on the south side.*
- *Five operational berths (2 cape size and 2 Panamax size berths and 1 OSV).*
- *Approach channel with a dredged depth of (-) 16.5 m CD and Berths with a dredged depth of (-) 15.5 m CD.*
- *Open cargo storage area of about 6,50,000 m^2.*
- *Covered area for cargo storage about 63,000 m^2 (Warehouses).*
- *Three numbers of dedicated railways siding within port premises and connected to main railway line between Nagore and Karaikal.*
- *Internal roads and Road connectivity to NH 45A & NH 67.*
- *Adequate tugs, mooring boats and navigational aids.*
- *Adequate Fire fighting capabilities*
- *Adequate Pollution Control & Monitoring systems*

Proposed Bulk liquid berth for handling LNG

The present proposal involves the development of Bulk Liquid Berth for handling LNG through Floating Storage Regasification Unit (FSRU)/Floating storage unit (FSU) with LNG vessel berthed alongside and connected to the shore by means of an approach jetty. The technical feasibility study was carried out by Royal Hoskoning DHV which indicated encouraging results in terms of technical feasibility and financial viability. For the proposed development of liquid berth for handling LNG, KPPL wanted to take up the necessary EIA and EMP studies with appropriate risk assessment and Disaster Management Plan.

Organization of present report

KPPL has awarded the overall EIA study to Indomer Coastal Hydraulics (P) Ltd., Chennai, an ISO 9001:2008 certified organization and QCI (NABET) accredited organization. Indomer has taken the assistance of Aditya Environmental Services Pvt Ltd, Mumbai, a QCI- NABET accredited agency for preparing the Terrestrial EIA and EMP and ROOTS EHS Advisory, Vadodara for carrying out the Risk assessment and Disaster Management plan. The primary surveys of soil, air, noise and water monitoring analysis were conducted through Creative Engineers & Consultants, Chennai, a QCI NABET accredited agency and a NABL accredited laboratory.

Details of LNG terminal proposed at Karaikal Port

It is proposed to maintain a depth of (-) 19.0 m CD alongside of the berth. LNG upto 5 MMTPA can be handled at this berth facility. Provision of Buffer LNG storage tanks within the port also comes under the proposed project. The LNG line from the port will be directly connected to the GAIL network which is within 4 km proximity of the port. For the development of LNG Terminal at Karaikal Port, the site was selected at the southern side of the port, after considering three locations within the port, i.e. Southern side of the port, Northern side of the port and Outer harbour. A terminal option analysis *was conducted. The mooring options like Stand alone/Twin jetty, Single jetty side by side mooring and submerged turret mooring was studied and the supply chain of LNG was arrived.*

Baseline data

*The baseline data for the **Terrestrial environment** including Ambient Air quality, Noise, Ground water quality, Surface water quality, meteorlogical data on Climate and Rainfall, Traffic, Land environment (Topography, Geology, Land use and Land cover, Soil and seismicity) were collected in October 2013. From the baseline data collected it shows that the measured parameters are within the acceptable limit and as such the terrestrial environment is not polluted.*

*The baseline data for the **Marine environment** was collected in August 2013 and the secondary data available on the physical parameters such as Wind, Wave, Storm and Tsunami were compiled. From the baseline data collected on Water quality, Sediment quality, Phytoplankton, its biomass and diversity, Zooplankton, its biomass and diversity, Macrobenthos, its biomass and diversity, Turtles, Corals, Mangroves and Fisheries, Coastal Vegetation it is concluded that these parameters are within the acceptable limit and as such the marine environment is not polluted. The coastal water is clean and productive.*

Modelling

The mathematical modelling studies for the proposed development of liquid berth were conducted on Tides and currents inside port basin, Sediment transport inside port basin, Dredge disposal, Oil spill analysis, Storm surge, Littoral drift, Shoreline erosion and Beach nourishment

From the modelling study, it could be seen that the current pattern do not alter due to the construction of LNG terminal as the berthing wharf will be abutted with the shore and the FSRU will not cause any interference to the prevailing flow since it is a floating facility. There is no significant change in sediment flux and there is no change in seafloor level due to the construction of the LNG terminal. The sediment dredged during the development of LNG terminal can be disposed in the existing disposal ground or alternatively, the sediments can be deposited along the northern side of the shoreline for beach nourishment purposes. This will help better shoreline management and beach stabilization.

Risk Assessment

The Risk Assessement study covers the following aspects:

- *Assessing risk levels due to the operations of the facility*
- *Identification of the risk mitigation measures to bring the potential risk within acceptable range*
- *To suggest general safety improvement measures.*
- *To help generate accident free hours*
- *To identify emergency scenarios and suggest mitigation measures.*

The factors like Site Meteorology, Climate, Rainfall, Temperature, Humidity, Wind and Atmospheric stability has been considered for the Risk Assessment. The risk and the disaster associated with Earthquake, Wildfire, Tsunami, Mud/landslide, Damfailure, Riverine floods, Cyclone, Flash floods, Thunderstorm and lightening, extreme weather conditions, Major Industrial accidents/industrial disaster/nuclear disaster, Fire, Explosion, Toxic release and disruptive activity have been studied.

For the natural disasters like Cyclone and Tsunami, a detailed disaster management plan and Preparedness plan is presented.

Impact assessment

*The impacts on the **Terrestrial environment** including the land, air, noise, water, ecology and Socio economic status is discussed. The impacts due to Equipment mobilization, Material transport, Erection and Assembling of land based facilities in the construction phase and Traffic movement and Operation of FSU/FSRU during operation phase is studied. It can be seen that the project will have Temporary insignificant negative impacts on terrestrial environment except Socioeconomic, where it will be Temporary insignificant positive in construction phase. Operation phase will have permanent insignificant negative impacts on terrestrial environment except Socioeconomic, where it will be Temporary insignificant positive. From the impact study it could be seen that the net impact due to proposed development will not have any appreciable impact on environment and all the activities indentified as part of the project have insignificant impacts.*

*In analyzing the impacts on the **Marine environment**, the influence of Construction of LNG terminal, Dredging & Disposal, Shoreline changes, Oil spill, Storms and Tsunami, Fisheries, Turtles and Mangroves, Discharge of Coldwater are considered.*

The coastline is presently stable and this part of coastline experieces low littoral drift and it behaves close to nodal drift. The examination of water quality of this region indicated that they do not vary substantially both in vertical and spatial directions indicating 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 compare to the Inter tidal benthic fauna. The proposed development is only within the existing basin and the cargo transfer takes place straight from the FSRU to the nearby GAIL network by means of pipeline system except a small quantity for supply to small time consumers. As such the impact due to construction of the marine facility to the marine environment will be very minimal.

Environmental Management Plan

Karaikal Port has a well documented Marine & Terrestrial Environmental Management Plan (EMP). This plan is in place since commencement of operation of the port facilities in April 2009 and improved/modified suitably to suit the requirements arising out of enhanced port facilities from a 2 berth system initially to the present level. It is suggested to implement the same EMP with suitable adjustments to take care of the specific requirement of LNG handling aspects.

*EMP for **Terrestrial environment** is prepared by taking into account the construction and operation phases of the Bulk Liquid Berth for handling LNG. The plan include measures to mitigate environmental and social impacts; plan of action for execution of mitigation measures; Environmental Monitoring Program; institutional mechanism for ensuring implementation; and budget allocated for environmental management. The mitigation measures and action plan for activities like Traffic Management during Construction of Berths, Environmental Management during Landside Construction, Solid Waste Management, Hazardous Materials Management, Occupational Health Safety during the Construction Phase is discussed.*

The mitigation measures and action plan for activities like Water Pollution Control, Environmental Management during Cargo Handling, Environmental Management at Cargo Storage Areas, Port Traffic Management Plan, Solid Waste and Hazardous Materials Management, Occupational Health and Safety and Terrestrial Environmental Monitoring Plan during the Construction Phase is discussed.

*Though the proposed port activities involves construction of bulk liquid berth primary to LNG terminal, leading to certain adverse impacts initially on **Marine environment,** there is sufficient scope for mitigation measures.*

In order to limit the damage to benthos at initial stage, the bed should not be disturbed much and it is suggested that the explosives should not be used. The construction materials should be placed above one another by using proper hoisting machineries and should not be dropped on the seafloor. There should not be any sudden increase in flow velocity within the port basin.

To control the Shoreline erosion, the Port authorities have to make necessary beach nourishment scheme for stabilizing the downdrift coastline. Regular monitoring of the shoreline is essential in order to design a suitable shore protection method if needed.Oil spill contingency plan is in place to handle any accidental spill. Oil spill contingency equipments like boom, skimmer and dispersant chemicals should be stored. Oil Spill Contingency Team established at Port may be further increased and strengthened. They should coordinate with National Oil spill Committee headed by Indian Navy.

Post project monitoring

Post project monitoring is an important aspect in Environmental Management Plan. Monitoring program has to be done 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. Karaikal Port is already having a well established and documented post monitoring programme to assess the terrestrial parameters (Ambient air quality, Noise, Water quality, Land) and marine parameters (Water and sediment quality and Biological parameters) on a regular basis. The same system can be continued for the proposed expansion. The regions to be monitored can be increased and the locations can be near the proposed Liquid berth.

The results of monitoring shall be reported to Ministry of Environment and Forests, Zonal office, Bangalore, State Department of Environment, Puducherry Pollution Control Committee and National Biodiversity Authority for NIMS authority annually or as required.

The monitoring has to be organized with qualified and experienced environmental team. Standard procedure shall be followed in sample collection and analysis.

1. INTRODUCTION

1.1. Background

Karaikal Port Private Limited (KPPL) is an all-weather Port developed by MARG Group on Build, Operate and Transfer format under Public Private Partnership in terms of the concession awarded by the Government of Puducherry. It is located on the east coast of India in Karaikal within the Union Territory of Puducherry. The Port is in operation since 2009 and it handled over 32 Million Tonnes of various cargoes including Liquid Petroleum. Presently KPPL is planning to set up a liquid cargo berth to handle LNG on the southern breakwater. Present report focusses on the Environmental Impact Assessement (EIA) and Environment Management Plan (EMP) and the Risk Assessment and Disaster Management Plan (DMP) aspects of the development of Bulk liquid cargo berth for handling LNG adopting Floating Storage Regasification Unit (FSRU) with LNG vessel berthed alongside and connected to the shore by means of a jetty.

1.2. Development of LNG Terminalat Karaikal Port

KPPL had engaged a Netherland based Consulting firm Royal Hoskoning DHV, to carry out a demand analysis of LNG requirement for the country as a whole and the region in particular so as to enable Karaikal Port to make appropriate investment decision. The study has conclusively revealed that the country's requirement of imported LNG during the next two decades and a little beyond would be in the order of 700 MMSCMD against the present level of import of 60 MMSCMD leaving a supply gap of about 640 MMSCMD. The technical feasibility study, carried out by Royal Hoskoning DHV has shown encouraging results in terms of technical feasibility and financial viability.

In addition, the market survey had pointed out the following aspects favouring the development of LNG terminal at Karaikal Port.

- The supply of coal from domestic source and from other countries is in decline phase.
- Future need for power is confidently expected from LNG, Nuclear power and Non conventional energy.
- Many countries like USA, Japan, Europe and Korea are switching over to LNG. The Planning Commission of India has given thrust in its 13th Five Year Plan by encouraging use of environment friendly fuel like LNG.
- GAIL is having an existing gas pipeline network of about 276 km long which is passing within 4 km of the Karaikal Port premises. Karaikal Port is in final stage of discussion with GAIL for connectivity to evacuate LNG through this pipeline.
- The region surrounding the Karaikal Port has bulk consumers of LNG such as a refinery (CPCL), six power plants and a petrochemical plant - all of which are connected to the GAIL grid. Thus, availability of LNG will help these units in working consistently and will also result in reduced air pollution in the area.

The above reasons have prompted KPPL to take an investment plunge in this sector so as to offer its share in the nation building exercise in respect of fuel sector which is the backbone of economic and industrial growth.

1.3. CRZ Notification, 2011

The proposed activity involves import of LNG through bulk carriers, unloading, storage, transfer and re-gasification of LNG. It requires waterfront facilities falling within the CRZ areas. The proposed activity is permissible as per clause 3 (ii) (a) and (b) of the CRZ Notification of 6th Jan 2011 and will require prior permission from Ministry of Environment and Forests and Climate Change, GoI after being recommended by the Puducherry State Coastal Zone Management Authority. The Notification states that an Environmental Impact Assessment (EIA) Report including marine and terrestrial components shall be prepared.

1.4. Earlier studies and availability of secondary data

The Marine Environment Impact Assessment report prior to the construction of the port was carried out by L&T - Ramboll in 2006. The Marine Environment Impact Assessment report for the Phase II expansion was prepared by the Karaikal Port in 2009. Since commissioning of the port in 2009, regular monthly monitoring of the marine environment and adjacent shoreline is being carried out by the port. The details of various reports available till date comprising the secondary data on morphology, air quality, noise, currents, tides, water quality, sediment quality, bottom benthic animals, biological organisms etc. are:

i) Environmental Impact Assessment report, L&T-RAMBOLL Consulting Engineers Limited, February, 2006.

ii) Mathematical modelling study for development of all weather port at Karaikal, INDOMER, October 2008.

iii) Monitoring of shoreline changes and Vettar river mouth during construction phase of Karaikal Port, INDOMER, 2008-2009, 2009-2010.

iv) Environmental Impact Assessment for the phase II Expansion of Karaikal Port, Karaikal Port, April 2009.

v) Impact of Disposal of Dredged Material, DHI, April 2009.

vi) Environmental Management Plan, Karaikal Port, January 2010.

vii) Oil Spill Contingency Plan, Karaikal Port, April 2010.

viii) Emergency Response Procedures & Disaster Management Plan, Karaikal Port, June 2010.

ix) Rapid Environmental Impact Assessment/Risk Assessment study of proposed Crude oil pipeline between Karaikal Port and CPCL, M/s Cholamandalam Risk services, 2010.

x) Rapid Marine Environmental Impact Assessment and Environmental Management Plan for the Construction of Berth No. 10 at Karaikal Port, Indomer, 2011.

The pre construction marine EIA studies carried out by L&T RAMBOLL included hydrography, flow pattern of the region, water quality, sediment quality and various eco-biological characteristics. The study showed that, in general, the dissolved oxygen (DO) concentrations indicate that the waters in this area were well oxygenated to provide a healthy environment for flora and fauna. Nitrate and phosphate concentrations recorded in the waters indicated that these micronutrients are present in normal concentrations for assimilation by the phytoplankton. An examination of the data revealed that the concentration of the toxic heavy metals in the seabed sediments varied considerably as Cadmium from 0.42 to 0.67 µg/g, Lead from 50.1 to 53.6 µg/g and Mercury from 0.21 to 3.0 µg/g. Diatoms such as *Coscinodiscus* sp., *Biddulphia* sp., *Pleurosigma* sp., *Nitzschia* sp., *Chaetoceros* sp., and *Asterionella* sp., constituted the bulk of the phytoplankton in the water column. The area exhibited high biomass values of zooplankton with rich diversity. The report further pointed out that the micronutrients released during dredging would be useful to aquatic biota.

1.5. Organisation of present EIA study for setting up LNG Terminal

KPPL has awarded the overall EIA study to Indomer Coastal Hydraulics (P) Ltd., Chennai, an ISO 9001:2008 certified organization and QCI (NABET) accredited organization vide SI.No.81 for Sector 27: Oil & Gas Transportation pipeline (crude and refinery/petrochemical products) passing through national parks/sanctuaries/coral reefs/ecologically sensitive areas including LNG Terminal and Sector 33: Ports, harbours, jetties, marine terminals, breakwaters and dredging. The demarcation of High Tide Line (HTL), Low Tide Line (LTL) and Coastal Regulation Zone (CRZ) for the proposed activities of KPPL was awarded to Institute of Remote Sensing (IRS), Anna University, Chennai which is an approved agency/institution by MoEFCC. Indomer has taken the assistance of Aditya Environmental Services Pvt Ltd, Mumbai, a QCI (NABET) accredited agency having accreditation in category 7(e), Ports, harbours, break waters, dredging for conducting Terrestrial EIA and EMP aspects and ROOTS EHS Advisory, Vadodara for carrying out the Risk Assessment and Disaster Management Plan. The primary surveys of soil, air, noise and water monitoring analysis were conducted by Creative engineers & consultants, Chennai, a QCI-NABET accredited agency and a NABL accredited laboratory. Copy of their accreditation documents are enclosed as **Annexure I.**

The copies of the accreditation of Indomer Coastal Hydraulics (P) Ltd., Chennai and Aditya Environmental Services Pvt Ltd as given by QCI-NABET are presented in **Annexure I** of this report.

2. CHAPTERIZATION

The EIA and EMP Report comprises twenty four chapters covering all the requirements spelt out in ToR and an attempt has also been made to provide additional information for completeness of the current exercise to facilitate better appreciation of the contents and the objectives of this report.

Chapter 1 - Introduction: This chapter gives an introduction about the Karaikal Port developed by MARG. It gives a brief introduction about the reports prepared earlier for the Karaikal Port and the way this EIA and EMP report is organized.

Chapter 2 - Chapterization: This chapter describes about the different chapters present in EIA and EMP Report.

Chapter 3 - Description of Karaikal Port: This chapter describes about the Geographical location of Karaikal Port and the coastal morphology of the surrounding region of the port.

Chapter 4 - CSR activities of KPPL: As a part of Corporate Social Responsibility, Karaikal Port has taken initiative to improve the livelihood and the education level of the people in Karaikal. KPPL has improved the lives of people who are socially deprived through its initiatives. It has adopted villages for development. KPPL keeps itself involved as a part of the Government, Corporate and public participation. KPPL has taken a keen interest towards helping the community and their progress in sustainability journey. The CSR activities done by the Karaikal Port is presented in detail in this chapter.

Chapter 5 - Description of existing facilities at Karaikal Port: The facilities existing in the Port are described in this chapter. The traffic at Karaikal Port, Quality Management system followed in the Karaikal Port is also discussed in brief in this chapter.

Chapter 6 - Development of LNG Terminal at Karaikal Port: This chapter presents the details of the LNG, its importance and the activities proposed in the Karaikal Port for handling LNG. The activity includes import of LNG through bulk carriers, unloading, storage, transfer and regasification of LNG. The various terminals concepts considered like FSRU/FSU, barge mounted regasification unit and stand alone/twin jetty and the corresponding mooring options are discussed. To transfer the gas, a local pipeline is available within 4 km of the port on the NH45A and can be easily connected to the GAIL's network. Various alternatives were evaluated among which, it was decided to develop an FSRU/FSU and onshore double banking concept with a shore connected full fledged jetty and approach trestle system on the southern side of the Port.

Chapter 7 - ToR compliances: This chapter deals with the compliances of ToR considered in 127th meeting of Expert Appraisal Committee of MoEFCC held on 29th October 2013, vide Letter No. F. No.11-41/2013-IA.III.

Chapter 8 - Scope of EIA: The scope includes both terrestrial and marine components. The environmental impacts have been identified and assessed qualitatively based on the data collected during one season. The Scope of the baseline environmental studies as per ToR on existing environmental status within the study area of 10 km radius for the proposed site are discussed in this chapter.

Chapter 9 - Terrestrial Environment: The methodology adopted for conducting primary surveys on Air quality, Water quality, Noise, Soil, Biological environment and the Socio economic study in discussed in this chapter.

Chapter 10 - Description of baseline terrestrial environment: The studies were conducted on various terrestrial environmental parameters through primary field visits, surveys and monitoring in the month of October 2013. This chapter describes about the baseline environmental conditions in and around the project site at Karaikal Port.

Chapter 11 - Impact assessment for Terrestrial Environment: The impacts on Land, Air, Noise, Water, Ecology and the Socio economic status are arrived based on the primary surveys conducted. This chapter describes about the various impacts associated with the development of bulk liquid berth for handling LNG during the construction phase and operation phase. The scaling devised for delineating impact matrix is also presented in this chapter.

Chapter 12 - Management Plan for Terrestrial Environment: The plan to mitigate the environmental and social impacts, the plan of action for execution of mitigation measures, environmental monitoring program, institutional mechanism for ensuring implementation and effective EMP is discussed in this chapter. Karaikal Port has already devised an Oil spill contingency plan, disaster management plan, environmental plan etc. and the same can be continued for the proposed expansion.

Chapter 13 - Baseline data for Marine Environment: The marine environment has been studied for the evaluation of baseline information as per the norms stipulated by MoEFCC. The primary data collection for water, sediment and biological parameters has been done in August 2013. The results of the physical, chemical, biological and ecological parmetersare presented in this chapter.

Chapter 14 - Mathematical modelling for Marine Environment: The models such as MIKE 21 Flow model, Sediment transport, Particle analysis, Oil spill analysis, Storm surge, Littoral drift, Shoreline erosion and Beach nourishment were used. This chapter presents the details of the Numerical models and the results.

Chapter 15 - Description of Marine Environment: This chapter explains the present marine environmental conditions such as the coastal morphology, oceanographic conditions and marine facilities that are present nearby. The study conducted on the marine environment indicates that the coastal waters are relatively clean and moderately productive.

Chapter 16 - Impact Assessment for Marine Environment: The proposed development is only within the existing basin and the cargo transfer will take place straight from FSRU to the pipeline network present nearby by means of pipeline system and hence the impacts on marine environment will be very minimal. The impacts due to Construction of LNG terminal, Dredging and disposal, Oil spill, Discharge of Cold water, Storm/Tsunami and the impacts on Shoreline, Fishes, Turtles and Mangroves are discussed in this chapter.

Chapter 17 - Mitigation plan for Marine Environment: The appropriate mitigation measures for the impacts discussed in the Chapter 16 are presented in this chapter.

Chapter 18 - Management Plan for Marine Environment: A well documented Marine EMP is available in Karaikal Port and it has been used since the commencement of operation of port facilities in April 2009. It is suggested to implement the same EMP with suitable adjustments for handling LNG.

Chapter 19 - Post Project Monitoring of Marine Environment: Karaikal Port is already having the well established and documented post project monitoring programme to assess the marine parameters on regular basis and the same system will be continued for the proposed LNG Terminal. The chapter describes monitoring programme at Karaikal Port.

Chapter 20 - CRZ: HTL/LTL and CRZ demarcation study was done by IRS, Anna University, Chennai. The essence of the report prepared by IRS is given in this chapter.

Chapter 21 - Risk Assessment: This chapter deals with assessing the Risk levels during operation, identification of appropriate Risk mitigation measures, to suggest general safety, to maintain accident free and to identify emergency scenarios and to suggest mitigation measures during the handling of LNG.

Chapter 22 - Vulnerability Profile of the Port: Ports are vulnerable to natural hazards of Ocean Geo-Tectonic and metrological origin. This chapter describes the possible occurrence of natural disasters and its impacts assessment and disaster management plan. Ports absorb forces of nature and act as shield for population immediately in landward shadow, though facing losses due to damage of infrastructure, cargos and other commercial losses.

Chapter 23 - Assessment of Risk in handling LNG: This chapter describes the various risks involved in handling LNG. The hazard scenario viz. Fire related risks of LNG, Failure frequency associated with loss of containment, Risk due to vessel collision and grounding and consequence analysis carried out for Pasquill and Gifford atmospheric stability and the results are presented in this chapter.

Chapter 24 - Disaster Management Plan: Emergency/Disaster is an undesirable occurrence of events of such magnitude and nature that address the affect operations, cause loss of human lives and property as well. In order to minimize the effect of such natural calamities an effective disaster management plan is required and the management plan is discussed in this chapter.

3. DESCRIPTION OF KARAIKAL PORT

The location of the port is shown in Fig. 3.1 and the satellite imagery is shown in Fig. 3.2. The Master plan for Karaikal Port development is shown in Fig. 3.3. The present layout with existing facilities is shown in Fig. 3.4. The proposed LNG terminal is shown in Fig. 3.5.

Karaikal Port is located along the east coast of India at about 9 km south of Karaikal town, under the Union Territory of Puducherry (Fig. 3.1). The declared geographical boundaries of this port are: Lat. 10°50’00” N to Lat. 10°52’00” N and Long. 79°51’09”E to Long.79°57’23”E. The total land allotted to develop the port area is about 600 acres. The inland formation exhibits low barren land with thorny bushes. The coastal orientation near the port location is nearly straight and it is oriented in N5°E direction. The coastal stretch comprises very low and narrow beaches. The port location is abutted by Vettar River on the south side and Paravanar river on the north side. The tidal influence in both the rivers is restricted due to the formation of sand bar at the mouth and the absence of fresh water flow from upstream. During rainy days, particularly in northeast monsoon, the rivers bring large quantity of fresh water discharge draining out from the neighbouring catchment basin and the mouths get open. The CPCL Oil Terminal is located about 500 m south of the southern breakwater. The Chemplast Sanmar Chemical Terminal is located about 500 m north of northern breakwater. The Nagapattinam minor port is located about 7 km south of Karaikal Port. The port provides a vital sea link for the rich hinterland thus holding the key for accelerated growth of the entire region. The new Nagore - Karaikal railway link is passing through the western side of the Port. Karaikal Port has constructed 6 numbers of dedicated railway sidings within port premises and has connected to main railway line running between Nagore and Karaikal. The hinterland connectivity to port has been provided by connecting the port with NH45A and NH 67.

QCI approved EIA experts – site study at the port

Harbour basin

Breakwaters

Harbour basin

Vettar river mouth

Sand bypassing – north side

Inter tidal zone

Beach – south side

Beach – north side

Cargo Stacking yard

Coal stacking yard

Vettar river

Paravanar river

CPCL oil terminal - south

Chemplast sanmar chemical terminal - north

Extended breakwater - south

GLANCE AT KARAIKAL PORT

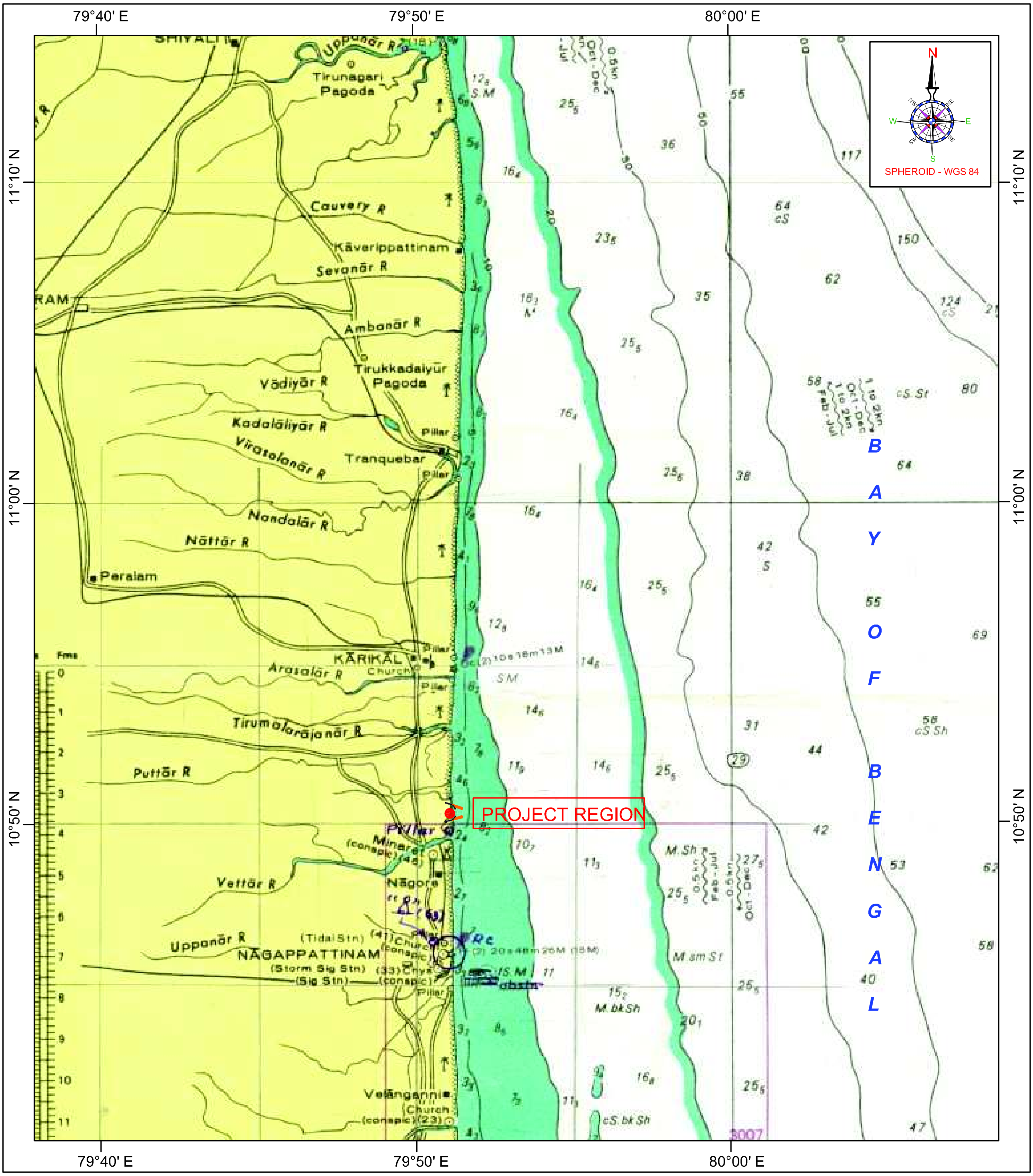
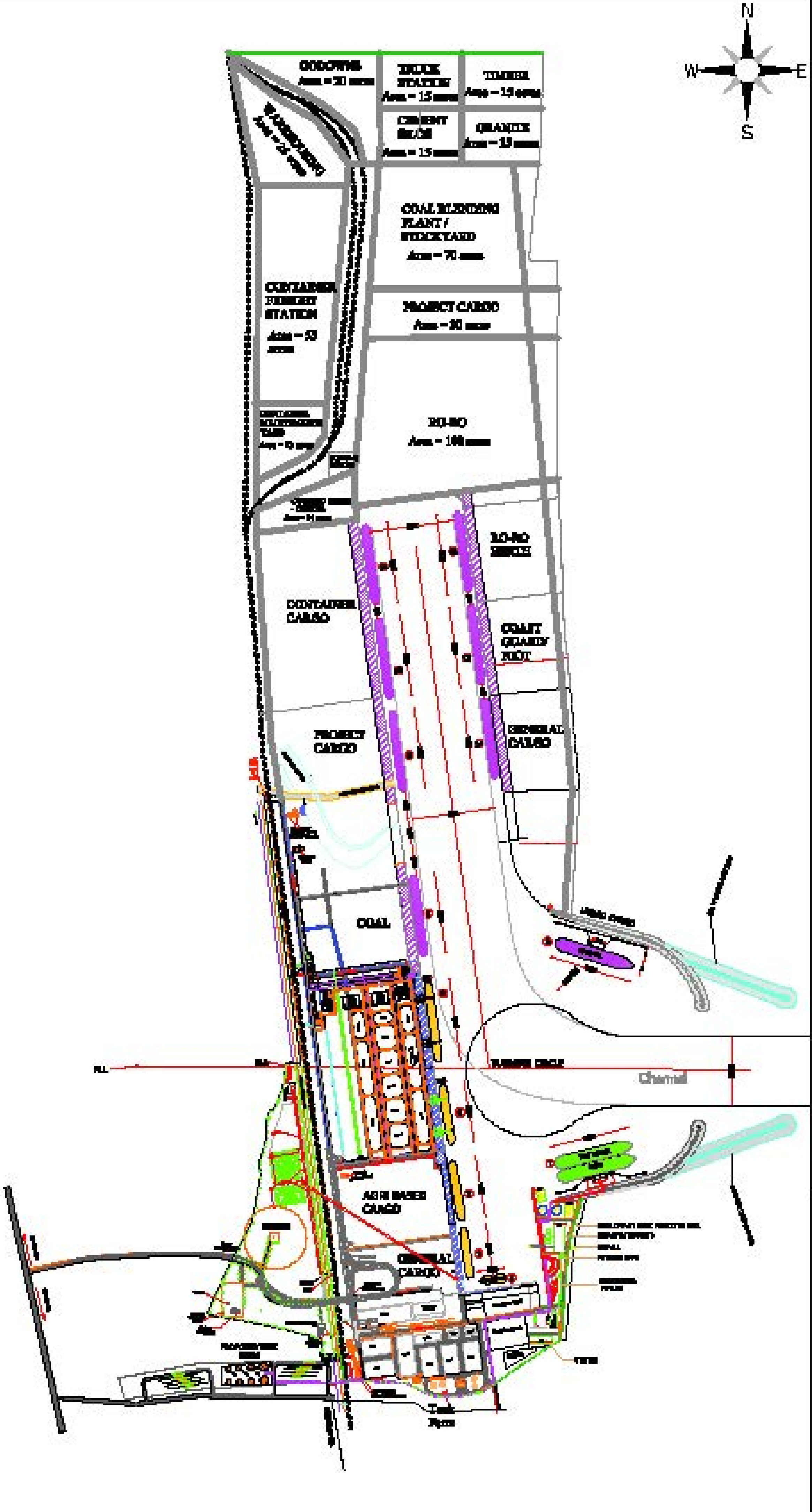


FIG. 3.1. LOCATION MAP - KARAIKAL PORT

FIG. 3.2. SATELLITE IMAGERY OF KARAIKAL PORT

KARAIKAL PORT MASTER PLAN



karaikal port

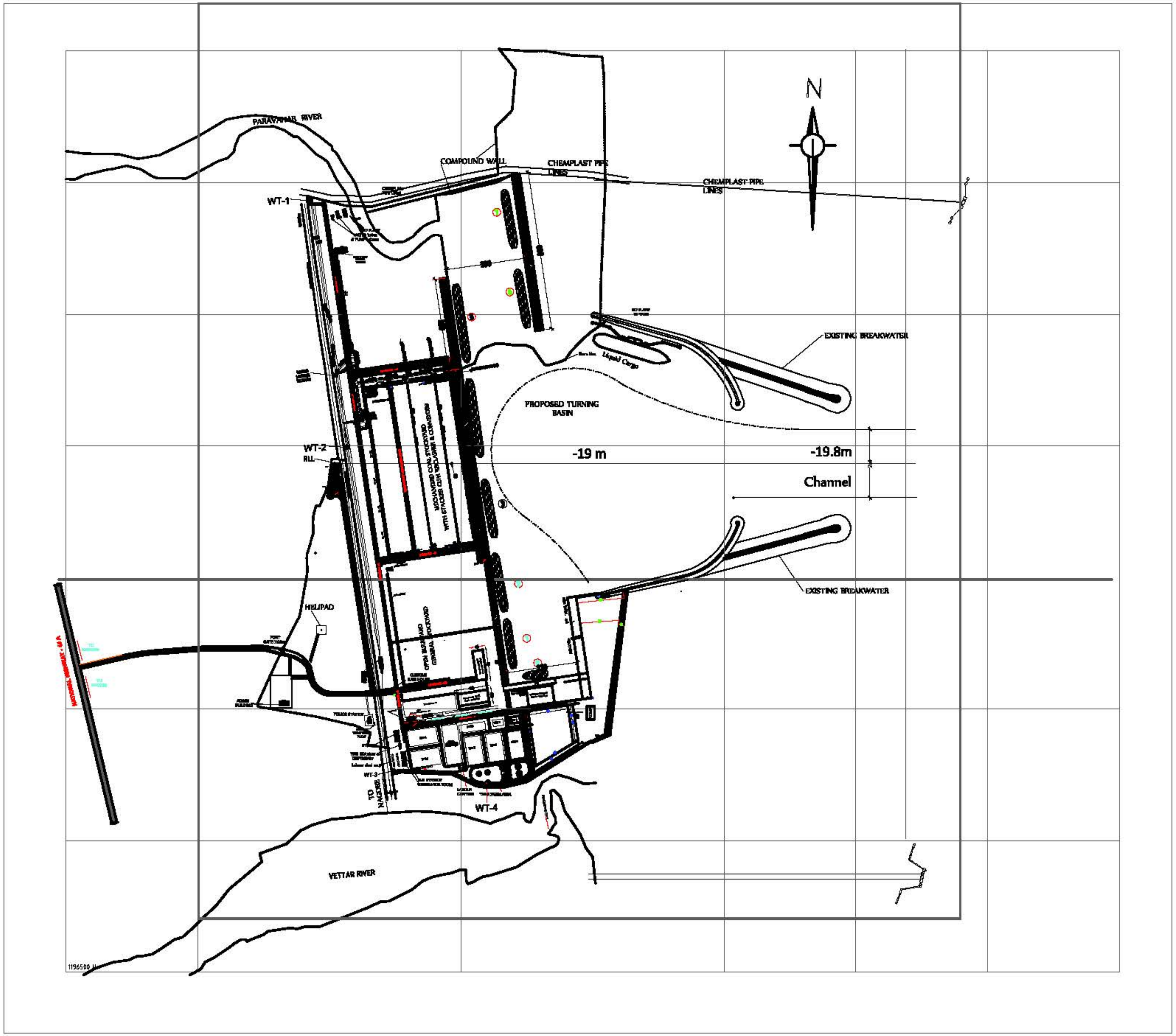


FIG. 3.4. PRESENT LAYOUT WITH EXISTING FACILITIES OF KARAIKAL PORT

FIG. 3.5. LAYOUT OF THE PORT WITH THE PROPOSED LNG TERMINAL

4. CSR ACTIVITIES OF KPPL

KPPL has taken a keen interest towards helping the community and their progress in sustainability journey.

At KPPL the approach towards CSR is made as a business model and as a holistic approach to the communities of impact. Through this model, the communities will grow in synchronous with the development happening around them thereby creating a balance in the system – both ecologically & economically. This is called in KPPL as “Inclusive Living” – simply including everyone in the process of creating and sharing progress.

KPPL through its initiatives has touched and improved the lives of people who are socially deprived. It has adopted three villages for development. KPPL keeps itself involved as a part of the Government, Corporate and public participation. Most importantly KPPL addresses the situational needs and demands of the villagers.

Amenities such as a medical help by way of medical camps, tuition classes for students during the after school hours, plying of school buses, have been provided for a better lifestyle. The people of these areas are supported through various community-building exercises ranging from providing sanitation facilities to build and maintain temples and village water ponds. Some of the major activities are listed below.

a) As part of Integrated Village Development programme (IVDP) total sanitation initiative was started at Keezhavanjore village. Through this initiative the village was developed as 100% sanitized village. 125 nos. of individual toilets were constructed.

b) An initiative for providing regular health care service for the villages of Keezhavanjore, Melavanjore and Vadakuvanjore villages, located near the vicinity of the Port. Weekly health camps are conducted in three villages by Port Medical Centre. Male, Female and Children are benefitted by this camp. medicines are distributed free of cost for diabetes mellitus and hypertension to the patients and other emergency medicines on need basis.

c) High Quality Litter Bins worth lakhs of rupees was handed over to Shri. J. Ashok Kumar, IAS, Collector, Karaikal and dumper bins to Nagapattinam Municipality in Nagapattinam.

d) Monthly driver and cleaner salaries are paid by Karaikal Port for the garbage vehicle maintained by Nagore Dhargah Sheriff.

e) Tree saplings were planted at General Hospital, Nagore.

f) Installed Reverse Osmosis (R.O) drinking water facility in Nagore & Nagapattinam.

g) Emergency outreach health support centres were set up in different areas of Velankanni, during the annual festival of Shrine Basilica.

KPPL has taken a keen interest towards helping the community and their progress in sustainability journey.

MSSRF Knowledge Connectivity Program: Various programs and meetings were organised for the fishermen and farmers in view to sensitize them with the latest technologies and information.

- 120 fishermen, 110 farmers and 100 SHG members received 2 audio advisories on daily basis
- 28 queries addressed through help line
- Fishermen feed back meeting is organized on regular basis and fisher folk from 5 villages participated.
- Phone in program **on "Career opportunities for fisheries related courses for fishermen children"** organized on 15.05.12. Totally 29 fishermen benefitted through this phone in program.
- Phone in program on **"Pest control methods in Vegetable Crops"** organized on 29.05.12. 20 farmers got benefitted.
- Community news paper distributed to all 300 subscribers on regular basis

Weekly annadhanam is provided to the orphanages in Karaikal on regular basis.

Distribution of Laptops to HSC toppers (two no.s) every year through the district collector Karaikal.

Trees were planted in the common areas of the Keezhavanjore village and Tree guards were distributed.

Refreshments were provided for Velankanni padayatras in connection with Good Friday and Annual car festival. This is done on regular basis year on year.

Sponsored refreshments for "SwachBharath Mission Campaign" launched by District Collector, Karaikal.

Livelihood: An initiative for developing sustainable income for rural women by promoting them as entrepreneurs through SELF HELP GROUP (SHG). Conveyance facilities and refreshments etc. were provided for SHG by KPPL.

Education: An initiative to reduce the school dropout and to provide special coaching for the students from Keezhavanjore, Melevanjore Mudhalimedu and Vadakuvanjore villages through organizing EVENING STUDY CENTERS. School buses were provided for nearby villagers' children.

Community Initiatives:

- Sponsoring "Clean Project" with Nagore Dargah Sheriff, Nagore
- Provided light refreshments for Vailankanni padayatras
- Contributing Welfare scheme for load men
- Contributed to the Construction of the temples in the villages
- Provided compensation for Fisherman whose nets get entangled.
- Providing sponsorship for celebration of Republic Day, Pongal, May Day, Vinayaka Chathurthi and Ayudha Pooja in the villages

Individual Toilets constructed in Keezhavanjore Village

Donated rice as a part of Thane relief fund

Health Support centers in Velankanni

Health care service in Keezhavanjore Village

Velankanni pilgrims water & food distribution

Women Self Help Group

Evening study centre

Annadhanam at old age home

MSSRF Knowledge Connectivity Program

Summer camp for students

5. DESCRIPTION OF EXISTING FACILITIES AT KARAIKAL PORT

5.1. Master Plan

The Master plan for the port development has been conceived taking into account the future cargo potential for the next 10 years. The master plan layout is shown in Fig. 3.3.

It is envisaged that the additional number of berth requirement will be six, which will cater to 45 MMTPA arising out of demand for Dry bulk cargoes such as coal, iron ore, fertilizers etc. plus containerized cargo, Liquid bulk cargoes including LNG and other unitized cargoes.

5.2. Existing port facilities

The layout of existing port facility is shown in Fig. 3.4. The main features of the existing port facilities are:

- Two breakwaters one on the north side and another on the south side.
- Five operational berths (2 cape size and 2 Panamax size berths and 1 OSV).
- Approach channel with a dredged depth of (-) 16.5 m CD and Berths with a dredged depth of (-) 15.5 m CD.
- Open cargo storage area of about 6,50,000 m^2.
- Covered area for cargo storage about 63,000 m^2 (Warehouses).
- Three numbers of dedicated railways siding within port premises and connected to main railway line between Nagore and Karaikal.
- Internal roads and Road connectivity to NH 45A & NH 67.
- Adequate tugs, mooring boats and navigational aids.
- Adequate Fire fighting capabilities.
- Adequate Pollution Control & Monitoring systems.

The port handles multiple cargoes of which the majority is coal and fertilizer import. In addition, bagged cement, project cargo and edible oils are handled including loading of offshore supply vessels. Crude import is transported by pipelines connecting to the CPCL line. Several parts of the port are under development, for example the container yard south of the offshore supply berth, the conveyors at the coal berth, the mechanized loading to the rail yard and the breakwater extension.

Breakwaters: There are two breakwaters, one on the northern side and the other on the southern side. The breakwaters are constructed with stones of different size with a filter layer over the seabed. The stones are placed and protected by concrete armour blocks. Concrete road is laid on the top of the breakwaters for a width of 7 m with a kerb wall on the seaside.

Berths: Karaikal port has five operational berths presently with a handling capacity of 21.5 MTPA of varied cargo comprising coal, general cargo, containers and liquid bulk cargoes such as edible oil, crude and petroleum products, OSV and PSV vessels etc. The total length of the berths is 1165 m with adequate backup storage and material handling facilities.

Turning circle: The diameter of the turning circle is 500 m and the depth is (-) 15.5 m CD.

Approach channel: At present, the length and width of the approach channel is 9750 m and 250 m respectively and the depth is (-) 16.5 m CD. The inner and outer channel has a dredged depth of (-) 15.5 m CD and (-) 16.5 m CD respectively and the region close to the berth has a dredged depth of (-) 15.5 m CD.

Backup area: There is a backup area behind each of the two berths for open storage of cargo. Cargo is handled in these berths using quay cranes, pay loaders etc. for efficient loading and unloading operations.

5.3. Road and Rail connectivity

The existing road leading to the project site from NH 45A has been widened and strengthened to aid the smooth port operations. The impacts associated with this activity on air and noise environments have been already taken care of by adopting suitable mitigation measures while making the road.

5.4. Traffic at Karaikal Port

The traffic to the port during last three financial years is presented below

Cargo	FY 2011-12 Actual (Million Tonne)	FY 2012-13 Actual (Million Tonne)	FY 2013-14 Actual (Million Tonne)	FY 2014-15 Actual (Million Tonne)
Coal	4.74	4.45	4.47	3.34
Fertilizer and other	1.27	2.12	1.77	1.46
Total (Million Tones)	6.01	6.57	6.24	4.80

Source: PFR for Installation of LNG Terminal - Updated

5.5. Integrated Management System (IMS) in the Port

In its pursuit of excellence towards Sustainable Development and leap beyond routine compliance, KPPL has been following and has integrated its ISO: 9000 Quality Management System (QMS), ISO: 14001, Environmental Management System (EMS), and OHSAS: 18001 Occupational Health and Safety Management Systems. The ISO certificates are given in Annexure I. All environmental initiatives are for the Port's long term objective of becoming water positive, carbon neutral and to ensure maximum possible recycling and reuse of wastes.

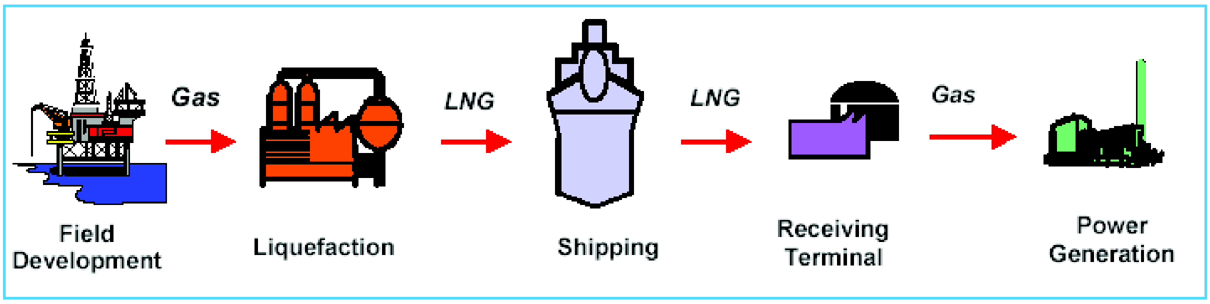
6. DEVELOPMENT OF LNG TERMINAL AT KARAIKAL PORT

6.1. LNG

Liquefied Natural Gas (LNG) is natural gas, primarily methane (CH_4), which has been cooled to the point of condensation. Typically the composition of LNG is 85 to 95% methane, along with a few percent of ethane, even less propane and butane, and possibly traces amounts of nitrogen. Liquefaction of the natural gas occurs at (-) 162°C under atmospheric pressure. Once liquefied, the LNG occupies only 1/600th of the original natural gas volume making it compact and easier to transport in large cryogenic ships. This property enables enormous volumes of natural gas to be transported as LNG in single bulk cargoes. The density of LNG is relatively low, varying between 410-500 kg/m^3, making its transportation by sea particularly efficient.

6.2. LNG Supply Chain

The LNG Supply Chain is illustrated below. The value chain incorporates four key stages: 1) extraction of natural gas, usually offshore, 2) liquefaction 3) transportation of LNG by liquid bulk carrier and 4) unloading at receiving end and 5) re-gasification of LNG into natural gas.



The process of LNG production involves the transport of the feed gas (natural gas) from the production fields via pipeline to a liquefaction plant. Prior to liquefaction, the gas is first treated to remove contaminants, such as carbon dioxide, water and sulphur to avoid them freezing and damaging equipment when the gas is cooled to (-) 162°C. The liquefaction plant is similar to a large refrigerator with compressors, condensers, pressure expansion valves and evaporators. LNG is stored as a ‘boiling cryogen liquid’, a very cold liquid at its boiling point at storage tank pressure which is slightly above atmospheric pressure. The LNG produced from the refrigeration process is piped to storage tanks and both are insulated to maintain the low temperature. LNG tanks are designed and constructed using special materials to contain the cryogenic liquid. LNG is then drawn from the storage tanks, loaded to specially equipped LNG carriers and transported to the receiving terminal where it is stored, to be regasified and supplied to end-users through pipeline, railway, barges and road tankers such as power plant, fertilizer plant and various industries including city gas distribution networks.

LNG trade is set to dramatically increase over the next decade with the development of new production facilities primarily in North America and Australia, and growth in demand from existing importers such as European countries, India and China. The upsurge in LNG marine transportation has created an unprecedented demand for new marine terminal facilities, both at the point of LNG production and at the point of reception. The worldwide existing FSRU Project and their vessel sizes are presented in Table 6.1.

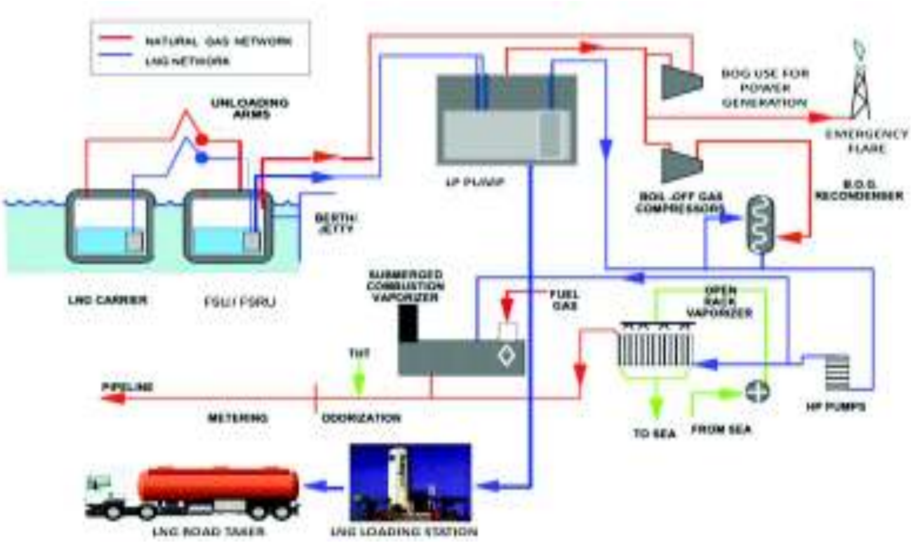
6.3. LNG Import terminal facility

The end of the supply chain is the receiving terminal. The typical onshore terminal consists of the following sections:

- Receiving
- Storage
- Regasification
- Boil-off Gas (BOG) recovery
- Final gas correction
- Auxiliary systems
- Control and safety systems

A LNG carrier delivers LNG to a receiving terminal. Following berthing, the LNG is pumped ashore via the carrier’s pumps through unloading arms to a cryogenic pipeline to the storage tanks. The length of the jetty where the loading arms are located is defined by specific site conditions, water depth and the overall length of the LNG carrier that have been selected to provide the maximum flexibility for the transportation requirements. In addition to the jetty, a turning circle will also be required to facilitate turning of the LNG carrier either on arrival or on departure.

Once the LNG tanker is docked and safely moored, LNG is gradually transferred onshore with the aid of the pumps inside the ship's tanks and the multi-purpose jetty. The jetty comprises liquid loading arms and vapour return loading arm. An insulated pipeline is used to transfer the LNG form the carrier to the terminal's LNG tanks with an unloading rate of approximately 10,000 to 15,000 m^3/hr. The capacity of the each tank varies between 60,000 $m^3$and 190,000 m^3 depending on the terminal size. Vapours generated in unloading are returned to the carrier via an insulated vapour-return pipeline, in order to keep positive pressure in the ships' tanks, thus a constant flow of pumped LNG. Besides, losses of electrical power, vapour are safely vented through the cold vent. When there is demand for Natural Gas, low pump pressures keeps the LNG moving from the tanks to the recondenser. It is the fact that stored in the storage tank; some LNG is heated to become vapour. This vapour or boil-off gas (BOG) is removed and processed by the BOG compressor before going to the recondenser. In the recondenser, BOG is recondensed and mixed with the LNG from the low pressure pumps. After that, through high pressure pumps, the LNG is moved to the vaporizers. Here the LNG is turned to Natural Gas and then transported to users with pipeline.



Receiving terminals to date are expected to operate close to 365 days per year and have spared equipment to achieve this availability. The one exception is that a shutdown may be necessary for a statutory inspection of vessels or maintenance of some critical items such as the flare. Spare equipment can be eliminated and cost savings achieved if line packing can be used or if some of the gas consumers can tolerate interruptions in the sendout supply.

The above process can be undertaken on an onshore terminal or floating terminal, the Floating Storage and Regasification Unit (FSRU) or variation thereon. Various terminal concepts are described in the following section.

6.4. Offshore LNG Import Terminal

The water depth of proposed locations is usually the variable that determines the type of main structure. An offshore LNG terminal receives LNG from oceangoing vessels, regasifies the LNG either immediately or subsequent to being stored, and delivers the LNG to the onshore market through a subsea pipeline. While offshore applications have been used successfully for a number of different petroleum products, only recent decade interest has been focused on offshore LNG facility. Such interest has been generated by the need to expand the opportunities to meet market requirements. The development and use of offshore facilities is an extension of the industry's experience over the past several decades from land-based LNG terminals, LNG ship design, and similar floating applications utilized in the petroleum sector, referred to as Floating Production Storage and Offloading (FPSO) units.

While considering siting of LNG offshore terminals, a wide range of possible locations present themselves. LNG vessels typically have a draft of 13.5 m and require at least an additional 1.0 to 1.5 m of depth to provide sufficient clearance from the sea bottom for safe maneuvering. This means that the minimum water depth for siting LNG offshore terminals will be determined by the minimum depth of water required for the safe maneuvering of the LNG vessels, which is approximately 14 m.

In addition to water depth, the distance to the shoreline has become an important factor, not only for the basic economic considerations of increased depth (in most cases) and increased pipeline length, but from that of visibility, that is visibility from the coastline. The issue of visibility from coastlines has become important in coastal areas that are not accustomed to offshore structures.

6.5. Floating Storage and Regasification unit (FSRU)/ Floating storage unit (FSU)

An FSRU consists of a modified/new build LNG vessel with a re-gasification unit retrofitted on to it. Typical FSRU facility is shown below. Existing LNG ships can be converted to FSRUs by making necessary changes to accommodate unloading arms, regasification system and utilizing the storage tank on the ship as the storage medium. The regasification process on a FSRU is similar to onshore regasification and only differs in terms of size and capacities.

Further to this, the concept of Floating Storage Unit (FSU) can be developed in which the regasification unit located onshore and LNG carrier can be used as a storage medium in order to save considerable time and cost on the construction of onshore LNG storage tanks.

Source: Hoegh LNG Lithuanian FSRU

The standard LNG vessel carrying LNG can be moored parallel or adjacent to a permanently moored FSRU or an FSU. The mooring arrangement can be a standalone mooring facility or side by side mooring for transfer of LNG from carrier to the FSRU/FSU. The liquefied gas is regasified on the onboard regasification unit (or onshore regasification unit in case of an FSU) and transferred via high pressure pipelines to the end users.

An FSRU/FSU can be moored on a permanent basis at the terminal until the onshore facilities are complete for operations. This may be assumed to be around 3-4 years depending on the commissioning of the onshore facilities.

6.6. Barge mounted regasification unit

This is similar to an FSU option with the regasification carried out on a custom built non-propelled regasification barge instead of onshore as shown below.

6.7. FSRU/FSU mooring options

FSRU is typically positioned in nearshore waters of 15 to 30 m water depth. The FSRU can be connected to the onshore transfer point via a high pressure sub-sea gas pipeline.

The various mooring options of a FSRU/FSU can be classified as follows:

- FSU/FSRU and LNGC moored stand alone/twin jetty.
- Single jetty side-by-side mooring: FSU/FSRU and LNGC moored Side-by-side
- Two separate jetties for LNGC and FSU/FSRU each.

6.7.1. Stand alone/twin jetty

The conventional FSRU and LNG Carrier are moored on a twin berthing facility independently on either side of the loading platform. The LNG is transferred from LNGC to FSRU through unloading and loading arms respectively. The gas is send-out from the FSRU to onshore through high pressure gas pipelines as illustrated below.

Features for Mooring Concepts

- The jetty is generally constructed in water depths less than 25.0 m and with operating wave heights less than 2.0 m.
- Cost of standalone jetty is higher compared to side-by-side mooring.

Facilitates smooth operating conditions and has minimum downtime.

6.7.2. Single jetty side-by-side mooring

The facility is a typical berthing facility consisting of a loading platform, berthing dolphins and mooring dolphins. The FSRU is moored to the jetty similar to an LNGC at a conventional LNG terminal. The LNGC moored directly to the FSRU, which is protected by fenders between the hulls. The LNG carrier transfers cargo to the FSRU through loading arms or flexible hoses on the FSRU, which is regasified on the FSRU and gas send-out is through pipelines either subsea or over a trestle as shown below.

Features for Mooring Concepts:

- Generally constructed in water depths less than 25.0 m and are designed to operate with wave heights less than 2.0 m.
- Considered to be of acceptable cost.
- Smooth operation with minimum downtime provided in sheltered environment.

Dolphin type mooring system

An alternative arrangement for the jetty is a set of multi-pile dolphins (mooring and berthing) to provide stability to the FSRU. A flexible gas transfer pipeline connects to a smaller gas transfer platform which in turn connects to the send-out pipeline.

- Generally constructed in water depths less than 25.0 m and are designed to operate with wave heights less than 2.0 m.
- Considered to be cost efficient.
- Smooth operation with minimum downtime. The jetty can be placed on the lee side of the breakwater which facilitates smooth unloading operations without downtime due to sheltered environment. The facility is possible for both side-by-side and standalone/twin jetty mooring.

Breakwater with Leeside jetty (Golar Freeze, Jabel Ali port, Dubai)

6.7.3. Submerged turret

The LNG vessel is moored directly to the FSRU via side-by-side mooring. The LNG carrier transfers cargo to the FSRU through loading arms or flexible hoses onboard of the FSRU, which is then regasified on the FSRU and gas is send-out through the turret system to the subsea pipelines.

Turret mooring

6.8. Routing of gas pipelines

There are two options considered for the routing of gas pipelines. The LNG from the liquid berth will sent to the regasification unit and then the regasified LNG will be routed along the south of the port. From the southern end, the R-LNG will be transferred by two options: option 1 - the pipeline will carry the R-LNG to GAIL's pipeline network located on the western side and option 2 - the pipeline will carry the R-LNG northward near to Chemplast pipeline. The routing of these two options of pipeline routings is shown in Fig. 3.5.

6.9. Cold water discharge

Cold water of 6500 m^3/hr with a temperature of 8°C will be mixed with the same quantity of seawater with ambient temperature of 28°C drawn from the Port basin and the total discharge of 13000 m^3/hr with a resultant temperature of 18°C will be released into the sea using sprinkler type diffuser laid along the slope of the breakwater. The details of the diffuser arrangement are shown in Section 14.1 - *Diffuser design–CORMIX model.*

Also the possibility of making use of the cold water for the refrigeration by fishing industry prevailing in the Nagapattinam region or the desalination plants for the Thermal energy will be explored.

6.10. Terminal Option Analysis

The following table shows the results of the multi-criteria analysis carried out for the selection of a suitable terminal concept for the development of an LNG terminal within the Karaikal port area.

Terminal Concepts Criteria	Conventional Jetty with onshore regasification	FSU with onshore regasification	FSRU	Barge mounted regasification unit
Land area requirement	• Large area land required	• Land area required is lesser compared to conventional terminal, however higher compared to a FSRU.	• Limited land area required	• Limited land area required
Time for commission	• Takes longer time to construct	• Shorter time to commission compared to conventional terminal.	• Reduced construction time, early gas send-out. Shorter time to conventional terminal. • Extensive planning not required to a conventional onshore regasification terminal (for FSRU). • Dependent on FSRU existing fleet or lead in time for converted/new build.	• Shorter time to commission compared to conventional terminal. • Depending on FSRU existing fleet or lead in time for converted/new build.
Regasification process and capacity	• Suitable for high throughputs. • Long term flexibility • Variety of regas/vaporisation options • Continuous gas	• Less capacity compared to onshore terminal • Variety of regas/vaporisation options • Possibility to combined with small LNG tanks onshore to increase send-out reliability during	• Less capacity compared to onshore terminal • Limited vaporisation options	• Less capacity compared to onshore terminal • Limited vaporisation options

	send out	cyclones.		
LNG Mooring and fluid transfer	• Conventional LNG terminal, no issues foreseen.	• Ship to ship off loading requires additional procedures, could limit supply options.	• Ship to ship off loading requires additional procedures, could limit supply options.	• Ship to ship off loading requires additional procedures, could limit supply options.
Capital expenditures	• Expensive	• Savings on construction of storage tanks, therefore lesser compared to conventional terminal. • FSU can be moved from one demand to another	• Lower capital expenditure and faster return on capital. • FSRU can be moved from one demand to another.	• High capital cost compared to FSRU, needs a FSU and barge regasification unit. However, cost comparable with new build FSRU.
Available technology	• Proven technology	• Proven technology	• Proven technology	• This is a new concept and no present operating installations identified. • Limited proven technology
Feasibility within the port	• The option is possible to develop provided land is available. • Feasible	• The option is possible if the land on the south port can be increased and developed for onshore reagasification facilities.	• Feasible	• The option can be engineered to be developed however not included due to: - Limited proven technology. - Ship to ship offloading and mooring issues.

6.11. Offshore Terminal option: advantages and disadvantages

Advantages	Disadvantages
The orientation is independent of approaching waves and current direction	Preferably operated offshore, high expenses on the submerged pipeline to the shore.
Easier permitting process	High costs involved in acquiring new build ships with turret and tower yoke options.
Reduction in safety and environmental concerns.	Some unloading downtime can be expected
Can be fabricated for existing vessels and available in new build	LNG transfer issues due to ship Motions

6.12. Need of the Project

In India, contribution of natural gas, as a primary energy source is only around 10% (Source: BP statistics, 2014) as compared to the world average of 24%. There is room for growth even accounting for the fact that gas may not be able to displace coal (attributable to fuel availability) in the power sector to the extent it may have in other developed countries. Overall macroeconomic conditions are likely to determine the demand for energy and the growth rate of energy demand. Demand growth has been very positive and sectors like consumer durables, cars, two-wheelers and telecommunications are seeing strong growth. The robust growth outlook for the Indian economy and the resultant increase in the end–user consumption of the natural gas is expected to drive the natural gas market in thefuture. The terminal at Karaikal will help southern region's customers particularly from Tamil Nadu and Puducherry state to meet existing shortages and incremental gas demand.

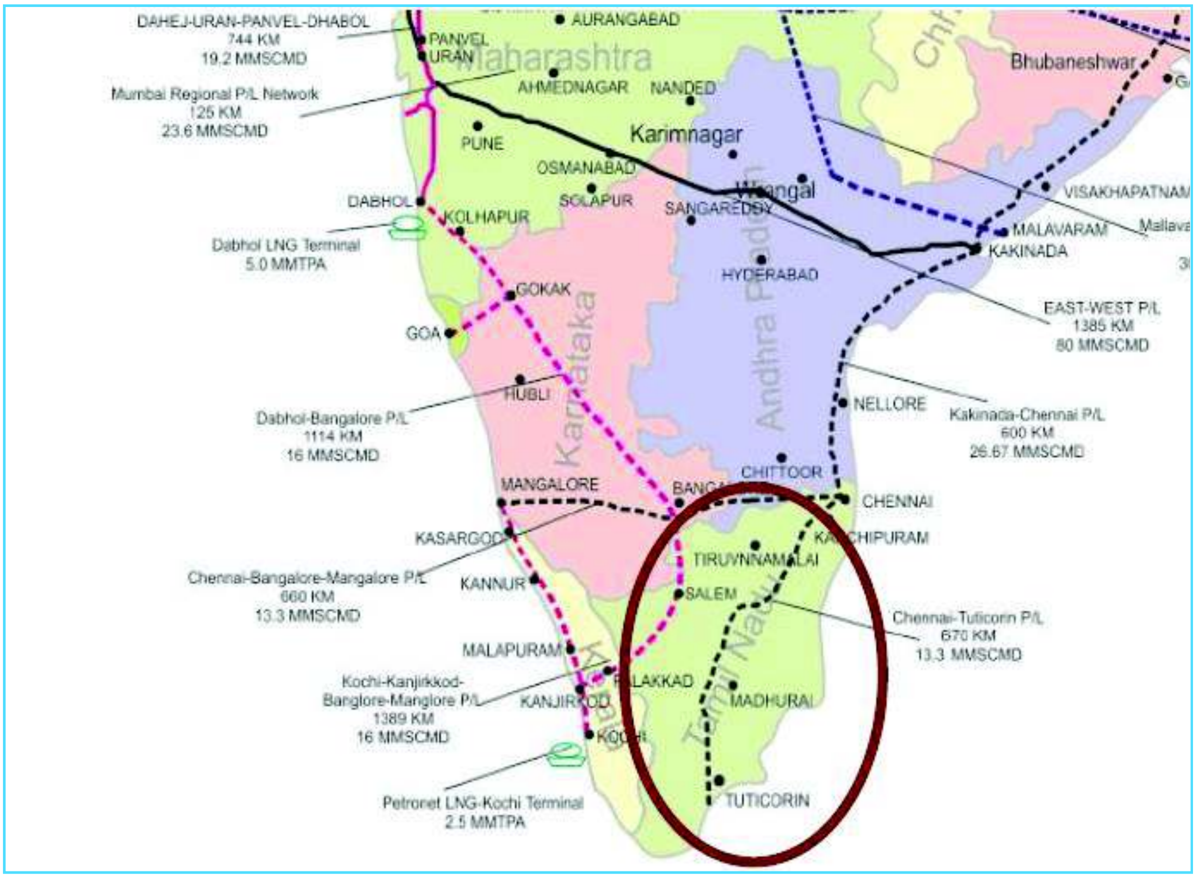
Environmental Benefits of LNG

Using natural gas to replace less environmentally benign fuels can help India address simultaneously a number of environmental concerns, such as smog, acid rain and greenhouse gas emissions.

- Natural gas, the cleanest fossil fuel, is a highly efficient form of energy.
- Natural gas burns cleaner than the other fossil fuels such as coal and oil due to the highly efficient combustion process, which produces very few by-products that are released into the atmosphere as pollutants.Due to the clean burning process, natural gas does not leave residues like soot or ash when compared to coal.
- Natural gas produces 70% less carbon dioxide emissions compared to other fossil fuels.
- Natural gas is non-toxic and is not poisonous to humans if inhaled in small volumes.
- Above all, Natural gas is a multi-user fuel. It is used inside the house for cooking, generating electric power, powering vehicles (by substituting for diesel and petrol), producing plastics, paints, fertilizers, refineries, dying in textiles, food processing, steam generation and many more uses.

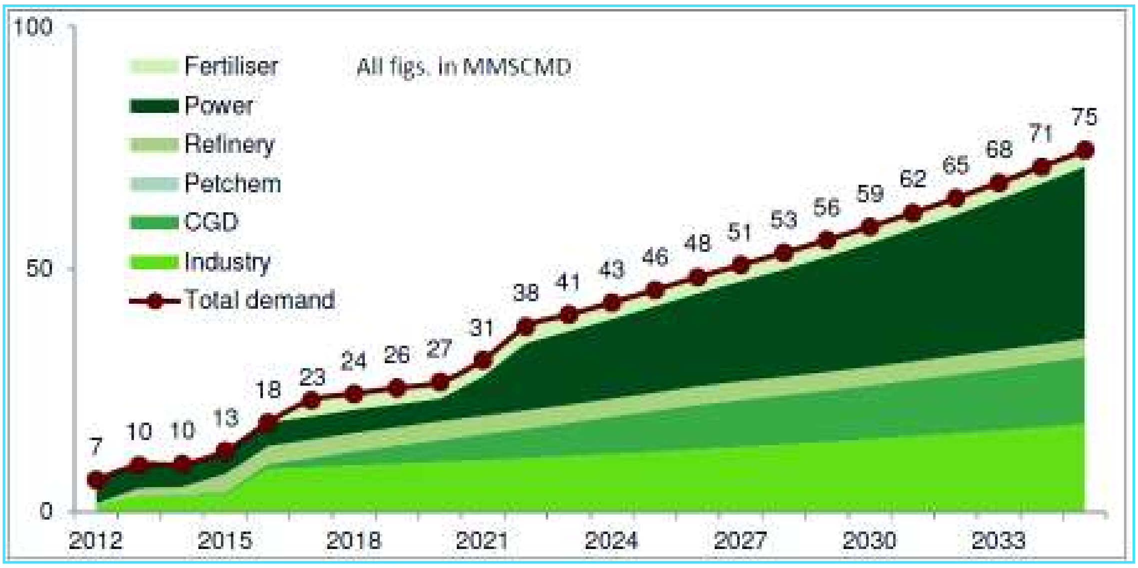
Gas demand from catchment area

The proposed terminal at Karaikal (Puducherry) will be best suited to supply the natural gas to the specific geographies (catchment area) based on economics.

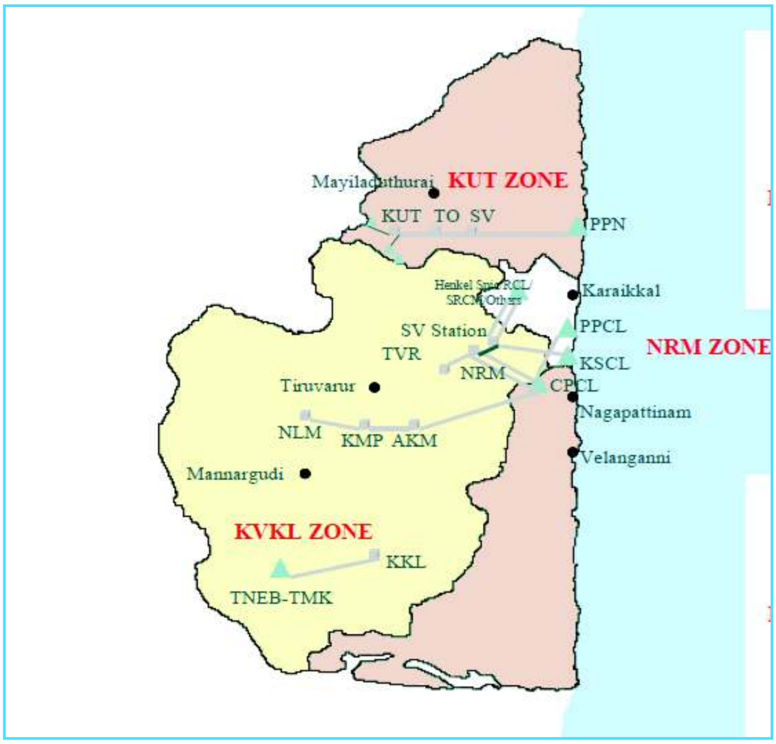


Proposed LNG Project at Karaikal Port and catchment area

The demand for natural gas in the catchment area is expected to increase from 7 MMSCMD in FY12 to 75 MMSCMD in FY35 at a CAGR of ~11%. Demand from the power sector contributes ~75% to the overall demand in FY12. However, this contribution is expected to decrease to 56% by FY35. The contribution to the overall demand from the fertilizer, industries and CGD and refinery sectors is expected to reach 4%, 20%, 16% and 4% respectively by FY35.



Gas demand from catchment area



Existing GAIL's Pipeline Network in the Catchment area

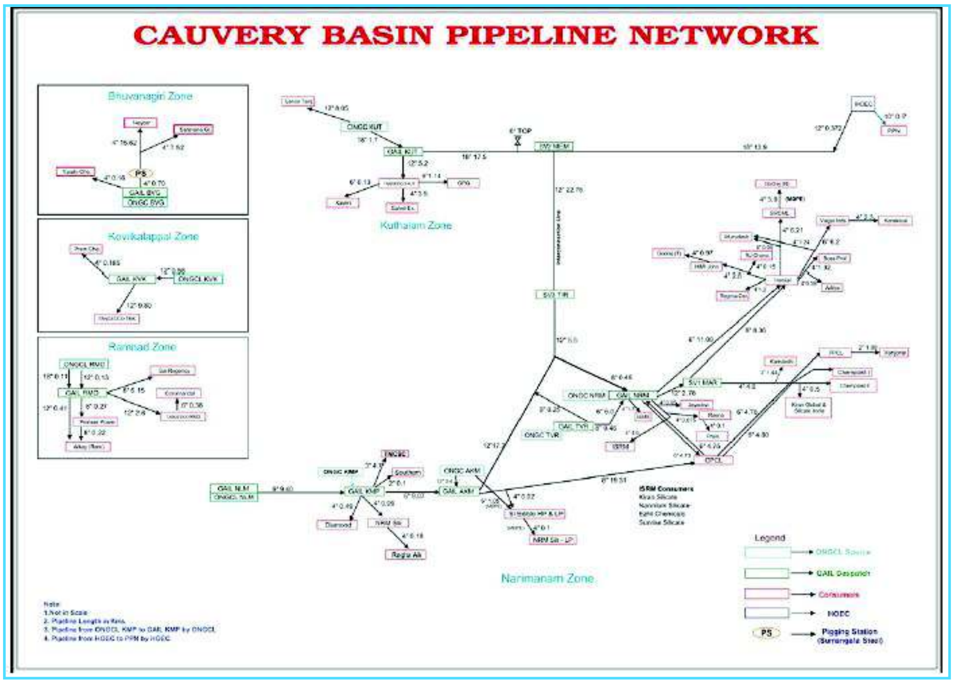
6.13. Evacuation method

R-LNG from Karaikal port intends to evacuate by following means:

i) <u>R-LNG through Pipelines</u>

- To GAIL's Cauvery basin pipeline network of 276 km, with capacity to transport ~ 8.6 MMSCMD. This local network is available within 4 km of the port on the NH45A and can be easily connected to the pipeline.
- Direct gas pipeline from Karaikal port to connect to GAIL's 18" inch Kuthalam Zone Pipeline to PPN power near Thirukadaiyur (approx. 35 km distance), which currently transports gas from HOEC fields.
- There is also a possibility to connect to the National Grid of pipelines. The nearest national grid now is Salem. However, IOC is planning a pipeline to run from Chennai to Nagapattinam & this will run very close to port once completed.

ii) <u>By Road trucks</u> / ISO containers in liquid form using dedicated Truck loading station in port.



6.14. LNG Project Site Justification

Several alternatives have been evaluated which among others include i) locating the terminal on the north breakwater region, ii) offshore as an SPM facility and iii) along the south breakwater.

With a shallow slope at Karaikal's foreshore, the required depths are available at approx. 30–40 km offshore leading to lengthy high pressure subsea gas pipeline therefore leading to high costs (approx. 2.0 Million USD per km).

Considering the pros and cons, the development of a Liquid Berth for handling LNG Import and facilities within the sheltered location of Karaikal port is preferred over an offshore option for the following reasons:

- High costs involved in acquiring new build ships with turret and tower yoke options.
- High expenses on the submerged pipeline to the shore.
- Some unloading downtime can be expected compared to sheltered condition
- LNG transfer issues due to ship motions
- High uncertainty in terms of technology
- High operational costs
- Out of port boundary

In view of the above disadvantages, offshore option is ruled out due commercial viability and smooth operation issue.

6.15. Location study for setting up LNG terminal in the port

The following possible locations were studied and analysed:

- Southern side of the port
- Northern side of the port
- Outer harbour

Option 1 - Southern side of the port

The southern area mainly consists of coal/other cargo berths, southern breakwater and port buildings including tank farms. The present Bulk Liquid Berth for handling LNG is proposed on the south breakwater and adjacent backup area, which is far away from other operational berths. The development of the Bulk Liquid Berth for handling LNG in the south of the port is therefore considered more preferable for a FSRU/FSU system.

Option 2 - Northern side of the port

The northern region consists of northern breakwater, a third party jetty (Sanmar liquid cargo jetty on the north of the northern breakwater) and River Paravanar flowing adjacent to the northern breakwater. In view of these issues locating the LNG facilities on the northern side is not an appropriate location at this stage. Further, routing of LNG pipelines will be extremely complex on the northern side.

Option 3 - Outer Harbour

The outer harbour region is also an option considered for the LNG terminal. The major disadvantage is the laying of subsea pipeline to the shore which is not only time taken but also costly. In addition, operation also depends on favourable weather conditions, which impose restrictions on the number of operational days. In these circumstances, it is not considered as a favourable option.

6.16. Selection of site: Southern side of the port

After detailed study and weighing the pros and cons of the all options, the most feasible, advantageous in terms of safety, technical feasibility, commercial aspects etc, location was emerged as Option-1 to locate the FSRU/FSU and setting up the berth. The preferred option fell in favor of developing the facility along the south breakwater. The final layout is shown in Fig. 3.5 and the highlights are as follows;

Safety aspects at Southern side of the port:

Availability of safety distance: Adequate safety distances are available from other passing ships and hence minimal risks are identified for the moored LNG carrier.

LNG vessel access, maneuvering and departure: The channel has adequate space for expansion of the existing channel to provide access to LNG vessels. Once in the basin, sufficient safety distances and area is available for maneuvering and berthing with assistance of tugs.

Berth orientation, Emergency exit: Berth located within the sheltered waters provides adequate tranquility within the basin; the berth is located close to the breakwater providing a safe and a quick exit of vessels in case of an emergency.

On the basis of the detailed study as discussed above, it was decided to develop an FSRU/FSU and onshore double banking concept with a shore connected full-fledged jetty and approach trestle system.

6.17. Description of proposed facilities at Karaikal Port

The present proposal involves the development of Bulk Liquid Berth for handling LNG and it is proposed to maintain a depth of (-) 15.5 m CD alongside of the berth. LNG upto 5 MMTPA can be handled at this berth facility. Provision of Buffer LNG storage tanks within the portalso comes under the proposed project. The LNG line from the port will be directly connected to the GAIL network which is within 4 km proximity of the port. The layout of the port with proposed LNG terminal is shown in Fig. 3.5.

Breakwaters: There are two breakwaters, one on the northern side and the other on the southern side. The proposed Liquid berth for handling will be setup along the south breakwater.

Berths: A Bulk Liquid Berth will be developed for handling LNG through FSRU/FSU with LNG vessel berthed alongside and connected to the shore by means of an approach jetty.

Turning circle: The diameter of the turning circle from the present 500 m and the depth of (-) 15.5 m CD will be increased to 600 m and (-) 19.0 m CD for the development of bulk liquid berth.

Approach channel: For the proposed LNG terminal requirement the length of the approach channel will be 11000 m, the inner and outer channel will be dredged to a depth of (-) 19.0 m CD and (-) 19.8 m CD respectively. The width of the approach channel will be 260 m.

6.18. Summary of LNG project description

The design capacity of the proposed LNG terminal will be 5 MMTPA (Million Tonne per Annum) with appropriate operational flexibility up to maximum 6 MMTPA. The proposed LNG terminal project will consist of development of following facilities.

A modern LNG Terminal facility will be developed to meet 3 main requirements:

- Full operability for a full range of LNG Carrier sizes equivalent to 20,000 m^3 up to more than 267,000 m^3.
- Constant & high number of transfers, 1 per week or more equivalent to more than 50 loadings per year
- Largest possible operability envelope in harsh conditions equivalent to a maximum up time (95%)

Summary of LNG Project	
LNG Terminal	
Design Sendout Capacity	Max. 5 MTPA (million tonnes per annum)
Peak sendout Capacity	Max. 6 MTPA (million tonnes per annum)
Floating Storage Unit (FSU)	
FSU 1 - Permanently Moored Ship	LNG Storage Capacity Max. Upto 267,000 m^3
FSU 2 - Permanently Moored Ship/Barge	LNG Storage Capacity Max. Upto 138,000 m^3
LNG Carrier accessible to terminal	
LNG carrier size range	20,000 to 267,000 m^3
Berth & Mooring System	
No of Berth/Jetty	One (650 Meter)
Mooring System	Combination of Breasting dolphins & Mooring dolphins
Capital Dredging – around 14 x 10^6 m^3	
Turning Circle • Diameter • Depth	 • 600 m from the existing 500 m • (-) 19.0 m CD
Approach channel • Width of approach channel • Depth at Outer channel • Depth at Inner channel	 • 260 m from existing 250 m • (-) 19.8 m CD • (-) 19.0 m CD

LNG Receiving system	
LNG unloading Rate	Upto 24,000 m^3/hour
LNG unloading arms	LNG: 2 sets; vapor: 1 set; common spare: 1 set
Flexible Cryogenic Hoses	LNG: 4 sets; vapor: 1 set; common spare: 1 set
Regasification System	
Gas Send Facility	Max. 18 MMSCMD (million standard cubic meter per day)
Peak send out Capacity	Max. 22 MMSCMD (million standard cubic meter per day)
Regas Technology	
There are a number of different types of LNG vaporizers in use today. The five most common applications included below and one or combination will be used: • Shell and Tube type Vaporizers (STVs) • Open Rack Vaporizers (ORVs) • Submerged Combustion Vaporizers (SCVs) • Combined Heat and Power units with SCVs and • Ambient air-Heated Vaporizers	
Onshore Storage Tanks	
Total Storage Capacity	Upto 380,000 m^3
Number of tanks	Upto 10
Pipelines & Onshore Receiving Facility / Gas Metering Station	
LNG Pipeline	Upto 24" Inches (approx 1 km)
Natural Gas Pipeline	Upto 36" Inches (approx 5 km)
Metering Station - Plot dimensions	100 m *100 m
Road Tanker/Truck Loading Station	
Plot dimensions	150 m *150 m
- Rubble mound shore protection wall is proposed to be constructed along the southern shore adjacent to area designated for truck loading facilities - Area between Rubble mound shore protection wall to be filled up with dredged material and to be used for truck loading facilities	
Primary Support Facilities and Systems	
Power requirement	Max 22 MW, 250 kVA
Ballast water requirement	• FSU: average 14,900 m^3/day • LNG Carrier: During unloading of LNG, an average of about 6,500 m^3/hour of sea water would be taken in by a 170,000 m^3 LNG carrier (and upto 7,500 m^3/hr for a 267,000 m^3 LNG carrier)
Sea water requirement for LNG vaporization	• FSU: approx 16,500 m^3/d • LNG Carrier: 710 m^3/hour by a 170,000 m^3 LNG carrier (and upto 850 m^3/hr for a 267,000 m^3 LNG carrier)
Other Utilities : Open drains and oily water treatment, fuel gas, utility water, the hypochlorite system, potable water, wash down, nitrogen generation and high pressure storage, wastewater treatment, diesel fuel, aviation fuel, the emergency flare system and fire and safety systems.	

The main components of the proposed LNG Regasification Facility are discussed in detail below.

The project comprises the following key components:

- A trestle jetty (the LNG jetty)
- mooring dolphins and breasting dolphins for the FSU/FSRU and for LNG carriers
- The FSU/ FSRU –permanently moored to the jetty;
- Onshore LNG Storage Tanks
- Regas unit
- LNG carriers supplying LNG to the FSU/ FSRU
- Gas Metering Station onshore
- Export gas pipeline – running from the FSU/FSRU/Onshore storage to the Gas Metering Station and then to GAIL tie in pipeline at port custom gate
- Road Truck loading station
- Utilities

6.18.1. Floating Storage Unit (FSU):

FSU conversion is a promising option for older tonnage that is coming off long-term charter. Ships that are 25 years or older are typically under about 126,000 m^3 capacity are the approximate size of vessels that have been converted to FSUs. Moss or membrane containment vessels can be converted into FSU. At first it may seem that membrane ships are well suited for conversion because they have flat decks suitable for locating regasification equipment. However, deck space is limited; it is above the cargo tanks and has LNG cargo lines. Moss ships have less apparent flat deck space but space is available between the cargo tanks, and above the ballast tanks and void spaces, and the areas are relatively free of pipelines. Typically, Moss containment is favored because Moss tanks are better than membrane tanks at withstanding sloshing loads. Also Moss tanks can be operated at any fill level, unlike membrane tanks, which have fill restrictions to prevent potential sloshing damage.

FSU, having tank capacities of 126,000 to 150,000 m^3 has been mostly in use. KPPL propose to use two LNG vessels of different sizes as a Floating Storage Unit will be positioned in two phases depending on the increase in market demand for natural gas. This will allow KPPL to source vessels at a competitive price compare to single larger vessel and use storage capacity optimally. The First large FSU will have the designed storage capacity upto 267,000 m^3 and other small FSU/barge will be approxupto 138,000 m^3. The second FSU can be a LNG vessel or a barge, and will be deployed only if it is needed.

Although it is proposed to use both LNG vessels as a Floating Storage unit (FSU) and Regasification unit will not be developed over the floating storage unit. However, in order to meet the commercial operation schedule and cost competiveness, KPPL may construct a Regasification Unit over one of the FSU. In this case, FSRUs will also serve the purpose of stop-gap arrangements until onshore facilities are developed.

6.18.2. LNG carrier acceptability at the port

The common size of LNG carrier for long haul now is 145,000 m^3. The rise of carrier size will result in changes in berth design, storage tank capacity, harbour design featuring channel depth and turning basin and harbour traffic control. With respect to economies of scale, the bigger the size of the LNG carrier is, more beneficial the project is. LNG tankers of 145,000 m^3 with maximum draft of 12.3 m typically need at least an additional about 1.5 m of depth to ensure safe manoeuvrings. This means that the minimum water depth for sitting a LNG vessel is approximately 14 m. The proposed facility shall have the ability to receive, berth, and unload LNG Tankers with the storage capacity of 20,000 m^3 to 267,000 m^3. The detailed vessel specifications are given in Table 6.2.

6.18.3. Jetty based berthing and mooring system

The FSU marine facilities shall consists of 8 breasting and 8 mooring dolphins to moor upto 267,000 m^3 FSU and a range of LNG carries from 20,000 m^3 to 267,000 m^3 to be berthed alongside an FSU. LNG ships would berth anytime of the day or night, subject to suitable weather conditions. Considering the FSU/FSRU as a permanent moored structure and shall not leave the berth even during adverse environmental conditions. The above mentioned 3 conditions together require a fully flexible LNG transfer system which can operate with minimum maintenance and ensure a long life time before any major change out programme is needed.

6.18.4. Development of multipurpose Jetty to handle other liquid bulk cargoes -LNG

The jetty system will comprise the berthing dolphins, mooring dolphins, approach trestle etc which can handle all types of liquid bulk cargoes such as LNG (as proposed now), petroleum products, edible oils, LPG, chemicals, crude oil etc and has the inbuilt flexibility. The jetty has a throughput capacity of some 6 to 7 MMTPA, which depends on the type of cargo, size of vessels and other factors having influence on the capacity. It is envisaged that even in the normal circumstances there will be a surplus capacity of 1 to 2 MMTPA. In the event of LNG demand which is forecast to be within a range of 3 to 5 MMTPA now, not materializing to this level, then this may result in further surplus capacity to the extent of shortfall in LNG traffic. This aspect has been considered in the planning process considering the technical and commercial aspect with a view of optimizing the potential throughput capacity of the proposed jetty system. In a way, the jetty will be a multi-purpose liquid bulk cargo handling jetty. The jetty will have provision for other liquid bulk Ship loading/unloading facilities with requisite pipeline manifold.

The LNG jetty will be constructed along the southern breakwater; the jetty will be upto 650 m long. The trestle structure will support the LNG pipline and vapour return lines, utilities including fire-fighting water supply and a upto 5 m wide roadway.

An LNGC-FSU/FSU side-by-side berthing and mooring typically consists of 4-6 fenders for berthing and 16-18 mooring lines for mooring a standard LNG carrier for a side by side mooring. The each mooring lines typically consists of 6 bowlines, 6 stern lines, 2-3 spring line from bow, 2-3 spring lines aft.

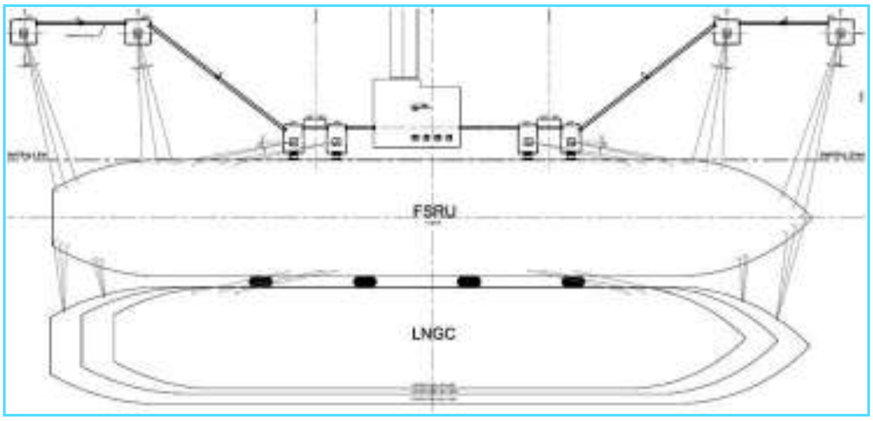
The berthing dolphins shall consist of concrete pile cap structures and provided with energy absorption fenders to accommodate the energy requirements during berthing and the wind/current/wave forces from moored vessels. Remotely operated quick release hooks and capstans shall be provided for vessels spring lines.

In general terms, the berthing dolphins shall consist of:

- Fendering
- Double Quick Release Hooks with integrated motorised capstans.
- Rope guard along frontal periphery of the dolphin.
- Area lighting and safety features;
- Walkway seatings.

The mooring dolphins shall consist of concrete pile cap structures. In general terms, the mooring dolphins shall consist of:

- The outer 2 dolphins shall have quadruple Quick Release Hooks (QRH) and inner 2 dolphins shall be equipped with triple quick release hooks with integrated motorized capstans.
- Rope guard along frontal periphery of the dolphin.
- Area lighting and safety features;
- Walkway seatings.



Typical Mooring arrangement

Pneumatic fenders

Use of Special Tugs

A large LNG tanker becomes difficult to steer and cannot easily change direction on its own when it slows down, so tugboats will help LNG carriers to steer and control their speeds as they arrive at, and leave the jetty. In general, four 3,000 to 4,000 HP tugboats will help an LNG carrier as it arrives at, and leaves the jetty.

- Four (4) tugs will be utilised for all berthing/unberthing operations.
- Two tugs will act as escorts from the channel entrance (2*65-80 t bollard pull).
  - Two harbour tugs (2*40 t - 60 t) will join the inbound vessel for vessel maneuvering in the vicinity of breakwater
  - Two escort tugs will be utilised for both inbound and outbound transits.
- A standby tug with full fire fighting capability will be on station whilst an LNG vessel is at the berth.

Typical berthing by using tugs

The access trestle consists of concrete crosshead supported on piles. The access road shall be supported on RCC beams and piping is supported by steel/concrete beams spanned between two concrete crossheads.

The width of the road way shall be 5.0 m with vehicle crash barriers and safety railings on either side of the roadway with minimum 1.2 m height. Provisions for a cable tray shall be made on the approach trestle to carry communication, electrical and other instrumentation lines.

The general requirements for the trestle are summarised below:

- The trestle shall connect the land based facilities to the unloading platform;
- The trestle shall be suitable to withstand all environmental loads from wind, waves, currents, earthquakes, etc. without losing its stability and function;
- The trestle shall provide support for all topside structures, facilities and superimposed loads, including:

- Support to piping such as gas transfer lines, waterlines, and utilities line. (Cryogenic lines if converted to a conventional LNG terminal in future).
- Support to electrical/instrumentation & control cables trays or ladders;
- Fire truck and 10 tonne capacity mobile crane in travelling mode only
- Underside of the cross beams shall be at sufficient level above SWL to avoid wave slamming and shall be set to minimum required soffit level.
- Access road may have prefab concrete deck slab elements connecting the loading platform to the shore. The road shall have clear width between kerbs of at least 3.5m;
- Pipe rack width: 5.5m
- Walkways;
- Area lighting;
- Safety equipment;
- Security equipment

6.18.5. LNG Receiving system (either through LNG Loading Mechanical Arms or Flexible Cryogenic Hoses)

LNG carriers would berth along the starboard side of the FSU; only one LNG carrier would be allowed to berth at a time. Each LNG carrier would be secured to the FSU using mooring lines equipped with quick-release hooks that would be permanently attached to the FSU. Floating pneumatic fenders would be used to separate and prevent contact between the hull of a moored vessel and the side of the FSU while the vessel was berthed at the FSU.

The unloading area near the carrier berth would support the primary equipment needed to safely unload LNG, including four LNG loading and vapor return arms; loading arm power packs and controls; LNG and vapor transfer piping and manifolds; gas and fire detection, fire protection, and firefighting facilities; life-saving equipment; telecommunications equipment; an access gangway; and a small crane. LNG loading and vapor return arms would be 16 -24 inch-diameter fixed structures attached along the starboard side of the FSU approximately mishap, with two arms serving as LNG loading lines, the third arm serving as a vapor return line, and the fourth arm serving as either a loading or vapor return line.

The loading arms would be similar in design to those used at existing onshore LNG terminals, but a more flexible articulation at the point of connection with the LNG carriers would permit LNG transfer under a wider range of sea state conditions. The transfer of LNG from the carriers would take place at a maximum rate of 4,000- 5,000 m^3 per hour per arm. The vapor line would be capable of transferring gas vapors generated during the unloading operation at a rate of 8,000-15,000 m^3 per hour. The portion of the hull beneath the LNG loading arms would be armored to provide additional structural protection in the event of an LNG spill during loading. The area also would be curbed to direct any spilled LNG overboard.

Example of LNG Unloading Arm Installation

The berthing area would be equipped with protective and emergency safety systems, including emergency release mechanisms in the LNG loading arms, protective steel ladding on the FSU in the vicinity of the loading arms, leak and fire detection and alarm systems and personnel protection equipment.

The expected frequency of LNG transfer cargo operations at Karaikal port would be one or two times per week and the average time between berthing and unberthing would be twenty hours. The berthing operation involves a tug-assisted approach of the LNG vessel to the FSU.

Flexible cryogenic Hoses Loading

The system uses 2 to 4, 20-inch diameter hoses, two for LNG and one for the vapor return, in a hanging catenary between a loading crane boom and the LNG tanker. The loading sequence is envisioned to occur as follows. The LNG shuttle tanker is brought into position assisted by tugs or dynamic positioning. A hawser is connected between the terminal or plant and the tanker and is maintained taut by tug assist, dynamic positioning or other means. The loading boom is positioned pointing toward the tanker. A winch line attached to the end fitting of the hoses is used to lower them into position to permit connection to the loading piping aboard the tanker.

When both the loading and vapor-return hoses have been connected and properly tested and recooled, transfer can begin. The disconnect sequence would occur in reverse order. When the loading system is not in use, the hose boom is rotated so that the tanker end of the hose string can be lowered into a protective cradle. This minimizes the fatigue loads on the hose and facilitates inspection, testing and maintenance of the hose.

Example of unloading of LNG through Flexible Cryogenic Hoses

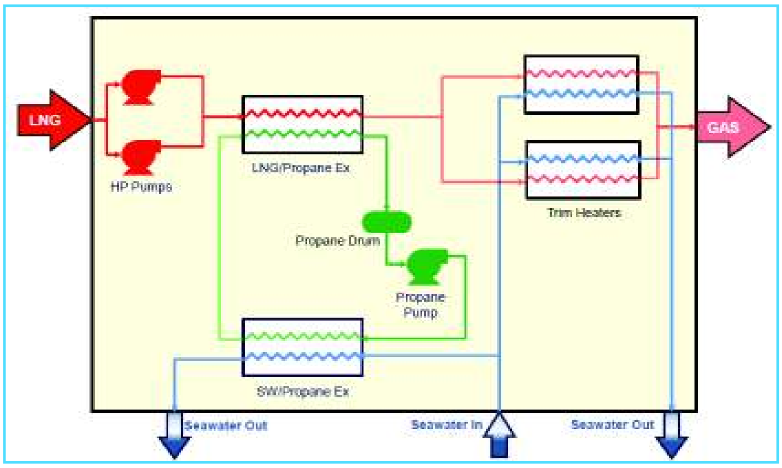
6.18.6. Regasification System

The equipment for regasifying the LNG, along with gas turbines for electricity generation, will be either located on the FSU's deck or on the onshore area. The regasification equipment will have a built-in N+1 redundancy, based on a peak day, with all other equipment planned based on a standard N+1 redundancy. The average sendout is purported to be 18 MMSCMD, with a maximum sendout of 22 MMSCMD.

There are a number of different types of LNG vaporizers in use today. The five most common applications include:

- Shell and Tube type Vaporizers (STVs),
- Open Rack Vaporizers (ORVs),
- Submerged Combustion Vaporizers (SCVs),
- Combined Heat and Power units with SCVs, and
- Other types, *i.e.* Ambient air-Heated Vaporizers

LNG vaporization would take place in a similar fashion to onshore. The LNG sendout pumps discharges LNG into the LNG vaporizers where it would be warmed. The facility will have more than one parallel vaporization train to warm up and convert the LNG to natural gas and deliver the gas to the pipeline at the required pipeline pressure of about 8 to 98 bar. Each vaporization facility would consist of smaller trains, each with an LNG sendout pump, a vaporizer, and a heating fluid handling system (seawater lift pump, air handling unit, or natural gas, depending on the source of heat).



Typical regasification process

6.18.7. Onshore LNG Storage Tanks

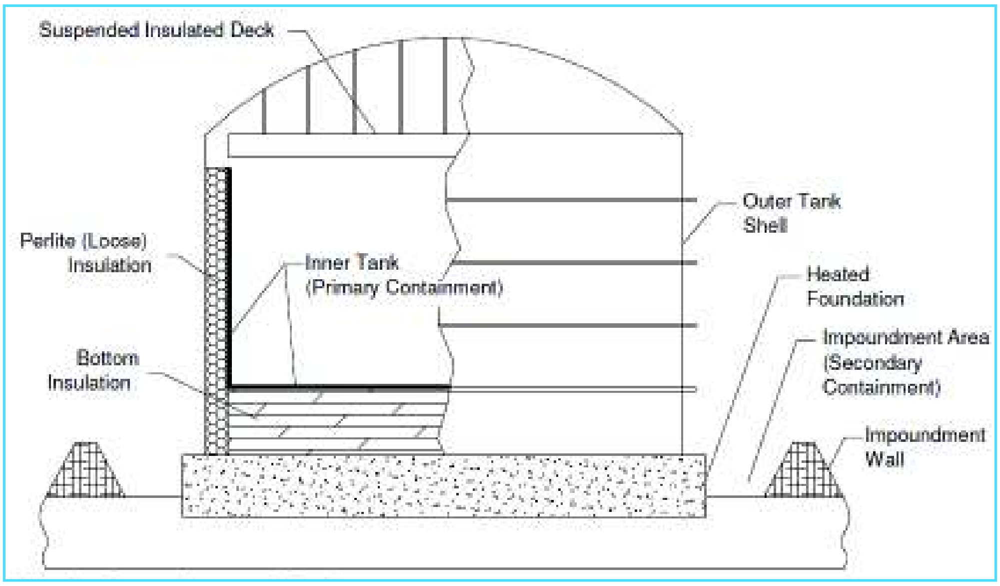
The required storage volume is dependent on the maximum parcel size arriving at the port and the required buffer storage to compensate for possible delays in shipping. The quantity of buffer storage is taken as a multiple of required buffer days and average send out rate per day.

The storage volumes have been determined for throughputs of 5 MMTPA for both floating storage and onshore tanks. Considering an onshore facility has higher flexibility with respect to storage and send-out, about 3-4 days buffer storage is assumed.

The floating storage i.e. FSU 1 (100,000 m^3 -267,000 m^3 and FSU 2 (30,000 m^3 -138,000 m^3) shall have maximum storage of 126,000 m^3 to 267,000 m^3 capacities which corresponds to the maximum design vessel - Qmax size. In case of an option with a smaller floating storage capacity this can be complemented with additional onshore tanks. For example, an FSU 1 of 130,000 m^3 is chosen in combination with onshore upto 10 storage tanks of each 20,000 m^3 – 190,000 m^3.

As stated earlier, each of the onshore and offshore LNG storage options considered above would require the construction of regasification/storage facilities onshore later on after realisation of the full market demand. As detailed above, the construction of onshore storage facility would not expected to meet the required scheduled for the project,therefore both storage options i.e. FSU 2 and onshore storage shall be analysed and developed considering the infrastructure flexibility and market needs.

One of the following LNG tanks types will be used for development of onshore storage facility: single containment tank, double containment tank, and full containment tank. The type of tank chosen depends largely on the remoteness and size of the site. The cross-sectional view of a typical single containment tank is shown below.

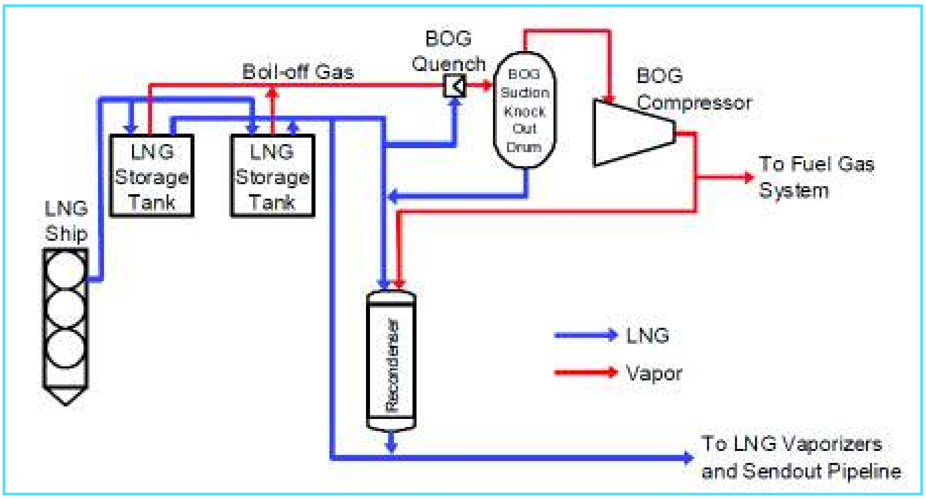


Typical single containment tank

6.18.8. Boil-off Gas Handling System

LNG is stored in large tanks insulated either by loose or compacted perlite or layers of polyurethane panels. The thickness of the insulation depends on the facility. For example, tanks located in LNG vessels have 2-3 feet of insulation while land based facilities have 4-5 feet of loose perlite. In spite of the insulation, there is a certain amount of heat that is transferred to the stored LNG, which causes it to vaporize within the storage tank, a process known as boil-off. In addition to insulation heat leakage, boil-off quantities are a function of barometric pressure changes, heat input from the internal LNG pumps, and “flashing” due to transfer of the LNG cargo from the ship to the storage tank. It is estimated that approximately 0.1 to 0.25% of the volume of LNG stored will boil-off each day. Failure to recover or utilize the boil-off volumes would have significant adverse cost implications for the Project. Except in an emergency, we do not plan to emit any methane into the atmosphere.

During unloading, the boil-off will be returned to the LNG vessel through the vapor return line. When there is no cargo transfer, the boil-off will either re-liquefy, compressed and combined with the sendoutvapor or used for fuel. The simplified diagram of the boil-off handling system for an onshore LNG terminal is shown below. Although this example is land-based, the design concept is applicable to offshore projects.



Typical Boil-off gas handling system

In all cases, the design specified a closed system for handling boil-off in a manner that did not allow escape or venting to the atmosphere during non-emergency operating periods. Under normal operating conditions, all of the boil-off gas would be compressed and flowed to a recondenser. The boil-off gas would be recondensed by a stream of cold LNG pumped from the storage tank and routed to the regasification units. In some cases, the recondenser would be designed to handle all of the boil-off generated including a portion of the flash gas generated during the unloading of an LNG cargo vessel. During periods when there is no regasification being undertaken, the compressed boil-off gas would become part of the fuel gas stream required for FSU operations.

Under emergency conditions when the storage tank is threatened with over-pressurization, the volume of boil-off gas would far exceed the volume that could be processed by normal operations. As such, an emergency system would be activated which would maintain safe operating pressures within the storage tank by either flaring the excess boil-off or venting directly to the atmosphere through emergency relief valves. At times such valves are heated to increase the buoyancy of the vented gas. The decision to flare or vent to the atmosphere under such conditions would be determined by the emergency conditions and the environmental sensitivities surrounding the project.

6.18.9. Pipelines & Onshore Receiving Facility / Gas Metering Station

- **LNG pipeline**: upto 24" inch diameter cryogenic LNG pipeline will be constructed comprised of an underwater adjacent to breakwater/or placed over Trestle upto the landfall point of onshore facility area to connect with onshore storage tanks and road tanker loading station. The length of the cryogenic LNG pipeline would be around 1km)

- **Natural gas Sendout pipeline**: Upto 36" inch diameter, approx5 km long pipeline will be placed adjacent to breakwater/or over Trestle upto the landfall point of onshore facility area and then connect with ORF and metering station and then up to port battery limit area, where it will get connected to GAILs proposed tie in pipeline. The onshore pipeline will have a shutdown valve, and a valve station for connecting branched parts in accordance with the design specifications defined by relevant codes and regulations.

  - Design pressure in connecting pipeline is 98 bar;
  - Minimal pressure in connecting pipeline is 5 bar;
  - Natural gas temperature in connection pipeline varies from 0°C to +15°C;
  - The length of a connecting pipeline is about 5 km;
  - Two valves stations.

- **Gas metering station: -** At the connection to the transmission system pipeline, a gas metering station is mounted for a custody measurement of the supplied natural gas. Gas metering station will be located in onshore area / FSU. Main technological equipment of gas metering station:

  - Ultrasonic and turbine meters (the main is turbine meter);
  - Flow regulators;
  - Pig Receiver;
  - Gas filters;
  - Online gas chromatograph;
  - Dew point analyzer.

Natural gas from vaporized LNG would pass through a custody transfer meter system before entering the pipeline. Metering capacity for the pipeline would match the peak discharge capacity from the LNG sendout pumps. This integrated system will be used for custody transfer application and also fitted with a separate monitor in the control room. For metering of send-out gas two ultrasonic in-line gas flow meters can be used. One unit will handle the peak gas flow with the other unit as a stand-by. Flow, temperature and pressure signals are usually transmitted to a flow computer with display and printer located in the control room, which can transmit to shore if desired. The system will be supplied with a certificate for fiscal accuracy and be periodically re-evaluated for accuracy.

Typical gas metering system

6.18.10. Road Truck/Tanker Loading Station

To make LNG available to customers who are not linked to the gas pipeline network, we proposed to supply LNG by cryogenic trucks. We would like to take LNG and its benefits to the doorstep of smaller customers by using specially-designed trucks. Though substantial, the demand for LNG from industrial zones is still not connected and are scattered. Since most industrial zones in focus are 250 km radius area, at this point of time only road transportation can meet the door-to-door requirement. Low fixed costs and short distance make road tankers more preferable. Moreover, road tankers offer high flexibility and durability.

The capacity of LNG carried through such tankers is upto 25 tonne, and the distance currently serve are upwards of 500 km. The transportation cost is insignificant to overall LNG price. The concept is as part of overall strategy of our project to sell gas directly to the customers with no connectivity. With road tanker deliveries, LNG is not regasified at the terminal but at the end user locations. A road tanker is comprised of a prime mover and a cryogenic vessel.

Example of LNG road tanker

6.18.11. Primary Support Facilities and Systems

The primary support equipment, facilities, and systems on the FSU include power generation equipment and the associated selective catalytic reduction (SCR) systems, recondensers and boil-off gas compressors, metering and odorization equipment and systems, an emergency flare, a ballast system, a utilities/seawater system, waste and water treatment systems, and management office and command control facilities.

Electric Power

Power generation for the FSU includes three 22-MW gas turbines with SCR for the control of NOx emissions and waste heat recovery units (WHRUs); this system will come as part of the FSU. Only two turbines are needed at any one time; the third turbine would serve as a spare. The primary fuel for the gas turbines would be natural gas and one of the generators would be able to use low sulfur diesel fuel to allow use in emergency situations.

Nitrogen plant

Plant uses air compressors and membrane nitrogen generating units to generate nitrogen gas. This gas is injected into the regasified LNG up to a maximum of 4% by volume to adjust its composition and heating value so that it meets the gas quality standards of the receiving pipeline if needed.

Ballast Water System

The FSU/FSRU would use a seawater ballast system to maintain its horizontal and vertical position. Ballast water would be held in compartments between the two hulls of the FSU/FSRU. The ballast water, along with other seawater requirements would be taken in through the FSU/FSRU's four seawater intakes, all of which would be on the bottom of the hull, approximately 40 feet below the water line. Ballast water would be discharged approximately 3 feet below the water line of the port. The average rate of seawater intake into and discharge from this system based on annual water usage would be approximately 14,900 m^3/day; the majority of the seawater would be used in the ballast system.

The ballast system for the LNG carriers while unloading would be similar to that proposed for the FSU/FSRU, as described above. During unloading of LNG, the carriers would take on seawater for ballast, with an average of 6,500 m^3/hour taken in by a 170,000 m^3 carrier (upto 7,500 m^3/hour taken in by a 267,000 m^3 carrier).

Cooling Water Systems

In the event that the LNG vaporization system is based on open loop technology, it would require the intake and discharge of approximately 16,500 m^3/d of seawater. Seawater intake would be through either the upper or lower sea chests positioned on either side of the hull. During normal operations, all cooling water intakes would be via the lower sea chests. Also, a typical LNG carrier would use approximately 710 m^3/h of seawater (850 m^3/hr for vessel of 267,000 m^3 carrier) for engine cooling while berthed alongside the FSU/FSRU at the Port.

In addition to use in the ballast system, seawater would be used for routine and emergency situations, including the following:

- General service pumps − to provide a water curtain for the LNG loading area.
- Inert gas scrubber cooling pump − for occasional use when storage tank inerting (purging with inert gas) or aerating would be required.
- Seawater cooling pump − for emergency use to cool the equipment on the FSU/FSRU if the glycol/water system fails.
- Firewater system – to provide fire-fighting water in the event of a fire; this system would be used only in an emergency and during monthly system tests.

Flare System

The cold (dry), hot (wet) and low-pressure flares will provide for the safe disposal of hydrocarbon fluids (gases) from pressure safety valves and blowdown valves during process upsets, emergencies, maintenance activities and shutdown conditions. It is likely that some flaring will occur during commissioning and start-up; however, it is not anticipated that flaring will be necessary during routine operations.

Flares are sized to accommodate what is expected to be the largest single event requiring gas release. The flares will be designed to provide smokeless flaring over a maximum range of operation. The flare stack will comprise five flares and one spare flare. The stack will be a steel structure and stand upto a maximum 100 m height.

Onshore Office

An existing office building will be rented or if need will be constructed for management of the LNG Regasification Project.

6.19. Regulatory Compliance

It should be noted that the FSRU's will comply with Order No. 8 of 2014 issued by the Directorate General of Shipping, Ministry of Shipping, Government of India, titled, "Notification for the application of Safety, Security and Environmental Protection provisions to Indian FSRUs/FRUs and non-Indian FSRUs/FRUs while operating in Indian waters", the FSRU is classified as a "specialized vessel" used in the storage, re-gasification and transfer of gases listed in the 'International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk', as amended (IGC Code) whilst at a fixed location and the DG Shipping Order is applicable to all FSRUs within the jurisdiction of India which includes territorial waters and Exclusive Economic Zone. The FSRU shall be complied with all the provisions of the DG Shipping Order in respect of the setting up, operation and maintenance of the disconnectable FSRU which will be anchored within Karaikal Port Limits.

6.20. Environmental aspects

Some of the project specific environmental aspects associated with the proposed development relate to the following tasks:

i) Construction of the jetty
ii) Dredging and disposal
iii) Marie EIA connected modeling study
iv) Tranquility study more specific to LNG vessels
v) Risk analysis of handling LNG
vi) Laying of pipeline, truck loading station and pipeline routing and the consequential terrestrial impact on land use
vii) Review of Disaster Management Plan
viii) Review of Environment Management Plan
ix) Emergency and rescue operations

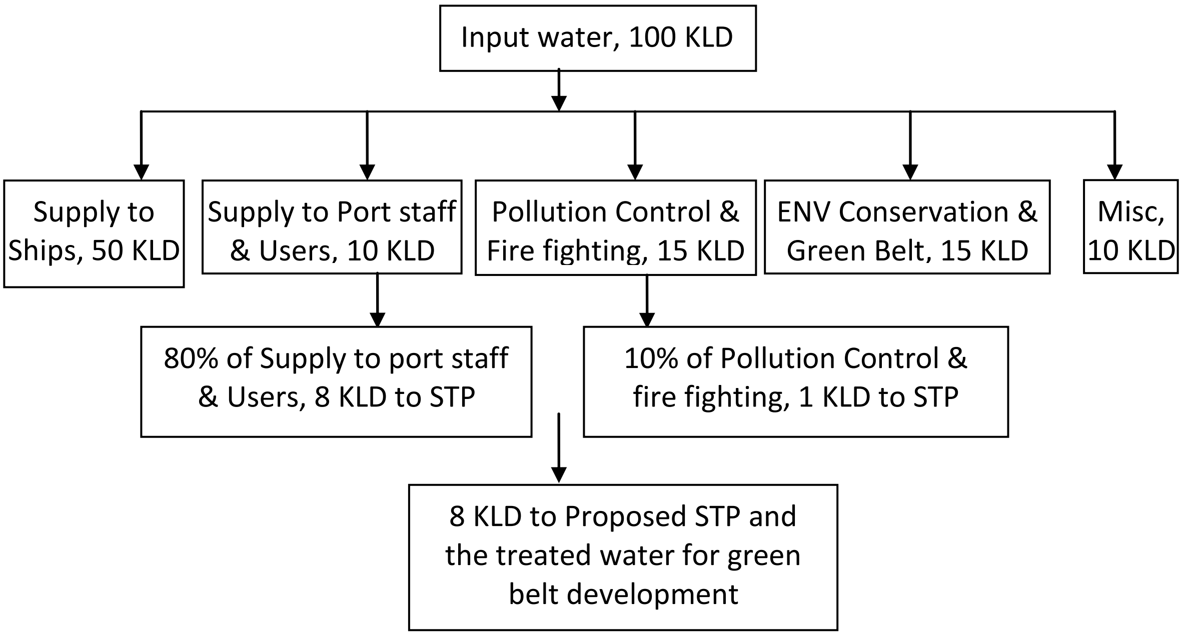
Aspects associated with the proposed development affecting the terrestrial environment are summarized as below;

6.20.1. Utilities required

Water Supply: The proposed project is expected to generate a staff/worker population of 50 numbers drawing need of 225 LD, which can be sustained on the existing port source. To fulfill the present water requirement of about 100 KLD is being sourced from the existing RO plant while the development has permission for Desalination plant of capacity 300 KLD; the capacity will be enhanced over a period in stages to 2 MLD.

The water requirement for the proposed development is as follows:

- Supply to Ships
- Supply to terminal staff and terminal users
- Pollution control and fire fighting systems and etc.
- Environmental conservation and maintenance of greenery in the port



Water Balance flow chart for proposed project activity

New STP of 50 KLD will be provided to treat the additional sewage. Flowchart of STP will be similar to existing STP and is presented above.

Power Supply

The onshore facilities power requirement is 12 MW, which will be sourced from the FSU/FSRU. Additionally upto 16 MW of onshore multifueled power unit will be installed to provide uninterruptible power supply for smooth terminal operation and dependent port operations. Further in case of any emergency, provision will be made which allows sourcing from the Grid.

6.20.2. Waste Generation and disposal

a) **Municipal waste:** Waste will be generated during operation phase due to additional ships coming into harbour (100 kg/d) which will be suitably handled as per rules within the existing Waste Management Plan as discussed in previous section.Existing compost area is being managed by Authorized agency.

b) **Construction or demolition wastes:** The Channel will be deepen to (-) 19.8 m and the amount of dredge generated will be about 14 x 10^6 m^3 of which 13.0 x 10^6 m^3will be dumped at approved dumping site, while the balance 1.0 x 10^6 m^3will be used for reclamation/beach nourishment. The berth area would be dredged up to (-) 15.5 m.

c) **Liquid Waste Bilge:** Generally the port does not accept Bilge, but whenever required,bilge water and oily wastes from Ships are transported on-shore through workboats (OSV's) and sent to registered/ approved recyclers for recycle/re-use.

d) **Hazardous wastes:** Will be generated during operation phase and will disposed off as per the extant regulations.

Details of the wastes are as below;

Summary of Waste generated and treatment

Type	QY	Treatment disposal
Biodegradable wastes	50 kg/day	Composting, Use as manure and landscaping
Non-Biodegradable wastes	50kg/day	Segregation and sale to authorized agencies
Hazardous Waste (Used/spent oil)	10TPA	Disposed through authorized recyclers/ reprocessors

6.21. Physical planning

Engineering Parameters

- Length of Jetty about 650 m between outer dolphins
- Dredging and disposal of about 14 x 10 ^{6} m^3 of soil
- Channel deepening to (-) 19.8 m CD
- Turning circle to be converted to turning basin of min width of 600 m
- Berth area dredging to (-) 15.5 m CD

Operational Parameters

- Cargo transfer arrangements like unloading Arms
- Gas pipeline on trestle & on land upto boundary wall
- Truck loading station
- Installation of fire fighting equipments
- Safety and Pollution control arrangements
- 2 x 60 -80 T bollard pull tugs

6.22. Proposed Schedule for Approval and implementation

Overall time, duration required for commissioning the project is estimated at 36 months from the date of environmental clearance. The time schedules for the major components are given below:

- All preliminary tasks like investigation, DPR etc. - 6 months.
- Jetty construction - About 18 months
- FSRU / FSU conversion - About 15 months (leased facility)
- Dredging activity - About 6 months.
- Unloading arms - About 6 months
- Gas pipeline connectivity - About 12 months.

Wherever possible all these major items will be taken as concurrent and parallel activities

6.23. Estimated Project Cost

Total project cost is expected to be about Rs. 2610 Crores for the components which are directly related to the development as per breakup given below:

S. No	Project Components	Capital Cost (Rs in Crores)
1	Dredging	494
2	Rubble mouth shore protection wall	85
3	Jetty , Trestle, mooring systems	124
4	Unloading LNG Arms	156
5	Regasification unit	143
6	Cryogenic Pipeline (~600 m)	10
7	Onshore Gas pipeline (~ 5km)	17
8	Utilities, Service facilities and buildings	65
9	Road Tanker Loading Station	22
10	FSU/FSRU	1495
Total		2610

Table 6.1. Worldwide Existing FSRU Project and their vessel sizes

Launched in	Project	Tank Capacity (m^3)
2007	Teeside Gasport (UK)	135,000
2008	Northeast Gateway (USA)	145,000
2008	Bahia Blanca Gasport (Argentina)	151,000
2009	Min Al-Ahmadi Gasport (Kuwait)	151,000
2009	Petrobras VT1 (Pecem , Braizil)	128,000
2009	Petrobras VT2 (Guanabara , Brazil)	138,000
2010	Neptune (USA)	145,000
2010	Dubai LNG (UAE)	125,000
2011	GNL Escobar (Argentina)	151,000
2012	West Java (Indonesia)	125,000
2013	Italy	138,000
2014	Petrobras VT3 (Guanabara, Brazil)	173,000
2014	Puerto Rico	170,000
2014	Jordan	160,000
2014	Lithuania	170,000
2014	Indonesia	170,000
2014	Chile	170,000

Table 6.2. Details of typical LNG vessel dimensions

Capacity (m^3)	DWT (ton)	Deplacement (ton)	Overall length (m)	Length between perpendicular (m)	Beam (m)	Moulded depth (m)	Draft max. (m)
250,000	122,500	177,000	369	354	55.7	31.2	12.8
220,000	108,000	158,000	365	341	53.8	30.5	12.5
200,000	100,000	146,000	340	325	51.3	28.0	12.0
168,000	84,500	125,000	298	285	48.7	28.0	11.9
163,700	84,000	125,000	292	280	45.2	27.5	11.6
145,000	74,400	110,000	288	274	49.0	26.8	12.3
137,000	71,500	100,000	290	275	48.1	28.0	11.3
125,000	66,800	102,000	272	259	47.2	26.5	11.4
87,600	53,600	74,000	250	237	40.0	23.0	10.6

7. ToR Compliances

7.1. ToR for LNG project

During 127th Expert Appraisal Committee meeting on CRZ, Infrastructure & Miscellaneous Projects dt. 29th October 2013, the Committee has proposed the following additional TOR vide No. F.No.11-41/2013-IA.III dt.29.10.2013 for the proposed project of development of Bulk Liquid Berth for handling LNG Terminal. The ToR is presented below.

तार :
Telegram : PARYAVARAN,
NEW DELHI
दूरभाष :
Telephone : 2436 8526
टेलेक्स :
Telex : W-66185 DOF IN
FAX : 4360678
भारत सरकार
पर्यावरण एवं वन मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT & FORESTS
पर्यावरण भवन, सी. जी. ओ. कॉम्पलेक्स
PARYAVARAN BHAVAN, C.G.O. COMPLEX
लोदी रोड, नई दिल्ली-110003
LODHI ROAD, NEW DELHI-110003

F.No.11-41/2013-IA.III **Dated: 14th November, 2013**

To
Chief Operating Officer,
M/s Karaikal Port Private Ltd.,
Keezavanjore Village, T.R. Pattinam,
Karaikal, Puducherry.

Subject: Finalization of ToR for development of Bulk Liquid Berth for handling LNG at Karaikal Port, Puducherry by M/s Karaikal Port Private Ltd. - Reg.

Dear Sir,

Kindly refer to your above proposal submitted to this Ministry. The project involves development of Bulk Liquid Berth for handling LNG at Karaikal Port, Puducherry. Karaikal Port is proposed to be an all weather port. As a part of a seamless future expansion plan, Karaikal Port proposes to set up a separate Bulk Liquid Berth as envisaged in the Master Plan with slight modification in the location of the berth within the port. It involves to develop a Bulk Liquid Berth primarily with LNG as the major cargo on this berth within the port along the southern breakwater using FSU (Floating Storage Unit/FSRU mode (Floating Storage Re-gasification Unit). The proposed Bulk Liquid Berth would provide a flexible option towards future growth of port for other liquid/gaseous petroleum cargoes too. The site location is latitude 10°50'8.95"N, longitude 79°50'50.05"E, village Khezhavanjoor, District Karaikal, Puducherry. The facilities will consist of Berthing Dolphins, Mooring Dolphins connected by an Approach Trestle from the South Break Water, ship size upto 230,000m^3 LNG vessel and a draft of around 13.5m and dredged to (-) 15.0m. The dredging involves widening of the turning basin and the proposed berth area. About 4.0 Miilion Cubic Metre of dredged sand is expected of which about 3.0 Miilion cum is proposed to be dumped in the sea in the designated dumping area at 10°50.4'N; 080°0.5'E. Balance 1 Miilion cum will be used for reclamation/ shore nourishment. The sea water will be used for converting LNG into gas.

- LNG Handling capacity – 5 MMTPA
- Draft at proposed Berth – 13.5 mtrs

The port has already a Desalination plant of 240 KLD capacity which will be enhanced over a period in stages to 2 MLD to cater the port's need. The rough estimated requirement of power is about 20MW. The port is in operation since 2009 and has handled over 20 Million Tonnes of various cargo including liquid petroleum.

The above proposal was considered in the 127th EAC meeting held on 28th – 30th October, 2013. The details as presented by the project proponents and after discussions, the following "Terms of Reference" were finalized to be suitably added to those furnished by the project proponent.

(i) Submit compliance status of EC/Consent in respect of the existing activities.

(ii) Submit HTL/LTL map prepared by an authorized agency on 1:4000 scale superimposed with project layout. Submit recommendation of SCZMA.

(iii) Submit the details of safety regulations applicable and its compliance.

(iv) Submit details of Risk Assessment, Disaster Management Plan including emergency evacuation during natural and man-made disaster like floods, cyclone, tsunami and earth quakes etc.

(v) Submit details of safety aspects associated with handling of LNG vis a vis other cargo in other facilities within the port.

(vi) Submit details of storage and regasification, distribution network etc and vulnerability of human habitation vis a vis LNG associated risks.

(vii) Type of LNG carriers proposed taking into account the future growth in vessel sizes beyond the present day market trend and the handling aspects of such vessels from environmental considerations.

(viii) Submit the details of shore line changes along with the shore protection if nay required.

(ix) Submit details of Environment Management Plan and Environment Monitoring Plan with parameters and costs.

(x) Submit the details of the fishing activity and likely impact due to the activity.

(xi) Details of land breakup along with land use plan and details of green belt development.

(xii) Details of solid/liquid wastes generation and their management.

(xiii) Water requirement, source, impact on competitive users.

(xiv) Submit the details of Oil Spill Contingency Management Plan.

(xv) Submit details of Environment Management Plan and Environment Monitoring Plan with parameters and costs. Comprehensive common environmental monitoring by Port Trust and other PPPs located within the port shall be prepared in a scientific way

(xvi) Submit the Details of Hazardous Wastes generated, and precautions planned during handling as well as compliance with Hazardous Waste Rules.

General Guidelines

(i) The EIA document shall be printed on both sides, as far as possible.

(ii) The status of accreditation of the EIA consultant with NABET/QCI shall be specifically mentioned. The consultant shall certify that his accreditation is for the sector for which this EIA is prepared.

(iii) On the front page of EIA/EMP reports, the name of the consultant/consultancy firm along with their complete details including their accreditation, if any shall be indicated. The consultant while submitting the EIA/EMP report shall give an undertaking to the effect that the model TORs have been complied with and the data submitted is factually correct (Refer MoEF Office Memorandum No. J-11013/41/2006-IA.II(I) dated 4th August, 2009).

(iv) While submitting the EIA/EMP reports, the name of the experts associated with/involved in the preparation of these reports and the laboratories through which the samples have been analysed should be stated in the report. It shall clearly be indicated whether these laboratories are approved under the Environment (Protection) Act, 1986 and the rules made there under (Please refer MoEF Office Memorandum No. J-11013/41/2006-IA.II(I) dated 4th August, 2009). The project leader of the EIA study shall also be mentioned.

(v) Environmental Management Plan presented before the EAC as a part of EIA report, shall be made part of Concessionaire Agreement/ other relevant documents. Proponent shall submit an undertaking in this regard.

(vi) Since most of the environmental issues are related to design parameters, following additional information should also be provided by PP apart from the information required as per

3

Chapter – 12 of the EIA Guideline manual for Highways (Disclosure of Consultant)

a) Name of the Design Consultant.

b) Name of the EIA consultant, EIA Coordinator, Functional Area Expert and details of accreditation.

(vii) The EIA report shall be prepared as per the EIA Notification, 2006, as amended from time to time.

Public Hearing should be conducted for the project in accordance with provisions of the Environmental Impact Assessment Notification, 2006 and the issues raised by the public should be addressed in the Environment Management Plan.

A detailed draft EIA/EMP report should be prepared as per the above additional TOR and should be submitted to the Ministry in accordance with the Notification.

The prescribed ToRs would be valid for a period of two years for submission of the EIA/EMP Reports, after public consultation.

Yours faithfully,

(Lalit Kapur)
Director (IA-III)

Copy to:
The Member Secretary, Puducherry Pollution Control Committee, 3rd floor, Housing Board Complex, Anna Nagar, Puducherry-5.

Shekar.
Recd on 26/Nov/2013

Point wise compliance of proposed ToR (by proponent) and additional ToR are given below:

ToR Item No.	ToR	Compliance
(i)	Submit compliance status of EC/Consent in respect of the existing activities.	Chapter 5
(ii)	Submit HTL/LTL map prepared by an authorized agency on 1:4000 scale superimposed with project layout. Submit recommendation of SCZMA.	Chapter 20
(iii)	Submit the details of safety regulations applicable and its compliance	Chapter 22
(iv)	Submit the details of risk assessment, disaster management plan including emergency evaluation during natural and man made disaster like floods, cyclone, Tsunami and earthquakes etc.	Chapter 20, 21 and 22
(v)	Submit details of safety aspects associated with handling of LNG vis a vis other cargo in other facilities within the port.	Chapter 21
(vi)	Submit details of storage and re-gasification, distribution network etc and vulnerability of human habitation vis a vis LNG associated risks.	Chapter 4, 20 and 21
(vii)	Type of LNG carriers proposed taking into account the future growth in vessel sizes beyond the present day market trend and the handling aspects of such vessels from environmental considerations	Chapter 4
(viii)	Submit the details of shoreline changes along with the shore protection if any required.	Chapter 12
(ix)	Submit details of Environment Management Plan and Environment Monitoring Plan with parameters and costs.	Chapter 10, 17 and 18
(x)	Submit the details of the fishing activity and likely impact due to the activity.	Chapter 11 and 15
(xi)	Details of land breakup along with land use plan and details of green belt development.	section 8.3
(xii)	Details of solid / liquid wastes generation and their management.	Chapter 7
(xiii)	Water requirement, source and impact on competitive users.	Chapter 7
(xiv)	Submit the details of Oil Spill Contingency Management Plan.	Chapter 16
(xv)	Submit details of Environment Management Plan and Environment Monitoring Plan with parameters and costs. Comprehensive common environmental monitoring by Port Trust and other PPPs located within the port shall be prepared in a scientific way	Chapter 10, 17 and 18 and Section 7.15
(xvi)	Submit the Details of Hazardous Wastes generated, and precautions planned during handling as well as compliance with Hazardous Waste Rules	Chapter 4 and 7

7.2. Earlier Environment/CRZ clearances

The environmental/CRZ clearances were sought phase wise for the projects as per details given below:

Previous Environmental Clearances obtained.

Date	Clearance	Phase	Aspects Covered
06.05.06	CRZ	1	Construction of Port with a) Cargo handling capacity of 4MTPA b) 2 berths c) 2 breakwaters d) Navigational channel dredged up to (-) 13.5 m CD e) Various buildings including warehouses and control tower
15.10.08	Amendment	1	Permission for Disposal of dredged material offshore
22.09.09	Environmental and CRZ	2	a) 3 additional berths for Coal, Edible oil/ Multipurpose & OSV/ PSV b) Enhancement of cargo handling capacity from 4MTPA to 20.5 MTPA c) Diameter of turning circle increased to 500 m with depth 15.5 m Length of Approach channel increased to 9750 m, width 250 m and depth to 16.5 m (dredging). Out of 20.5 mcm dredged material, 15 mcm to be disposed offshore and rest used for beach nourishment d) Water from Desalination RO plant to be used in port e) Waste water treatment by STP of capacity 50 KLD
04.06.10	Amendment	2	Replacement of berth 7 by berth 4 for handling Coal instead of edible oil/ Multipurpose
25.10.10	Environmental clearance	-	Handling 1 MTPA Crude oil for M/s CPCL
03.02.15	Environmental clearance		Validity of Phase II Environmental Clearance issued on 22.09.2009 has extended upto 21.09.2017

Consent to operate

Consent to Operate have been obtained from Puducherry Pollution Control Committee and are listed as below:

Consent to operate obtained from

NO	Dated	Valid up to	Types of Cargo
7162/PPC/HWM/JSA/2012/697 Authorization under HAZARDOUS WASTE Rules	12.07.12	31.05.15	• Used/spent Oil (23 KLA) • Waste residue containing oil (0.12 MTA)
PPCC/CON/AIR/TRP/KKL/JE/2015/589 Authorization under AIR (OPERATE)	16.07.15	31.01.16	• Coal (6 MTPA) General Cargo (Textile, machinery, Timber, Steel, Containers, Granite, Marble slabs, Iron Ore, Fertilizers, Clay, Gypsum, Limestone, Agro Products like Sugar, Red Chilies, Wheat, Corn etc; Salt & Cement (in Bags only) (2 MTPA) • Crude Oil & other petroleum products (1.0 MMTPA) • Edible Oil (2.5 MMTPA)
PPCC/CON/WTR/TRP/KKL/JE/2015/589 Authorization under WATER (OPERATE)	16.07.15	31.01.16	

7.3. Compliance to Environmental clearance and CTO conditions

The point wise compliance to Environmental clearance conditions is submitted by Karaikal Port authorities to the Southern Region office of MoEFCC at Bangalore, the Puducherry state Pollution Control Committee.

8. SCOPE OF EIA

The scope of the baseline environmental studies as per the ToR is to conduct study of the existing environmental status within the study area of 10 km radius from the proposed site for significant environmental components as below.

i) Assessment of existing Environmental status with respect to physical (current/wave/swells etc.), chemical, biological, sediment quality, flora and fauna, etc. and identification of impacts on them.

ii) Assessment of marine water, ground water, and surface water quality at project site and impact of proposed activities on the same.

iii) Assessment of Ambient Air Quality, and it should be stipulated with National Ambient Air Quality standards and impact of the project on Ambient Air Quality of the surrounding.

iv) Prediction and evaluation of impact of the project in terms of short term and long term effects of different aspects of project construction and operation.

v) Preparation of an Environmental Impact Statement (EIS).

vi) Preparation of an Environmental Management Plan (EMP) outlining control strategies for mitigation of adverse impacts, if any.

vii) Risk analysis and DisasterManagement Studies, for the proposed project activities.

viii) Outline a Post Project Monitoring Plan (PPMP) to ensure that the EMP achieves.

The environmental studies are based on one season data, environmental impacts have been identified and assessed qualitatively, EMP is drawn through which environmentally quality will be maintained.

TERRESTRIAL EIA

9. TERRESTRIAL ENVIRONMENT

9.1. Land Environment

Baseline Land Environment was assessed with the help of available geographic/road maps, toposheets. Soil characteristics at and near the project site were identified for various land uses/land forms. Also official Maps/Plans such as Regional Plan of Karaikal district were used. Land environment may be affected due to unscientific methods of disposal of dredge spoils, treated/untreated wastewater and /or disposal of hazardous & non-hazardous solid wastes.

Land Use/land cover studies were undertaken using satellite images and field survey for ground truthing and were undertaken as 1:50000 scale mapping of Land Use/Land Cover with cropping pattern delineation in the buffer area of 10 km around the Karaikal Port.

Land Use/land Cover methodology:

i) Software Used: Image processing software Erdas Imagine version 9.1 was used for raster data creation. Standard GIS software Arc map version 9.2 was used for GIS vector data creation. Additionally the final cartographic layout and digital copy of the maps were prepared in ARC Map software, Erdas Imagine, Arc map version 9.2.

ii) Satellite Data used:

Landsat 5: MSS images at 30 m resolution
Landsat 8: MSS images at 30 m resolution
Multiple vintage satellite images of vintage ranging from February 2009 to August 2013 were utilized to create the LU/LC map for the study area

iii) Overview of methodology:

The map data was prepared based on the categorization of datasets as follows

- GIS data creation
- Raster data creation
- Field survey for information collection and data validation
- Cartographic map layout at 1:50000 scale

GIS data creation: GIS data encompasses all the data in vector format like boundaries related to Reserve Forest, Bird Sanctuary, Heritage Site, Human Settlements or Habitation and site boundary for Karaikal Port Pvt. Ltd. Additionally this data also includes transportation layer comprising of road and railway network data. A detailed points of Interest layer is also provided as a GIS dataset which contains information of names of places and features like lakes, rivers etc. This vector data was created using a combination of sources like best available satellite images of latest vintage, Topographic maps at 1:50000 scale, representative maps provided by AESPL and authentic third party information sources.

Raster data creation: LULC is the distribution of natural as well as man-made features on earth surface. LULC map was generated using unsupervised classification methodology on LISS III satellite images. Spectral Signature based digital classification technique was used for level II classification. Ground observations in the form of GPS locations and their corresponding attributes were collected during the field work. Signatures of various land use land cover classes mapped were validated in the field and additional information in terms of cropping pattern and its delineation were collected and incorporated in the data set.

Field survey: Basic LULC maps data prepared in house was first plotted and hard copy prints of the same with Lat/Long Grid display were taken. Additionally the entire data set was imported into the GPS instrument (Trimble JUNO Series) so that online analysis of the data sets could also be facilitated in the field. The field observation points were collected with information of geographic co-ordinates against the cropping pattern. Additional reference points for each of the LULC classes as well as features name attributes were also validated/ collected on field to confirm proper mapping of the class through satellite image interpretation as well as the use of ancillary source information. The observations from the field visit were compiled and incorporated in the map to ensure a high mapping accuracy of the feature classes.

Cartographic map layout at 1:50000 scale: The complete datasets was then plotted and a standardized cartographic look was given to the various datasets. Soft Copy plots of the same at 1:50000 scale was prepared for final delivery.

9.2. Air Environment

The preliminary information regarding the study area relevant to air environment was collected through survey. The baseline status of the primary air pollution parameters in the ambient air within the impact zone was assessed during month of October in pre monsoon season of the year 2013. Six monitoring stations were selected in the study area including site for this purpose. Based on the reconnaissance studies and existing/proposed activities at site PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO were identified as air pollutant parameters of concern for undertaking primary surveys in the study area.

Similarly, meteorological data pertaining to parameters such as wind direction, wind Speed, temperature, relative humidity and cloud cover were collected at project site. Climatological tables from India Meteorological Department were also used to understand general long term trend in past.

Since, proposed project will increase the traffic levels for transportation of LNG, traffic counts were taken at three strategic locations providing access to the site.

9.3. Noise Environment

Noise level measurements during day and night time were carried out at the project site and in the neighbouring areas (generally at the AAQM sites) to identify the prevailing baseline status of noise environment.

9.4. Water Environment

Available water resources (surface and ground) in the study area were identified for analysis and 5 stations were selected, each to conduct surface and ground water analysis and assess the water quality.

9.5. Biological Environment

The available maps, Google Earth image and the LULC maps prepared were studied to identify various habitats in and around the study area. Field studies were carried out in the study area to list species in different identified habitats during the survey period in October 2013.

9.6. Socioeconomic Environment

Data on demographic patterns and literacy status was collected for the study area. Data sources include official Statistical records of Department of Census 2011.

9.7. Impact Prediction

The various environmental and social impacts which are likely due to the development activities within the Port limits were studied in detail for the construction and operation phases. The impacts have been assessed taking into consideration the existing baseline status of the terrestrial and socio-economic components.

9.8. Environment Management Plan

Based on the types of impacts identified, an Environment Management Plan (EMP) was prepared. Adherence to EMP will ensure minimal impact on environment due to the proposed project.

9.9. Facilities established at Karaikal Port

Facilities observed in KKPL

The Karaikal port has facilities for handling multiple cargos as given below:

BERTHS 1, 2 and 3: Procedure for handling cargo like coal and iron ore

- Cargo handled using ship or shore based cranes (2 nos) with grabs which load cargo on to tippers.
- Tippers then take the cargo to stack yard
- Wheel loaders are used to shift cargo from stack yard on to tippers
- Tippers discharge the cargo on to Railway wagons or truck for dispatch to destination

Procedure for handling fertilizers

- Generally grabs are provided which transfer the cargo to silos with hoppers
- The fertilizers are then loaded onto trucks and taken to warehouse where they are bagged using machines or manually.
- The bags are then loaded on to trucks, weighed / counted and transported to destination in closed wagon.

Procedure for handling Crude oil

- Compatible unloading arm is provided to unload crude oil and then pump it through connector to CPCL (Chennai Petroleum Corporation Ltd) dedicated pipeline about 1 Km to the south of Karaikal Port

BERTH No. 4: It has been provided to have fully mechanized unloading of cargo as follows:

- Cargo is unloaded through ship unloader on to conveyor which transfers cargo to stock yard (stacker/reclaimer)
- The cargo is then transferred through conveyors to Wagon loading system (WLS) or Truck loading System (TLS)

9.10. Environmental Aspects

From the above description, it is apparent that the existing activities involve handling and re-handling of different types of cargo like Iron ore/coal/fertilizer. Material handling is done using variety of equipments like

- Shore/ship based cranes (diesel operated)
- Tippers/wheel loaders/ trucks (using diesel)

Thus, major environmental pollution from port activities is

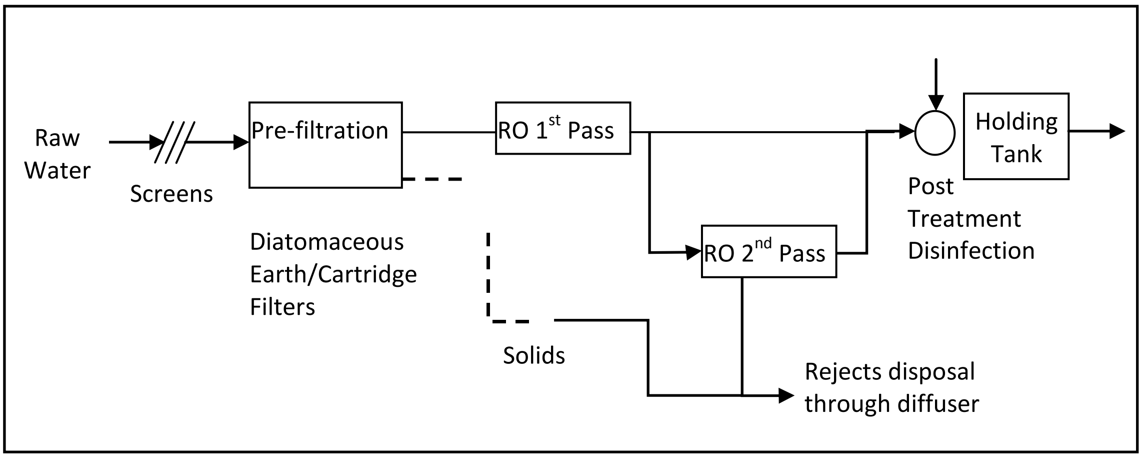
- Gaseous air pollution (SO_2, NO_X, CO) due to burning of diesel in material handling equipment
- Noise due to material handling and movement of mobile machineries
- Dust due to handling and re-handling of cargo

9.11. Raw Water Source and Treatment provided

Desalination plant

Water requirement is about 350 CMD, which is sourced through Reverse Osmosis treatment of seawater.

Scheme of reverse osmosis is presented in below:



Scheme for Raw Water Treatment using RO

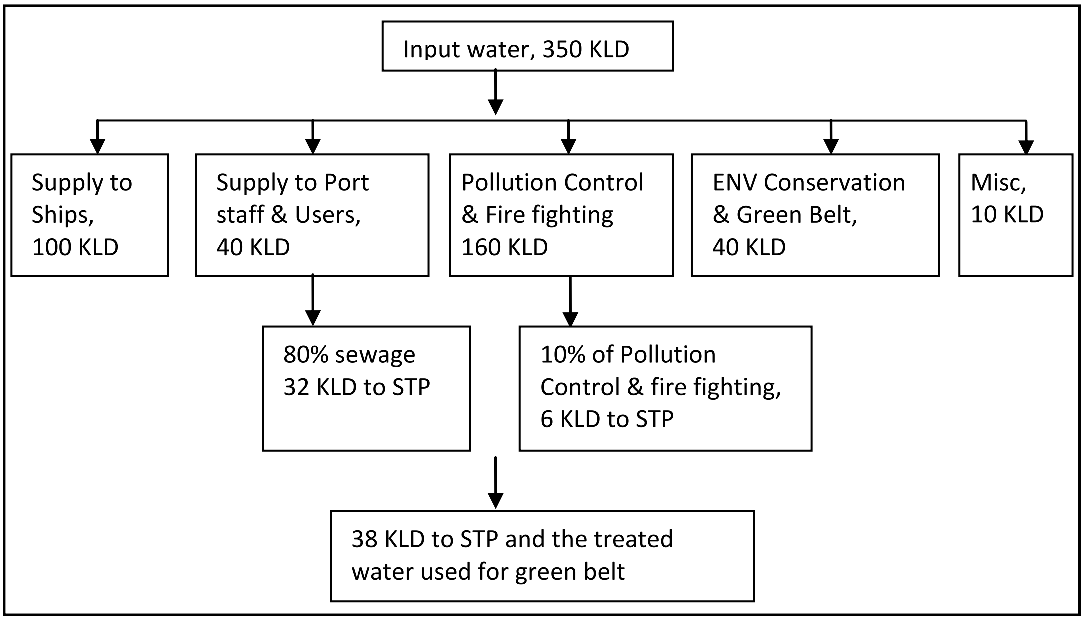
The characteristics of water before and after treatment are presented in Table 9.1.

Water Balance

Water is required in the port for following activities

- Supply to ships
- Supply to port staff and port users
- Pollution control and fire fighting purposes
- Environmental conservation and maintenance of greenery in the port
- Miscellaneous

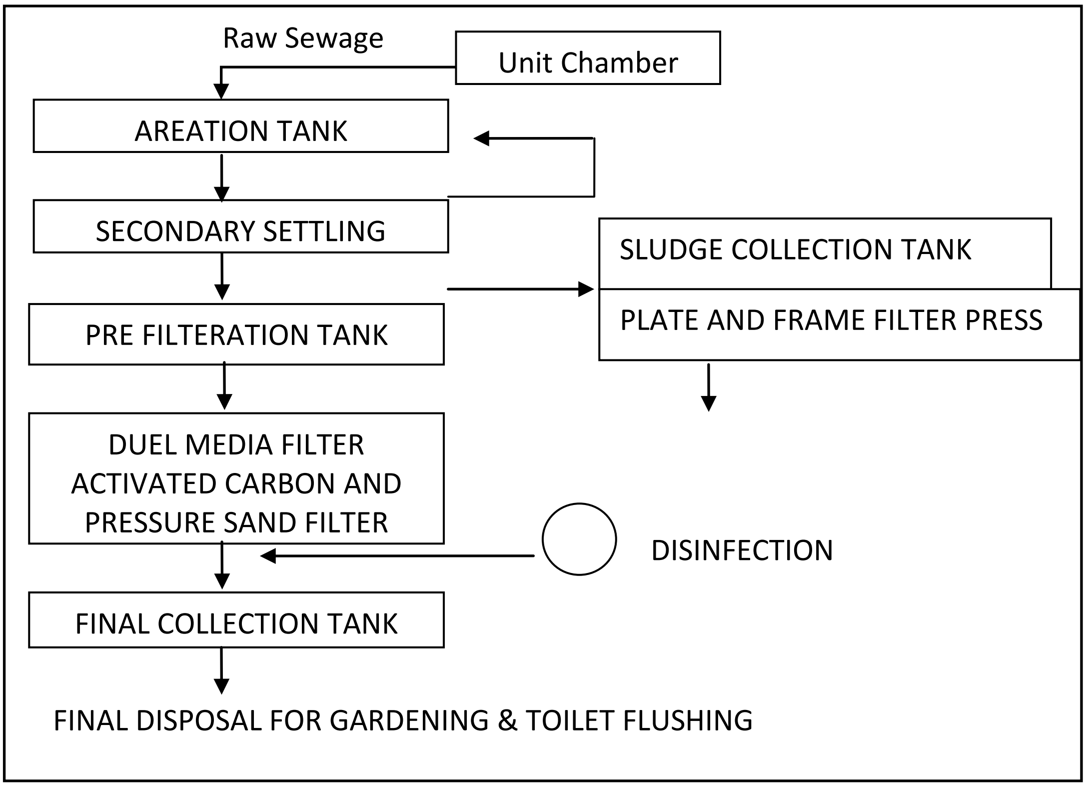
The water balance diagram showing water use for different purposes is presented below:



Water balance for present infrastructure

9.12. Effluent/sewage generation, treatment and disposal

To mitigate impacts on marine water quality from disposal of untreated sewage, Sewage treatment Plant (STP) of total 30 KLD capacity is provided near port operational area and near main operational building clusters. The Capacity of STP unit is to be enhanced up to 50 KLD & Scheme of sewage treatment is given below:



Block diagram of sewage treatment plant of 50 KLD

The treated sewage water is used for Green belt development and toilet flushing. The characteristics of STP treated water are presented in Table 9.2. The sludge is dried and used as manure for greenbelt. The floor washings of equipment workshops are conveyed through an oil-water separator and subsequently treated at STP.

Electrical load

The requirement of electric power is for following operations

- Mechanized cargo handling equipment at the berths
- Cargo transfer system from berth to stack yard/plant
- Backup area equipment
- Lighting of the port
- Miscellaneous

The requirement of electric power for the above-mentioned activities is presently about 5MW and envisaged to go upto 12 MW with completion of mechanization facilities. Two DG sets having capacity 500 kVA are provided in the port presently.

9.13. Waste Generation, Treatment and Disposal

From Land Based Operations

The waste generated during the port activities, their treatment and disposal facilities are presented below:

a) Municipal

The present municipal waste generated is about 300 kg/day and is categorized as liquid and solid for discussion.

Liquid waste: The domestic waste water after collection is pumped to Sewage Treatment Plant (STP), from where this treated water is used for watering the plants as green belt development and also for dust suppression from the coal stacks in the port. The Run off during dust suppression by water sprinkling into sea is prohibited by passing it through an oil-water separator, primary treatment (Settling) and subsequently treated at STP.

Solid waste: Two Bin system of collection wherein Bio Degradable and Non Bio Degradable Waste Dust bins are located at the all the points of generation. The collection is done in a motorized vehicle by workmen using proper PPEs and for disposal. Construction waste is re-used within port site for filling of low lying areas. STP sludge is dried into cakes and is used as manure in greenbelt. Other wastes which can be re-cycled are sold. Biodegradables wastes, such as kitchen wastes are Vermi-composted and used in garden beds

Vermi-compost using kitchen waste

Vermi-compost being used in garden beds

Hazardous Waste

The points of generation are during Vehicle maintenance and in repair Work shop, Heavy machinery maintenance workshops, electrical department etc.

The various categories/types of HW generated in existing port against the Authorization quantities are presented in Table 9.3 giving the final disposal technique/methodology.

From Ships

i) **Liquid waste:** Generally the port does not accept Bilge, but whenever required of bilge water and oily wastes from Ships are transported on-shore through workboats (OSV's) and sent to approved recyclers for recycle/re-use.

ii) **Solid waste:** The garbage collection facility for visiting ships is provided through registered Chandlers. After collection of the domestic wastes and its segregation the inerts are disposed in the identified Municipal Waste site in Karaikal while the recyclables are given to the relevant Recyclers. The other kinds of wastes such as Lead Acid Batteries, E-Waste, Metal scrap etc are handled respectively as per norms.

iii) **Other Wastes:** ***Lead Acid Batteries*** after having completed the scheduled life term are replaced by registered Dealers who pass on the old used batteries to the registered Lead Recycler. ***E-Waste*** generated in the Karaikal Port is sent to the Corporate Office in Chennai. After accumulation of certain quantities E-Waste is sold to the E-Waste Collector who either refurbishes the same and sells in the seconds market or is given to the E-Waste recycler for a price.

9.14. Air Pollution Protection measures undertaken

a) Erection of Fabric barrier (6 m and 15 m height) to arrest coal dust: Dust separation screens made of high quality polymer meshes have been erected around the coal open storage yards to a height of 15 m which act as wind barriers and also stops the dust from being carried by the wind. Similar quality nets have also been erected on the entire boundary wall adjacent to railway sidings, stretched to a height of 06 m to act as a secondary barrier in addition to the aforesaid primary screen. This serves as a near foolproof air pollution preventive mechanism to arrest the coal dust from flying off.

Fabric barrier erected to arrest the dust particles carried by the wind outside the port

b) Height of coal stock piles are normally maintained as less than 10 m such that the air strikes the width and not the length.

Fabric barrier along the coal stock pile

Inside view of the coal stock area surrounded by Fabric barrier

c) Sprinklers provided to suppress dust during handling: Dust Suppression Sprayers (DS 150) are being extensively used in Rack & Truck loading areas. The water spray of this machine has a range of 150 to 200 m throwing capacity with area coverage of 60,000 sq.m. The blower can rotate 320 degrees horizontally and -10 to +45 degrees vertically.

The coal stock area being sprinkled with water avoid dusting

It consumes water at an average of 150 - 200 liters per minute. These help in trapping fine air borne dust particles and are found to be one of the best mechanisms to control dust.

Dust Suppression Sprayer loaded on Truck

Tower Mounted Dust Suppression Sprayer

d) An automatic Tyre Wash system is installed for easy dirt removal from heavy vehicles carrying coal. The machine helps in removing the contaminants from the underneath of the vehicle ensuring contaminants are not carried over. The used water after sediment separation is recycled

e) As part of Green Belt Development, the port has planted nearly 140,000 hybrid casuarina saplings and other variety plants around the periphery of the port premises and coal plots with Participation of Self Help Group (SHG) members.

9.15. Environmental monitoring program at port

Continuous ambient air quality is monitored through CAAQMS installed in 3 locations and meteorological data through 1 station.

In addition, AAQ is monitored monthly using High Volume Samplers and Respirable Dust Samplers through MoEFCC recognized laboratory. The overall environment monitoring program is as shown below.

Continuous Ambient Air Quality Monitoring Station (CAAQM) installed at 3 locations on port

Current Environmental Monitoring program

Type of Monitoring	Parameters	Frequency
Air Quality (within Port)	PM_{10}, $PM_{2.5}$	Continuous Ambient Air Quality Monitoring Station at 3 locations North/Southeast/Northwest
Air Quality (surrounding villages)	PM_{10}, $PM_{2.5}$, SO_2, NO_x, CO	Once a month; through MoEFCC recognized laboratory
RO treated Water Quality	As per IS 10500:2012	Once a month; through MoEFCC recognized laboratory
STP Outlet	pH, Colour, DO, BOD, Oil & Grease, Coliform	Once a month; through MoEFCC recognized laboratory
Noise level	L_{eq} Day & Night Time	Once a month; through MoEFCC recognized laboratory
MET Data (within Port)	Wind Speed, Wind Direction, Temperature, Humidity, Rainfall	Continuous Monitoring Station

Table 9.1. Characterization of water

Sl.No	Parameter	Water Characteristics		
		Aug 2013	Sep 2013	Oct 2013
1	pH	6.76	7.07	6.98
2	Colour	5 Hazen	5 Hazen	5 Hazen
3	Total Dissolved Solids (TDS) (mg/L)	1131	1372	1232
4	Coliform (MPN/100 ml)	Absent/ 100 ml	Absent/ 100 ml	Absent/ 100 ml

Source: KPPL

Table 9.2. Characteristics of STP treated Water

Parameter	STP inlet (Untreated)	STP outlet (Treated)	CPCB standards
pH	6.83	6.9	6.5-9.0
Colour	250 Hazen	Clear Solution	No Noticeable Colour
DO (mg/L)	1.5	5.2	3.0 or higher
BOD (mg/L)	34	11	5
Total suspended Solids (mg/L)	126	14	100
Total Dissolved Solids (mg/L)	1537	1392	2100
Oil & Grease (mg/L)	6	4	10
Coliform	1600 MPN/100ml	350 MPN/100ml	500/100 ml
Chloride (mg/L)	492	499	1000
Sulphate (mg/L)	19	9	1000
COD (mg/L)	234	80	250

REF: STP outlet analyzed by Chennai Mettex Lab Pvt Ltd an NABL approved Lab

Table 9.3. Characteristics of water before and after treatment (HW generation treatment and disposal)

Cat No. as per Sch A of HW Rules, 2008	Description of Waste	Authorization Qty (MTPA)	Actual Generation quantity (MTPA) 2012-13	Method of Treatment/final disposal
5.1 of Schedule I	Used/Spent Oil	23 KLA		Stored on concrete floor under covered roof and disposed through authorized recycler
5.2 of Schedule I	Waste residue containing Oil	0.12 MTA		

10. DESCRIPTION OF BASELINE TERRESTRIAL ENVIRONMENT

10.1. Introduction

This chapter describes the baseline environmental conditions in and around the Project site at Karaikal Port. The baseline conditions were studied for an area of 10 km with the proposed project site as centre. The studies were conducted on various terrestrial environmental parameters through primary field visits, surveys and monitoring in the month of October 2013 in order to assess the impacts of the proposed development activity of BULK LIQUID BERTH for Handling LNG at Karaikal Port. A review of secondary/published data available for the region was also taken in account for assessing the prevailing environment.

10.2. Site and Surroundings

The Karaikal Port is located south-east of Vanjoor village and falls in the Thirumalairayan Pattinam Commune Panchayat taluka of Karaikal district in Puducherry Union Territory. The Study area covers a small portion of Karaikal taluka on its North and Neravy Commune Panchayat Taluka & Thirunallar Commune Panchayat taluka on its North-West of Karaikal district in Puducherry union territory and a small portion of Neravy Commune Panchayat of Karaikal district is falling in the TamilNadu state in its north west. The major portion of the study area falls in Nagapattinam Taluka of Nagapattinam district in TamilNadu state. The port is situated south of Karaikal town (9.26 km) and north of Nagapattinam about (7.62 km) and these two are the nearest towns having population of 102,838 and 227,587 as per census 2011 survey.

The access to the port is through a metalled road branching off from NH45A (connecting Puducherry-Nagapattinam). The nearest railhead and major habitation is 3 km to the south viz Nagore (Tamil Nadu). A rail alignment traverses along the western boundary of the Karaikal Port Site. To the either sides of Karaikal port, i.e., south and north- two captive jetties belonging to Chennai Petroleum Corporation Ltd and Sanmar Group are respectively are seen.

The site identified for the development of BULK LIQUID BERTH for Handling LNG is in within the harbor basin, along the southern breakwater of Karaikal Port.

Geographical location of Karaikal Port Pvt. Ltd. is represented in Fig. 10.1 and Fig. 10.2 covers the complete Study Area inclusive of the 10 km buffer zone around the Karaikal Port Pvt. Ltd. in Open Series Map No C44H13. Geographical area details are presented below.

Study area details for Karaikal Port Pvt. Ltd.

POINT	LATITUDE	LONGITUDE
A	10° 50' 52.52"N	79° 50' 30.82"E
B	10° 50' 54.22"N	79° 51' 11.21"E
C	10° 50' 17.64"N	79° 51' 06.73"E
D	10° 50' 31.68"N	79° 51' 51.28"E
E	10° 50' 14.09"N	79° 51' 49.87"E
F	10° 50' 03.75"N	79° 51' 12.47”E
G	10° 49' 39.52"N	79° 51' 08.40"E
H	10° 50' 13.65"N	79° 51' 05.09”E
I	10° 49' 48.17"N	79° 50' 40.86”E
J	10° 49' 50.87"N	79° 50' 24.56”E
K	10° 50' 21.32"N	79° 50' 35.12"E
Study Area (313 sq.km)	10° 50' 18.00"N	79° 50' 51.45"E

10.3. Land Environment

10.3.1. Topography

The study area is located near Karaikal town which is one of the four regions of the Union Territory of Puducherry in India. Karaikal town about 16 km north of Nagapattinam and 12 km south of Tarangambadi is the regional headquarters. Karaikal region is made up of the Communes of Karaikal, Kottucherry, Nedungadu, Thirunallar, Neravy and Thirumalairayan Pattinam. Karaikal is a small coastal enclave of territory which was formerly part of French India. Karaikal is bounded on the North and South by Nagapattinam district of TamilNadu state, on the west by Thirunallar district (also belonging to Tamil Nadu), and on the East by Bay of Bengal.

The study area is a typical coastal plain and forms a part of the fertile Cauvery delta five rivers running across. The river Vettar flowing just beneath the site through the Nagapattinam district of Tamil Nadu, the other is the Uppanar river which is lying in the south of the study area and flows through the Nagapattinam town of Nagapattinam district of Tamil Nadu, the other river named Puravadaiyanar river is flowing along the north border of the port through the Karaikal district and Nagapattinam district, third river Tirumalarajanar which lies in the north of the study area is flowing through the Karaikal district and the fourth river named Aransalar and its tributary Vanjirar river lies on the north of the study area and flowing through the Karikal district.

The project site vicinity exhibits flat terrain features with a gentle slope towards east Bay of Bengal. The seashore in general is flat in this region. The stretch between the coast and back up land area varies from 1.4 to 1.5 m above MSL, while the levels increase from 0.7 m on the bank of the river. The average levels in the port area are 1.5 m above MSL.

The map in Fig. 10.3 below shows that the belt near shore on landside, surrounding has elevation below 10 m and is gently sloping land.

10.3.2. Geology

The study area is completely covered by a thick mantle of alluvium, Fig. 10.4. The geology of Karaikal region is represented by Cuddalore Sandstone of cretaceous period overlain by Karaikal beds followed by alluvial, blown sands belonging to recent and Sub Recent Age.

Mineral found in these parts of Tamil Nadu and Pudduchery includes brick clays, Kankar, Sea shells, Ilmenite and garnet sands. In the 10 km study area, salt pans are noticed. Numbers of mineral bearing areas are seen such as Ilmenite.

10.3.3. Land Use and Land Cover

The land use in the immediate vicinity of the port site is mixed as industrial and agricultural patterns are coexisting. There are a few isolated Casurina plantations along the coast and some disused aquaculture ponds in the southwest portion of the project site. The region has good irrigation system with numerous irrigation drains, which are catering the agricultural needs of the region. Paddy is the main crop while other grown are pulses, cotton, ragi, bajara, groundnut and Gingelly banana and vegetables.

LULC is the distribution of natural as well as man-made features on earth surface. The LULC data collected is classified on bases of National Natural Resources Information System (NNRIS) scheme of classification. The classification scheme is given in Table 10.1 and their respective definitions in Table 10.2.

On above classification grounds the area distributions along with percentage distribution of the different LULC classes within the study area are shown in Table 10.3 and Fig. 10.5 respectively.

The pie-diagram describing the land-Use & Land Cover classes and their percentage shares are shown in Fig. 10.6. The total cultivable area in the study area is approximately 31.34 km^2 which includes land under Kharif cropped area, Rabi crops and double cropped areas. Plantation covers the area of 1.72 km^2 out of the total area. Out of the total area 312.09 km^2 urban class covers the area of 8.62 km^2, village/town class covers the area of 8.71 km^2, industrial class covers the area of 1.10 km^2, open class covers the area of 80.92 km^2, low dense tree cover class acquires the area of 20.14 km^2, mangroves covers the area of 0.10 km^2, canals covers the area of 0.05 km^2, river covers the area of 4.34 km^2, ponds class covers the area of 2.79 km^2, sea class covers the area of 147.44 km^2 and open wet class covers the area of 4.81 km^2.

10.3.4. Soil

a) Reconnaissance: Soil types found here in this study area are i) Red soil ii) Black soil iii) Alluvial soil and iv) Colluvial soil. The study area has deltaic alluvial type of soil around as vivid through the map given in Fig. 10.7.

b) Soil Sampling location: The characteristics of the soil were analyzed at five locations in the study area during pre monsoon season in October 2013 description of soil sampling location is presented in the table below and the location are shown on map in Fig. 10.8.

Code	Region	Justification
Soil 1	West of Port	Agricultural land just west of site. May be affected by port activities and proposed expansion
Soil 2	Site (Within port)	Site soil, to ascertain suitability for green belt development
Soil 3	North West of Site station (approx 1 Km)	Fallow land; close to port
Soil 4	South of PIPDC Karaikal	Natural undisturbed site
Soil 5	Kizhayoor South	Agricultural land

Soil Quality: From the data presented its seen that the soil is a mixture of Sand Silt and Clay exhibiting Sandy nature. Soil analysis results at station 5 shows higher concentration of elements such as Calcium, Magnesium, Nickel, Zinc, Copper, Lead, Potash, Iron and Nutrients compared to other stations in the study area. Soil analysis results of study area, Karaikal are presented in Table 10.4.

10.3.5. Seismicity

Geographical statistical analysis of Indian subcontinent as seen from the representation in below Fig. 10.9 shows that almost 54% of the land is vulnerable to earthquakes.

Bureau of Indian Standards [IS-1893 (Part-1): 2002], based on various scientific inputs from a number of agencies, has grouped the country into four seismic zones viz. Zone-II (Low intensity zone), III (Moderate intensity zone), IV (Severe intensity zone) and V (Very severe intensity zone). Of these, Zone V is the most seismically active region, while zone II is the least.

The proposed project area and surrounding region falls under Zone III (low damage risk zone) as per the seismic map of India as seen on IMD website [prepared from IS: 1893 (Part 1) – 2002], Fig. 10.9.

10.4. Meteorological Data

10.4.1. Climate and Rainfall

The study area experiences tropical maritime type of climate with small daily range of temperature and moderate rainfall. The average temperature at the shoreline is 28°C as read from the Fig. 10.10.

The historical data for 16 years given below in Table 10.5 shows that the highest temperature is 39.8°C and lowest 19.1°C. The relative humidity at day time is 79% and at night 74%. The period from April to August is the hot season with maximum temperature reaching 39.8°C, while December to February is the cold season with the minimum temperature reaching 29.1°C in January.

The region receives rain under the influence of both southwest and northeast monsoons. Most of the precipitation occurs in the form of cyclonic storms caused due to the depressions in Bay of Bengal chiefly during Northeast monsoon period. November is the month of heaviest rainfall. The diurnal ranges of temperature are generally small throughout the year, being highest in May and June, and the least during November to February.

10.4.2. Meteorological Data during Study Period

The temperature during the study period ranges from 35.1°C to 21.1°C with relative humidity remained high 92.6% being the monsoon season in the study area as given in Table 10.6.

The wind rose diagram (Fig. 10.11) gives the information regarding the speed and the direction of the wind of Project site during the sampling season. It can be observed from the below wind rose diagram that the direction of the wind is predominantly from the South-West direction with a maximum speed of 30-40 km/hr.

10.5. Ambient Air Quality Monitoring (AAQM)

A methodically designed Air Quality Surveillance Program (AQSP) should form the basis to determine the impact assessment on air environment, which ultimately helps in formulating a sound Environmental Management Plan (EMP). The basic considerations for designing such program include:

- Representative selection of sampling locations (primarily guided by the topography & micrometeorology of the region)
- Adequate sampling frequency
- Inclusion of all the major pollution parameters

All these aspects were given due consideration for devising an optimal scheme for AQSP for Environmental Impact Assessment (EIA) around the project site.

10.5.1. Reconnaissance

The study area to the North and west of KPPL primarily comprises large tracts of agriculture/open-scrub land and is distinctly rural in character. The area to the south is urbanized and comprises forms of Nagore and Nagapattinam. Air pollution sources in the study area includes traffic carrying goods to/from the port along the NH 45A (from

Nagapattinam to Gundlupet) and 67 (from Viluppuram to Nagapattinam) and SH's 49 (from Thiruvanmiyur to Puduchery), 67 (from Nagore to Nachiyar), 147 (from Kumbakanam to Karaikal) and 148 (from Nagore to Vettar). The KPPL and village Vanjore is surrounded by small and medium industries of mixed type (including chemical units like ONGC Kiran Global Chems Ltd, Chemplast Sinmar, Vann Chemical, Sunchem Products, etc) Iron and steel sector units like W. Ferro Alloys, RKN Vanjore Silicates and other units such as Pudduchery Power Corporation Ltd, Laxmi Polyethylene, etc.) Major industrial units observed in the study area include Cavery basin Refinery of CPCL (Chennai Petroleum Corporation Ltd) at Boothangudi , (Aprox 3.8 km to South West), Narmanam has Turbine Power station of TNEB at Uthamasolapuram village (Approx 4.5 km Southwest) Chemplast Sanmar at village Melavanju and ONGC Traffic along North and other state highway is secondary source.

10.5.2. Ambient Air Quality Monitoring

The prime objective of this AAQ study was to establish the existing regional background levels within study zone of proposed project. Major sources of air pollution were identified as medium and small-scale units spread over surrounding 10 km area as discussed above. The fluctuation of AAQ within the study zone of proposed project will be governed by overall regional emissions and micrometeorology.

A network of six monitoring stations has been designed to assess the baseline air quality based on the prevailing wind pattern in the study area given in Table 10.7 and Fig. 10.12. The AAQM results are presented in Table 10.8 and are within the limits as prescribed by Central Pollution Control Board (CPCB) norms.

Comparison of Ambient Air monitoring results with NAAQ standards indicates PM_{10}, $PM_{2.5}$, SO_2, NO_x, CO, NH_3 & nMHC etc have concentration levels below the specified norms for ambient air.Hence ambient air in the 10 km study zone is well within the norms laid down by CPCB.

The ambient air quality at the port site is monitored on monthly basis through MoEFCC recognized Laboratory and the results of same are summarized in Table 10.9.

10.6. Noise Environment

10.6.1. Reconnaissance

Noise levels can cause disturbance to the surrounding environment, if it not in the limits. Hence the Noise levels were monitored in the study area in such a way that the present noise levels in the possibly affected area can be noted with respect to the quiet residential and rural zones.

10.6.2. Noise Quality Monitoring

The Noise levels were studied at 6 stations within study area as mentioned below.

Sampling stations for Noise level study

Station Code	Location/ Village
N 1	Site
N 2	Kizhayoor south
N 3	Vaddakku vanjur
N 4	Near Nagore railway station
N 5	Near fishery university
N 6	Road junction

Noise level data collected for day time/night time is presented Table 10.10

The noise levels at the road side stations N2 & N3 shows higher values due to vehicular activity corresponding to traffic and commercial activities while at stations N4 & N6 the noise levels are even more higher due to heavy vehicular traffic & few industries located in the region with respect to the permitted levels of CPCB for Residential, Commercial and Industrial limits for both day and night averages. Station N1 (Project site) & N2 (Fishery university) show low noise levels as they are far away from traffic source.

Noise levels being monitored by KPPL every month through MoEFCC recognized Laboratory; data for the same is presented Table 10.11.

10.7. Traffic

10.7.1. Reconnaissance

The port is situated south of Karaikal town and north of Nagapattinam about 10 km, on the west by Thirunallar district (also belonging to Tamil Nadu), on the East by Bay of Bengal and is well connected on 3 sides by road. It is expected that the proposed development would impact on the traffic in this network. Nagore (Tamil Nadu) is the nearest railhead and major habitation 3 km away. The access to the port is through a metalled road branching off from NH45A (Connecting Puducherry-Nagapattinam).

To the either sites of Karaikal port, i.e., south and north are two captive jetties belonging to Chennai Petroleum Corporation Ltd and Sanmar Group respectively.

10.7.2. Traffic Survey

The study area was studied for traffic levels at 3 stations, as indicated in Fig. 10.13 and data for the traffic levels monitored as presented in Table 10.12.

The motor cycle forms the major type of traffic at all stations that are monitored, while car and auto rickshaw form the second. Traffic at around T3 site is low when compared to all other stations. Traffic of heavy vehicles such as Trucks and buses is high from Melavanjur to Karaikal and North up and down. Traffic study at selected stations in study area Karaikal is presented in Table 10.13.

10.8. Water Environment

10.8.1. Ground Water

Reconnaissance

Ground water occurs under both phreatic and confined conditions in all the three major group of geological formations, viz., Cuddalore sandstones, Karaikal formations and Alluvium formations. The eastern and northern parts of the region are characterized by saline groundwater hence unfit for both domestic and irrigation purposes and further development. The occurrence of potable water bearing aquifers are limited to the western part of the Karaikal Region In Nagapattinam district, the bulk of rural water supply is from ground water by means of dug wells, hand pumps (filter point) and tube wells owned by individuals. Fig. 10.14 describes the ground water hydrology and potential of the area surrounding the Project area. Ground water sampling stations are given below.

Ground Water Quality Monitoring

The Ground water quality was assessed at 5 stations as described below and shown in Fig. 10.15.

Ground water sampling stations

Code	Region	Justification
GW 1	West of Site(bore well)	Aim was to understand the baseline characteristics of the groundwater from bore wells/ wells/ hand pumps/ tap water in the study area by sampling these in the study area. Essential to confirm that there is no contamination of ground water due to port and its proposed essential.
GW 2	Near Nagore Railway Station(bore well)	
GW 3	Near Fishery University(bore well)	
GW 4	Kizhayoor South(bore well)	
GW 5	~2 km North West of Site AQ station (bore well)	

The ground water results are given in Table 10.14. The ground water has alkaline tendency with other nutrient parameters being in range except nitrate which is high at GW1. Heavy metals are mostly below detectable levels. The GW1 site show highest number of microbes. Ground water at locations GW2 and GW5 show that water is very high in hardness.

10.8.2. Surface water

Reconnaissance

Mainly five rivers flow through the study area. The river Vettar flowing just south of the project site through the Nagapattinam district of Tamil Nadu; river Uppanar lying in the south of the study area and flowing through the Nagapattinam town of Nagapattinam district of Tamil Nadu; the river Puravadaiyanar flowing through the Karaikal district and Nagapattinam district; river Tirumalarajanar which lies in the north of the study area is flowing through the Karaikal district and the river Aransalar and its tributary Vanjirar river lies on the north of the study area and flowing through the Karikal district. Numbers of small and large sized lakes are seen spread out in study area but dry out during summer seasons.

Surface water Quality Monitoring

The surface water quality was assessed at 5 stations, Fig. 10.16 on following criteria as given in Table below:

Code	Region	Justification
SW 1	Near Site	Effect of port activities may be visible
SW 2	Lake Southwest of Fisheries University (~1 km)	At the junction of major roads, in a highly populated area, possibly receiving wastes/ sewage
SW 3	~1.7 km North West of Site AQ station	Possibly contaminated
SW 4	Lake South of PIPDC Karaikal	Relatively away from populated area; natural & undisturbed
SW 5	Sivan Kulam	In highly populated areas, may be receiving wastes/sewage

The surface water results are given in Table 10.15 below and historic data of STP outlet characterization is given in Table 10.16. The pH shows alkaline nature of surface water at all stations. The nutrient parameters are in desirable limits and heavy metals are below detectable levels. The fecal counts show presence with higher number in SW1 and SW2 stations. The results show the surface water at SW1 has highest TSS and TDS, with higher sulphates and higher number of fecal counts.

10.9. Ecology and Biodiversity

10.9.1. Introduction

Anthropogenic activities bound to disturb species in surrounding, which leads to hamper ecosystem. Repetitive such disturbance may aggravate the situation unless corrective measures are adopted.

Generation of base-line data and knowing the type and extent of pollutants/activities can help to prepare a realistic EMP.

10.9.2. Physical Setting

The Site & Study area under consideration lies in the Nagapattinam district, a coastal district in Tamil Nadu on the shores of Bay of Bengal with a coastline of approx. 187 km. The district receives around 70% (1000 mm) of the total rainfall during the North-east Monsoon (October to December) and the temperature varies seasonally from 26°C to 32°C. The soil types in the district are sandy coastal alluvial soil and Riverine alluvial soil. The forest cover in the district is approx. 4633 hectares which is mostly Tropical dry-evergreen forests and scrublands in the inlands and mangrove forests at the coast.

10.9.3. Survey and Findings

Study Area

Study area is considered as the region falling within the radial distance of 10 km around proposed site. According to bio-geographical zone classification of India, entire study area falls under ‘Coasts’. Entire study area is covered in Toposheet no 58N/13; Open Series Map no. C44H13.

Terrestrial ecology & biodiversity study pertaining to Environmental Impact Assessment report for proposed FSRU for LNG at Karaikal port was carried out in October 2013. Field visit to site and surrounding reveals that, study area has flat terrain, referred as 'Coastal Plains' as commonly seen in east coastal region. Based on the topography, climatic conditions, soil types, availability of habitable area; the study area possess different habitats like scrub land, water bodies, agricultural fields, human settlements etc. These habitats possesses different characteristic which supports typical composition of flora and fauna within them. Study was carried out by visiting locations, taking care that all such habitats were covered. Listing of flora and fauna was done based on actual sighting, indirect evidences such as calls, droppings, burrows, pugmarks and other signs etc., interviewing locals, literature survey, data collected from forest officials and internet references. Occurrences of species in respective habitats are presented in Table 10.17 and 10.18.

Human Settlements: Human habitation in study area is rural in nature except, part of Nagapattinam and Karaikal and Nagore. Villages in study area are found in hamlets situated intermittently within agricultural fields. Plantation along road side (*Samania saman, Borasus flabelifer, Peltophorum pterocarpum, Eucalyptus etc.*) around the houses (*cocos nucifera, Anona squamosa, Moringa olifera* etc.) in public gardens, along the seashore (*Caesurina equisetifolia*). For the purpose of listing the species; open/waste area adjacent to human settlement are also considered in this habitat.

Mela Vanjore

Nagore (Thethi Nagar)


Vadakku Vanjore Near CPCL Colony

Images showing Human settlements in project area, Karaikal

Scrub Land: Scrub land in study area is dominated by *Prosopis juliflora*. Patches of *Prosopis juliflora* forest are seen behind Puducherry Industrial Promotion Development and Investment Corporation (PIPDIC) area. This designated area is encroached by vegetation as it is abandoned. Similarly other places such as along bank of Vettar River, besides CPCL refinery at Boothnagudi, Akkaraikulam Lake near Nagapattinam etc. These are the only parts in study area that has some wild fauna.


Abandoned Puducherry Industrial Promotion Development & Investment Corporation area

Along with the *Prosopis juliflora* common shrubs that are found are *Calotropis gigentia, Ziziphus jujube, Acacia nilotic, Tephrosia pururia, Borasus flabelifer* etc.


Image showing areas near Nethaji Nagar (Karaikal) (left) & CPCL Colony (right)


Vegetation along Vettar River




Images showing fauna observed behind PIPDIC during field studies in project area

Scrubs in study area seem to be in anthropogenic pressure because of fire wood and disposal of waste material and grazing by surrounding populace. Such activities are not only thinning the vegetation cover but also cause threat to faunal life within it.

Firewood cutting near Nethaji Nagar (Karaikal) and behind PIPDIC

Water Bodies: Almost 50% of study area is covered by water bodies; majority of it is Bay of Bengal. Besides saline water body (which is out of scope of this study), several ponds were observed in villages. These fresh water bodies observed with algal growth, covered with floating aquatic angiosperms like *Lemna, Pistia,* and Echornia etc. this may be because of primary use for washing/cleaning purpose. Of them, some ponds observed to invite avifauna and few mammalian species. The study area has five prominent rivers viz. Arasalar, Tirumalarajanar, Puravadalyanar, Vettar, and Uppanar. Along with several small streams/tributaries they form good network. Several cannels emerging out of them feeds water to surrounding agriculture. For the purpose of listing species, waterlogged areas, manmade canals, rivers, creeks, ponds are also included in this section.

Image showing Sivan Kulam Lake in Nagore (left) & Canal from Puravadalyanar River near Kannappan Iron & Steel Company (right)

Lake near Panangudi and aquatic species therein

Lake behind PIPDIC and fauna observed (Cow & Sand Piper)

Checkered Keel back in Canal near vilage Neravy Pied Kingfishers

Commom floral speies observed in water bodies are *Ipomoea aquatica, Typha,* Nymphia *sp., Eichhornia crassipes Lemna* etc. Common faunal species are brahminykite, Kingfishers etc.

Agricultural Fields: This is major land use in study area. Rice being the predominent crop, Green gram, black gram, Sugarcane, groundnut, Gingelly and cotton are other principal crops. Due to sufficient water availablity from Cauvery irrigation canal system, double cropping is practiced. The normal cropping system is Rice (Kuruvai/ Kharif) - Rice (late

Samba / Rabi) - Rice fallow crops (pulses/ cotton /gingelly). Other vegetable crops like Lady's finger, Brinjal, Raddish, Tomato and greens are usually sown during August (Adipattam) and January (Thaipattam) in this region. Trees of Mango, Sapota, Annona, Guava, Amla, Papaya, Coconut and Tamarind are being maintained in this region. Forest out turn is only from timber.

Livestock animals here in this region are Cattle, Buffalo, Sheep and Poultry. Faunal species like sqirrel, cattle egrets, green bee eater, kingfisher etc. were observed commonly in the study area. During study period practice of ship grazing in field, ploughing, sowing, appling of fertilizers etc. were observed.

Borasus along field boundary is common in the study area. Asian Open Bill Storks in Rice field

Indian Tree Pie and Yellow wattled lapwing in Rice field

Sheep grazing and Indian roller common sighting around fields

Beside these habitats, study area also has shrimp farming and avifauna like Brahminy kite, kingfisher etc. are observed around it. Creeks feeding water to these shrimp farms exhibits mangroves at few places.

Aquaculture in project area, Karaikal

Similarly, at few places in industrial area plantation is seen along the boundary having plants like *Azadirachta indica, Panama pinnata, Cocos nucifera, Vinca rosea* etc. List of flora (Table 10.17 and fauna Table 10.18).

Site: Actual proposed site is along the southern breakwater and hence no question of affecting terrestrial flora fauna, however transportation of LNG is part of proposed activity and will be through existing Karaikal port area. The port area observed to have green belt which is yet not fully developed/grown stage. Species like *Terminalia cattapa, Caesurina equisetifolia, Nerium indicum, Peltophorum pterocarpum, Cocos nucifera, delonix regia, Samania saman, Alamanda cathertica, Cynodon dactylon, Cycus, Plumeria alba, Vinca rosea, Duranta plumeri, wedelia* are planted along the boundary, internal roads and coal handling area. Other than developed green belt, at some places within site observed wild vegetation like *Prosopis juliflora, Calotropis gigentia, Tephrosia purpuria* etc are observed insite.

Rabbit and Ducks are observed within site in captivity; Other than captive faunal members, birds like myna, cattle egret, kite, *dogs* were observed to visit the site.

Green belt development at Site

10.10. Socio economic Status

The socio-economic conditions have been arrived through collection of secondary data from Department of Census Operation of Pudduchery and Tamil Nadu.

10.10.1. Demography and Literacy

The total population per sq.km of Study area as per Census 2011 is given below. Further it is also registered that this region shows good literacy of 76.50% as per 2011 Census.

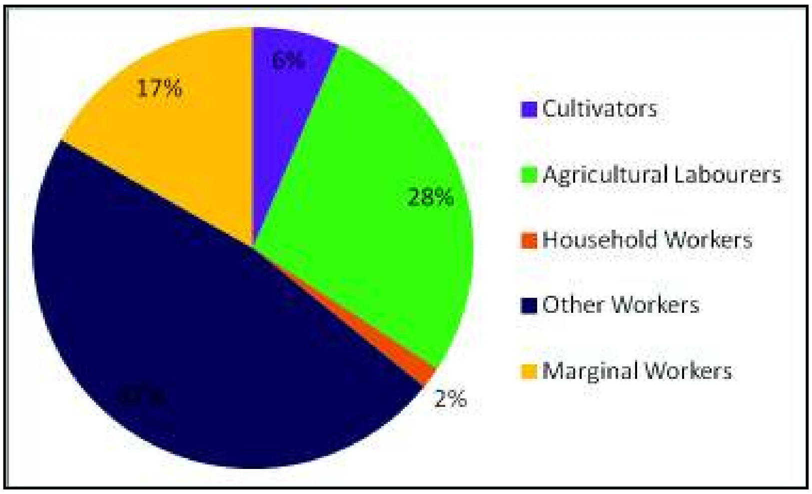
District	Villages
Nagapattinam	Pannangudy, Attur, Kottamangalam, Agarakondagai, Nagore Kottagam), Kohur, Sellur, Tittacheri (TP), Kuttalam, Vadagarai, Kattumavadi, Vazhkkudi, Okkur, Tenkarai, Budangudi, Uttamacholapuram, Narimanam, Panangudi, Gopurajapuram, Sengamangalam, Palaiyur, Turaiyur, Vengidangal, Thethi, Manjakollai (CT)
Karaikal	Vanjiur, Thirumalairayanpattinam (CT), Neravy, Kizhamanai

The study area has a birth rate of 16.5/1000 population, death rate of 6.5/1000 population with respect to 2011-12 profile.

The occupational structure, rural population located and urban population around the study area are shown in Fig. 10.17 and Table 10.19 gives the details of population & literacy details in study area.

10.10.2. Occupation pattern

Agriculture is the main occupation and fishing being the second most important activity is shown below. The work population details are given below in tabular format Table 10.20 and the industrial expanse in the study area is represented in Fig. 10.18. Fishing being the second important activity there are no major fish landing centers in surrounding area, while number of small fishing boats are seen and other activities of boat repair yard area long river bank. Small fishing communities are also involved in pisci-culture in tanks/ponds.



Pie chart representation of occupation patterns in Karaikal region.

10.10.3. Archaeological & Histological Importance

The Archaeological and historical importance are given in Table 10.21.

Table 10.1. Classification scheme of Land Use Land Cover Classes

Level I	Level II	Level III
Habitation	Residential	Urban
		Village
	Industrial Area	Industrial Area
Agriculture	Permanent Fallow	Permanent Fallow
	Kharif	Kharif crop
	Rabi	Rabi crop
	Double Crop	Double Crop
	Plantation	Plantation
Wasteland	Open	Open
	Low Dense Forest	Low Dense Tree Cover
	Dense Forest	Dense Tree Cover
	Mangroves	Mangroves
	Reserve Forest	Reserve Forest
	Wildlife Sanctuaries	Wildlife Sanctuaries
Others	Roads/Rail	State Highways
		National Highways
		Other Roads
		Rail Track
	Mining Area	Mining Area-Present
Water	River/Nallahs/Drainage	Drainage/Nallahs
		Canals
		River
	Ponds	Ponds
Heritage Site	Heritage Site	Heritage Site

Table 10.2. Definition of all Land Use Land Cover Classes

Sl. No	Class	Class Definition
1	Urban	Areas within urban perimeters, inclusive of suburban areas surrounding big cities. These areas are clearly visible and demarcated through the difference in the spectral values and signatures of these features in the satellite images
2	Village/ Town	Low density of built-up, generally surrounded by farmlands/agricultural fields,
3	Industrial	Heavy Industrial areas whether it be tank farms, chemical plants, junk yards, truck terminals, or other industries with large amounts of outside storage of materials and/or equipment. Shipyards, Mostly situated outside the main city. Warehouses, tin shed buildings/maintenance yards near railway station. Interpreted through their characteristic large footed building footprints, spectral tonal and textural variation in satellite images.
4	Permanent Fallow	Land left unseeded for a season or more in order to increase its productivity. It may have undergone plowing and harrowing and has been left unseeded for one or more growing seasons.
5	Kharif crop area	Cultivated land, which are usually sown with the beginning of the first rains in July, during the south-west monsoon season.
6	Rabi Crop area	Cultivated land, which are usually sown in the winter season.
7	Double Crop	Cultivated land in both Kharif and Rabi season.
8	Plantation	Orchards and vegetation grown with manual efforts. Areas with planted trees which are, or have been, used for the harvesting of tree fruit crops. Often forming a distinctive block and displaying a highly organized (often grid) pattern of planting.
9	Open	No buildings, no vegetation e.g. desert, beach, and open lands mostly barren.
10	Low dense Tree Cover	Low density of trees, Low vegetation, bushes, scrubs with low tree density.
11	Dense Tree cover	All kinds of dense forest (70-85% dense trees in unit area) in rural areas, over hills/ mountains, Natural parks with high tree density.
12	Mangroves	A tree or shrub that grows in muddy, chiefly tropical coastal swamps, typically having numerous tangled roots above ground that form dense thickets.
13	Reserve Forest	Reserve Forest demarcation as published in SOI Toposheets at best available scales. (Noted forests accorded a certain degree of protection. Which are often upgraded to the status of wildlife sanctuaries, which in turn may be upgraded to the status of national parks) Delineated from Toposheet.
14	Wildlife Sanctuaries	Naturally occurring sanctuary that provides protection for species from hunting, predation or competition, or it may refer to a protected area, a geographic territory within which wildlife is protected. Delineated from Toposheet.

Sl. No	Class	Class Definition
15	State Highways	Digitized from latest vintage satellite images and classified based on reference to ancillary map sources. Validated through field survey.
16	National Highways	Digitized from latest vintage satellite images and classified based on reference to ancillary map sources. Validated through field survey.
17	Other Roads	Digitized from latest vintage satellite images and classified based on reference to ancillary map sources. Validated through field survey.
18	Rail Track	Digitized from latest vintage satellite images and classified based on reference to ancillary map sources. Validated through field survey.
19	Mining Area-Present	Open excavation on the ground that is clearly visible in satellite images. Mainly for extraction of minerals or matter for industrial purposes.
20	Drainage/ Nallahs	Flowing water bodies or water channels that are clearly visible and identifiable on the source satellite image used for classification of the LULC data.
21	Canals	Man made dynamic flowing water bodies.
22	River	Only Dynamic (flowing) water bodies. Clearly visible and distinguishable on the source satellite images for data creation have been captured
23	Ponds	Inland permanent water bodies. This class will consist of lakes & dams. Seasonally waterlogged areas.
24	Heritage Site	A natural or man-made site, area, or structure recognized as being of outstanding international importance and therefore as deserving special protection.
25	Sea	Sea, Ocean, water beyond coastline away from land.
26	Open Wet	Areas displaying high moisture content close in proximity to large water bodies

Table 10.3. Percentage Distribution of LULC Classes within Study Area, Karaikal

Class Code	Class Name	Area (Sq. Km)	Distribution (%)
1	Urban	8.62	2.76
2	Village/Town	8.71	2.79
3	Industrial Area	1.10	0.35
5	Kharif crop	8.54	2.74
6	Rabi crop	18.30	5.86
7	Double crop	4.50	1.44
8	Plantation	1.72	0.55
9	Open	80.92	25.93
10	Low Dense Tree Cover	20.14	6.45
12	Mangroves	0.10	0.03
21	Canals	0.05	0.02
22	River	4.34	1.39
23	Ponds	2.79	0.90
25	Sea	147.44	47.24
26	Open Wet	4.81	1.54
	Total Area (Sq.Km)	**312.09**	**100**

Table 10.4. Soil analysis results of study area, Karaikal

Sl.No.	Parameter	S 1	S 2	S 3	S 4	S 5
1	Sand (%)	45.22	62.97	49.92	42.9	58.26
2	Silt (%)	44.92	28.55	27.24	25.33	22.36
3	Clay (%)	9.86	8.48	22.83	31.77	19.39
4	Soil Texture	Loam	Sandy Loam	Sandy-Clay Loam	Clay Loam	Sandy Loam
5	Bulk density (g/cm$^{3)}$	1.69	1.81	1.56	2.02	2.25
6	Porosity (%)	37	43	41	32	39
7	Water holding capacity (Inches/foot)	1.26	1.95	1.87	1.15	1.75
8	pH @ 25°C	8.9	9.1	7.74	5.66	8.3
9	Electrical Conductivity (µmhos/cm)	502.3	3083	3430	53.58	148.6
10	Calcium (mg/kg)	717.3	1040.3	954.9	669.5	1379.6
11	Magnesium(mg/kg)	487.9	9.1	1269.5	486.5	1707.1
12	Sodium (mg/kg)	77.3	492.3	1424	334.1	544.5
13	Potassium (mg/kg)	249.5	233.7	471.4	169.6	366.3
14	Organic Carbon (mg/kg)%	0.149	0.118	0.37	0.229	0.46
15	Total Nitrogen (mg/kg)	661.2	132.7	795.8	2386.1	3435.3
16	Phosphorous (mg/kg)	13.5	0.08	1.74	0.5	7.9
17	Cadmium (mg/kg)	BDL (D.L-0.3)	BDL (D.L-0.3)	0.12	BDL (D.L-0.3)	BDL (D.L-0.3)
18	Chromium(mg/kg)	31.1	24.5	31.2	24.1	30.9
19	Cobalt (mg/kg)	4.41	3.21	0.12	5.27	5.83
20	Copper (mg/kg)	5.7	5.1	13.08	7.33	16.03
21	Nickel (mg/kg)	10.8	8.43	13.23	8.62	14.27
22	Lead (mg/kg)	0.22	1.41	4.17	3	5.59
23	Manganese(mg/kg)	43.27	51.07	75.48	18.67	62.22
24	Zinc (mg/kg)	8.93	6.54	33.85	10.7	44.81
25	Iron (%)	0.74	0.54	0.82	0.65	0.89

Note: Samples analyzed by M/s Creative Engineers, a NABL approved Laboratory (Annexure-II)

Table 10.5. Historical climatological data for Karaikal District

Months (1973-1990)	Air Temperature (°C)		Relative Humidity (%)		Wind Speed (km/hr)
	Max	Min	Day	Night	(Av)
Jan	29.1	19.5	83	74	10.5
Feb	30.5	19.9	82	72	9.5
Mar	33.2	21.7	80	74	9.6
Apr	36.8	23.6	79	76	12.0
May	39.8	23.8	74	73	16.7
June	39.1	24.3	69	66	18.2
July	38.0	23.2	2	68	16.0
Aug	36.9	22.7	75	70	15.4
Sep	35.4	22.6	78	75	12.5
Oct	34.1	22.2	83	78	9.2
Nov	31.4	21.0	86	79	9.8
Dec	29.5	20.3	85	79	11.5
Av (16yrs)	**39.8**	**19.1**	**79**	**74**	**12.6**

Source: Govt. of India, Ministry of Earth Sciences, India Metrological Department

Table 10.6. Climatological data averages in the study area

Date (dd/mm/yy)		Temp (Deg C)	R Humidity (%)	Speed (Km/hr)	Cloud cover (Octas)
10/09/13	Min	21.1	28.3	6.8	2
	Max	34.6	83.2	42.5	6
11/09/13	Min	26	60.2	4.4	2
	Max	32.2	86.3	42.5	4
12/09/13	Min	26.5	68.6	6.8	1
	Max	29.5	89.4	19.9	5
13/09/13	Min	24.2	62.5	8.9	1
	Max	31.6	92.3	30.1	7
14/09/13	Min	26	60.2	9	1
	Max	31.4	83.2	25.2	5
15/09/13	Min	26.3	60.2	4.4	2
	Max	32.2	89	36.7	5
16/09/13	Min	26.2	61.2	7.7	2
	Max	31.5	83.1	42.5	6
17/09/13	Min	24	63.1	6.6	2
	Max	32.3	92.6	36.2	7
18/09/13	Min	26.1	57.6	9.7	2
	Max	32.6	89.1	34.6	5
19/09/13	Min	26.2	54	5.9	3
	Max	33.6	86.2	31.1	7
20/09/13	Min	27.3	56.2	4.1	2
	Max	32.4	83.1	42.4	7
21/09/13	Min	27.1	50.2	11.7	2
	Max	34.2	83.2	38	5
22/09/13	Min	26	43.2	10.4	0
	Max	35.1	85.2	31.3	5
23/09/13	Min	26.4	43	8.5	3
	Max	34.3	87.3	22.2	6
24/09/13	Min	27	50.1	7.4	2
	Max	33.2	88.6	28.3	6
25/09/13	Min	27	55.4	8.8	2
	Max	33.3	84.4	31.1	7
26/09/13	Min	26.4	60	4.2	2
	Max	32.5	83.4	34.2	6
27/09/13	Min	27	55	6.6	2
	Max	33.6	84.3	30.7	7
28/09/13	Min	27	54.3	5.5	0
	Max	33.6	84.3	26.9	5
29/09/13	Min	27	45	10.5	1
	Max	34.4	89.4	32.8	6
30/09/13	Min	26	45.1	8.6	2
	Max	33.3	85.2	31.6	6
Study Period (Avg)	**Min**	**21.1**	**28.3**	**4.1**	-
	Max	**35.1**	**92.6**	**42.5**	-

Table 10.7. Air Quality Monitoring Station description

Station Code	Site Justification	Direction Justification
AQ1-Keezhaiyur South	Populated area	Downwind for SE winds during September and Upwind for SE winds during October
AQ2-Fisheries University	Fisheries University is an important receptor	Upwind for W winds in September and October
AQ3-Port Road Junction	Residential area, close to road approaching port, traffic will increase with port expansion	Upwind for SW winds in September and October; Downwind for NE winds in Oct
AQ4-Near Nagore Rly stn	Residential Area	Upwind for SW winds in Sept and Oct; Downwind NE winds in Oct
AQ5-Site	Proposed expansion site for port	
AQ6-Tsunami Houses, Vadakku Vanjur	Close to port and important receptor as a residential area	Downwind for S winds in Sept

Table 10.8. Air quality results in study area at selected sampling stations, Karaikal

Parameter		PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3)	SO_2 (µg/m^3)	NOx (µg/m^3)	CO (mg/m^3)
AQ1	Min	76.20	31.20	4.10	8.10	BDL(D.L-1.144)
	Max	97.40	41.20	6.70	9.70	
	Av	86.68	36.20	5.50	9.00	
	98th Percentile	96.57	40.95	6.66	9.66	
AQ2	Min	65.60	29.30	4.70	7.30	BDL(D.L-1.144)
	Max	83.40	37.60	7.30	10.50	
	Av	76.83	33.63	6.00	9.06	
	98th Percentile	83.16	37.40	7.23	10.42	
AQ3	Min	73.10	29.40	4.80	6.60	BDL(D.L-1.144)
	Max	89.70	38.90	7.20	9.70	
	Av	81.53	34.89	5.84	8.51	
	98th Percentile	89.20	38.69	7.14	9.69	
AQ4	Min	61.80	25.80	4.50	7.30	BDL(D.L-1.144)
	Max	81.40	36.30	6.90	11.40	
	Av	71.43	30.49	5.66	9.25	
	98th Percentile	80.85	36.01	6.86	11.30	
AQ5	Min	62.90	27.90	4.40	7.70	BDL(D.L-1.144)
	Max	81.30	36.90	7.00	9.50	
	Av	72.38	33.36	5.81	8.74	
	98th Percentile	81.08	36.77	6.97	9.47	
AQ6	Min	71.80	30.90	5.80	7.70	BDL(D.L-1.144)
	Max	93.90	38.60	8.30	12.20	
	Av	82.89	34.74	7.08	10.33	
	98th Percentile	93.41	38.404	8.272	12.13	
Std*		100	60	80	80	4.0

Note: Environmental sampling/analysis carried by M/s Creative Engineers, a NABL approved Laboratory (Annexure-II)
Carbon monoxide (CO) - (D.L – 1.144), BDL- Below Detection Limit
*As prescribed by CPCB under National Ambient Air Quality Standards (NAAQS)

Contd...

Table 10.8. Air Quality Parameters (Contd.)

Parameter	AQ1	AQ2	AQ3	AQ4	AQ5	AQ6	Std*
Ammonia (NH_3) (µg/m^3)	32.1	48.2	18	25.1	43.1	39.2	400
Lead (Pb) (µg/m^3)	BDL (DL-0.001)	0.48	BDL (DL-0.001)	0.25	0.55	0.36	1.0
Ozone (O_3) (µg/m^3)	BDL (D.L-19.62)	BDL (D.L-19.62)	BDL (D.L-19.62)	BDL (D.L-19.62)	BDL (D.L-19.62)	BDL (D.L-19.62)	180
Benzene (C_6H_6) (µg/m^3)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	05
Benzopyrene (BaP) (ng/m^3)	BDL (D.L-0.8)	BDL (D.L-0.8)	BDL (D.L-0.8)	BDL (D.L-0.8)	BDL (D.L-0.8)	BDL (D.L-0.8)	01
Arsenic (As) (ng/m^3)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	06
Nickel (Ni) (ng/m^3)	3.4	7.53	BDL (D.L-3.0)	5.7	8.6	BDL (D>L-3.0)	20
NMHC (µg/m^3)	ND (D.L-0.5)	ND (D.L-0.5)	ND (D.L-0.5)	ND (D.L-0.5)	ND (D.L-0.5)	ND (D.L-0.5)	-

Note: Environmental sampling/analysis carried by M/s Creative Engineers, a NABL approved Laboratory (Annexure-II)
BDL- Below Detection Limit. *As prescribed by CPCB under National Ambient Air Quality Standards (NAAQS)

Table 10.9. Air quality parameters at Karaikal Port

Parameter	CPCB std	Sep 12	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
Particulate matter (PM_{10}) µg/m^3	100	68.8	59	58.4	63.2	67.2	64.1	62.8	66.8	64.3	59.9	61.9	67.4	72.8
SO_2 µg/m^3	80	6.1	5.6	BDL	5.6	6.2	5.8	6.7	6.2	10.6	8.4	7.9	9.7	8.5
NO_X µg/m^3	80	10.9	8.3	6.6	8.3	9.6	8.2	10.2	8.2	5.5	13.6	14.6	17.3	18.2
CO mg/m^3	4	1.35	1.25	BDL	BDL	BDL	BDL	1.25	BDL	BDL	1.35	1.3	1.4	1.6

Source: Data provided by KPPL

Table 10.10. Noise levels at selected stations in project area

	Log (dBCA)						
	N 1	**N 2**	**N 3**	**N 4**	**N 5**	**N 6**	**Standards***
Day	52.7	55.6	55.6	59.5	53.0	57.9	55
Night	44.7	45.7	45.3	46.8	41.5	46.9	45

*Ambient Noise Standards as prescribed under Environmental Protection Act, 86
Note: Environmental sampling/analysis carried by M/s Creative Engineers, a NABL approved Laboratory (Annexure-II)

Table 10.11. Noise levels (Av) monthly monitoring results at Karaikal Port

CPCB std	Sep 12	Oct 12	Nov 12	Dec 12	Jan 13	Feb 13	Mar 13	Apr 13	May 13	Jun 13	Jul 13	Aug 13	Sep 13
65 (Day)	56.3	58.05	58.27	60.11	58.26	59.85	58.35	60.08	57.59	57.51	60.05	54.54	55.95
55 (Night)	46.17	43.04	46.37	46.52	48.68	48.71	44.75	43.72	49.17	47.7	50.38	45.64	47.41

Note: Data provided by KKPL

Table 10.12. Traffic levels (Average) monitored in study area

Site	Full Buses	Mini Bus/Van	2Axle truck	Multi axle	Motor cycle	Tractor trailor	LCV	Car/ Jeep	Auto rickshaw
TS1 (Melavanjur to North	220	432	198	271	3535	46	609	2059	454
TS1(North to Melavanjur)	143	162	216	169	3060	39	307	1166	196
TS1 (Melavanjur to East)	386	68	66	43	3883	12	196	693	1068
TS1 (East to Melavanjur)	380	57	109	49	4214	12	177	656	1092
TS1 (Melavanjur to West)	112	80	71	185	2684	18	209	367	1298
TS1(West to Melavanjur)	119	74	55	125	2708	21	217	328	967
TS1 (Melavanjur to Karaikal)	475	238	362	526	2544	27	559	1088	213
TS1(Karaikal to Melavanjur)	293	136	256	177	4170	18	470	1703	122
TS2 (Port/Nagapattinam to Karaikal)	287	164	164	85	4654	23	343	1226	80
TS2 (Port/Nagapattinam to Karaikal)	294	98	174	119	5318	20	493	1290	101
TS2 (Avg) (Port/Nagapattinam to Karaikal)	291	131	169	102	4986	22	418	1258	91
TS2 (Karaikal to Port/Nagapattinam)	298	174	155	142	4448	26	338	1202	70
TS2 (Karaikal to Port/Nagapattinam)	305	119	152	161	7458	11	397	1500	99
TS2 Avg (Karaikal to Port/Nagapattinam)	302	147	154	152	5953	19	368	1351	85
TS3 (Main road to Karaikal)	4	7	115	319	1121	8	49	164	5
TS3 (Main road to Karaikal)	10	8	23	320	1309	4	30	146	5
TS3 Avg (Main road to Karaikal)	7	8	69	320	1215	6	40	155	5
TS3 (Karaikal to Main road)	5	7	95	396	1302	16	41	138	7
TS3 (Karaikal to Main road)	11	2	33	284	1204	3	19	136	6
TS3 Avg (Karaikal to Main road)	8	5	64	340	1253	10	30	137	7

Table 10.13. Traffic study at selected stations in study area Karaikal

Sites	Full Buses	Mini Bus/ Van	2 Axle truck	Multi axle	Motor cycle	Tractor trailor	LCV	Car/ Jeep	Autorickshaw
TS1(Melavanjur to North	220	432	198	271	3535	46	609	2059	454
TS1 (North to Melavanjur)	143	162	216	169	3060	39	307	1166	196
TS1 (Melavanjur to East)	386	68	66	43	3883	12	196	693	1068
TS1 (East to Melavanjur)	380	57	109	49	4214	12	177	656	1092
TS1 (Melavanjur to West)	112	80	71	185	2684	18	209	367	1298
TS1 (West to Melavanjur)	119	74	55	125	2708	21	217	328	967
TS1 (Melavanjur to Karaikal)	475	238	362	526	2544	27	559	1088	213
TS1 (Karaikal to Melavanjur)	293	136	256	177	4170	18	470	1703	122
TS2 (Port/Nagapattinam to Karaikal)	291	131	169	102	4986	22	418	1258	91
TS2 (Karaikal to Port/Nagapattinam)	302	147	154	152	5953	19	368	1351	85
TS3 (Main road to Karaikal)	7	8	69	320	1215	6	40	155	5
TS3 (Karaikal to Main road)	8	5	64	340	1253	10	30	137	7

Table 10.14. Ground water quality at sampling stations in study area

Parameter	GW1	GW2	GW3	GW4	GW5	CPCB Std*	
						Requirement	Permissible
PH at 25°C	8.57	8.06	8.35	8.35	7.99	6.5-8.5	No relaxation
Colour	<5	<5	<5	<5	5	5	15
Total suspended Solids (mg/L)	3	42	2	38	3	-	-
Total Dissolved Solids(TDS)(mg/L)	765	2250	223	1484	2356	500	2000
Total Hardness as $CaCO_3$ (mg/L)	23.1	451	145.2	330	495	200	600
Iron as Fe (mg/L)	BDL (D.L-0.01)	BDL (D.L-0.01)	BDL (D.L-0.01)	BDL (D.L-0.01)	BDL (D.L-0.01)	0.3	No relaxation
Aluminium as Al (mg/L)	BDL (D.L-0.03)	BDL (D.L-0.03)	0.11	0.07	0.09	0.03	0.2
Copper as Cu (mg/L)	BDL (D.L-0.02)	BDL (D.L-0.02)	BDL (D.L-0.02)	BDL (D.L-0.02)	BDL (D.L-0.02)	0.05	1.5
Zinc as Zn (mg/L)	BDL (D.L-0.02)	BDL (D.L-0.02)	BDL (D.L-0.02)	BDL (D.L-0.02)	BDL (D.L-0.02)	5	15
Magnesium as Mg (mg/L)	BDL (D.L-1.0)	36.9	10.6	47.5	71.3	30	100
Calcium as Ca (mg/L)	10.1	118.8	40.5	52.8	79.2	75	200
Nitrate as NO_3 (mg/L)	2152.8	11.2	3.8	4.3	12.5	45	No relaxation
Sulphates as SO_4^{2-} (mg/L)	5.6	74.9	11.9	60.8	55.4	200	400
Sulphide as H_2S (mg/L)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	0.05	No relaxation
Fluoride as F (mg/L)	0.64	0.19	0.57	0.73	0.23	1	1.5
Chloride as Cl (mg/L)	382.8	784.8	52.6	612.5	1158.1	250	1000
Total Ammonical Nitrogen (mg/L)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	0.5	No relaxation
Total Alkalinity as $CaCO_3$ (mg/L)	323.4	382.2	176.4	323.4	3131.6	200	600
Phenolic compounds as C_6H_5OH (mg/L)	BDL (D.L-0.1)	BDL (D.L-0.1)	BDL (D.L-0.1)	BDL (D.L-0.1)	BDL (D.L-0.1)	0.001	0.002
Mineral Oil (mg/L)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	0.5	No relaxation
Total Chromium as Cr (mg/L)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	0.05	No relaxation
Total Arsenic as As (mg/L)	BDL (D.L-0.01)	BDL (D.L-0.01)	BDL (D.L-0.01)	BDL (D.L-0.01)	BDL (D.L-0.01)	0.01	0.05
Mercury as Hg (mg/L)	BDL (D.L- 0.0005)	BDL (D.L- 0.0005)	BDL (D.L- 0.0005)	BDL (D.L- 0.0005)	BDL (D.L- 0.0005)	0.001	No relaxation

Parameter	GW1	GW2	GW3	GW4	GW5	CPCB Std*	
						Requirement	Permissible
Lead as Pb (mg/L)	BDL (D.L-0.01)	0.03	0.05	0.06	0.05	0.01	No relaxation
Cyanide as CN (mg/L)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	0.05	No relaxation
Boron as B (mg/L)	BDL (D.L-0.1)	BDL (D.L-0.1)	BDL (D.L-0.1)	BDL (D.L-0.1)	BDL (D.L-0.1)	0.5	1.0
Anionic detergents as MBAS(mg/L)	BDL (D.L0.1)	BDL (D.L0.1)	BDL (D.L0.1)	BDL (D.L0.1)	BDL (D.L0.1)	0.2	1.0
Faecal Coliform (MPN/100ml)	1600	<2	<2	23	23	Shall not be detectable in any 100 ml sample	
E.coli (MPN/100ml)	900	<2	<2	13	23	Shall not be detectable in any 100 ml sample	
Faecal Streptococci (MPN/100ml)	130	<2	<2	<2	<2	Shall not be detectable in any 100 ml sample	

**Permissible limits as per IS 10,500 Drinking water quality standards*

Note: Environmental sampling/analysis carried by M/s Creative Engineers, a NABL approved Laboratory (Annexure-II)

Table 10.15. Surface water quality at selected sampling stations

Parameter	SW1	SW2	SW3	SW4	SW5	CPCB Std*	
						Requirement	Permissible
PH at 25°C	8.13	8.4	8.27	8.35	9.2	6.5-8.5	No relaxation
Colour	50	60	70	20	30	5	15
Total suspended Solids (mg/L)	280	240	392	62	98	-	-
Total Dissolved Solids(TDS)(mg/L)	4264	1658	308	965	1421	500	2000
Chemical Oxygen Demand (mg/L)	47.8	51.7	55.7	3.9	111.5	3.0 mg/L or higher	-
Biochemical Oxygen Demand (mg/L)	14	16	18	BDL (D.L-2.0)	32	5mg/L	-
Total Hardness as $CaCO_3$ (mg/L)	858	204.6	70.4	321.2	132	200	600
Iron as Fe (mg/L)	0.44	0.79	3.2	BDL (D.L-0.01)	BDL (D.L-0.01)	0.3	No relaxation
Aluminium as Al (mg/L)	0.06	0.46	5.54	BDL (D.L-0.03)	BDL (D.L-0.03)	0.03	0.2
Copper as Cu (mg/L)	BDL (D.L-0.02)	BDL (D.L-0.02)	BDL (D.L-0.02)	BDL (D.L-0.02)	BDL (D.L-0.02)	0.05	1.5
Zinc as Zn (mg/L)	BDL (D.L-0.02)	BDL (D.L-0.02)	BDL (D.L-0.02)	BDL (D.L-0.02)	23.3	5	15
Magnesium as Mg (mg/L)	21	30.6	3.6	51.7	14.1	30	100
Calcium as Ca (mg/L)	52.8	30.8	22	42.2	4.2	75	200
Nitrate as NO_3 (mg/L)	5.6	3.9	5.6	3.3	29.9	45	No relaxation
Sulphates as SO_{42-} (mg/L)	99.9	27.2		49.9		200	400
Sulphide as H_2S (mg/L)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	0.05	No relaxation
Fluoride as F (mg/L)	0.59	0.59	0.47	0.57	0.20	1	1.5
Chloride as Cl (mg/L)	2464.6	851.9	81.3	698.7	603.0	250	1000
Total Ammonical Nitrogen(mg/L)	1.4	0.93	0.67	BDL (D.L-1.0)	0.46	0.5	No relaxation
Total Alkalinity as $CaCO_3$(mg/L)	313.6	411.6	164.6	86.2	407.7	200	600
Phenolic compounds as C_6H_5OH(mg/L)	BDL (D.L-0.1)	BDL (D.L-0.1)	BDL (D.L-0.1)	BDL (D.L-0.1)	BDL (D.L-0.1)	0.001	0.002
Mineral Oil (mg/L)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	BDL (D.L-1.0)	0.5	No relaxation
Total Chromium as Cr (mg/L)	BDL (D.L□ 0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	0.05	No relaxation
Total Arsenic as As (mg/L)	BDL (D.L-0.01)	BDL (D.L-0.01)	BDL (D.L-0.01)	BDL (D.L-0.01)	BDL (D.L-0.01)	0.01	0.05
Mercury as Hg (mg/L)	BDL (D.L□ 0.0005)	BDL (D.L□ 0.0005)	BDL (D.L□ 0.0005)	BDL (D.L□ 0.0005)	BDL (D.L□ 0.0005)	0.001	No relaxation

Lead as Pb (mg/L)	BDL (D.L-0.01)	BDL (D.L-0.01)	BDL (D.L-0.01)	BDL (D.L-0.01)	BDL (D.L-0.01)	0.01	No relaxation
Cyanide as CN (mg/L)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	BDL (D.L-0.05)	0.05	No relaxation
Boron as B (mg/L)	BDL (D.L-0.1)	BDL (D.L-0.1)	BDL (D.L-0.1)	BDL (D.L-0.1)	BDL (D.L-0.1)	0.5	1.0
Anionic detergents as MBAS(mg/L)	BDL (D.L0.1)	BDL (D.L0.1)	BDL (D.L0.1)	BDL (D.L0.1)	BDL (D.L0.1)	0.2	1.0
Faecal Coliform (MPN/100ml)	900	33	<2	<2	1600	Shall not be detectable in any 100 ml sample	
E.coli (MPN/100ml)	500	27	<2	<2	900	Shall not be detectable in any 100 ml sample	
Faecal Streptococci (MPN/100ml)	50	<2	<2	<2	130	Shall not be detectable in any 100 ml sample	

BDL - Below Detectable limit (DL - Detectable limit)

Table 10.16. STP outlet characteristics

Parameter	**CPCB standards**	**Sep 12**	**Oct 12**	**Nov 12**	**Dec 12**	**Jan 13**	**Feb 13**	**Mar 13**	**Apr 13**	**May 13**	**Jun 13**	**Jul 13**	**Aug 13**	**Sep 13**
pH	6.5-9.0	6.82	6.91	6.83	6.91	6.82	7.8	7.16	7.02	7.26	7.25	7.04	7.03	6.96
Colour	No Noticeable Colour													
DO (mg/L)	3.0 mg/L or higher	7.2	7.5	6.9	7.2	7.1	7.3	7.2	7.4	7.5	6.8	7.3	7.4	6.9
BOD (mg/L)	5mg/L	4	3.2	3	3.5	4.6	4	3.4	3	4	4	4.5	4	4.6
Oil & Grease (mg/L)	10mg/L	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<2
Coliform (MPN/100 ml)	500/100 ml	17	21	26	34	30	45	60	50	45	50	80	40	65

Source: Data provided by Karaikal Port Pvt Ltd.

Table 10.17. List of flora observed/reported in study area during study period

Sr. No.	Scientific Name	Common/ Local Name	Family	Scrub	Human Settlements	Agricultural Fields	Water Bodies
Trees							
1.	*Acacia nilotica*	Babhul	Mimosaceae	✿		✿	
2.	*Acacia auriculiformis*	Australian babhul	Mimosaceae		✿		
3.	*Achras sapota*	Chiku	Sapotaceae			✿	
4.	*Aegle marmelos*	Bael fruit tree	Rutaceae		✿	✿	
5.	*Albizzia lebbek*	Shirish	Mimosaceae		✿		
6.	*Alstonia scholaris*	Satvin	Apocynaceae		✿		
7.	*Anona squamosa*	Sitaphal	Anonaceae		✿		
8.	*Azadirachta indica*	Nimb	Rutaceae	✿	✿	✿	
9.	*Barringtonia acutangula*	Newar	Lecythidaceae				✿
10.	*Bauhinia sp.*	Kanchan	Caesalpiniaceae		✿		
11.	*Borassus flabilifer*	Tadgola	Aracaceae	✿	✿		
12.	*Calystemon lanceolatus*	Bottle Brush tree	Myrtaceae		✿		
13.	*Carica papaya*	Papaya	Caricaceae		✿		
14.	*Caryota urens*	Bherli maad	Arecaceae	✿			
15.	*Cassia fistula*	Bahava	Caesalpiniaceae		✿		
16.	*Cassia siamea*	Siamean Casia	Caesalpiniaceae		✿		
17.	*Casuarina equisetifolia*	Suru	Casuarinaceae				✿
18.	*Cocos nucifera*	Naral	Arecaceae		✿		✿
19.	*Delonix regia*	Gulmohar	Caesalpiniaceae		✿		
20.	*Eucalyptus sp.*	Nilgiri	Myrtaceae		✿		
21.	*Ficus benghalensis*	Vad	Moraceae		✿	✿	
22.	*Ficus racemosa*	Umbar	Moraceae		✿		
23.	*Ficus hispida*	Kala Umbar	Moraceae		✿		
24.	*Ficus religiosa*	Pimpal	Moraceae		✿	✿	
25.	*Gliricidia maculata*	Giripushpa	Fabaceae			✿	
26.	*Gmelina arborea*	Shivan	Verbenaceae	✿		✿	
27.	*Lannea coromandiliana*	Shemat	Anacardiaceae	✿			
28.	*Leucaena leucocephala*	Subabhul	Mimosaceae		✿		

Sr. No.	Scientific Name	Common/ Local Name	Family	Scrub	Human Settlements	Agricultural Fields	Water Bodies
29.	*Mangifera indica*	Aamba	Anacardiaceae		✿	✿	
30.	*Mimusops elengi*	Bakul, Ovali	Sapotaceae		✿		
31.	*Moringa olifera*	Shevga	Moringaceae		✿		
32.	*Morinda tinctoria*	Noni	Rubiaceae	✿			
33.	*Murraya exotica*	Kunti	Rutaceae		✿		
34.	*Murraya koehnigii*	Kadipatta	Rutaceae		✿		
35.	*Musa paradisiaca*	Kel	Musaceae		✿		
36.	*Myristica fragrans*	Ran jaiphal	Myristicaceae		✿		
37.	*Neolamarckia cadamba*	Kadamb	Rubiaceae		✿		
38.	*Peltophorum pterocarpum*	Sonmohar	Caesalpiniaceae		✿		
39.	*Pithecellobium dulce*	Vilayti Chinch	Mimosaceae		✿	✿	
40.	*Plumeria alba*	Chapha	Apocynaceae		✿	✿	
41.	*Plumeria rubra*	Khurchapha	Apocynaceae		✿	✿	
42.	*Polyalthia longifolia*	-	Apocynaceae		✿		
43.	*Pongamia pinnata*	Karanj	Fabaceae			✿	✿
44.	*Roystonia regia*	Bottle Palm	Arecaceae		✿		
45.	*Samanea saman*	Kinhai	Mimosaceae		✿		
46.	*Spathodea campanulata*	Pichkari	Bignoniaceae		✿		
47.	*Tamarindus indicus*	Chinch	Mimosaceae	✿		✿	
48.	*Tectona grandis*	Sag	Verbenaceae			✿	
49.	*Terminalia catapa*	Lal Badam	Combretaceae		✿		
50.	*Thespesia populnea*	Ran Bhend	Malvaceae			✿	✿
51.	*Trema orientalis*	Charcoal tree	Ulmaceae	✿			
Shrubs							
1.	*Astracantha longifolia*	-	Acanthaceae				✿
2.	*Bauhinia racemosa*		Leguminoceae		✿		
3.	*Bougainvillea spectabilis*	Bougainvillea	Nyctaginaceae		✿		
4.	*Clerodendrum inerme*	Kadu Mendi	Verbenaceae		✿		

Sr. No.	Scientific Name	Common/ Local Name	Family	Scrub	Human Settlements	Agricultural Fields	Water Bodies
5.	*Calotropis gigentia*	Rui	Asclepiadaceae		❁		
6.	*Datura stomnium*	Dhotra	Solanaceae		❁		
7.	*Duranta plumier*	--	Verbenaceae		❁		
8.	*Hibiscus rosa-sinensis*	Shoe flower	Malvaceae		❁		
9.	*Ixora coccinia*	Lokhandi	Rubiaceae		❁		
10.	*Jatropha curcus*	Moghali Erund	Euphorbiaceae	❁		❁	
11.	*Nerium indicum*	Kanher	Apocynaceae		❁		
12.	*Prosopis juliflora*	--	Mimosaceae	❁			
13.	*Ricinus communis*	Erand	Euphorbiaceae		❁		
14.	*Rosa indica*	Rose	Rosaceae		❁		
15.	*Tabernemontana coronaria*	Tagar	Apocynaceae		❁		
16.	*Tabernemontana varigata*	Tagar	Apocynaceae		❁		
17.	*Vitex negundo*	Nirgudi	Verbenaceae		❁		❁
18.	*Xanthium strumarium*	Chor	Solanaceae	❁		❁	
19.	*Ziziphus rugosa*	Bor	Rhamnaceae	❁			
Herbs							
1.	*Acalypha indica*	--	Euphorbiaceae		❁		
2.	*Achyranthus aspera*	Aghada	Amaranthaceae	❁			
3.	*Amaranthus spinosus*	Math	Amaranthaceae		❁		
4.	*Ageratum conyzoides*	Goat weed	Asteraceae	❁	❁		
5.	*Alternanthera sessilis*	--	Amaranthaceae		❁		
6.	*Boerhavia diffusa*	Punarnava	Nyctaginaceae		❁		
7.	*Catharanthes rosious*	Sadafuli	Apocynaceae		❁		
8.	Cassia tora	Takla	Caesalpiniaceae	❁		❁	
9.	Cassia alata	--	Caesalpiniaceae		❁		
10.	*Celosia argentea*	Kombada	Amaranthaceae		❁		
11.	*Colocasia esculanta*	Alu	Araceae				❁
12.	*Cyperus rotundus*	--	Cyperaceae				❁
13.	*Eclipta alba*	Maka	Asteraceae				❁
14.	*Eichhornia*	Water	Pontederiaceae				❁

Sr. No.	Scientific Name	Common/ Local Name	Family	Scrub	Human Settlements	Agricultural Fields	Water Bodies
	crassipes	Hyacinth					
15.	*Hibiscus esculantus*	Ladies finger	Malvaceae			❀	
16.	*Hyptis suaveolens*	--	Lamiaeae	❀	❀		
17.	*Ipomoea carnea*	Besharam	Convolvulaceae				❀
18.	*Lantana camara*	Ghaneri	Verbenaceae	❀			
19.	*Lycopersicon esculantum*	Solanaceae	Tomato			❀	
20.	*Martinia diandra*	--	Pedaliaceae		❀		
21.	*Pedalium murex*	--	Pedaliaceae	❀	❀		
22.	*Physalis minima*	Kapal fodi	Solanaceae	❀	❀		
23.	*Polygonum glabrum*	--	Polygonaceae				❀
24.	*Portulaca sp.*	China rose	Portulacaceae		❀		
25.	*Raphanus sativus*	Radish	Brassicaceae			❀	
26.	*Solanum melongena*	Brinjal	Solanaceae			❀	
27.	*Solanum xanthocarpum*	Ringan	Solanaceae		❀	❀	
28.	*Tephrosia purpurea*	Wild Indigo	Fabaceae	❀		❀	
29.	*Tribulus terrestris*	--	Zygophyllaceae	❀			
30.	*Tridax procumbens*	--	Asteraceae	❀	❀	❀	
31.	*Wedelia sp.*	Wedelia	Asteraceae		❀		
Climbers/Creepers							
1.	*Antigonon leptopus*	Ice-cream creeper	Polygonaceae		❀		
2.	*Cocculus hirsutus*	Kavli	Menispermaceae	❀			
3.	*Cucurbita sp.*	--	Cucurbitaceae			❀	
4.	*Dioscorea bulbifera*	Karanda	Dioscoriaceae				
5.	*Ipomoea aquatica*	Nalichi Bhaji	Convolvulaceae				❀
6.	*Ipomea digitata*	Railway creeper	Convolvulaceae		❀		❀
7.	*Cuscuta reflexa*	Amarvel	Convolvulaceae	❀	❀		
Grasses							
1.	*Andropogon sp.*	-	Poaceae		❀		
2.	*Apluda mutica*	Grass	Poaceae	❀	❀		
3.	*Cynodon ductylon*	Harli	Poaceae	❀	❀		
4.	*Cyperus rotundus*	-	Cyperaceae				❀
5.	*Eleusine coracana*	Nachani/Ragi	Poaceae			❀	

Sr. No.	Scientific Name	Common/ Local Name	Family	Scrub	Human Settlements	Agricultural Fields	Water Bodies
6.	*Heteropogon contortus*	-	Poaceae	⊛			
7.	*Saccharum arundinaceum*	Wild cane	Poaceae				⊛
8.	*Oryza sativa*	Rice	Poaceae			⊛	
9.	*Panicum miliare*	Wari	Poaceae			⊛	
10.	*Paspalum scrobiculatum*	-	Poaceae		⊛		
11.	*Typha sp.*	Elephant Grass	Typhaceae				⊛

⊛ Indicates presence of species in habitat

Table 10.18. List of Fauna Observed/Reported in Study Area during study period

Sr. No.	Scientific Name	Common/ Local Name	Family
Mammals			
1.	*Bandicota benghalensis*	Indian bandicoot	Muridae
2.	*Bos indicus*	Cow	Bovidae
3.	*Bubalus bubalis*	Buffalo	Bovidae
4.	*Canis lupus familiaris*	Dog	Canidae
5.	*Capra hircus*	Goat	Bovidae
6.	*Equus Asinus*	Donkey	Equidae
7.	*Felis catus*	Cat	Felidae
8.	*Funambulus palmarum*	3 Striped Squirrel	Sciuridae
9.	*Herpestes edwardsi*	Common Mongoose	Herpestidae
10.	*Lepus nigricollis*	Indian Hare	Leporidae
11.	*Presbytis entellus*	Common Languor	Cercopithecidae
12.	*Pteropus giganteus*	Flying fox	Pteropodidae
13.	*Rattus sp.*	Rat	Muridae
14.	*Sus cristatus*	Pig	Suidae
15.	*Equus ferus*	Horse	Equidae
Reptiles			
1.	*Calotes rouxii*	Wild Lizard	Agamidae
2.	*Calotes versicolor*	Common Garden Lizard	Agamidae
3.	*Dendrelaphis tristis*	Bronze back tree snake	Colubridae
4.	*Echis carinatus*	Saw-Scaled Viper	Viperidae
5.	*Mabuya carinata*	Common Skink	Scincidae
6.	*Naja naja*	Nag	Elapidae
7.	*Xenochrophis piscator*	Checkered Keelback	Colubridae
8.	*Varanus bengalensis*	Monitor Lizard	Varanidae
Birds			
1.	*Accipiter badius*	Indian Shikra	Accipitridae
2.	*Phalacrocorax fuscicollis*	Cormorant	Phalacrocoracidae

3.	*Himantopus himantopus*	Blak Winged Stilt	Recurvirostridae
4.	*Egretta garzetta*	Little Egret	Ardeidae
5.	*Lanius schach*	Rufous backed shrike	Laniidae
6.	*Ardea cinerea*	Grey Heron	Ardeidae
7.	*Amaurornis phoenicurus*	White Breasted Water hen	Rallidae
8.	*Anastomus oscitans*	Asian Open bill Stork	Ciconiidae
9.	*Acridotheres fuscus*	Jungle Myna	Sturnidae
10.	*Acridotheres tristis*	Common Myna	Sturnidae
11.	*Alcedo atthis*	Small Blue Kingfisher	Alcedinidae
12.	*Anthus rufulus*	Paddy field Pipit	Motacillidae
13.	*Apus apus*	Common swift	Apodidae
14.	*Ardeola grayii*	Pond Heron	Ardeidae
15.	*Artamus fuscus*	Ashy wood swallow	Artamidae
16.	*Bubulcus ibis*	Cattle Egret	Ardeidae
17.	*Centropus sinensis*	Crow-Pheasant	Cuculidae
18.	*Ceryle rudis*	Lesser Pied Kingfisher	Cerylidae
19.	*Columba livia*	Blue Rock Pigeon	Columbidae
20.	*Corvus splendens*	House Crow	Corvidae
21.	*Dendrocitta vagabunda*	Indian Tree Pie	Corvidae
22.	*Dicrurus adsimilis*	Black Drongo	Dicruridae
23.	*Eudynamys scolopacea*	Koel	Cuculidae
24.	*Halcyon smyrnensis*	White-breasted Kingfisher	Halcyonidae
25.	*Haliastur indus indus*	Brahminy Kite	Accipitridae
26.	*Hirundo smithii*	Wire tailed Swallow	Hirundinidae
27.	*Merops orientalis*	Small Bee-eater	Meropidae
28.	*Motacilla maderaspatensis*	White browed Wagtail	Motacillidae
29.	*Nectarinia asiatica*	Purple Sunbird	Nectariniidae
30.	*Passer domesticus*	House Sparrow	Passeridae
31.	*Pavo cristatus*	Common Peafowl	Phasianidae
32.	*Turdoides striatus*	Jungle Babbler	Timaliidae
33.	*Upupa epops*	Indian Hoopoe	Upupidae
34.	*Vanellus indicus*	Red Wattle Lapwing	Charadriidae
35.	*Pitta brachyura*	Indian Pitta	Pittidae
36.	*Coracias benghalensis*	Indian Roller	Coraciidae
37.	*Vanellus malabaricus*	Yellow-wattled lapwing	Charadriidae
38.	*Francolinus pondicerianus*	Grey Francolin	Phasianidae
39.	*Milvus migrans*	Black Kite	Accipitridae
Butterflies			
1.	*Pachliopta hector*	Crimson Rose	Papilionidae
2.	*Ariadne merione*	Common Castor	Nymphalidae
3.	*Pelopidas mathias*	Small Branded Swift	Hesperiidae
4.	*Danaus chrysippus*	Plain Tiger	Nymphalidae
5.	*Danaus genutia*	Striped Tiger	Nymphalidae
6.	*Euploea core*	Common Crow	Nymphalidae
7.	*Eurema hecabe*	Common Grass Yellow	Pieridae
8.	*Catopsilia pyranthe*	Mottled Emigrant	Pieridae

Table 10.19. Population & literacy details in Study area

Study area	Households (No)	Population			Total Literate	Male Literate	Female Literate
		Total	Male	Female			
	28951	119511	58610	60901	76.50	81.23	71.94

Source: Census data 2011

Table 10.20. Occupation details in study area

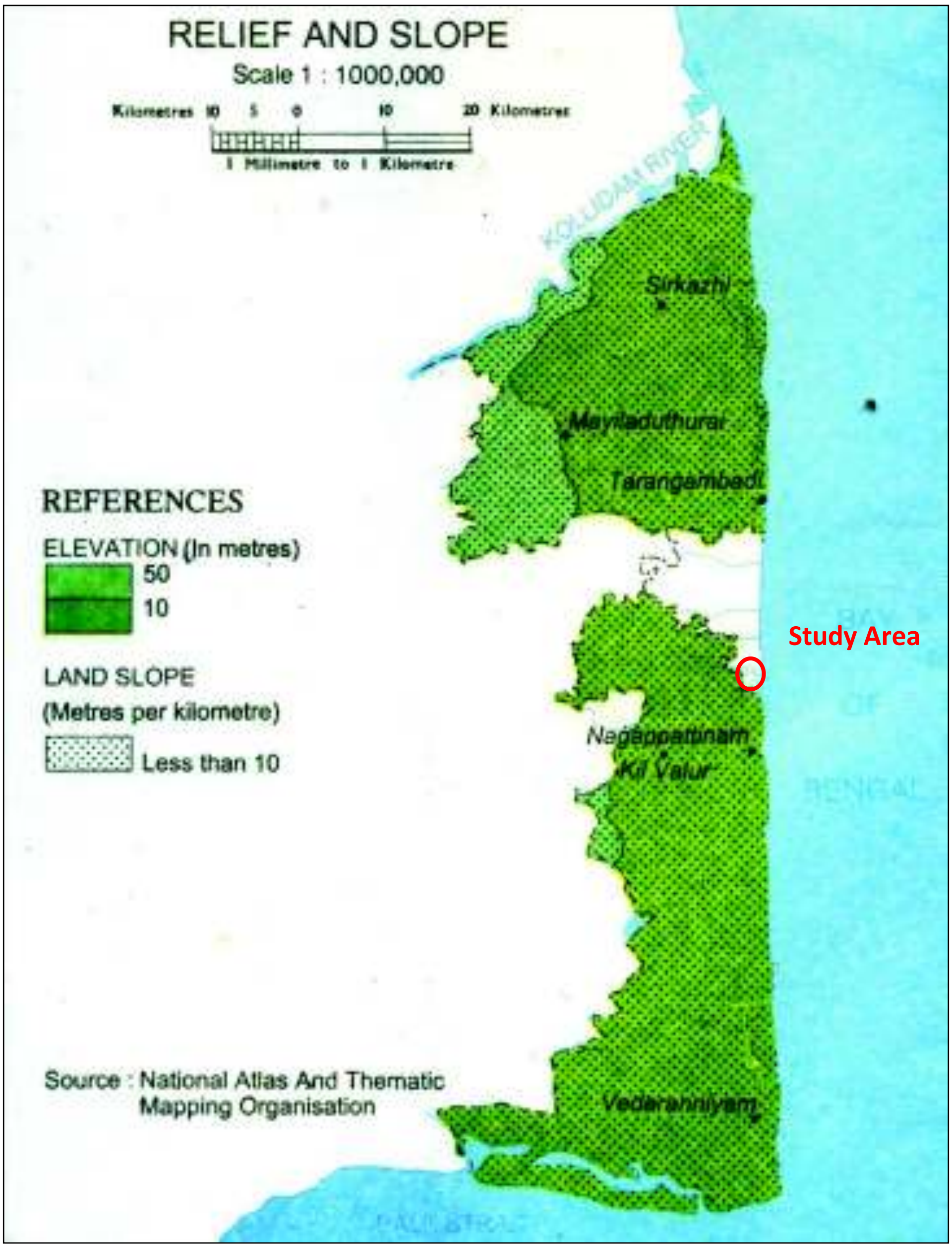
Sl.No.	Study Area	
1	Cultivators	6.4
2	Agricultural Laborers	27.8
3	Household Workers	1.6
4	Others	47.3
5	Marginal Workers	16.8

Table 10.21. Major cultural importance in the project region

Cultural important places	Distance from the Project site
Nagore Minaret	2.5-3 km to the southeast of the project site
Thirunallar Temple	9 km to the northeast of the project site
Velanganni Church	About 20 km to the southeast of the project area
Tranquebar	20 km north of the project site
Ekambaresvara temple, Settur, Karaikal	About 16-17 km to the northwest of the project site
Svayambunathaswamy temple, Nedungadu, Karaikal	About 16.5-17.5 km to the northwest of the project site

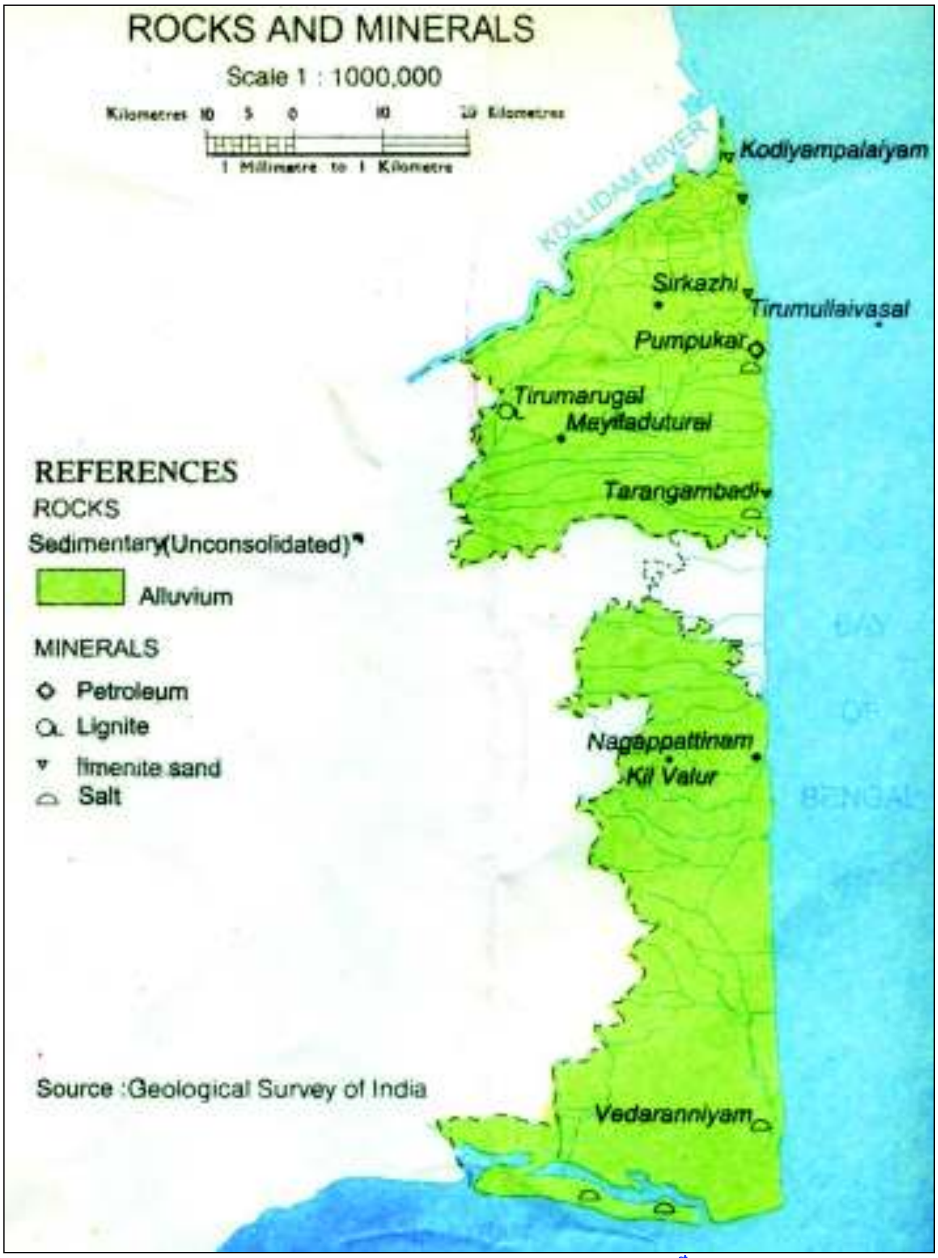
Fig. 10.1. Geographical Location of Karaikal Port

Fig. 10.2. Location of Project (Study area 10 km)



Source: National Atlas and Thematic Mapping Organization, Govt. of India, 1st Edition 2000

Fig. 10.3. Map showing elevation & land slope in the study region, Nagapattinam District.



Source: National Atlas and Thematic Mapping Organization, Govt. of India, 1st Edition 2000

Fig. 10.4. Map showing rock and mineral availability, Nagapattinam District

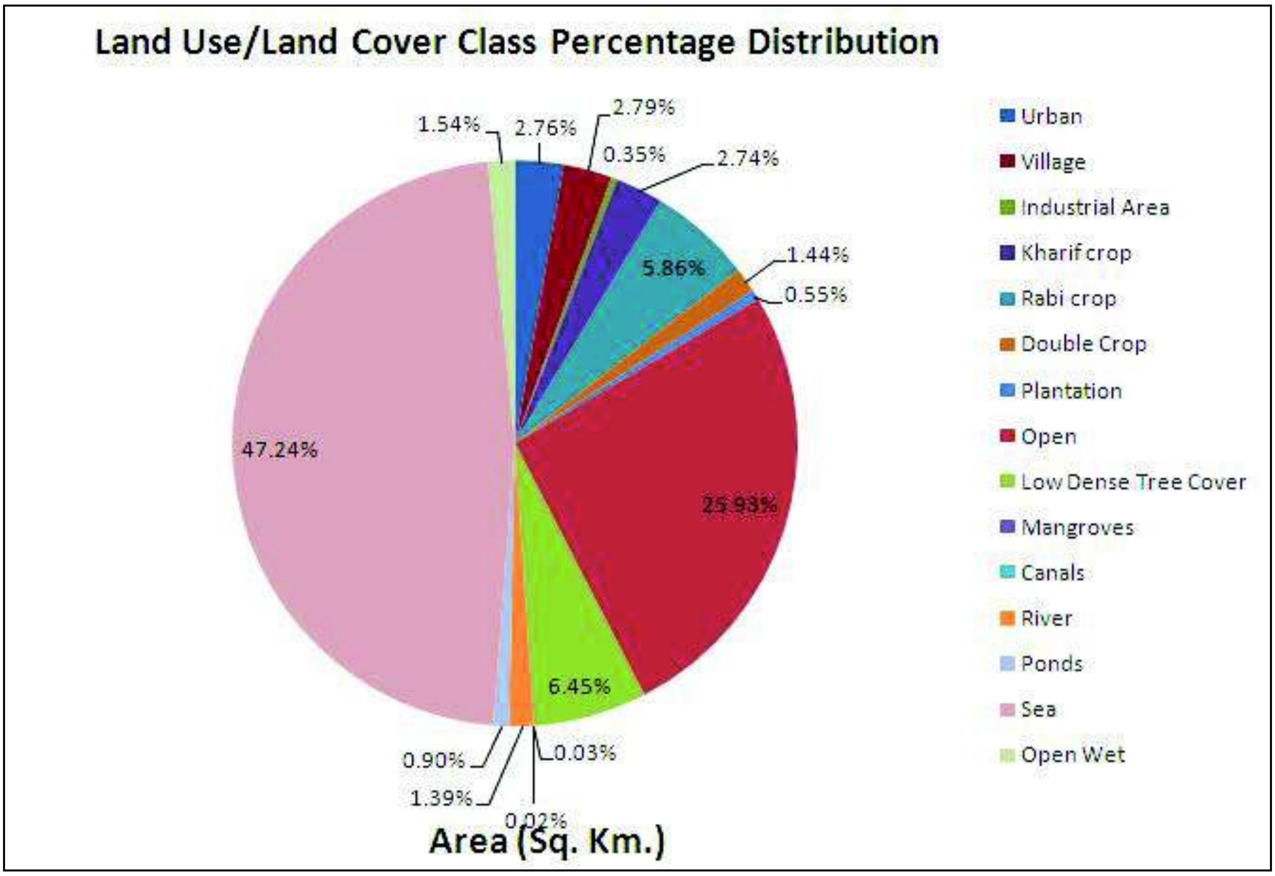


Fig. 10.5. Percentage distribution of the different LULC classes within the study area

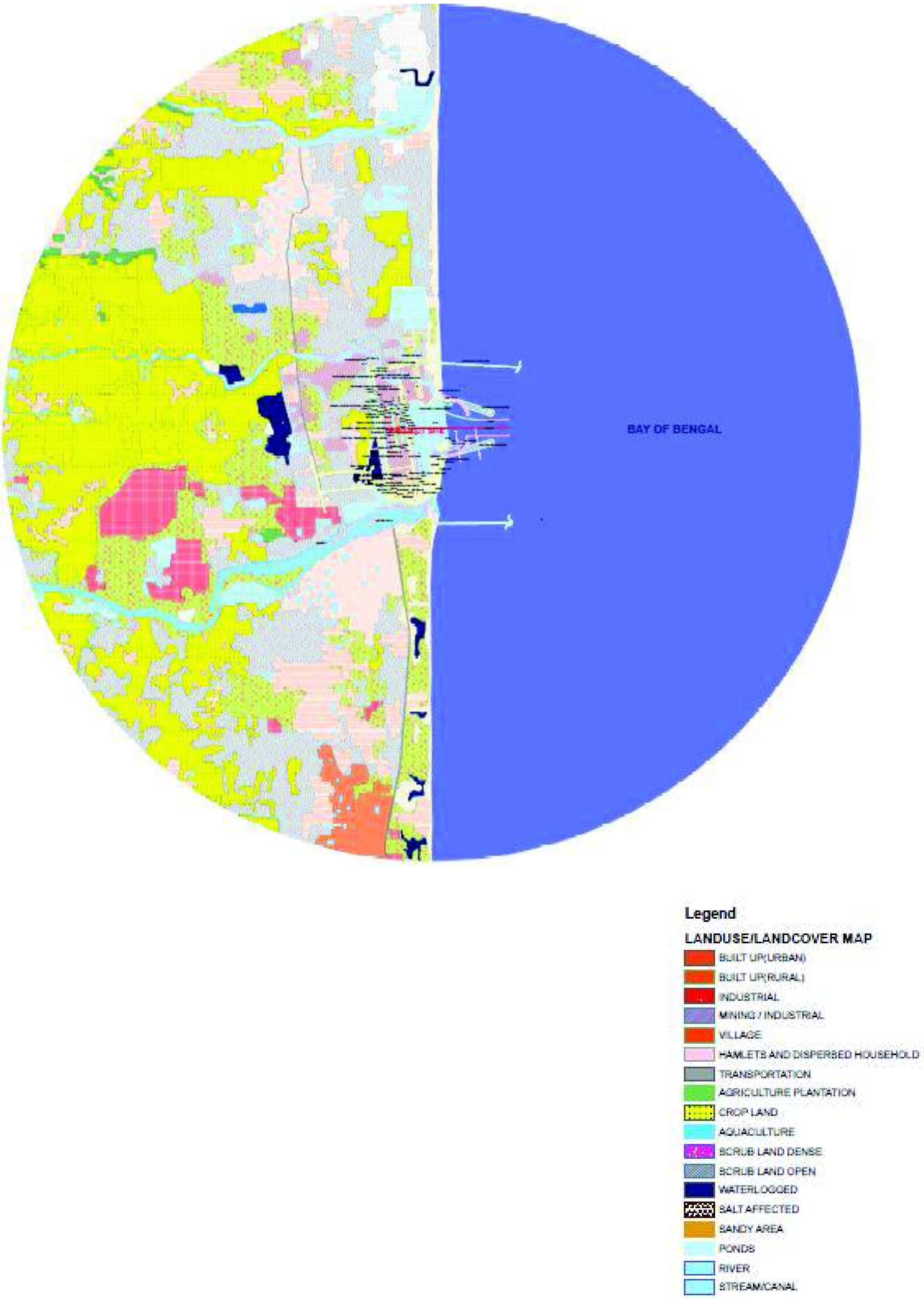
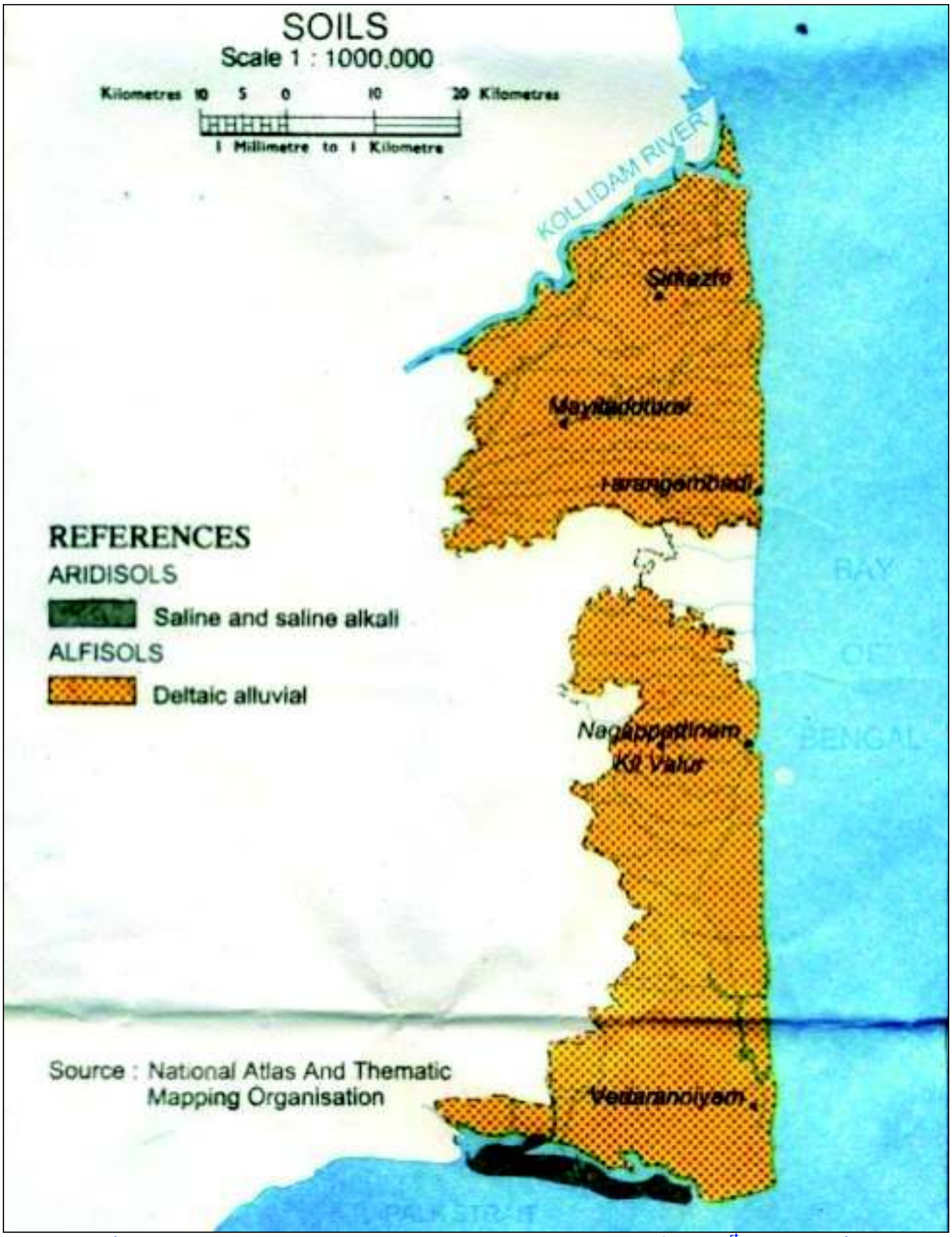


Fig. 10.6. Map showing Land use land cover around Karaikal Port Site



(Source: National Atlas and Thematic Mapping Organization, Govt of India, 1st Edition 2000)

Fig. 10.7. Map showing soil type, Nagapattinam District

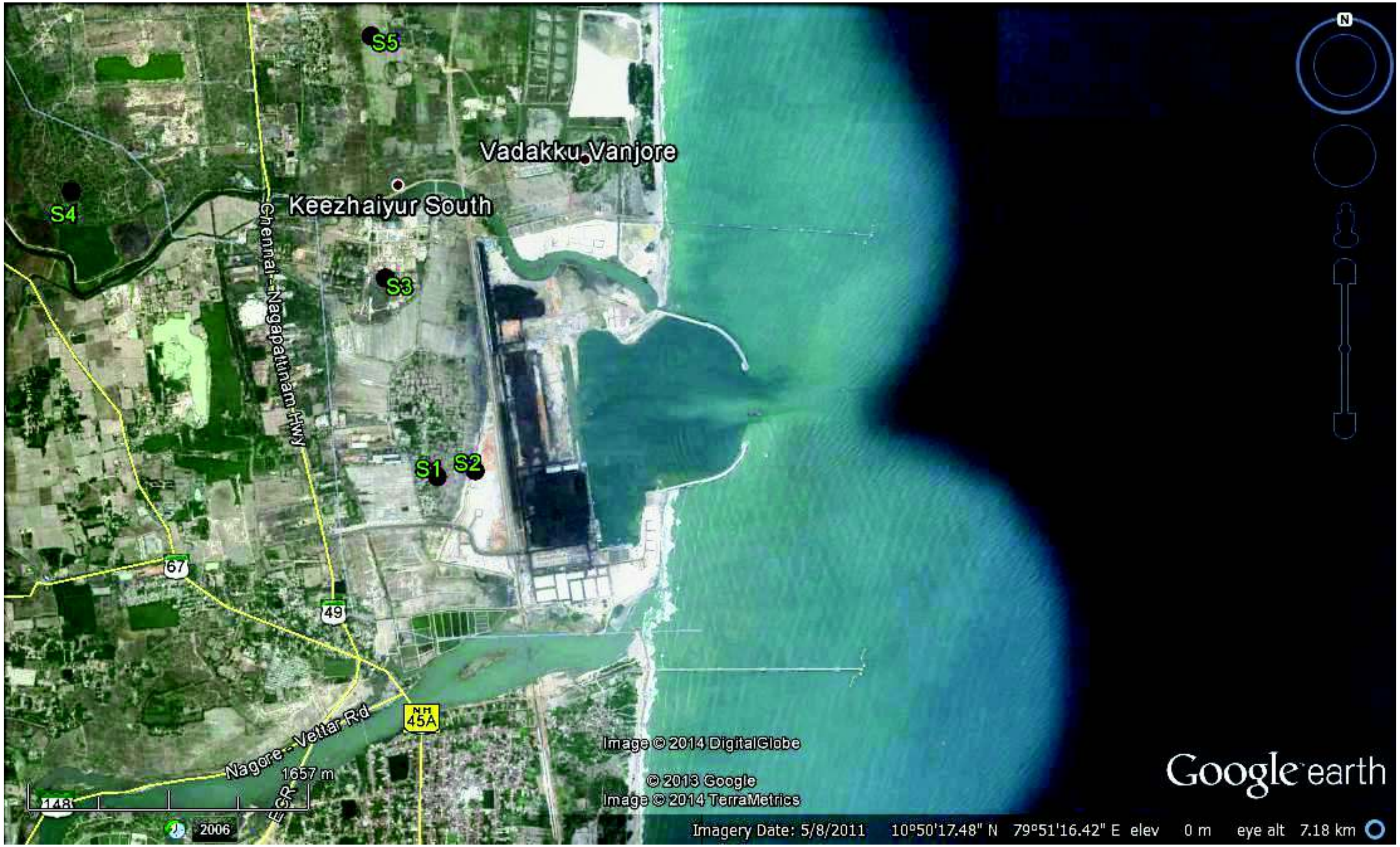


Fig. 10.8. Map showing sampling stations for Soil analysis

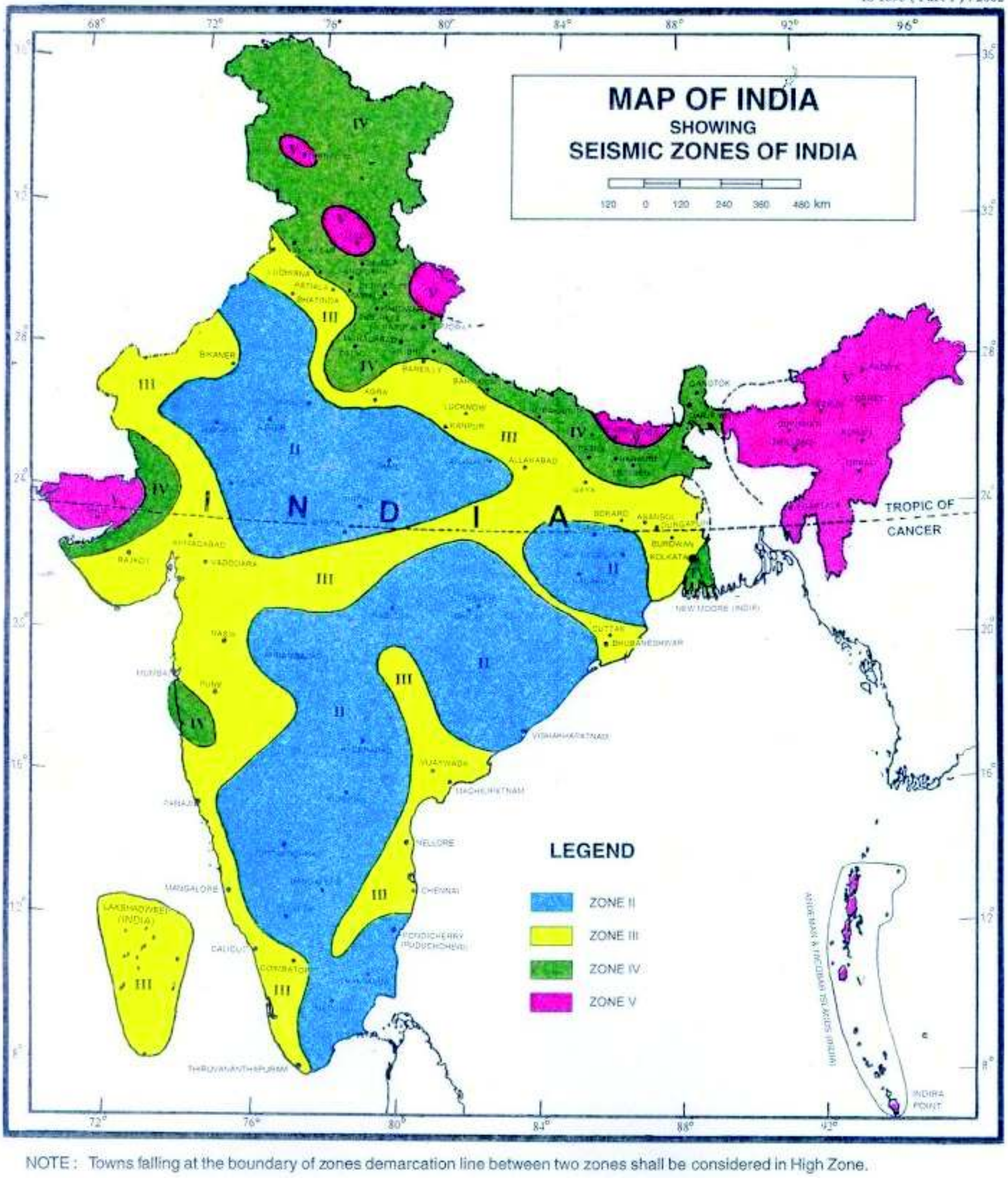


Fig. 10.9. Map showing seismic zoning of Indian sub-continent

Source: http://www.imd.gov.in/section/seismo/static/seismo-zone.htm

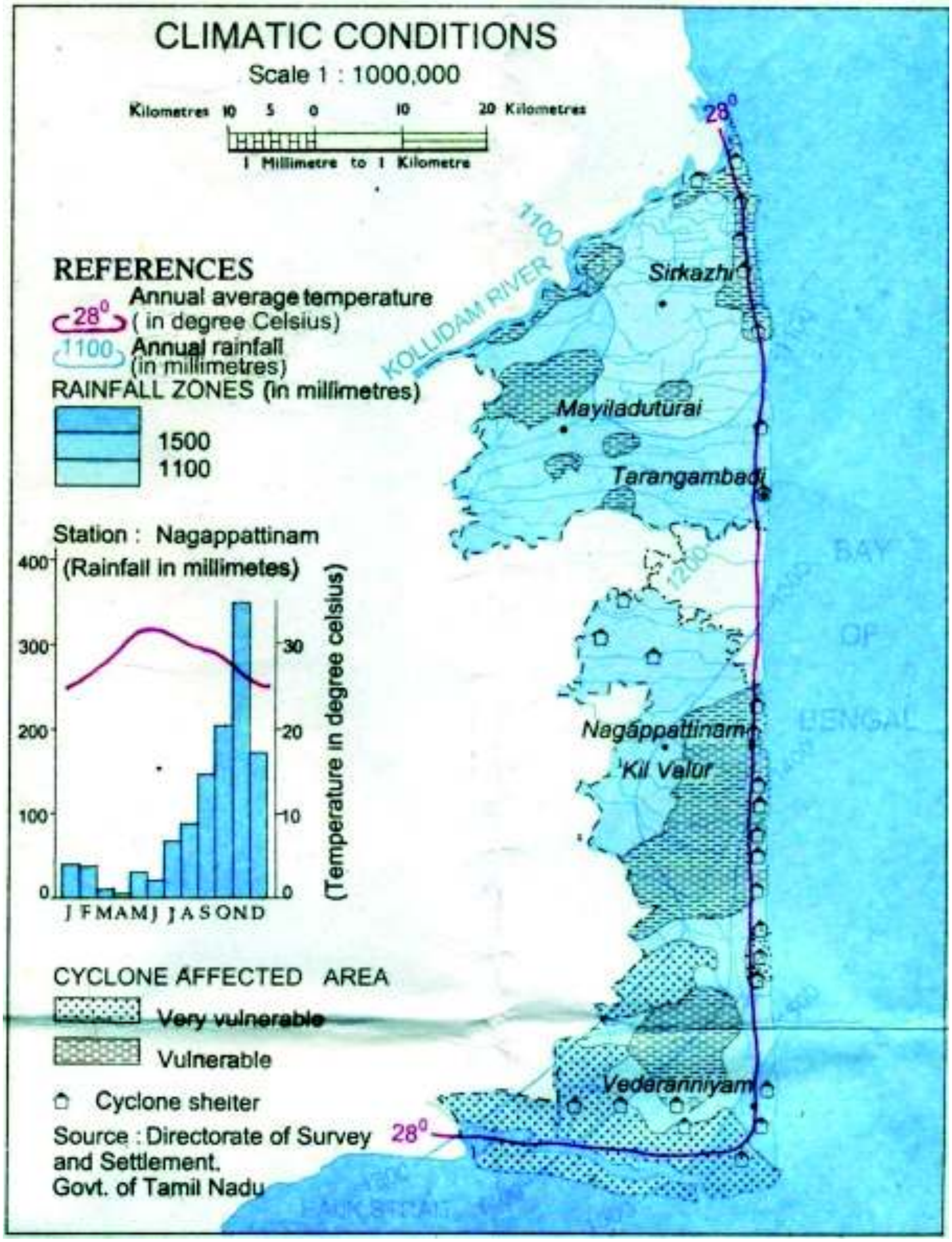


Fig. 10.10. Climatic conditions of the study region, Nagapattinam District

(Source: National Atlas and Thematic Mapping Organization, Govt of India, 1st Edition 2000)

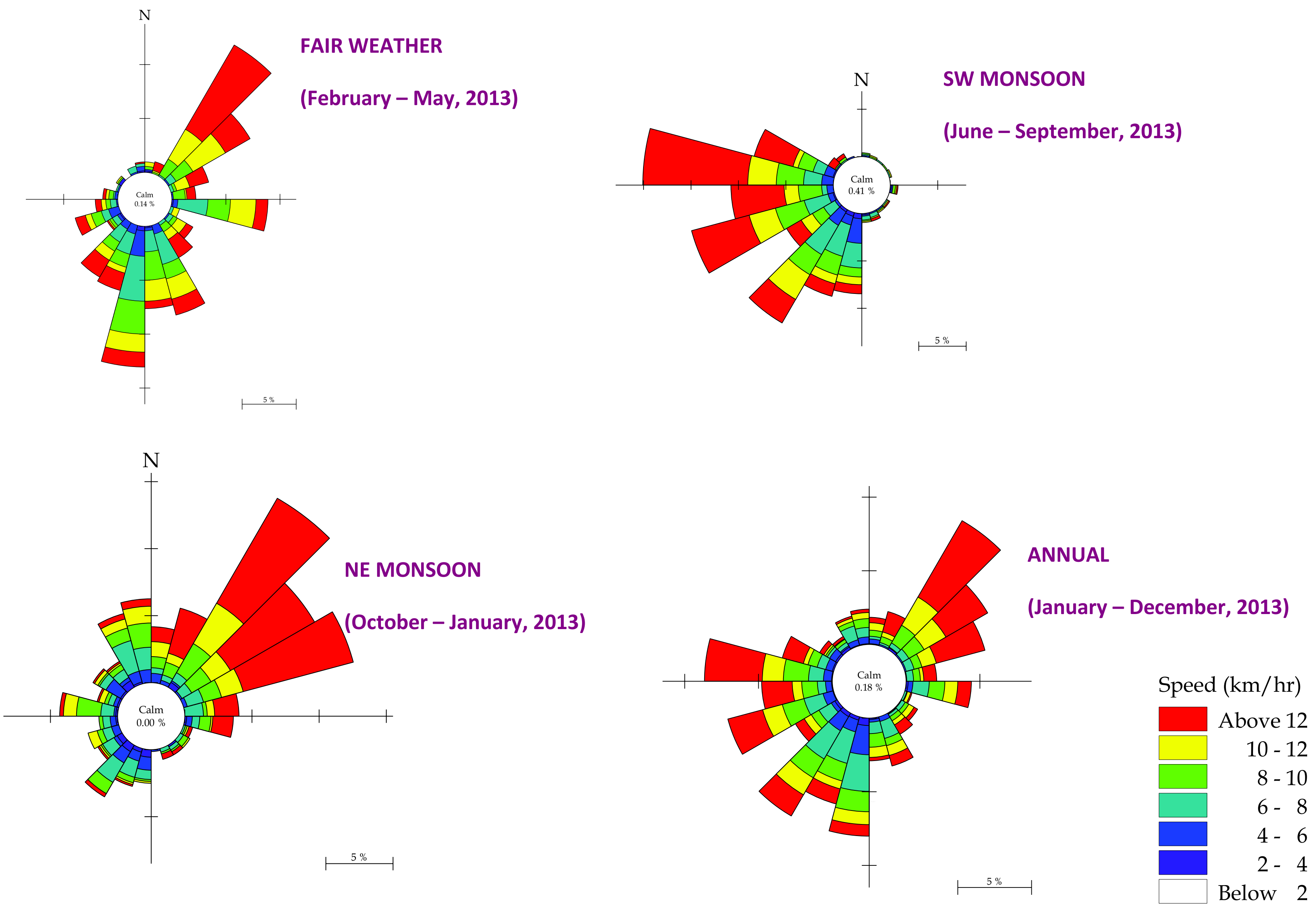


Fig. 10.11. Rose diagram for wind in 2013 – Karaikal

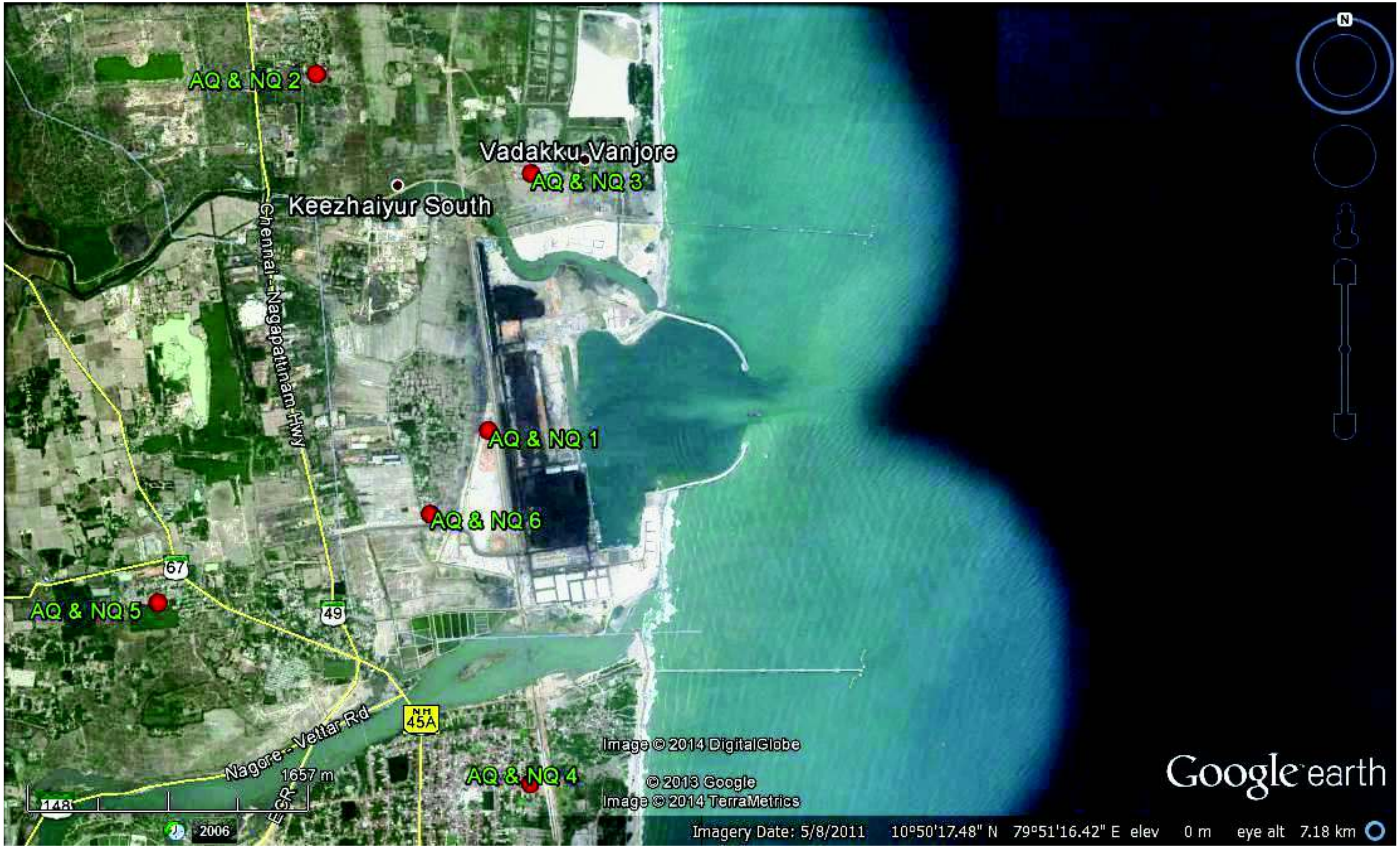


Fig. 10.12. Map showing sampling stations for Air and Noise quality

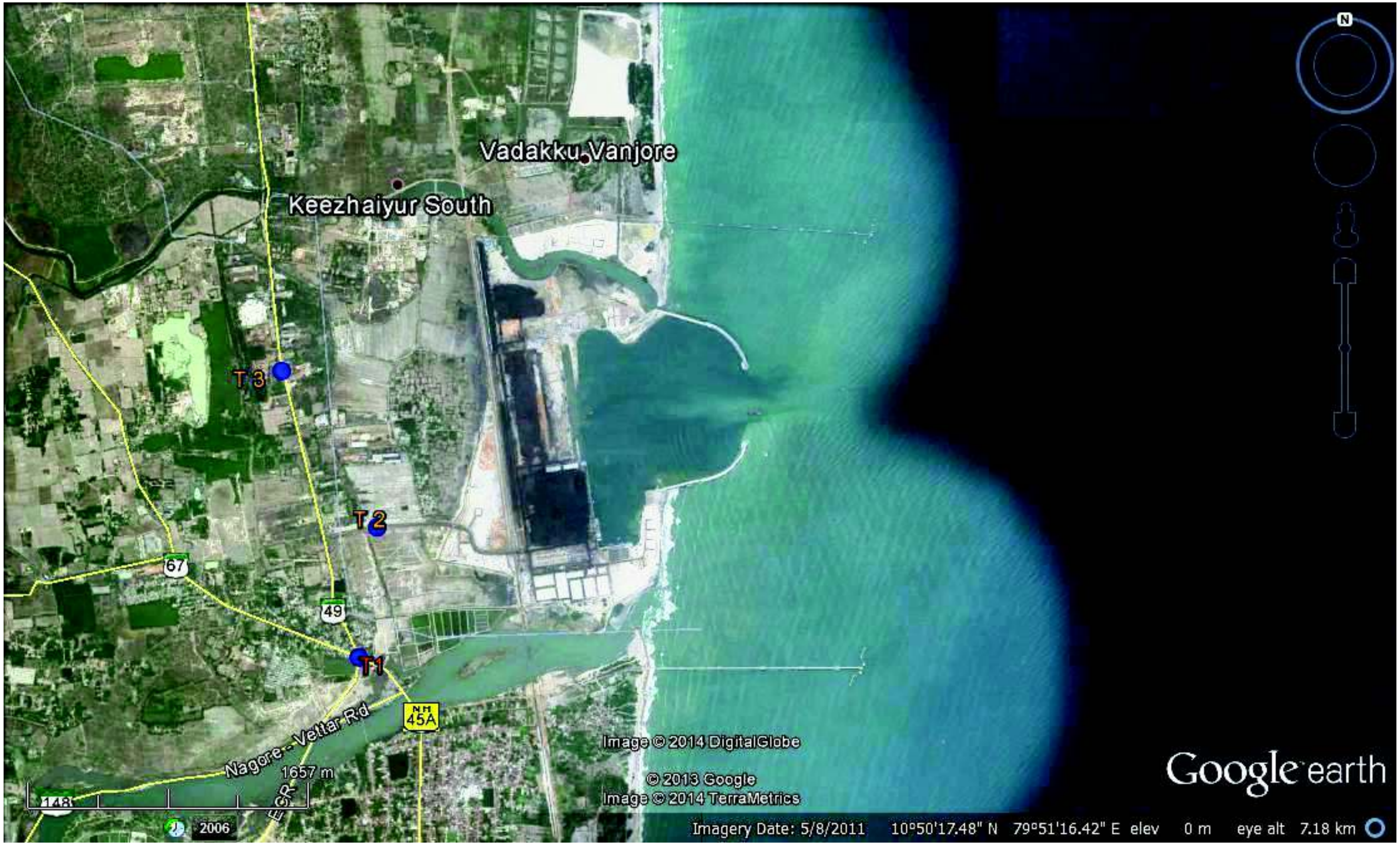


Fig. 10.13. Map showing stations surveyed for traffic study

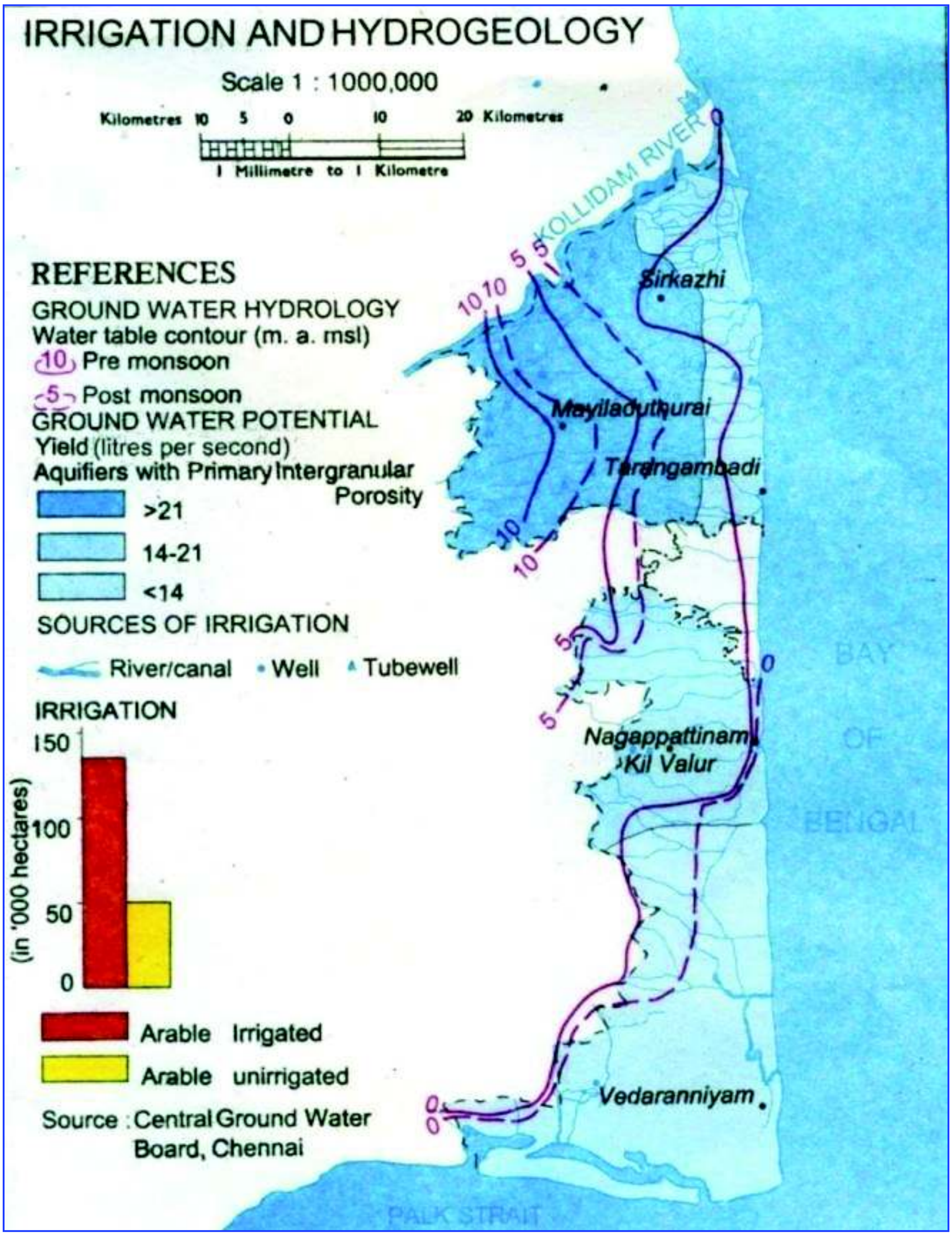


Fig. 10.14. Irrigational and hydro geological map, Nagapattinam District

(Source: National Atlas and Thematic Mapping Organization, Govt of India, 1st Edition 2000)

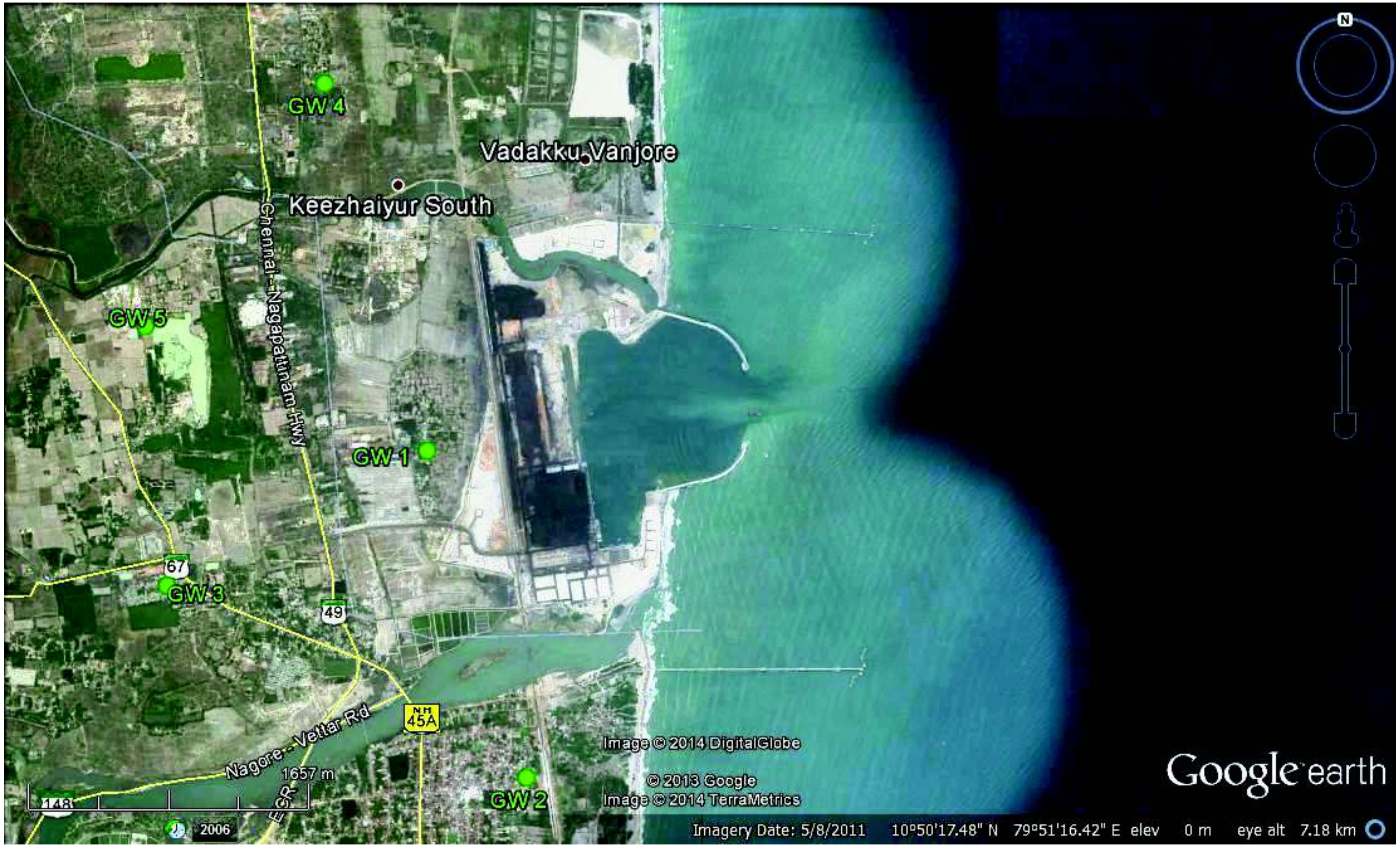


Fig. 10.15. Map showing ground water sampling stations

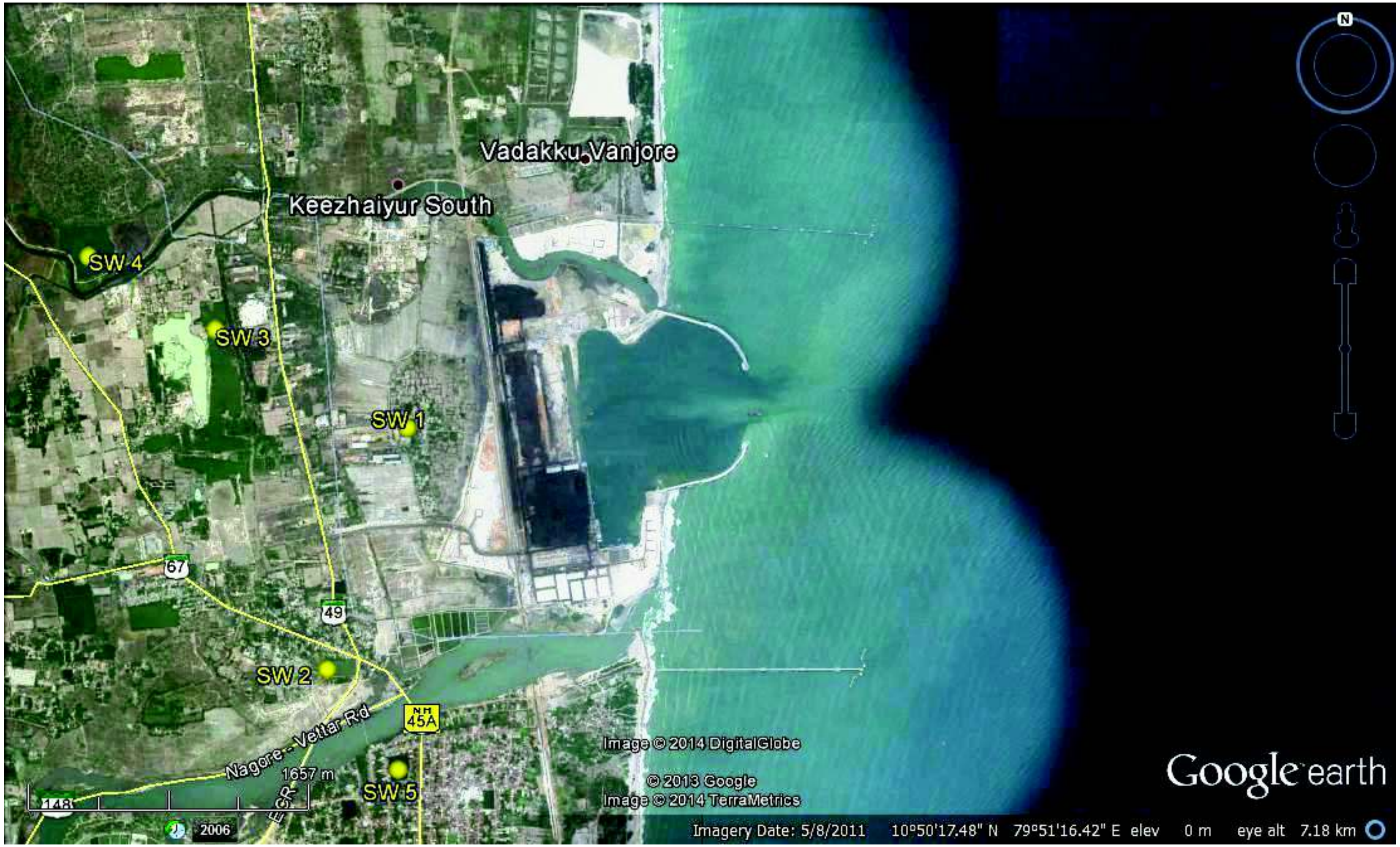


Fig. 10.16. Map showing surface water quality sampling stations

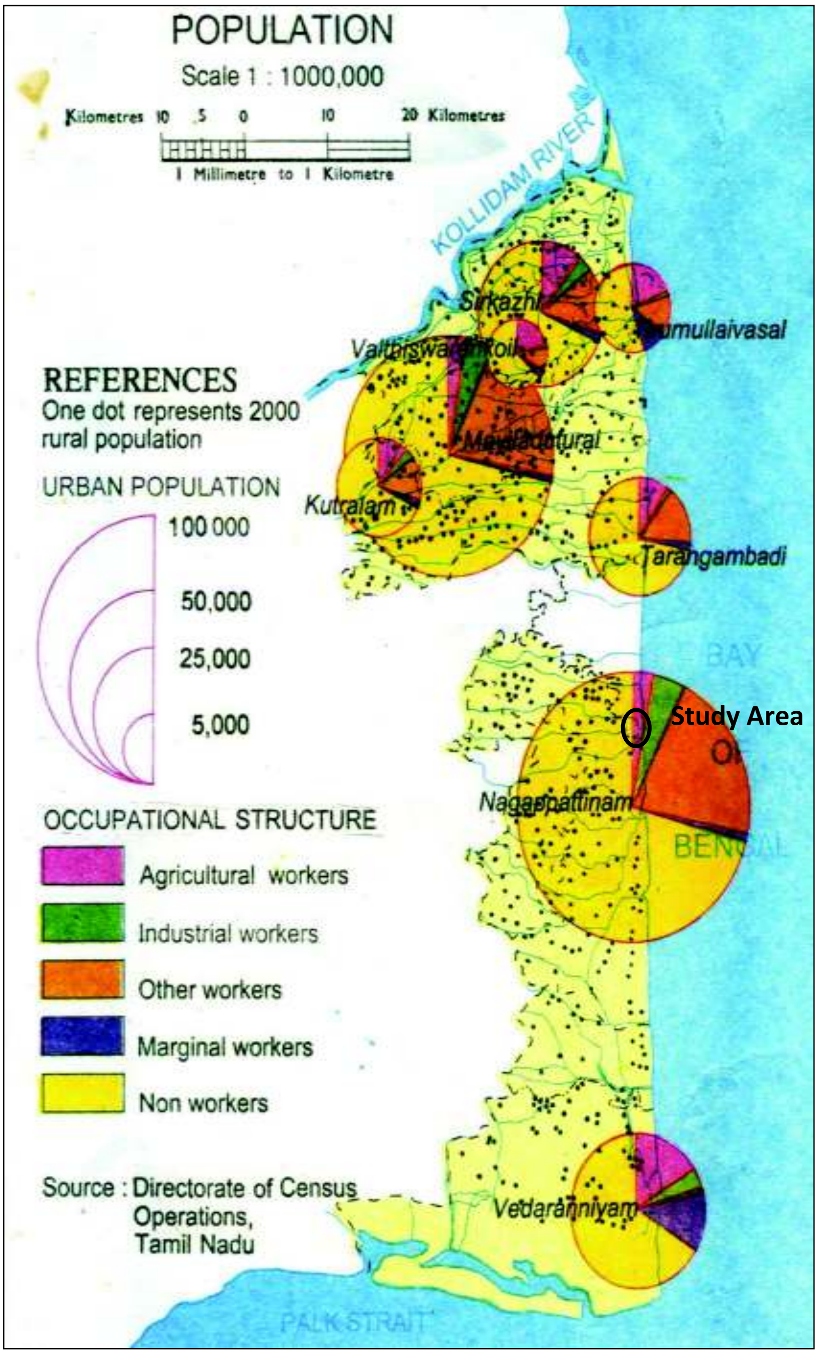


Fig. 10.17. Map representing population details in the study region.
(Source: National Atlas and Thematic Mapping Organization, Govt of India, 1st Edition 2000)

(Source: National Atlas and Thematic Mapping Organization, Govt. of India, 1st Edition 2000)

Fig. 10.18. Map showing industrial expanse in the study region, Nagapattinam District

11. IMPACT ASSESSMENT FOR TERRESTRIAL ENVIRONMENT

11.1. Environmental Impacts of the Project

11.1.1. Land

Construction Phase: The proposed development of Bulk liquid berth for handling LNG will be set up within the port premises along the existing southern breakwater and the backup area, which would have minimum permanent/ temporary changes in the Land use, cover or topography.

Widening of the turning basin will create dredged sand, which will be disposed off at the approved dumping site and small volume to be used as beach nourishment.

The port has good connectivity being located as NH47 and NH 67 and present roads are adequate to cater to additional truck traffic. However this may cause increased dust levels to the surroundings if proper dust covers are not provided.

Transportation Impact is increasing hazards during transportation adequacy of water

Operational Phase: Except for the transportation of LNG, entire operation will be carried out in subtidal region of port, hence will give rise to port traffic. Additional domestic waste from LNG vessel etc will be generated (100 kg/day) which will be handled by chandlers and disposed off as per existing practice.

Traffic: Proposed to connect to LNG grid of GAIL, however a portion is also for off-loading the LNG through truck/tanker also during constructional phase there will be increase in the truck activity by 30 numbers/day.

11.1.2. Air

Construction Phase: Temporary occurrence of emissions due to construction equipments, transport of construction material, dust from handling of materials, etc would be there for short period.

Operational Phase: Emissions during operational phase such as from vessels will comply with MARPOL regulations, will, from production process "LNG gasification", Boil off gas management will be taking place as in LNG terminals.

11.1.3. Noise

Construction Phase: Noise generated from construction activities will be predominantly confined within port site and will impact construction workers at site, however PPE are provided to personnel employed in the port limits. Impacts due to these activities would be short-term in nature and localized.

Operational Phase: There will be minor negative impact because of high noise level due to increase in vehicular activity (additional tankers about 30 no.s/day).

11.1.4. Water

Construction Phase: The Water requirement for construction phase will be minimal. Treated sewage will be used to meet dust sprinkling/landscaping requirement.

Operational Phase: Additional water requirement of the proposed facilities will be marginal and will be sourced from desalination plant and outsourced water. The existing desalination plant (based on RO) will be suitably expanded with additional modules for treatment of sea water. Sea water will bedischarged after dilution to meet temperature requirement of 18˚C sourced for cooling purposes for converting LNG into gas, and is discharged under treatment. However it does not undergo any change/reaction etc and hence does not affect nearby water bodies, drainage or run off.

11.1.5. Ecology

There is no vegetation on adjoining land mass where re-gasification unit may be installed. Thus, there is no direct tree cutting involved in the project.

11.1.6. Socioeconomic

The land for the project is located in existing port premises and involves no rehabilitation and resettlement. No staff colony will be established, and hence there will be change in land use and land cover.

About 50 labours will be employed during construction phase giving preference to local labours.

Operational phase will have 50 staff employed drawing positive development in terms of employment potential and ancillary industries in nearby locals using existing infrastructure for transportation.

Impact Identification Matrix delineates impacts on various environmental attributes against the different activities of the constructional and operational phases of the proposed project. Project activities are divided into two phases as described below.

Phase Wise Project Activities

Phase	Sub Component	Remark
Construction	Equipment Mobilization	Mobilize Cranes/Trucks/Road Construction Machineries etc.
	Material Transport & Storage	Transporting of Construction Materials
Operation	Traffic Movement	Transportation of Gas through Capsules
	Operation of FSRU/FSU	Conversion of LNG in to Gas and transportation

Scaling for delineated impact matrix is devised below.

Scaling of Impacts

Attribute	Description	Notation
Duration of Impact	Permanent Duration	P
	Temporary Duration	T
Severity of Impact	Appreciable	1
	Significant	2
	Major	3
	Severe	4
Type of Impact	Positive (Beneficial)	+ ve
	Negative	- ve

Based on the importance of each environmental parameter, a value has been assigned to each parameter (called weightage). Ultimately the final assessment is made according to the impact scale discussed below:

Significance of Impact

Total Score	Significance of Impact
Up to 1000	No appreciable impact on environment
1000-2000	Low adverse impact. Appropriate mitigating measures required
2000-3000	Significant impact. Major control measures
3000-4000	Major impact. Project Site/ industrial technology to be reviewed
4000-5000	Not suitable. Alternative Site to be considered

The extent of each of these impacts on various environmental attributes have been rated and presented in table below.

Project Activities	Environmental Issues							
	Land use	Soil	Water	Ambient Air Quality	Ambient noise levels	Ecology & Biodiversity	Traffic & transport	Socioeconomic
Weightage	50	50	50	75	75	100	100	75
Construction Phase								
Equipment mobilization	0	0	0	T -1	T -1	0	T -1	0
Material transport and storage	0	T -1	0	T -1	T -1	0	T -1	T +1
Erection and Assembling of land based facilities	0	0	0	T -1	T -2	0	0	T +1

Project Activities	Environmental Issues							
	Land use	Soil	Water	Ambient Air Quality	Ambient noise levels	Ecology & Biodiversity	Traffic & transport	Socioeconomic
Weightage	50	50	50	75	75	100	100	75
Operation Phase								
Traffic movement	0	0	0	P -1	P -1	0	P - 2	P + 1
Operation of FSU/FSRU	0	0	0	P -1	P -1	0	0	P +1
NET Impact	0	-1	0	-5	-7	0	-4	+4
Score	0	-50	0	-375	-450	0	-400	+300
NET	-975							

From this, it can be seen that the project will have Temporary insignificant negative impacts on terrestrial environment except Socioeconomic, where it will be Temporary insignificant positive in construction phase. Operation phase will have permanent insignificant negative impacts on terrestrial environment except Socioeconomic, where it will be Temporary insignificant positive. From above matrix, the net impact due to proposed development will be (-) 975, indicating no appreciable impact on environment. Hence it may be noted that all the activities indentified as part of the project have insignificant impacts.

12. MANAGEMENT PLAN FOR TERRESTRIAL ENVIRONMENT

Environmental Management Plan (EMP) for phase II development of the Port was prepared and presented as part of Environmental clearance process and was approved by Expert Appraisal Committee of the MoEF. Since, the Phase II development is yet in progress, the EMP prepared is being modified to take into account construction and operation phases of the Bulk Liquid Berth for handling LNG. This includes plan to mitigate environmental and social impacts; plan of action for execution of mitigation measures; Environmental Monitoring Program; institutional mechanism for ensuring implementation; and budget allocated for environmental management. EMP is a dynamic document, which will be reviewed periodically and will be amended based on Environmental Monitoring Program.

12.1. Construction Phase – Mitigation measures and action plans

For each of the construction activities, which are likely to cause impacts on environment, mitigation measures and action plan are presented in following paragraphs.

12.1.1. Traffic Management during Construction of Berths

Measures proposed to be adhered to mitigate impacts during construction of cargo berths are presented below.

- Trucks with construction material susceptible for fugitive suspension are covered with tarpaulin.
- A Transportation Management Plan is adopted for movement of trucks transporting construction materials and traffic is regulated.
- Vehicles deployed conform to emission norms (air/noise) of CPCB and have valid Pollution under Control (PUC) certificates.
- Dumpers and trucks comply with standards for exhaust emissions and noise levels

12.1.2. Environmental Management during Landside Construction

Measures proposed to be adhered to mitigate the impacts during the landside construction activities are presented below.

Construction Yard

- During planning, all precautions are taken to prevent / minimize disturbance to adjacent properties / habitations. If unavoidable, same are restored with consent from affected persons.

- Adequately sized construction yard are provided at the site for storage of construction materials, equipment tools, earthmoving equipment, etc. In addition, temporary field offices and worker amenities are provided at site. Appropriate spill control measures and labelling / handling procedures are maintained.

- Drainage system is provided at construction yard. Measures are taken to prevent silting of natural drainage due to runoff from construction areas.

- Proper area is demarcated for storage of construction material. This enables proper management of the materials including control of seepage and spillage thereby preventing contamination of the project area.

Movement of Machinery and Equipment

- Movement of material is mostly during non-peak hours and regulated during peak hours. Mobile equipment such as intermittently used machines and transport vehicles are either switched off or throttled down to a minimum.

- On-site vehicle speeds are controlled to reduce excessive dust suspension in air and dispersion by traffic.

- Construction equipment and transport vehicles are periodically washed to remove accumulated dirt.

Noise Level Control

- During construction, a noise level is being maintained below threshold levels stipulated by Central Pollution Control Board (CPCB) by selecting appropriate equipment, machinery and using enclosures. Procurement of machinery /construction equipment is done in accordance with specifications conforming to source noise levels less than 85 dB (A).

- Only well-maintained construction equipment, which meets the regulatory standards for source noise levels, is used. Any equipment emitting high noise, wherever possible, is oriented so that the noise is directed away from sensitive receptors.

- Noise attenuation is practiced for noisy equipment by employing suitable techniques such as acoustic controls, insulation and vibration dampers. The attenuation devices are properly maintained throughout the construction period.

- High noise generating activities such as piling and drilling are scheduled to minimize noise impacts.

- Personnel exposed to noise levels beyond threshold limits are provided with protective gear like earplugs, muffs, etc. especially construction personnel involved in pile driving operations. Rotation of personnel is also being adopted.

- Periodic maintenance of the equipment to be used in the developmental works is carried out. Worn out parts will be replaced and rotating parts are lubricated to minimize noise emissions.

- Ambient noise levels are be monitored.

Dust suppression

Water sprinkling is being carried out to suppress fugitive dust during earthworks and along unpaved sections of access roads.

Environmental /Safety Awareness

Environmental/safety awareness program are provided to the personnel involved in operational and developmental works.

Wastewater Management

The environmental management for sanitary wastewater, vehicle wash water, hydro test water and storm water is addressed below:

- An adequate drainage system is provided at the site with separate collection streams to segregate the storm run-off from roads, open areas, material storage areas, vehicle wash water and other wastewater streams. Suitable measures are also be taken to prevent the washing away of construction materials into the drainage system.

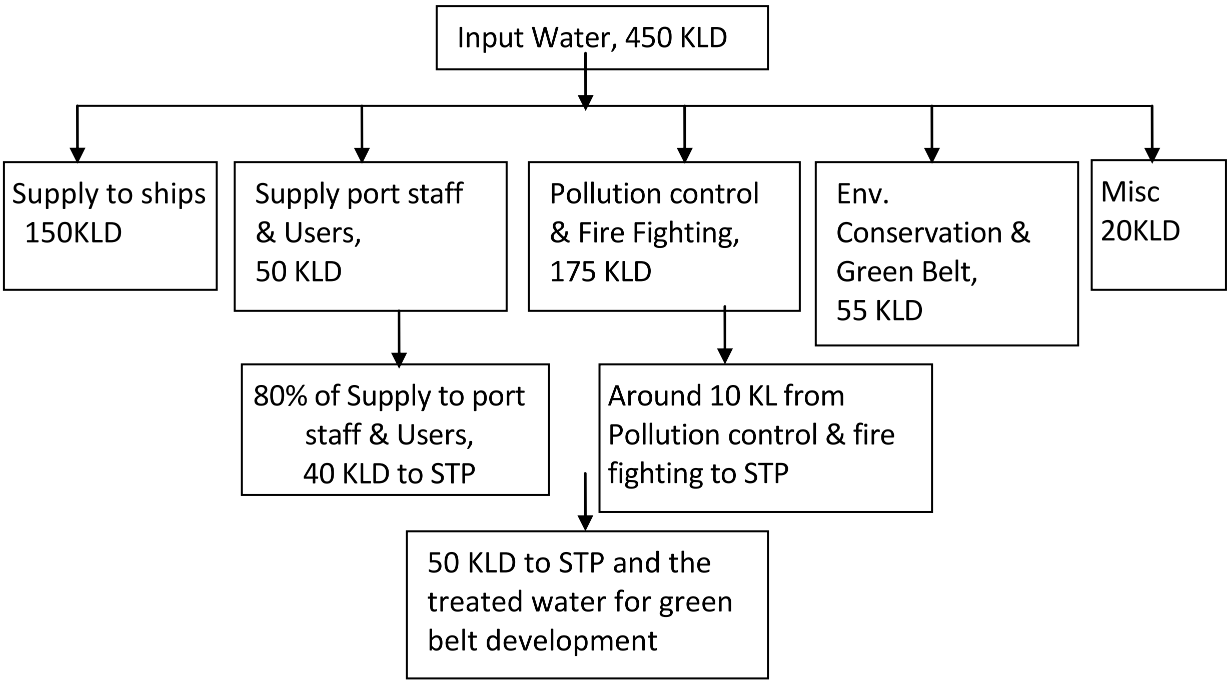
- Contaminated storm water is collected and conveyed to sedimentation tank for removing grit.

- The sewage generated at site is collected in holding tank and periodically transferred to Sewage Treatment Plant (STP).

- The sewage generated in the labour camps located offsite also is handled in a similar way.

- Hydro test water virtually free from contaminants except for traces of corrosion product. Unless it is suspected to contain any contaminants, hydro test water are discharged into surface drains for discharge on land.

- If there are any accidental spillages of hazardous substances on soil that may pose the risk of contaminating run off, such areas will be immediately remediated.



Water Balance flow chart for proposed project activity

Based on the water balance studies, sewage to STP was 40 KLD for Phase II development and additional sewage will be 10 KLD. KPPL has provided higher capacity of STP (50 KLD) (details is enclosed as Annexure III) which is sufficient to treat total 47 cmd sewage generated in Phase II and Bulk Liquid Handling Berth projects.

12.1.3. Solid Waste Management

The various types of solid wastes generated during the construction phase are segregated into two main categories, viz., non-hazardous and hazardous. All non-hazardous wastes are covered under solid waste management.

- Construction wastes are used within port site for filling of low lying areas.
- Composted bio-degradable waste used as manure in greenbelt.
- Other wastes such as metal scrap which can be re-cycled are sold.
- General refuse generated on-site is collected in waste skips and separated from construction waste.
- A local authorised waste handler employed to remove general refuse from the site, separately from construction waste and hazardous wastes, on regular basis to minimise odour, pest and litter impacts.
- The burning of refuse at construction sites is prohibited.

12.1.4. Hazardous Materials Management

The Hazardous materials such as lubricants, paints, compressed gases, and varnishes etc., stored in closed shed under lock and key as per the prescribed/approved safety norms. Adequate safety equipment such as fire extinguishers kept inside the shed.

- Used lead acid storage batteries - They are being given to the seller of the storage batteries for recycling.
- Used oils and lubricants – they are stored in the secured place in our raw material storage ware house and electrical sold to recycles periodically.
- Electronic and electrical waste – used electric bulbs, computer and electronic circuits etc they are stored in a secued way in the maintaince stores and given to the authorised recyclers.

12.1.5. Environmental Management at Construction Workers Camp

During the construction phase of the port large-scale employment in the form of skilled and semi-skilled labours is generated of which majority of the works will be sub-contracted. As the construction period will span about 30 months, temporary workers camps is set up for semi-skilled labourers in the project area. The following aspects are taken into consideration before setting up the worker camps:

- The camps are adequately equipped with all the necessary facilities such as water supply, power supply, wastewater collection, solid waste collection and sanitation.
- The domestic wastes generated from the camps are disposed at approved disposal sites.
- No bore wells sunk for the drinking water requirements.

Specifically Bulk Liquid Handling Berth activity will require about 50 Workers during operational phase and locals will be preferred, for which no worker camp is required.

12.1.6. Occupational Health Safety

Due care taken to include necessary clauses in respective construction work contracts for maintaining strict compliance of occupational health standards for workers during construction period including provision and mandatory usage of personal protective devices, noise protection, fire protection gadgets to mitigate occupational health hazards.

- Care taken to avoid all sources of ignition at the places of flammable material storage areas through erection / display of appropriate sign boards.
- Welding personnel are properly trained and will wear necessary Personal Protection Equipment.
- Safety procedures prominently displayed at various construction sites.
- Medical facilities including first-aid provided at construction yard.
- Periodic health check-ups undertaken for early detection and control of communicable diseases.
- Training and awareness programs on occupational health, safety and fire fighting are periodically conducted including re-training.
- Hazardous materials stored as per prescribed safety norms in locations with restricted entry and with fire-fighting facilities.
- The skilled worker will be deployed who are competent to handle construction jobs including safety
- The work permit system will be followed for high risk operations like working in confirmed space, work at height etc.
- Tool box talk technique to make aware the worker for possible hazardous will be undertaken.

12.2. Operation Phase - Mitigation Measures and Action Plan

12.2.1. Water Pollution Control

To mitigate the impacts on the marine water the following measures are/will be adopted:

- Generally the port does not accept Bilge, but whenever required, bilge water and oily wastes from Ships are transported on-shore through workboats (OSV's) and sent to approved recyclers for recycle/re-use.

- Drainage system is provided. The drainage system for berthing and backup area is planned comprising storm water, oily wastes, and sewage collection pipelines. This system will be suitably augmented for handling storm water in proposed Bulk Liquid Handling Berth.

- The residual water generated due to the sprinkling activities on the cargo is collected into the liquid waste network, having suitably located oil-water separators, settlement traps, collection pits etc.

- Sewage is collected and treated at Sewage Treatment Plant (STP). Sewage from Bulk Liquid Handling Berth will also be sent to the STP. The treated sewage water will be used for development of greenbelt.

- Floor washings of equipment workshops is conveyed through an oil-water separator and subsequently treated at STP. Treated sewage water is re-used in greenbelt.

- Stockpile runoff is managed. The storm runoff and the runoff generated due to sprinkling at berth and stockyard is conveyed through settlement traps and collection pits where the iron ore and coal particles and any other solid particles are separated from the stream.

- Discharge of wastes into sea is prohibited. Discharges of wastes, dumping of ship wastes (sullage / sewage), bilge water, solid wastes, etc. is prohibited as per MARPOL Convention.

- The Port is equipped with all modern pollution control mechanism to contain the marine pollution from the port operational areas. Pollution control facilities are designed with a possibility of recycling the wastes especially the treated wastewater.

Good labour management is recommended to follow good sanitation practice. As the construction period is expected of about 30 months and strictly a day-time activity, good labour management is practicable. No more than 50 labours will be required at construction site, and period of construction may not be more than 30 months.

12.2.2. Environmental Management during Cargo Handling

- Fully mechanized material handling system with covered conveyors is provided for handling of Coal and Iron Ore. The Bulk Liquid Handling Berth will have compatible unloading arms which are attached to the manifold of the LNG carrier and LNG is transferred onshore storage tanks or to a floating storage units using ship pumps

- This will help prevent fugitive emissions to a minimum.

- To mitigate impacts on air quality from handling of Coal, dust suppression equipment are provided for efficient control of dust pollution on environment at loaders /unloaders, belt transfer points in transfer towers, stockyards and wagon loader. Dust suppression system consists of pumps; storage tank and water spray nozzles. It is ensured that Dust Suppression System is effectively functioning.

- In order to suppress the dust generated during loading and unloading of cargo, regular water sprinkling along the access road and berthing areas is carried out. Mechanical sprinklers are installed along the stockyards to control the fugitive dust from the stockyards.

- In addition, KPPL also has planted green belt along the boundary.

- The cargo like fertilizer, cement and rice is handled in bags which are securely packed.

To handle dry bulk cargo (Coal), the following mitigation measures are followed to control emissions.

- Regularizing truck movement between stockyard and hinterland ensuring prevention of unnecessary truck movement, speeding and idling of the truck engines.

- Environmental Awareness program to Drivers involved in cargo movement from stockyard to hinterland.

- Minimizing cargo spills during loading / unloading and transfer operations.

- Decreasing the drop height of the cargo during loading / unloading operations.
- Regular co-ordination with the weather station so as to have adequate time to implement measures to reduce the fugitive emissions in case of high wind speeds / gusts of wind.
- Prioritise undertaking suitable measures for green belt development around the operational area.

Further, it is ensured that the noise levels do not exceed 65 dB (A) during daytime and 55 dB (A) during night-time. The measures that are proposed to achieve this include decreasing the drop height of the cargo during loading / unloading operations.

12.2.3. Environmental Management at Cargo Storage Areas

Storm water runoff is directed into open concrete lined channels alongside the roads and paved areas in the cargo storage area and other areas of the port. Mitigation measures are proposed to be adopted to minimize the impacts from wastewater and runoff generated from cargo storage areas. The storage area is provided with an extensive drainage system so that the contaminated water from the stockyard area does not flow directly into the natural water bodies or into the groundwater system.

The polluted runoff from berths and stockpiles of Coal in the cargo storage areas is intercepted and directed to settling ponds adjacent to the stockpile area. The settling pond is having two sections, with entry being controlled by sluices. While one section is being cleaned, the other section can receive runoff. After settling, the ponds are used to supply water to the dust suppression system. To prevent land pollution and thereby impacts on groundwater quality, the stockpile area is capped by an impermeable layer (such as clay) to prevent contamination of the groundwater.

The runoff from uncontaminated areas is discharged into the greenbelt area. Mobile dust extractors are provided to sweep the roads.

Greenbelt developed all around Coal stockyards. During operation phase, noise is generated by cargo handling equipment, DG sets, ship engines and vehicles. Workers exposed to excessive noise are provided PPE such as ear plugs, muffs, etc.

12.2.4. Port Traffic Management Plan

The transportation of the cargo to and from the Port will contribute to increase in traffic on the existing road network. The Bulk Liquid Handling Berth project will result in increase in LNG carrying trucks by about 30 numbers per day. The increase in traffic will lead to traffic congestion, increase in dust levels, noise pollution and risk of accidents. In order to contain these impacts the following measures will be taken up:

- The proposed liquid berth will result in additional road traffic of LNG which will be transported on public roads using National Highway. The percentage of LNG transported through road transport will be quite low (only about 30 numbers per day) since major quantity will be transported by pipelines laid by GAIL. Due precautions will be taken in transporting LNG through road transport which will include :

  - Use of PESO approved trucks for transportation of LNG
  - Regular thickness testing of trucks
  - Use of trained drivers
  - Vehicles to be equipped with TREMCARD in local language and English
  - Vehicles to display warnings as required under Motor Vehicles Rules
  - Vehicles to be provided with speed controllers or riders to ensure that no over speeding can occur

- A Port Traffic Management Plan is adopted for movement of trucks and traffic is regulated.

- Avenue plantation along the access roads especially at areas prone to the emissions due to the cargo movement will be undertaken.

- Based on the traffic density / vehicular movements anticipated from the port, adequate parking facilities provided.

- All the vehicles involved in transhipment of cargo are covered adequately with tarpaulins in order to protect the road users from the wind-blown dusts.

- Periodic maintenance of the vehicles involved in transportation activities is carried out.
- It's made mandatory that all vehicles involved in the cargo transhipment are equipped with Pollution under Control (PUC) certificates.

12.2.5. Solid Waste and Hazardous Materials Management

Composted bio-degradable waste and STP sludge dried into cakes are used as manure in greenbelt. Other wastes which can be re-cycled are sold. Hazardous materials are stored as per prescribed safety norms in locations with restricted entry and with fire-fighting facilities.

Proposed Bulk Liquid handling berth activity will have additional ships coming into harbor generating hazardous wastes which will disposed off through authorized recyclers.

12.2.6. Occupational Health and Safety

Potential hazards, safety procedures, emergency measures etc. will be displayed at suitable locations at all workplaces to mitigate occupational hazards.

- Port workers are provided with Personal Protective Equipment (PPE) and usage of the same is mandatory.
- Workers at different units are trained properly to follow safety norms strictly to prevent incidences/accidents periodically and also re-trained.
- About the procedures to be followed under emergency situations to minimize the intensity of impacts.
- Awareness programs conducted periodically for the workers regarding occupational hazards, safety aspects, emergency preparedness and environmental protection.
- Strict enforcement for use of personal safety and protective devices provided to them, while they are on duty.
- Hazardous materials stored as per prescribed safety norms in locations with restricted

entry and with fire-fighting facilities.

- Medical facilities including first-aid provided.
- Periodical medical check-up will be done of all employees regularly every six month
- Only qualified and competent enployees will be employed.
- Work place monitoring will be done as required by factories act
- Standard operating procedures SOP's will be made to hazardous/ risky operation and workers will be trained in that.
- Some of the employees will be trained in fire- fighting operations and others in first- aids techniques.
- Full time HSC officers will be available to manage the OH&S of the employees.

12.3. Terrestrial Environmental Monitoring Plan

The proposed development plan is of a Bulk Liquid Berth for handling LNG adopting storage Gasification Unit (FSRU) with LNG vessel berthed alongside and connected to the shore by means of an approach jetty system, has minor impacts as identified and addressed in previous chapter. Based on this some suggested precautionary measures are laid down to be strictly followed to eliminate possible episodic and irreversible impacts.

As to study whether due to proposed project any further significant environmental impacts occur during its operation lifetime, environmental monitoring covering both the marine and terrestrial environments is recommended to carry out as follows:

Environmental Monitoring program recommended

Terrestrial Parameters	Parameters	Frequency
Ambient Air Quality	PM_{10}, $PM_{2.5}$, SO_2, NOx and non methane hydrocarbons	24 hrs. once in a month
Noise	Leq day time and night time	24 hrs. twice during operation of vessel in month
Sewage from STP	pH, TSS, COD, BOD, Oil and Grease	Once per month at outlet of STP
DG sets	As per EP Act, 1986	Once per quarter

Terrestrial Parameters	Parameters	Frequency
	(TPM, SO_2, NO_x, CO and nMHC)	
RO reject	TDS, chloride, salinity	Once per quarter
Biodiversity /ecological survey	Growth of trees planted, progress of green belt versus planned	Once per year for first three years and once per three years after wards
Sediment Quality Parameters	Objective of Monitoring	The objective of sediment quality monitoring is to list out changes in sediment quality during construction phase and use the results in planning of respective operations.
	Parameters to be monitored	Physical, chemical and biological parameters as cried out in phase I
	No. of locations	Three Locations (3) 1.Harbor Basin 2.Breakwater area 3.Port approach channel
	Frequency of Measurements	The samples will be collected on a monthly basis commencing one week prior to commencement of construction at that location and spread over for construction period of that work.
	Compliance	At present, there are no standards for sediment quality in India. However, there will not be marked variations in the sediment quality during the entire construction phase.

12.4. EMP Budget

The EMP budget is to the tune of 1.82 Crores for the entire port. The apportioned budget for the proposed project will be to the tune of 18 lakhs.

Component	Operational and Management Cost (Rs lakhs)
STP/ETP	5
Hazardous waste	2
Solid Waste	1
Landscaping	2
Socio-economic	5
Occupational Health and safety	3
Total	18

12.5. EMP Organization

For effective implementation of EMP, senior person from Environment Department of Karaikal port will monitor the construction activities for compliance of good construction practices by the civil contractor which will be responsibility of KPPL. All the activities and the environs in the vicinity will be photo documented for future references.

Port already has **Oil spill contingency plan, disaster management plan, environmental plan** etc, which will be extended to include the additional cargoes for handling, storages, use and spillage of hazardous substances.

MARINE EIA

13. BASELINE DATA FOR MARINE ENVIRONMENT

The present status of the marine data collection for the construction of *Liquid Cargo Berth* under the expansion of the existing project was carried out by Indomer in August 2013. The marine environment has been studied for the evaluation of baseline information as per the norms stipulated by the Ministry of Environment and Forests, Climate Change (MoEFCC), Govt. of India. The chemical and biological samples were collected at ten locations in the open sea covering 10 km radius. In addition, the intertidal benthos was studied at four locations, two on the northern side and two on the southern side of the port. The study area covered approximately 150 km². The sampling locations are shown in Fig. 13.1 and the details are presented in Table 13.1. The various studies carried in the coastal region on physical, chemical and biological aspects are explained below.

Physical parameters

Wind,
Storm,
Tsunami,
Waves,
Tides,
Currents,
Bathymetry,

Water quality parameters

Temperature,
pH,
Salinity,
Dissolved Oxygen,
Bio-Chemical Oxygen Demand,
Chemical Oxygen Demand,
Total Nitrogen,
Total phosphorus,
Turbidity,
Ammonia-N,
Nitrite-N,
Nitrate-N,
Inorganic phosphate,
Total suspended solids,
Total Phenolic Compounds as C_6H_5OH,
Total Petroleum Hydrocarbons,
Cadmium as Cd,
Lead as Pb,

Mercury as Hg,
Chromium as Cr, and
Oil and Grease.

Sediment quality parameters

Sediment characteristics,
Total Nitrogen,
Total Phosphorous,
Total organic carbon,
Calcium Carbonate as $CaCo_3$,
Cadmium as Cd,
Lead as Pb,
Mercury as Hg,
Chromium as Cr,
Phenols,
Total Petroleum Hydrocarbon.

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,
Turtles, Corals, Mangroves and
Fisheries.

Environmental study

Assessment of fishery resources in the area,
Assessment of costal and marine ecosystem,
Assessment of impact due to construction of LNG terminal
Assessment of impact due to Dredging
Verification of littoral drift & shoreline changes
Assessment on the impact due to oil spill
Recommendation on the mitigation measures and,
Preparation of Environment Management plan.

13.1. Methodology

Physical

Wind: Data provided by Karaikal port for one year 2013 (January 2013 to December 2013).

Waves: National Institute of Oceanography, Goa, has collected wave data close to the port location by deploying Datawell Directional Wave Rider Buoy. The wave data were measured at 15 m water depth at latitude: 10^o 45' N and longitude 79^o 56' E. The information on significant wave height, zero crossing wave period, wave direction corresponding to peak energy were recorded at 3 hourly interval for a period of one year from 1st January 1996 to 31st December 1996.

Tides: Measured data provided by Karaikal Port for August 2013.

Currents: The variation of measured current speed and direction available with Indomer at 2 locations south of port location was i.e. for 7 days from 11.02.08 to 18.02.08 at 500 m offshore and for another 7 days from 18.02.08 to 25.02.08 at 1500 m offshore were compiled

Bathymetry survey

Configuration of survey: The survey vessel provided by Karaikal Port was used for data collection. The echosounder transducer was mounted on the star board side of the vessel by positioning it at 1.0 m below the sea surface. The DGPS receiver antenna was mounted on the mast vertically in line with the transducer, so that it represents the exact coordinates of the location where the depth is simultaneously measured by the transducer. The Heave Sensor was attached in line with transducer stem on the boat deck in order to measure the residual vertical displacement of the boat induced by external disturbances and to carry out the correction. The DIGIBAR-PRO sound velocity meter was used to measure the sound velocity across the vertical and entered as input for calibrating the transmitting frequency of the instrument. The bar check was also carried out by lowering the rigid plate at different depths and comparing with the displayed depth. The necessary inputs were given in HYPACK data collection software before the commencement of the survey. The planned track lines were displayed on the monitor at wheel for navigation. Watch guards were positioned at bow, transducer/antenna, heave sensor and at rear end. The data were continuously collected at onboard PC along each transect. After a day of data collection was completed, entire data were down loaded to external hard disc and stored. The recorded data included: date, time, and latitude, longitude, X coordinate, Y coordinate, heave and depth. The depth data were recorded at 0.5 sec interval. A tide recorder was erected at site and the water level variation was recorded separately in the internal memory. The recorded depth data were processed in the laboratory by applying corrections for tidal variation and transducer draught.

Echosounder: ODOM Echotrac CVM Digital Dual Frequency Echo sounder manufactured by ODOM Hydrographic Systems, USA was used for the survey. This echosounder is incorporated with the cutting edge technology, features and reliability of the Echotrac MKIII, plus the ease and flexibility of operation of a networked Windows interface. It operates in dual frequency consisting of 200 kHz on higher band and 33 kHz in lower band. It can be operated from 0.2 m to 1500 m water depth with 0.01 m accuracy. The Echotrac CVM transceiver units are compact rack mount package that is ideally suited to survey vessel installations. It supports Chart-functionality in one optional format and a laptop with a full size color LCD as an "electronic chart". The optional color LCD laptop offers internal data storage (in .XTF format) and playback of the analog return signal digitized to full 16-bit resolution. It contains a dual channel board. All channels feature a robust design and frequency agility enabling the operator to precisely match the transceiver to almost any existing transducer. Operator selectable TVG curves serve to optimize the Echotrac for both shallow and deepwater bottom detection tasks and for Sonar imaging. The Echotrac CVM features unsurpassed interfacing flexibility, offering 2 serial ports that can be configured to interface with computers and motion reference units. It has an Ethernet port that outputs the 16 bit samples of the acoustic data for further processing and supports a number of output formats that are compatible with most common Echo Sounder strings.

Technical specifications

Frequency	:	High Band : 200 kHz Low Band : 33 kHz
Input Power	:	110 or 220 V AC or 24 VDC 50 watts
Resolution	:	0.01m / 0.1 ft.
Accuracy	:	0.01m / 0.10 ft. +/-0.1% of depth @ 200 kHz 0.01 m / 0.30 ft. +/- 0.1% of depth @ 33 kHz
Depth range	:	0.2 – 200 m / 0.5 – 600 ft. @ 200 kHz 0.5 – 1500 m / 1.5 – 4500 ft. @ 33 kHz
Sound Velocity	:	1370 – 1700 m/s
Resolution	:	1 m/s
Depth Display	:	On control PC
Clock	:	Internal battery backed time, elapsed time, and date clock
Annotation	:	Internal – date, time, GPS position External – from RS232 Port or Ethernet
Interfaces	:	2 x RS232 serial ports, baud rate selectable 4800-19200. Input from external computer, motion sensor, and sound velocity. Outputs to external computer. Ethernet interface. Heave – TSS1 and sounder sentence
Blanking	:	0 to full scal
Software	:	Echotrac Control supplied. Chart View display and logging software.

Heave Compensator: **TSS HS-50** Dynamic Motion Heave Sensor manufactured by TSS (UK) Ltd., UK was installed onboard. This measure the component of the heave induced at echo sounder transducer. The measured heave is corrected from the depth values and the true depth is recorded in computer. The system is connected via. RS232 communication to the computer onboard enabled through HYPACK data collection software.

Hydrographic Survey Software: HYPACK survey software was used for data collection and processing. It is integrated, first generation hydrographic survey software developed by Coastal Oceanographical INC., USA. It works in MS Windows operating environment. The HYPACK's design program allows to import background map in CAD's DFX or Microsoft's DGN format. It enables to quickly create planned survey lines, plotting sheets and bottom coverage grids in a graphical environment. It gives the flexibility to support multiple navigational systems (GPS, range/range, and range/azimuth), echo sounders (single and dual frequency, multiple transducers and multibeam), magnetometers, ROV-tracking systems, telemetry tide systems and many other devices. It contains the post processing module to analyze and prepare the chart. *The survey tracks were planned using this software for accurate maneuvering of the vessel and to keep the accuracy of the track. The post processing of the survey data and preparation of map were carried out using this software.*

Data recording: The Echosounder, Heave compensator and Beacon DGPS receiver were interfaced through HYPACK software with onboard PC. The entire system was supported by AC Power Generator installed onboard. The position and depth were recorded along the preplanned transect at 500 millisecond interval continuously.

Tidal corrections: The necessary tidal corrections were applied for the collected bathymetry data based on the measured tides.

Horizontal controls

Reference station: The DGPS Beacon Transmitter installed at Nagapattinam port *by Department of Lighthouse and Navigation, Nagapattinam* port was taken as *reference station*. The transmitting frequency of this reference station DGPS Beacon transmitter was 323 kHz.

Mobile station: The horizontal positioning of the mobile unit was carried out using **Hemisphere R100 Series** DGPS Beacon Receiver. It combines high-performance GPS reception with a DGPS-capable receiver in a lightweight, durable housing and comes with a separate antenna. It gives the horizontal position to an accuracy of close to 1 m. The GPS receiver also contains technology enabling *WAAS/EGNOS*, *OmniSTAR* or *Beacon* real time differential capabilities. When used with a Real- time Kinematic (RTK) Base station, the GPS receiver provides RTK positioning for high-accuracy, centimeter-level applications. A standard GPS receiver provides the following features: •10 Hz (10 positions per second) output rate •12 GPS (C/A code L1, C/A code L2 (for the OmniSTAR XP/HP and RTK models)) tracking channels, code carrier channels •Sub meter differential accuracy (RMS), assuming at least five satellites and a PDOP (Position Dilution of Precision) of less than four (when used with Satellite Based Augmentation Systems (SBAS) correction).

The system configuration is enabled with

- LED display and keypad
- Outputs a 1 PPS (pulse per second) strobe signal on both ports. This signal enables an external instrument to synchronize its internal time with a time derived from the very accurate GPS system time.
- SBAS such as WAAS (Wide Area Augmentation System) differential correction 1
- Beacon differential correction
- Omni STAR VBS capability
- Omni STAR XP/HP capability in the XP/HP and RTK models
- RTK positioning capability, In the RTK model only
- EVEREST ™ multipath rejection technology
- Two connectors that support both CAN 2.0B and RS-232:
- –CAN: J1939 and NMEA 2000 messages
- –RS-232:
- NMEA-0183 output: GGA, GLL, GRS, GST, GSA, GSV, MSS, RMC, VTG, ZDA (the default NMEA messages are GGA, GSA, VTG, and RMC).

Reference spheroid: WGS 84 spheroids was followed for entire surveys and for the presentation in the report.

Water quality

Water samples were collected at eight locations (stn. S3 to stn. S10) in the coastal water and two locations inside harbour basin (stn. S1 and stn. S2) as indicated in Table 13.1 and Fig. 13.1. 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 of Winkler B (alkaline KI) were added. The stopper is then inserted and the bottle 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^{o}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 liter glass bottles. Sample for Phenol estimation was collected in a pre cleaned 1 liter plastic container.

Method of analysis

Temperature: Temperature was noted immediately after the water sampler was retrieved using a graduated centigrade thermometer, which was graduated from 0 to 50° C with 0.1° C accuracy.

pH: pH was measured immediately after collection of water samples using a portable digital pH meter (Hanna Instruments, model RI 02895) having an accuracy of $\pm$ 0.2 pH. The instrument was calibrated using standard pH buffers.

Salinity: Salinity values were determined by Mohr-Knudsen titration method, wherein the chlorosity was first obtained by titration of sample with silver nitrate solution. From chlorosity value, salinity was determined from the Knudsen hydrographic table (Strickland and Parson, 1972).

Dissolved Oxygen (DO): Dissolved Oxygen content of the water samples were analyzed by Winkler's method. The precipitate of manganese (II) hydroxide is dissolved by acidification (50% HCl), liberating the manganese (III) ions, which reacts with iodide ions previously added to water sample together with potassium hydroxide. The iodine ions liberated by oxidation of iodine ions was titrated against sodium thiosulphate. The end point of the titration (blue$\rightarrow$ colourless) is indicated by using starch as an indicator.

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 1st and 3th day gives 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.

Total Suspended Solids (TSS): The TSS of seawater samples were 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 at 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

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 color 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 colored 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.

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 (TPHC): 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 as mg/l.

Sediment Characteristics

Method of collection: Seabed sediment samples were collected at eight locations (stn. S3 to stn. S10) in the coastal waters and two locations inside harbour basin (stn. S1 & stn. S2). Intertidal zone sediment samples were also collected at 4 locations (two in the north and two in the south of the project site) for inter tidal benthos analysis (stns. IB1 to IB4). The sediment sampling locations are shown in Fig. 13.1. Seabed sediments were collected using van Veen grab, stored in two plastic bags. One fraction was fixed in buffered 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 hand held shovel using a quadrant ($0.25m^2$). After collection, the scooped sample was sieved using a hand held sieve (500 micron) and organisms were sorted out and transferred to polythene bags, fixed, labeled and stored for further analyses (identification) 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: 63µ, 125µ 212µ, 300µ, 425µ, 500µ, 600µ, 1000µ and 2000µ. 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 $MgCl_2$ were 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 sediment 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 colored complex which was measured at 880 nm using a spectrophotometer.

Calcium Carbonate: Calcium Carbonate content 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.

Phenols: Phenols in sediment sample was extracted with a suitable solvent and the concentration of phenols was estimated in a Gas chromatography system (GC) with Flame Ionization Detector (FID). The method followed was according to EPA 3540C & EPA 8041A.

Total Petroleum Hydrocarbons (PHC): The fractions of the PHC were estimated using a Gas chromatography with Flame Ionization Detector (GC/FID) following the method of NWTPH-HCID. This method is used to identify petroleum products containing components from C7 to C30 range. EPA method 3510 has been adapted as the extraction procedure. The various fractions analyzed were: Octane, Nonane, Decane, Undecane, Dodecane, Tridecane, Tetradecane, Pentadecane, Hexadecane, Heptadecane, Octadecane, Nonadecane and Eicosane.

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 (According protocol to USEPA 3050 B).

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 wavelengths (According protocol to USEPA 3050B).

Biological Parameters

Primary Productivity: Primary Production was estimated at eight locations (stn. S3 to stn. S10) in the coastal waters and two locations inside harbour basin (stn. S1 & stn. S2) (Fig. 13.1). From the water sampler, 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 an unit area.

Phytoplankton: Phytoplankton samples were collected at eight locations (stn. S3 to stn. S10) in the coastal waters and two locations inside harbour basin (stn. S1 & stn. S2) (Fig. 13.1) 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 l lit. Clean polyethylene bottles for population estimation and preserved with Lugol's iodine. Total sedimentation time was 72 hours. After sedimentation of phytoplankters, 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, 1 ml 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 eight locations (stn. S3 to stn. S10) in the coastal waters and two locations inside harbour basin (stn. S1 & stn. S2) (Fig. 13.1). 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 8 locations in the coastal waters and 2 locations inside harbour basin (Fig. 13.1). The intertidal benthos samples were collected at 4 locations along the beach (stns. IB1, IB2 , IB3 and IB4) as shown in Fig. 131.1. 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. Wet weight was taken to calculate the biomass of benthic organisms.

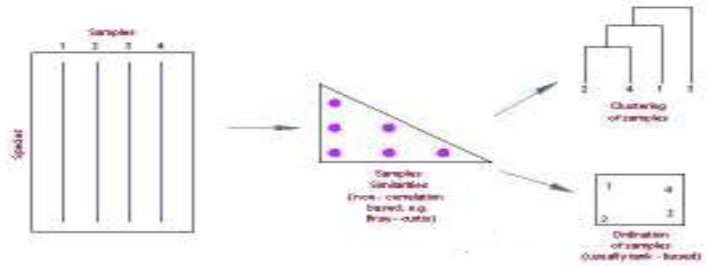
Microbiology: The microbiological samples were collected at eight locations (stn. S3 to stn. S10) in the coastal waters and two locations inside harbour basin (stn. S1 & stn. S2) (Fig. 13.1). Samples were collected in sterilized bottles and transported for analysis. Spread plate method was used to culture 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 the Deputy Director, Department of Fisheries, Government of Puducherry at Karaikal.

Coastal vegetation*:* The shore plants over the sand dunes 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.

13.2. Results

13.2.1. Physical Parameters

Wind: The variation of wind speed and direction for one year from January 2013 to December 2013 is shown in Fig. 13.2. The variation of wind speed and direction measured at Karaikal Port are presented as seasonal wind roses in Fig. 9.11. (Data Provided by Karaikal Port).

Tides: The tides in this region are semi-diurnal. The variation of measured tides from 01.08.13 to 31.08.13 is shown in Fig. 13.3. It showed a spring tidal range of 0.80 m and a neap tidal range of 0.30 m. (Data Provided by Karaikal Port).

The design tide levels w.r.t. CD for Karaikal port is followed as per the Nagapattinam tide. The design tide levels as presented in Naval Hydrographic Chart (No. 3007) are given below.

Mean High water Spring	:	0.6 m
Mean High Water Neap	:	0.5 m
Mean Sea Level	:	0.3 m
Mean Low Water Neap	:	0.2 m
Mean Low Water Spring	:	0.0 m

Currents: Based on the past data collected, the variation of measured current speed and direction for 7 days from 11.02.08 to 18.02.08 at 500 m offshore and for another 7 days from 18.02.08 to 25.02.08 at 1500 m offshore are shown in Fig. 13.4. At 500 m offshore, the current speed varied between 0.02 to 0.20 m/s. The current persisted unidirectional around 340˚ from 11.02.08 to 14.02.08 and around 180˚ from 15.02.08 to 18.02.08. At 1500 m offshore, the current speed varied between 0.02 to 0.14 m/s. The current remained mostly southward between 180˚ and 225˚. But for two days i.e. on 20.02.08 and 21.02.08, the current direction was around 340˚. Available literature reports that the nearshore currents varies between 0.05 m/s to 0.2 m/s, and the flow is directed towards north during April to September and towards south during November to February, indicating that the coastal currents are dominated by the seasonal wind.

Waves: The wave characteristics measured at 15 m water depth are presented as monthly wave roses in Fig. 13.5. The monthly predominant measured wave characteristics at 15 m depth are presented in Table 13.2. At 15 m water depth, the significant wave heights vary around 0.5 m from March to May, 0.75 m from June to October, 0.75 m to 1.5 m from November to January. The predominant zero crossing wave periods remain around 5 s over the whole year. The predominant wave direction prevails around 90° during March to May, 100° to 105° in June to October, and 65° to 85° in November to February. The frequent occurrence of storms and depressions during northeast monsoon temporarily increases the wave activity in this region.

Bathymetry: The combined bathymetry map of the open sea including the Approach channel and Port basin based on the survey conducted in October 2013 is shown in Fig. 13.6. The survey indicates that the seabed is very flat and remains shallow. Approach Channel: The channel is spread by 13 m, 14 m and 15 m depth contours. The eastern part is mainly distributed by 14 m depth values. The depth contour of 13 m is generally occupied on the western side and further the presence of 14 m and 15 m contour patches are identified.

Storm: The tracks of cyclones which had crossed the coast near Nagapattinam (within 150 km on either side) during 1877 to 2013 are presented in Table 13.3. It indicates that totally 99 storms had occurred within 300 km of the project region. The occurrence of storms in this region was more frequent in November (46) followed by October (20) and December (18). Among them, 5 storms had crossed the coast within 150 km around the project region between the years 1877 and 2013.

Tsunami: Occurrence of Tsunami is an extremely rare phenomenon along the Indian coast. The past history shows that the periodicity of occurrence may range from 300 to 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. Recently the Tsunami occurred on 26.12.04 with an epicenter near Indonesia in Bay of Bengal and had a dreadful devastation effect along the entire Tamilnadu coast. The magnitude of impact was very severe along the coastal stretch between Nagapattinam and Cuddalore. During this tsunami, the water level rise (tsunami run up) along the stretch of Karaikal port was around 2.5 m – 3.5 m. The backshore in the project region was low and flat and hence the run up of Tsunami has intruded to a longer distance till the East Coast Road.

In case of a repetition of such a rare event along the coast, we can expect a run up of 2.5 m due to Tsunami, but it will be on the shore face on either side of the breakwaters. The water depth inside the port is (-) 14.5 m CD and hence the rise in water level due to propagation of Tsunami will be negligibly small. Also the breakwaters and wharfs will protect the basin and backup area from the impact of Tsunami.

The aspects on changes in current circulation, littoral drift & shoreline erosion, storm surge elevation and dredging & disposal are discussed under mathematical modelling studies as presented in Chapter 14.

13.2.2. Water Quality

The seawater samples were collected at 10 locations, i.e. at 8 locations in open sea (stns. S3 to S10) and at 2 locations inside the port basin (stns. S1 and S2). The sampling locations are shown Fig. 13.1 and details are presented in Table 13.1. The estimated water quality parameters on temperature, pH, salinity, dissolved oxygen, Bio-chemical oxygen demand, chemical oxygen demand, turbidity, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, phosphate-phosphorus, total nitrogen, total phosphorus and total suspended solids, biochemical oxygen demand and chemical oxygen demand are given in Table 13.4. The results of cadmium, lead, mercury, total chromium, oil and grease, phenols and total petroleum hydrocarbons are presented in Table 13.5.

Temperature: Steep gradients of coastal waters temperature across the depths bear direct impact on the productivity and animal colony of the region. The temperature varied from 28.0° C to 29.0° C in harbour basin at stns. S1 and S2. The values varied from 27.5° C to 29.0° C in coastal waters at stns. S3 to S10 (Table 13.4). There was no significant variation in temperature with the distance from the shore. The variation of temperature across the water column was insignificant and followed normal pattern indicating the absence of significant stratification in the water column at nearshore.

Salinity: The salinity of the collected water samples varied between 34 ppt and 35 ppt both in harbour basin (stns. S1 to S2) and coastal waters at stns. S3 to S10 (Table 13.4). The results indicate that the salinity lie within the normal range in this region during the period of study.

***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 coastal waters. During the present study, the pH of the coastal waters samples varied from 8.1 to 8.2 in harbour basin at stns. S1 and S2. The values varied between 8.1 and 8.3 in coastal waters at stns. S3 to S10 (Table 13.4). The result shows that the pH values lie within the normal range of coastal waters.

Dissolved Oxygen (DO): Among the dissolved gases in water, oxygen is the most important parameter 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.

DO values varied from 5.12 to 6.08 mg/l in harbour basin at stns. S1 and S2. The DO values varied between 4.64 to 6.08 mg/l in the coastal waters at stns. S3 to S10 (Table 13.4).

Biochemical Oxygen Demand (BOD): Rate of aerobic utilization of oxygen is an 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.

In the present study, the BOD values varied from 1.44 to 2.88 mg/l in harbour basin at stns. S1 and S2 and from 1.12 to 3.20 mg/l in the coastal waters stns. S3 to S10 (Table 13.4). In general the surface values were higher than the subsurface values. The low BOD values observed at these stations indicate that oxidisable organic matter brought to the nearshore waters are effectively assimilated in coastal water. The narrow 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 in the water column. In the present study, the COD varied from 18.3 to 22.1 mg/l in harbour basin at stns. S1 and S2. The COD values varied from 17.1 to 31.0 mg/l in the coastal waters stns. S3 to S10 (Table 13.4). It is observed that both the values (minimum and maximum) were recorded from bottom water.

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 coastal waters 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 0.11 to 0.53 µmol/l in harbour basin at stns. S1 and S2. The concentrations of ammonia varied from 0.05 to 0.42 µmol/l in coastal waters at stns. S3 to S10. The minimum (0.05 µmol/l) was recorded at stn. S7 (surface) and maximum (0.42 µmol/l) was recorded at stn. S3 (bottom) (Table 13.4). The values are in normal range and indicate a healthy environment.

Nitrite-Nitrogen (NO_2-N): Nitrite is an important element, which occurs in coastal waters 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.

Referring to Table 13.4, Nitrite concentration ranged from 0.20 to 1.00 µmol/l in harbour basin at stns. S1 and S2. The minimum value of 0.20 µmol/l was recorded at stn. S1 (surface) and a maximum of 1.00 µmol/l was noticed at stn. S2 (bottom). The concentrations varied from 0.21 µmol/l to 1.48 µmol/l in the coastal waters at stns. S3 to S10. The minimum value of 0.21 µmol/l was recorded at stn. S10 (surface) while the maximum of 1.48 µmol/l was noticed at stn. S3 (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 coastal waters and is considered to be the only thermodynamically stable oxidation level of nitrogen in coastal waters. 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.

Referring to Table 13.4, Nitrate concentration ranged from 1.30 to 2.03 µmol/l in harbour basin at stns. S1 and S2. The minimum of 1.30 µmol/l was recorded at stn. S1 surface water and maximum of 2.03 µmol/l was noticed at stn. S1 (bottom). The concentrations varied from 1.25 µmol/l to 4.41 µmol/l in the coastal waters at stns. S3 to S10. The minimum of 1.25 µmol/l was recorded at stns. S5 and S10 surface water while the maximum of 4.41 µmol/l was noticed at stn. S6 (bottom).

Total Nitrogen: Referring to Table 13.4, the total nitrogen concentrations varied from 7.33 to 9.82 µmol/l in harbour basin at stns. S1 and S2. The minimum of 7.33 µmol/l was recorded at stn. S2 (surface) and maximum of 9.82 µmol/l was noticed stn. S1 (bottom). The concentrations varied from 7.58 µmol/l to 11.06 µmol/l in the coastal waters at stns. S3 to S10. The minimum of 7.58 µmol/l was recorded at stn. S5 (surface) while the maximum of 11.06 µmol/l was noticed at stn. S8 (bottom).

Phosphate (PO_4-P): Referring to Table 13.4, the concentrations of Phosphate varied from 0.16 to 0.71 µmol/l in harbour basin at stns. S1 and S2. The concentration varied from 0.12 µmol/l to 0.82 µmol/l in the coastal waters at stns. S3 to S10. The minimum of 0.12 µmol/l was recorded at stn. S3 (surface) while the maximum of 0.82 µmol/l was noticed at S10 (bottom).

Total Phosphorus: The Total Phosphorus concentrations varied from 3.73 to 4.76 µmol/l in harbour basin at stns. S1 & S2. It varied from 2.04 µmol/l to 5.02 µmol/l in the coastal waters at stns. S3 to S10. The minimum of 2.04 µmol/l was recorded at stn. S7 (surface) while the maximum of 5.02 µmol/l was noticed at stn. S3 (bottom).

Total Suspended Solids (TSS): Total Suspended Solids in coastal waters originate either from autochthonous (biological life) or allochthonus (derived from terrestrial matter) sources. It varied from 60 mg/l at stn. S2 (surface) to 78 mg/l stn. S1 (bottom) inside harbour basin. The values ranged from 48 mg/l to 96 mg/l in the coastal waters at stns. S3 to S10 (Table 13.4). The results of total suspended solids indicate a similar trend with the turbidity values, having low values at surface compared to the bottom layers.

Turbidity: Turbidity is another measure to understand the suspended particulate matter load in the water column which is one of the major factors known to control the photosynthesis. The measured turbidity varied from 3.2 NTU at stn. S2 (surface) to 4.4 NTU at stn. S1 and S2 (bottom) in harbour basin. The values varied from 2.4 to 9.4 NTU in the coastal waters at stns. S3 to S10 (Table 13.4). The minimum (2.4 NTU) value was noticed in stn. S4 at surface. The maximum of 9.4 NTU was noticed in stn. S8 at bottom. The turbidity of the nearshore waters in the surface region was found within normal ranges indicating the existence of clean water.

The water quality parameters observed both harbour basin and coastal waters do not show much variation and the water remains clean without any contamination or organic load.

Trace metal concentration: Concentrations of trace metals in coastal waters 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 indicator of metal pollution.

Knowledge of the trace metal concentration in coastal waters 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, pH, salinity, turbidity and dissolved oxygen concentration also significantly affect metal-organism interactions.

The nominal presence of trace metals, which occur in coastal waters, are found to be necessary to promote growth of marine organisms. The concentration levels of Cadmium (Cd), Lead (Pb), Chromium (Cr) and Mercury (Hg) measured at all 10 locations (harbour basin and coastal water) across the depths are presented in Table 13.5.

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 coastal water. 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 in the study region was < 0. 01 mg/l at all 10 locations both harbour basin and coastal waters (Table 13.5).

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. During the study period, the concentration of mercury observed was <0.002 mg/l at all 10 locations both harbour basin and coastal waters (Table 13.5).

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 in the coastal waters samples was estimated as lead strongly gets accumulated in fishes especially with shell fish. The lead concentration in the present study existed <0.001 mg/l inside the basin and in coastal waters at stns. S1 to S10 (Table 13.5).

Total Chromium (Cr): In dissolved form, chromium is present either as anionic trivalent Cr $(OH)_3$ or as hexavalent CrO_4^{2-}. The amounts of dissolved Cr3+ ions are 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 has 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 coastal waters fish lies between 7 and 400 ppm, and for algae at 0.032 - 6.4 ppm. The chromium concentration in the study region was < 0.001 mg/l at all 10 locations both harbour basin and coastal waters (Table 13.5).

Phenol: The main source of Phenolic compounds in coastal waters 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 < 0.001 mg/l in all 10 locations both harbour basin and coastal waters (Table 13.5).

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 total Petroleum hydrocarbons values were < 0.1 mg/l at all 10 locations (Table 13.5). Ten fractions (Decane, Docosane, Dodecane, Eicosane, Hexacosane, Hexadecane, Octacosane, Octadecane, Tetracosane and Tetradecane) were analyzed and none of the fractions was above 0.05 mg/l.

Oil & grease: The concentration of oil & grease in the study area was < 2.0 mg/l in all 10 locations both harbour basin and coastal waters (Table 13.5).

13.2.3. Sediment Quality

Sediment size distribution: The size distribution of the seabed sediments are shown in Table 13.6. The seabed is primarily composed of silty sand.

The percentage composition of total nitrogen, total phosphorus, total organic carbon and calcium carbonate in sediment samples are given in Table 13.7.

Total Organic Carbon: Total organic carbon content ranged from 0.64% at stn. S1 to 2.86% at stn. S2. The total organic carbon ranged from 0.50% to 2.71% in coastal waters at stns. S3 to S10. The minimum value of 0.50% was recorded at stn. S3 while the maximum of 2.71% was recorded at stn. S4 (Table 13.7).

Total Nitrogen: Total nitrogen content of the sediment samples varied from 1.49 mg/g at stn. S1 to 2.67 mg/g at stn. S2 in harbour basin. The total nitrogen content ranged from 1.53 mg/g to 2.78 mg/g in coastal waters at stns. S3 to S10. The minimum value of 1.53 mg/g was recorded at stn. S9 while the maximum of 2.78 mg/g was recorded at stn. S4 (Table 13.7).

Total Phosphorus: Total phosphorus content in the sediments varied from 0.22 mg/g at stn. S1 to 0.38 mg/g at stn. S2 in harbour basin. The values ranged from 0.05 mg/g to 0.48 mg/g in coastal waters at stns. S3 to S10. The minimum of 0.05 mg/g was recorded at stn. S5 while the maximum of 0.48 mg/g was recorded at stn. S7 (Table 13.7).

Calcium Carbonate: The calcium carbonate content in the sediments varied from 6.42% at stn. S1 to 10.66% stn. S2 in harbour basin. The values varied from 5.04% to 9.86% in coastal waters at stns. S3 to S10. The minimum of 5.04% was recorded at stn. S10 and maximum of 9.86% was noticed at stn. S6 (Table 13.7).

The concentration of lead, cadmium, mercury, total chromium, phenols and total petroleum hydrocarbons in the bottom sediments are presented in Table 13.8.

Lead (Pb): The concentrations of lead in the study area varied from 3.0 mg/kg at stn. S1 and 3.4 mg/kg at stn. S2 in harbour basin. The concentrations of lead values ranged from <0.3 mg/kg at stn. S7 to 2.95 mg/kg at stn. S3 in coastal waters.

Cadmium (Cd): The concentration of cadmium varied from 0.125 mg/kg at stn. S1 and 0.126 mg/kg at stn. S2 in harbour basin. The concentrations of cadmium ranged from <0.03 mg/kg to 0.219 mg/kg in coastal waters at stns. S3 to S10. The minimum of <0.03 mg/kg was recorded at stn. S10 and maximum of 0.219 mg/kg was noticed stn. S9.

Mercury (Hg): The concentration of mercury in the study area was <0.1 mg/kg at all the 10 stations both harbour basin and coastal waters.

Total Chromium (Cr): The concentration of total chromium in the study area was found to be varying between 10.53 mg/kg at stn. S1 and 10.59 mg/kg at stn. S2 in harbour basin. The concentrations of total chromium ranged from 9.56 mg/kg to 89.06 mg/kg in coastal waters at stns. S3 to S10. The minimum of 9.56 mg/kg was recorded at stn. S4 and maximum 89.06 mg/kg was noticed at stn. S6.

Phenol: The concentration of phenol in the study area was <1.0 mg/kg both harbour basin and coastal waters.

Total Petroleum Hydrocarbons: The concentration of total petroleum hydrocarbon in the study area was <0.5 mg/kg both harbour basin and coastal waters.

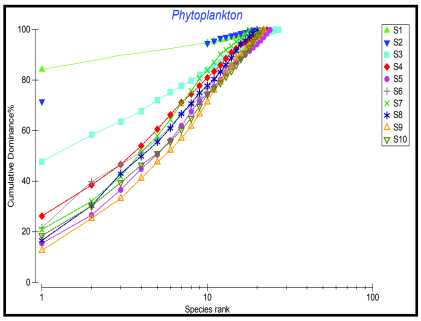
13.2.4. Biological Parameters

Biological status of an area is an essential pre-requisite 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 coastal waters bed 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 coastal water bed, provide information regarding the integrated effects of stress due to disturbances, if any and hence are good indicators of an 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 coastal waters and the sunlight for photosynthesis. This primary production is an important source of food for the higher organisms in the marine environment. The measured primary productivity results are shown in Table 13.9. The results indicate that the area is good productive and the values varied from 360 to 480 mg C/m^3/day in harbour basin. The values ranged from 360 to 600 mg C/m^3/day in coastal waters. It appears that the northern zone is slightly higher in productivity. The higher values of 600 mg C/m^3/day was recorded at stn. S4 at 2 km radius and stn. S8 at 10 km radius. At stn. S2 inside the harbour basin, stn. S5 at 2 km radius and stn. S7 at 5 km radius recorded slightly lower values. In general, seven stations recorded more values (480 mg C/m^3/day) compared to the average value (468 mg C/m^3/day) recorded in the study area. The values are compared to other productivity values recorded along the east coast of India. A comparative statement of primary production along the east coast of India is also given in Table 13.10. Various phytoplankton groups were observed and their percentage compositions are shown in Table 13.11.

The floral diversity fluctuated from 33 to 39 species in the harbour basin and the phytoplankton diversity ranged from 35 to 42 species in coastal waters. 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 34638 nos./l at stn. S2 and 68939 nos./l at stn. S1 in harbour basin. The coastal waters phytoplankton population varied from 7166 nos. /l to 31643 nos./l at stns. S3 to S10 (Table 13.12). The most dominant species found in this region are *Pseudonitzschia* sp. (49.04%), *Pleurosigma normanii* (3.91%), *Thalassiothrix frauenfeldii* (3.52%) and *Thalassionema nitzschioides* (2.84%) among Pennales, *Rhizosolenia alata* (8.58%) and *Coscinodiscus radiatus* (2.22%) among Centrales.

As many as 64 species of phytoplankton (net and unit samples put together) represented by 3 diverse groups namely, diatoms (51 species consisting of 36 centrales and 15 pennales), dinophyceans (12) and cyanophyceae (1). There were relatively fewer (43) species in the unit samples. The detailed account on species composition and distribution at different stations in the surface waters are listed in Tables 13.11 and 13.12.

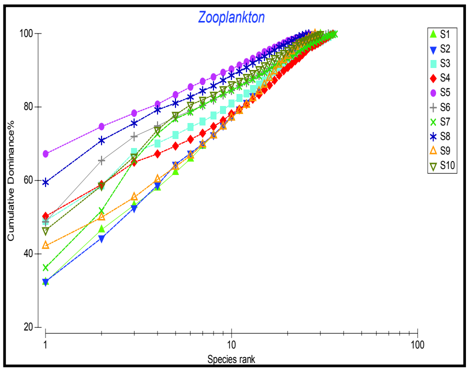


Overall, bacillariophyceans remained the largest group (20 species). In general, *Rhizosolenia alata*, *Pseudonitzschia* sp., *Pleurosigma normanii*, *Thalassiothirx frauenfeldii* and *Prorocentrum micans* to be found at all stations. Overall, pennales formed the bulk (67%) of the population followed by centrales (22%), dinophyceans (10%) and Cyanophyceans (1%). The same thing was also reflected in the population numbers. *Rhizosolenia alata, Thalassiosira subtilis*, *Navicula henneydii*, *Thalassiothirx frauenfeldii*, and *Prorocentrum micans* were recorded in good numbers at all the stations.

Rhizosolenia alata and *Pseudonitzschia* sp. was the dominant species found at all station. *Trichodesmium erythraeum* was observed at stns. S7 to S10.

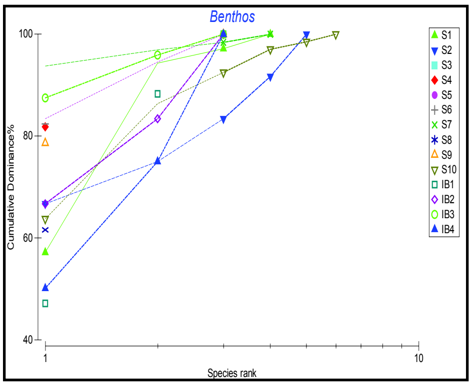
Based on the studies using *Primer* software, the Shannon-Wiener (H‘) diversity showed the diverse nature of project area is between 1.269 and 4.141. The similarity in species composition and abundance among stations varied from 42.37% to 71.47% with an average similarity percentage of 56.86%. The dominance plot for all the stations showed straight curves indicating normal condition of the environment.

Zooplankton: The zooplankton species diversity fluctuated from 27 at stn. S2 to 30 at stn. S1 tinside harbour basin. Coastal waters zooplankton species diversity varied from 26 to 36 at stns. S3 to S10. Various zooplankton groups and their percentage composition observed at various stations are shown in Tables 13.13 to 13.14. 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 71740 nos./100 m^3 at stn. S1 and 104436 nos./100 m^3 at stn. S2 inside harbour basin and the zooplankton population from coastal waters ranged between 80346 nos./100 m^3 to 243789 nos. /100 m^3 at stns. S3 to S10 (Table 13.13). The minimum (80346 nos./100 m^3) was recorded at stn.S9 and maximum (243789 nos. /100 m^3) was noticed at stn. S5. The percentage occurrence of various groups also varied from place to place.



The zooplankton biomass varied from 30.1 ml/100m^3 at stn. S1 to 71.8 ml/100m^3 at stn. S2 inside harbour basin and the coastal waters varied from 31.1 ml/100m^3 to 67.7 ml/100m^3 at stns. S3 to S10 (Table 13.14). The minimum of 31.1 ml/100m^3 biomass was recorded at stn. S7 and maximum of 67.7 ml/100m^3 was noticed at stn. S5. Zooplankton population in this region was mostly dominated by the following species. *Evadne* species (44.16%) among cladocerans and copepods represented by *Temora turbinata* (14.52%), *Acartia erythraea* (7.35%), *Paracalanus parvus* (4.25%), *Acrocalanus gracilis* (2.87%) and *Eucalanus attenuatus* (2.17%). In general, *Tintinnopsis* sp., among tintinnids, *Sagitta* sp., Bivale veliger larvae, *Acartia erythraea*, *Acrocalanus gracilis*, *Eucalanus* *attenuates*, *Paracalanus parvus*, *Temora turbinata*, Copepod nauplii, *Corycaeus danae*, *Evadne* sp., Mysid larvae, *Lucifer* sp., Oikopleura larvae and Fish eggs to be found at all stations.

The Shannon-Wiener (H') diversity clearly showed the rich diversity of the project area (2.228 – 3.777). The similarity in species composition and abundance among stations varied from 62.42% - 82.57% with an average similarity percentage of 73.02%. The dominance plot for all the stations showed straight shaped curves indicating normal condition of the environment.

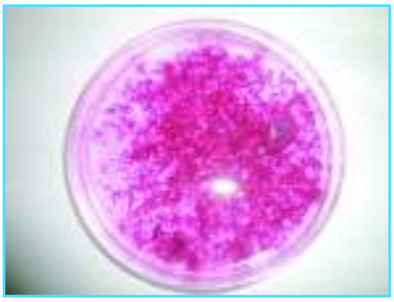


Benthos: Benthic faunal population in an environment depends on the nature of the substratum and the organic matter content of the substratum.

Subtidal benthos: The sediment characteristics of the study area showed very fine sand followed by silt & clay and medium sand. The numerical abundance of the benthic fauna varied from 120 nos./m^2 at stn. S2 to 350 nos./m^2 at stn. S1 inside harbour basin and coastal waters the benthic fauna ranged from 130 nos./m^2 to 660 nos./m^2 at stns. S3 to S10 (Table 13.15). The faunal population mainly consists of Polychaetes followed by Amphipods, Bivalves, Gastropoda and Mysids. *Amphiouxis* sp., of cephalochordate was recorded at stn. S10.

Intertidal benthos: The intertidal faunal population is shown in Table 13.15. The existence of fauna appeared to be low in all the stations (IB1 to IB4). The numerical abundance of the inter tidal benthic fauna varied from 90 to 360 nos./m^2. Amphipods were the dominant group followed by Polychaetes and *Emerita* sp. Gastropods were completely absent in the study area. However, a few *Donax* sp. (bivalves) were recorded at IB4.

In general, the subtidal benthic population was about 3 to 4 times more than intertidal benthic population. Polycaetes was the dominant group found at the subtidal region. Polychaetes were collected from almost all the ten subtidal benthic region with the maximum of 590 nos./m^2 at stn. S7 followed by number from stn. S10. The minimum of 80 nos./m^2 number of polychaetes were recorded at stns. S2 and S8.



Crustaceans dominated by amphipods were the second abundant group in the subtidal and intertidal benthic population followed by molluscan groups and cumacea. However, mysids and cumacea were completely absent at the intertidal region. The molluscan forms recorded at the subtidal region were mostly at all stations expect were completely absent at stns. S3 and S10. On the other hand two third of the polychaetes recorded at the sub-tidal region were all from stns. S1 to S10. Overall, the highest number of organisms at the subtidal region was recorded at stn. S10 and the minimum at stn.S2. At the intertidal region IB3 recorded the most number of organisms followed by IB1, IB2 and IB4. It is concluded that the subtidal area of this region is more diverse and moderately populated than the intertidal region.

The Shannon-Wiener diversity was low in the project area *(0.4364 – 1.585). Similarly the Margalef richness (d) values were also low *(*0.3398 – 0.8355). 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. In the project area there are routine port activities like dredging, oil and possibly other chemical contamination, which may cause stress or contamination. These factors obviously have contributed to low number of organisms/species. The similarity in species composition and abundance among stations widely varied from 15.76% to 82.87% with an average similarity percentage of 50.00%. The dominance plot for all the stations showed steep rise curves possibly because of low number of organisms.

Microbiology: Micro-organism distributions in the marine and brackish environment play an important role in the decomposition of organic matter and mineralization. Since the last two decades, water quality analyses were 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 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. Regular monitoring of 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 13.16 and 13.17 respectively. In the water samples, population density enumerated from all the stations varied from 0.02 to 5.62 × 10^3 CFU/ ml with a minimum of 0.02 ×10^3 CFU/ml at stn. S1 and the maximum of 5.62 × 10^3 CFU/ml at stn. S2 inside harbour basin. The bacterial population from coastal waters ranged from 0.01 to 6.08 x 10^3 CFU/ml at stns. S3 to S10. The minimum of 0.01 x 10^3 CFU/ml was recorded at S5 and maximum of 6.08 x 10^3 CFU/ ml was noticed at S7.

In the sediment samples, population density enumerated from all the stations varied from 0.05 to 5.65 ×10^4 CFU/g inside harbour basin. The minimum of 0.05 ×10^4 CFU/g at stn. S1 and maximum of 5.65 ×10^4 CFU/g was at stn. S2. The bacterial population from coastal waters ranged from 0.01 to 6.18 x 10^4 CFU/g at stns. S3 to S10. The minimum of 0.01 x 10^4

CFU/g was recorded at stn. S4 and maximum of 6.18 x 10^4 CFU/g was noticed at stn. S7 (Table 13.17).

The bacterial colonies were identified up to generic level. Organisms isolated were normally expected in all coastal waters, under moderate human influence. The total counts in the water sample at the surface closer to the coastal areas were found to be higher due to terrestrial run off and towards the open coastal waters, the counts were 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 indicate 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.

Turtle: Coastal waters turtles are endangered species, which are protected under Schedule I of the Indian wildlife Protection Act 1972 and its amendment in 1991. They are also protected under international conventions such as Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES 1973) and the Bonn Convention on

Migratory Species (CMS 1979) to which India is a signatory. Coastal waters turtles are listed as "critically endangered," "endangered," or "threatened" on the World Conservation Union (IUCN) Red List.

During the period of survey, no stranded or dead turtles (Olive Ridleys) were noticed on the Karaikal coast. However, earlier surveys conducted by others (Bupathy *et.al.,*2006) indicate that the average turtle mortality of Nagapattinam coast, of which Karaikal forms a part, is only 3/km over a period of one year (mainly January – April period). Further, it was also shown that mortality of turtles in the area was largely due to fishing activities. The nesting density is also low for this region i.e. 7 to 15/km for one year. It must also be pointed out that no data specific for Karaikal exist and so the data available for the Nagapattinam coast only has to be taken for drawing conclusions.

Corals: No coral communities were noticed in the project site. Sub-tidal samplings conducted at 10 locations spread over 150 km^2 also did not yield any clue for the presence of corals. Further the Karaikal Port is abutted with two rivers i.e. Vettar in south and Paravanar in north, which carry lot of silt and deposit it in the coastal waters bed during monsoonal rains. This creates an unfavourable condition for development any coral community in this region.

Mangroves: There are no well established mangrove vegetation in the project area. However, small patches of short shrubs of mangrove plants were noticed along the banks of the Vettar mouth. Fringing mangroves, essentially *Avicennia* sp. in isolated patches were seen on the banks of the Paravanar river also. During rainy waters, as the river carries lots of silt and water, they get normally submerged. During fair-weather season, the tidal influence helps them to recover and re-establish. However, the presence of mangroves is very much limited in the vicinity of the Karaikal port.

Coastal Vegetation: Salt marsh plants like *Prosopis juliflora, Sesuvium* sp., *Casuarina litorea, Ipomea pes-caprae, Spinifex littoreus,* and *Calotropis* sp. were found to be sparsely distributed along the coastline. The shore plants over the salt marsh were collected and herbaria were prepared for further identification in the laboratory.

Prosopis juliflora

Sesuvium sp.

Casuarina litorea

Ipomea pes-caprae

Spinifex littoreus

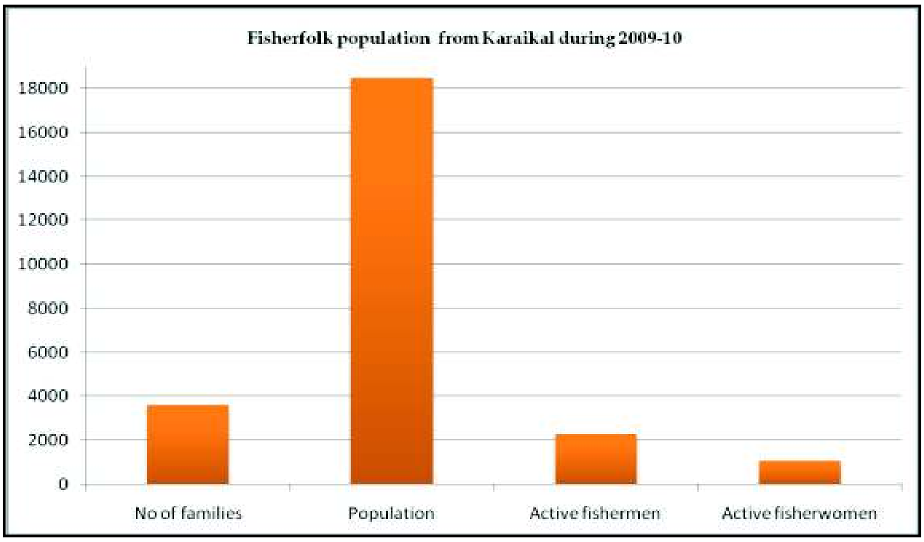
Calotropis sp.

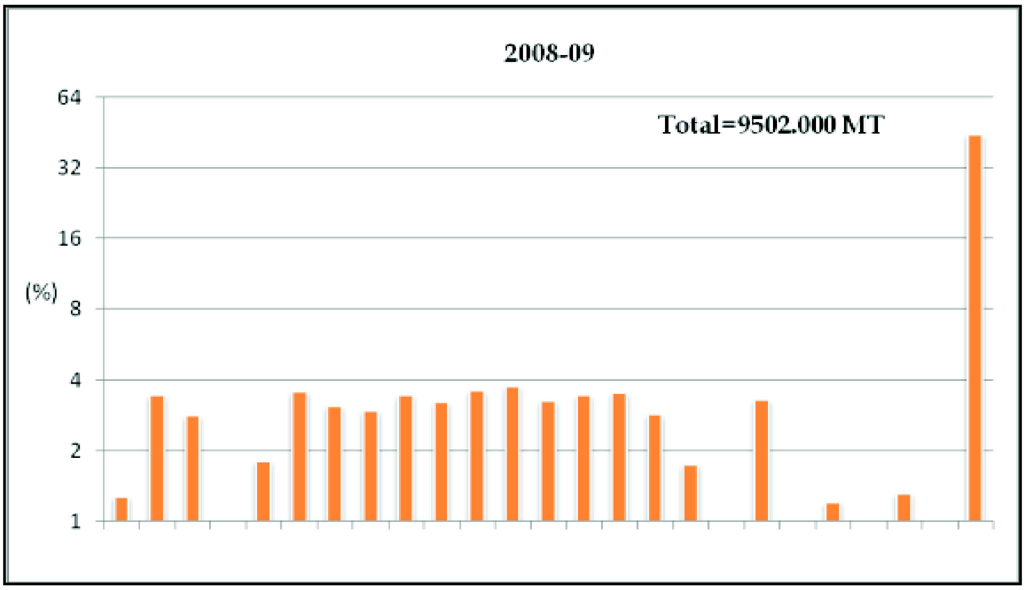
Fisheries: Karaikal has a total number of 10 fishing villages along the 20 km long coastline. The available data indicate that the yearly fish landings are not constant and fluctuate widely. The annual marine fish landings in Karaikal region are shown below:

Year	Marine
2008-09	9,807.15
2009-10	11,360.00
2010-11	11,640.40
2011-12	15,663.00
2012-13	13,041.77

** Source- Department of fisheries & fishermen welfare, Karaikal.*

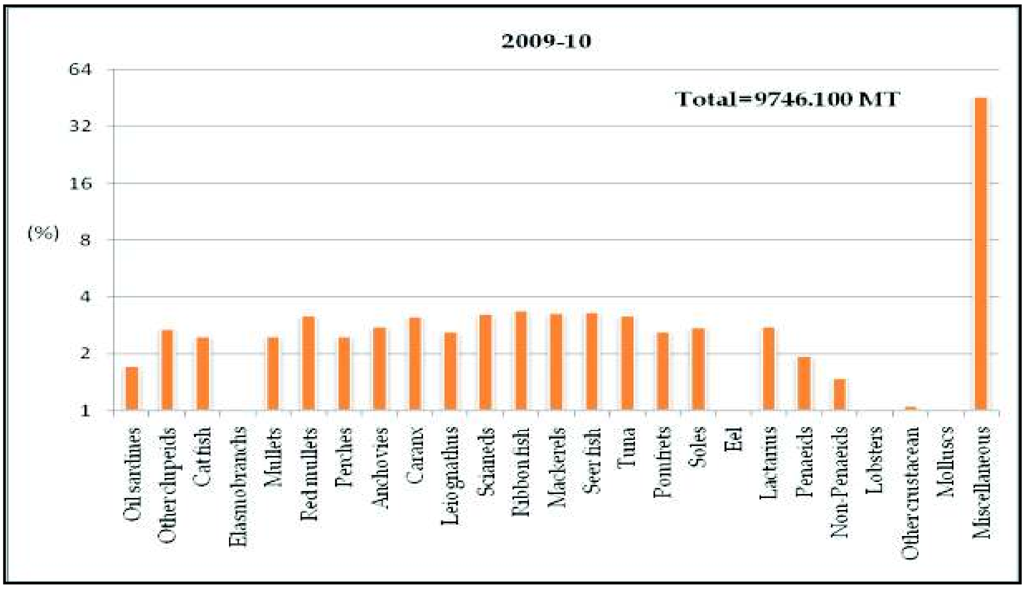
Seventy percent of the catch is by mechanized boats. According to the recent survey conducted by the Karaikal Fisheries Department (2009-10), the total fishermen population is about 18,462, with 3464 families (Table 13.18), out of which only 2,271 are active men and over 1,100 are active fisherwomen.





A variety of fishing crafts, like mechanized boats, wooden vallams, FRP vallams, wooden catamarans, FRP catamarans, are used in this region (Table 13.19). About 251 mechanized boats, 389 FRP catamaran, 26 Wooden catamaran with OBM, 1 FRP catamaran without OBM and 45 wooden catamaran without OBM and non-mechanized boats are engaged in fishing activities during day and night. Among the fishing gears, Gill nets, Trawl nets, Seine nets, Tangle nets, Hook nets, Bag nets, Lift nets etc. are primarily used for fishing by these communities. However, trawl nets and gill nets are the most popular gears among the fishing communities.

The seasonal landings/ commercially important fishes of Karaikal district are given in Table 13.20. In general, the dominant species of the Karaikal region are fishes such as sharks, skates, oil sardines, lesser sardines, *Thrissocles*, Perches, *Caranx*, *Chirocentrus*, anchovies, silver bellies, seerfish, eels, ribbon fish, clupeides, *Sphyraena* sp., mullets, *Leiognathus*, mackerels, tunnies, Pomfrets, sciaenids, Trichiuridae, crabs (*Portunus sanguinolentus*) and penaeid prawns represented by *Penaeus monodon, P. indicus, Metapenaeus monoceros* and *M. dobsoni.*



Marine fish production from Karaikal region

Experimental trawl surveys: In order to assess the fishery potential of the region, exploratory and experimental fishing has to be done. 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 12 - 14 m depth. Two types of bottom trawls, shrimp trawl with 34 m head-rope and cod end mesh size of 10mm and fish trawl 40 m head-rope with a cod end mesh size of 20 mm are available. However, in the present study the fish trawl net was used.

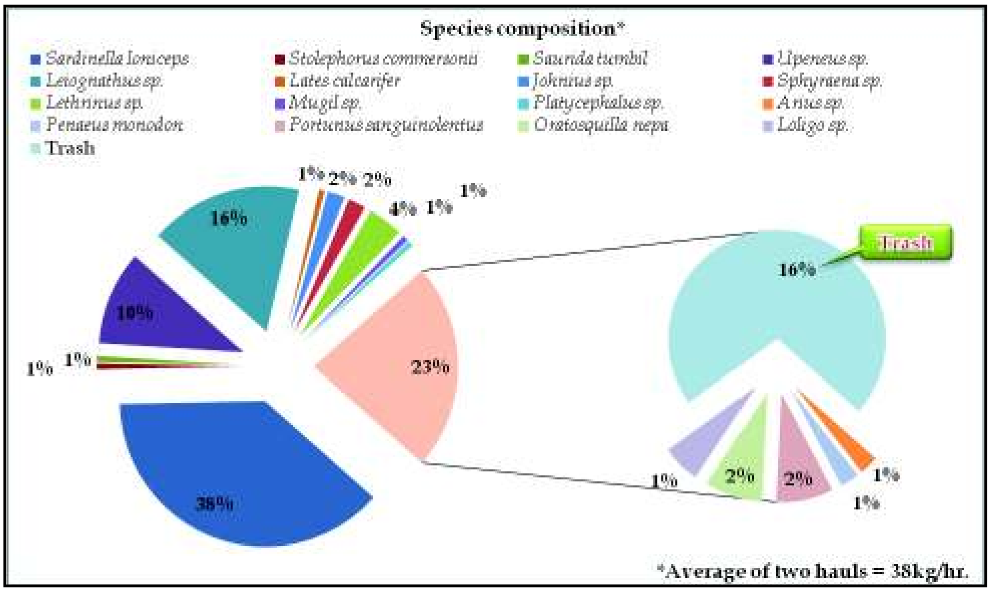
Totally two hauls were carried out on 12 August, 2013 during day time and the details are given below.

Sl. No.	Location of Hauls		Haul-1	Haul-2
1	Date		12.08.13	12.08.13
2	Gear		Fish net	Fish net
3	Starting time		2.30pm	4.00pm
4	Closing time		3.30pm	5.00pm
5	Duration haul		1:00 hr.	1:00 hr.
6	Started	Latitude	10˚ 49‘ 25.58”N	10˚ 48‘ 43.90”N
		Longitude	85˚ 53‘ 29.46”E	85˚ 54‘ 49.63”E
7	Finished	Latitude	10˚ 52’ 8.34”N	10˚ 51’ 26.67”N
		Longitude	85˚ 53’ 28.86”E	85˚ 54’ 49.05”E
8	Distance (m)		5000	6000
9	Depth (m)		12.0	14.0
10	Water Temp. (°C)		28.5	28.5
11	Salinity (ppt)		35.0	35.0
12	Total catch (kg)		40	36

The duration of each haul was approximately 1hr 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 (Table 13.21). Fish samples including prawns and crabs collected from the trawl survey were also examined for the maturity stage. 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.

Fish species were identified using the following literature. (1) ”The Marine and Fresh water Fishes of Ceylon”(Munro,1982), (2) Commercial Coastal waters Fishes of India (Talwar & Kacker,1984), (3) FAO species identification sheets for fishery purposes - Field guide Commercial marine and brackish water species of Pakistan, (1984), (4) Field guide for identification of Marine Fishery Resources, Fishery Survey of India, (2004) and (5) Finfish resources of Pitchavaram mangrove ecosystem (Ramaiyan *et. al.,* 2002).

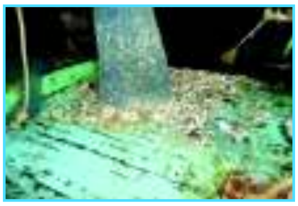
The catch rate ranged from 40 kg/hr. to 36 kg/hr with a mean value of 38 kg/hr. The estimated total biomass of the water body area is 157 km^2 (Volume of area Лr^2; 22/7 x 10 km x 10 km) and the rest of the area (157km^2) is terrestrial. Based on the experimental trawl survey from the water body, the biomass was calculated to be 11.932 tonnes with an estimated population density of 76 kg/km^2. The haul wise composition of catch is given in Table 13.21. A set of photographs on trawling operations and groups of fishes collected are given in the following pages.



The catch in general was poor with an average of 38 kg/hr. *Sardinella longiceps* (oil sardine) was dominant in both the hauls recording 17 kg and 12 kg respectively. This was followed by *Leiognathus* sp. recording an average of 6.5 kg. Mullidae family represented by *Upenus* sp. was the third dominant group of fishes caught from this area. *Saurida tumbil*, *Stolephorus commersonii*, *Johnius* sp., *Lethrinus* sp., *Arius* sp., *Platycephalus* sp. and quality fishes like *Lates calcarifer*, *Mugil* sp., and *Sphyraena* sp., were all netted in small quantity. Among the decapods crustaceans *Portunus sanguinolentus* crab and shrimp *Penaeus monodon* were caught in small numbers. *Loligo* sp., the squid was also caught in less percentage. The trash mostly constituted jelly fishes and stomatopod *Squilla* forming an average of 7 kg. The oil sardines are normally caught in good numbers from the coast during this period forming a major fishery. However, oil sardine landings nowadays are a common feature in the southeast coat of India also, which needs detailed meteorological and hydrographical studies.

Shooting of trawl net

Hauling fish catch

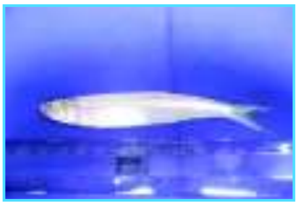


Opening of the fish catch

Assorted fish catch

Lates calcarifer

Rastrelliger kanagurta



Stolephorus commersonii

Terapon sp.

Leiognathus sp.

Arius sp.

Lepturacanthus savala

Siganus sp.

Mugil sp.

Platycephalus sp.

Johnius sp.

Sphyraena sp.

Pomacanthus sp.

Sardinella longiceps

Ambassis sp.

Saurida tumbil

Trypauchen sp.

Upenus sp.

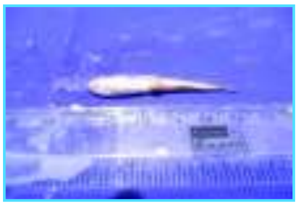
Megalaspis cordyla

Lethrinus sp.

Pomadasys sp.

Johnius sp.

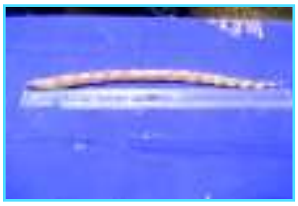
Arothron sp.



Plotosus sp.

Cynoglossus macrostomus

Tetrodon sp.



Leiuranus sp.

Uroconger lepturus

Portunus sanguinolentus

Charybdis sp.1

Charybdis sp.2

Calappa lophos

Octopus sp.

Sepia sp.

Loligo sp.

Penaeus indicus

Penaeus monodon

Salmasis bicolor

Sorting fish catch

13.2.5. General conclusions on ecological status

It is always advantageous to assess the "Ecological Status" of a region before any major project is initiated so that the baseline status that was recorded can be used as a reference in future assessments. This will help us to monitor the environment systematically and would enable us to take any mitigation 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 of such general methods is the classification of Shannon -Weiner diversity Index as given below:

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 between 3.1 – 4.0 indicating the region is without any major pollution and can be classified as a “moderately polluted”. Continuous post monitoring of the environment would indicate the possible changes in the ecological status. As pointed out earlier, the diversity index for sediment is low because of the possible anthropogenic influence due to port activities. These values can be taken for comparison to assess the ecological status in future and the values may possibly reduce further, if there is going to be any pollution or stress because of the port operations. The region is also known to support good fishery indicating a healthy status of the environment.

Table 13.1. Details of Measurement locations – Marine Environment

Stn. No	UTM Coordinates (WGS 84)		Water depth (m)	Measurement depth from surface (m)
	X (m)	Y (m)		
WATER SAMPLING				
S1	373973	1197810	12.0	*S, M, B*
S2	374257	1198157	13.0	*S, M, B*
S3	375257	1198140	7.0	*S, M, B*
S4	375689	1199512	6.0	*S, M, B*
S5	375760	1196837	7.0	*S, M, B*
S6	377257	1198106	8.0	*S, M, B*
S7	379256	1198073	12.0	*S, M, B*
S8	375692	1208053	8.0	*S, M, B*
S9	375692	1188260	7.0	*S, M, B*
S10	384256	1197989	16.0	*S, M, B*
INTERTIDAL BENTHOS				
IB1	374401	1206027	-	
IB2	374286	1199345	-	
IB3	374176	1196404	-	
IB4	374005	1190715	-	

S = Surface, M = Mid depth, B = Bottom

Table 13.2. Measured wave characteristics at 15 m water depth

Month	Wave height (m)	Wave period (s)	Wave direction (deg. N)
January	1.5	5	85
February	1.25	5	85
March	0.5	5	80
April	0..5	5	90
May	0.5	5	90
June	0.75	5	105
July	0.75	5	105
August	0.75	5	100
September	0.75	5	100
October	0.75	5	100
November	1.25	5	65
December	1.25	5	75

$H_{s\,=}$ Significant wave height
$T_{z\,=}$ Zero crossing wave period

Table 13.3. Number of occurrence of cyclones and storms within 300 km on either side of the port location (1877 and 2013)

Month	Occurred in the vicinity
January	3
February	1
March	1
April	3
May	7
June	-
July	-
August	-
September	-
October	20
November	46
December	18
Total	**99**

Table 13.4. Water quality parameters

Station		Temp (°C)	Salinity (ppt)	pH	DO (mg/l)	NH_3-N (µmol/l)	NO_2-N (µmol/l)	NO_3-N (µmol/l)	Total Nitrogen (µmol/l)	PO_4-P (µmol/l)	Total phosphorus (µmol/l)	Total suspended solid (mg/l)	Turbidity (NTU)	BOD (mg/l)	COD (mg/l)
S1	S	29.0	35.0	8.2	5.76	0.11	0.20	1.30	8.95	0.20	3.82	70	3.8	2.24	22.1
	M	28.5	35.0	8.2	5.44	0.22	0.53	1.69	8.95	0.34	4.05	74	4.2	1.92	19.6
	B	28.5	35.0	8.2	5.12	0.43	0.54	2.03	9.82	0.71	4.76	78	4.4	1.92	18.3
S2	S	29.0	34.0	8.1	6.08	0.17	0.37	1.51	7.33	0.16	3.73	60	3.2	2.88	21.5
	M	28.5	35.0	8.1	5.44	0.32	0.77	1.56	8.45	0.26	3.87	74	4.0	2.56	19.6
	B	28.0	35.0	8.2	5.28	0.53	1.00	1.64	9.70	0.71	4.76	76	4.4	1.44	22.1
S3	S	28.5	35.0	8.2	6.08	0.15	0.77	1.60	8.95	0.12	3.61	70	4.0	2.24	26.5
	M	28.0	35.0	8.2	5.92	0.16	0.94	2.38	9.08	0.20	4.85	70	4.2	2.08	27.2
	B	27.5	35.0	8.3	5.60	0.42	1.48	4.15	10.44	0.52	5.02	72	4.8	1.12	26.5
S4	S	29.0	34.0	8.1	5.76	0.13	0.31	1.34	8.08	0.18	3.71	66	2.4	1.92	29.1
	M	29.0	35.0	8.2	5.44	0.21	0.38	1.60	8.21	0.20	4.13	72	3.4	2.24	28.4
	B	28.5	35.0	8.2	5.28	0.30	0.71	4.15	9.02	0.58	4.26	90	7.2	2.40	31.0
S5	S	28.5	35.0	8.2	5.44	0.12	0.26	1.25	7.58	0.13	4.34	48	3.9	2.56	25.3
	M	28.0	35.0	8.1	5.12	0.22	0.37	1.43	8.21	0.17	4.76	64	4.4	1.92	22.8
	B	28.0	35.0	8.2	4.64	0.23	0.82	2.51	10.44	0.24	4.86	86	6.2	1.44	26.5
S6	S	29.0	35.0	8.1	5.44	0.10	0.68	1.56	7.77	0.17	2.46	70	5.2	1.60	22.8
	M	28.5	35.0	8.2	5.28	0.11	0.71	1.51	8.33	0.16	2.77	80	5.9	1.44	25.9
	B	28.5	35.0	8.2	4.96	0.17	0.94	4.41	10.07	0.29	3.57	80	6.3	1.44	21.5
S7	S	29.0	35.0	8.2	5.60	0.05	0.37	1.43	8.33	0.39	2.04	62	2.9	2.08	24.6
	M	28.5	35.0	8.2	5.44	0.09	0.65	1.56	9.20	0.37	3.30	66	3.5	2.24	24.0
	B	28.5	35.0	8.3	5.12	0.22	0.71	3.89	9.95	0.48	3.40	72	3.9	1.92	19.6
S8	S	28.5	34.0	8.2	5.44	0.16	0.37	1.38	8.45	0.41	2.25	72	3.1	2.24	21.5
	M	28.0	35.0	8.2	5.28	0.19	0.57	1.43	9.70	0.59	2.82	78	4.8	2.08	23.4
	B	27.5	35.0	8.2	4.96	0.27	0.94	1.86	11.06	0.69	3.03	96	9.4	1.76	17.1
S9	S	28.5	34.0	8.2	6.08	0.07	0.51	1.43	8.02	0.16	2.51	72	3.7	3.20	22.1
	M	28.5	35.0	8.3	5.60	0.10	0.56	1.64	8.70	0.27	2.56	72	4.1	2.08	19.6
	B	28.0	35.0	8.3	5.12	0.11	0.71	2.42	8.95	0.33	3.40	76	5.0	1.60	24.6
S10	S	28.5	35.0	8.1	5.44	0.09	0.21	1.25	7.71	0.27	2.72	66	3.8	2.24	24.6
	M	28.0	35.0	8.1	5.28	0.11	0.55	1.30	9.73	0.29	2.82	66	4.0	2.08	22.1
	B	28.0	35.0	8.2	4.80	0.20	0.63	1.86	10.65	0.82	2.88	74	4.2	1.60	22.8

S = Surface, M=Middle, B = Bottom

Table 13.5. Concentration of Heavy Metals, Phenol, Total Petroleum Hydrocarbons and Oil and grease in seawater

Stations	Heavy metals (mg/l)				Phenols (mg/l)	Total Petroleum Hydrocarbons (mg /l)	Oil and Grease (mg/l)
	Cadmium as Cd	Mercury as Hg	Lead as Pb	Total Chromium as Cr	C_6H_5OH		
S1	<0.01	<0.002	<0.001	<0.001	<0.001	<0.1	<2.0
S2	<0.01	<0.002	<0.001	<0.001	<0.001	<0.1	<2.0
S3	<0.01	<0.002	<0.001	<0.001	<0.001	<0.1	<2.0
S4	<0.01	<0.002	<0.001	<0.001	<0.001	<0.1	<2.0
S5	<0.01	<0.002	<0.001	<0.001	<0.001	<0.1	<2.0
S6	<0.01	<0.002	<0.001	<0.001	<0.001	<0.1	<2.0
S7	<0.01	<0.002	<0.001	<0.001	<0.001	<0.1	<2.0
S8	<0.01	<0.002	<0.001	<0.001	<0.001	<0.1	<2.0
S9	<0.01	<0.002	<0.001	<0.001	<0.001	<0.1	<2.0
S10	<0.01	<0.002	<0.001	<0.001	<0.001	<0.1	<2.0

Table 13.6. Sediment size distribution

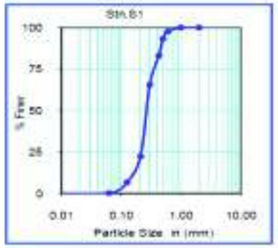
Sample	Classification of Soil	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)	Silt (%)
S1	Fine sand	6.73	27.92	65.22	0.13
S2	Fine sand with silt	-	-	22.40	77.60
S3	Fine sand	9.23	35.60	54.60	0.58
S4	Fine sand with silt	-	-	35.18	64.82
S5	Fine sand with silt	-	-	55.85	44.15
S6	Fine sand with silt	-	4.56	61.30	34.14
S7	Fine sand with silt	-	1.04	58.24	40.73
S8	Fine sand with silt	-	-	31.26	68.74
S9	Fine sand with silt	-	1.00	36.61	62.39
S10	Fine sand	8.54	31.55	57.78	2.13

Table 13.6. Contd...

Table 13.6. Contn...

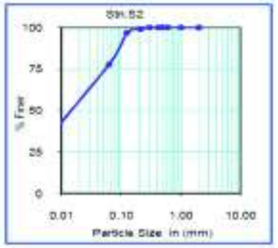
Station: S1

Sieve size (mm)	Weight Retained (gm)	Cumulative weight retained (gm)	% of Cumulative weight retained	Cumulative % finer
[1]	[2]	[3]	[4]	[5]
2	0	0	0	100
1	0	0	0	100
0.6	2.63	2.63	2.63	97.37
0.5	4.1	6.73	6.73	93.27
0.425	10.12	16.86	16.86	83.14
0.3	17.8	34.65	34.65	65.35
0.212	43	77.65	77.65	22.35
0.125	15.8	93.45	93.45	6.55
0.063	6.42	99.87	99.87	0.13
0.001	0.13	100	100	0
	100			



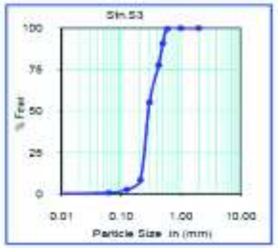
Station: S2

Sieve size (mm)	Weight Retained (gm)	Cumulative weight retained (gm)	% of Cumulative weight retained	Cumulative % finer
[1]	[2]	[3]	[4]	[5]
2	0	0	0	100
1	0	0	0	100
0.6	0	0	0	100
0.5	0	0	0	100
0.425	0	0	0	100
0.3	0	0	0	100
0.212	1	1	1	99
0.125	2.18	3.18	3.18	96.82
0.063	19.18	22.36	22.36	77.64
0.001	77.64	100	100	0
	100			



Station: S3

Sieve size (mm)	Weight Retained (gm)	Cumulative weight retained (gm)	% of Cumulative weight retained	Cumulative % finer
[1]	[2]	[3]	[4]	[5]
2	0	0	0	100
1	0	0	0	100
0.6	0.31	0.31	0.31	99.69
0.5	8.91	9.23	9.23	90.77
0.425	13.24	22.47	22.47	77.53
0.3	22.35	44.82	44.82	55.18
0.212	46.86	91.69	91.69	8.31
0.125	5.74	97.43	97.43	2.57
0.063	1.99	99.42	99.42	0.58
0.001	0.58	100	100	0
	100			



Station: S4

Sieve size (mm)	Weight Retained (gm)	Cumulative weight retained (gm)	% of Cumulative weight retained	Cumulative % finer
[1]	[2]	[3]	[4]	[5]
2	0	0	0	100
1	0	0	0	100
0.6	0	0	0	100
0.5	0	0	0	100
0.425	0	0	0	100
0.3	0	0	0	100
0.212	0.08	0.08	0.08	99.92
0.125	0.58	0.66	0.66	99.34
0.063	34.52	35.18	35.18	64.82
0.001	64.82	100	100	0
	100			

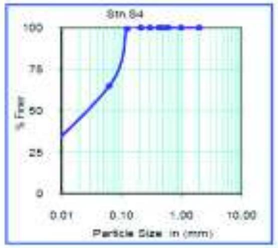
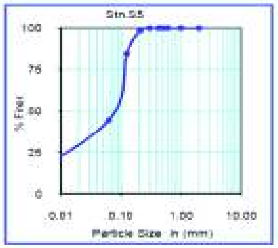


Table 13.6. Contd...

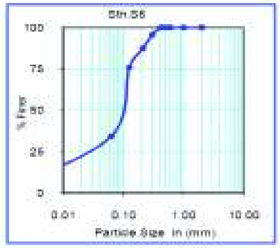
Station: S5

Sieve size (mm)	Weight Retained (gm)	Cumulative weight retained (gm)	% of Cumulative weight retained	Cumulative % finer
[1]	[2]	[3]	[4]	[5]
2	0	0	0	100
1	0	0	0	100
0.6	0	0	0	100
0.5	0	0	0	100
0.425	0	0	0	100
0.3	0	0	0	100
0.212	1.52	1.52	1.52	98.48
0.125	14.02	15.54	15.54	84.46
0.063	40.31	55.85	55.85	44.15
0.001	44.15	100	100	0
	100			



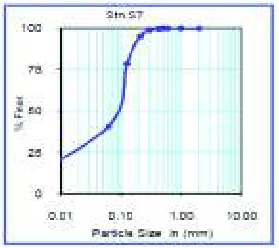
Station: S6

Sieve size (mm)	Weight Retained (gm)	Cumulative weight retained (gm)	% of Cumulative weight retained	Cumulative % finer
[1]	[2]	[3]	[4]	[5]
2	0	0	0	100
1	0	0	0	100
0.6	0	0	0	100
0.5	0	0	0	100
0.425	0	0	0	100
0.3	4.56	4.56	4.56	95.44
0.212	8.12	12.69	12.69	87.32
0.125	11.52	24.21	24.21	75.79
0.063	41.65	65.86	65.86	34.14
0.001	34.14	100	100	0
	100			



Station: S7

Sieve size (mm)	Weight Retained (gm)	Cumulative weight retained (gm)	% of Cumulative weight retained	Cumulative % finer
[1]	[2]	[3]	[4]	[5]
2	0	0	0	100
1	0	0	0	100
0.6	0	0	0	100
0.5	0	0	0	100
0.425	0.43	0.43	0.43	99.57
0.3	0.61	1.04	1.04	98.96
0.212	3.69	4.73	4.73	95.27
0.125	16.56	21.29	21.29	78.71
0.063	37.98	59.27	59.27	40.73
0.001	40.73	100	100	0
	100			



Station: S8

Sieve size (mm)	Weight Retained (gm)	Cumulative weight retained (gm)	% of Cumulative weight retained	Cumulative % finer
[1]	[2]	[3]	[4]	[5]
2	0	0	0	100
1	0	0	0	100
0.6	0	0	0	100
0.5	0	0	0	100
0.425	0	0	0	100
0.3	0	0	0	100
0.212	3.69	3.69	3.69	96.31
0.125	6.59	10.28	10.28	89.72
0.063	20.98	31.26	31.26	68.74
0.001	68.74	100	100	0
	100			

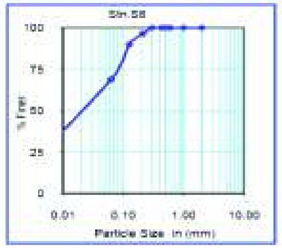
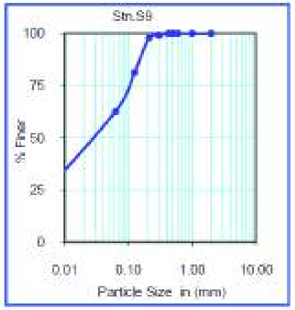


Table 13.6. Contd...

Station: S9

Sieve size (mm)	Weight Retained (gm)	Cumulative weight retained (gm)	% of Cumulative weight retained	Cumulative % finer
[1]	[2]	[3]	[4]	[5]
2	0	0	0	100
1	0	0	0	100
0.6	0	0	0	100
0.5	0	0	0	100
0.425	0	0	0	100
0.3	1	1	1	99
0.212	1.19	2.19	2.19	97.81
0.125	16.55	18.74	18.74	81.26
0.063	18.87	37.61	37.61	62.39
0.001	62.39	100	100	0
	100			



Station: S10

Sieve size (mm)	Weight Retained (gm)	Cumulative weight retained (gm)	% of Cumulative weight retained	Cumulative % finer
[1]	[2]	[3]	[4]	[5]
2	0.22	0.22	0.22	99.78
1	1.21	1.43	1.43	98.57
0.6	2.39	3.82	3.82	96.18
0.5	4.72	8.54	8.54	91.46
0.425	14.72	23.26	23.26	76.74
0.3	16.83	40.09	40.09	59.91
0.212	18.66	58.76	58.76	41.24
0.125	28.54	87.3	87.3	12.7
0.063	10.58	97.87	97.87	2.13
0.001	2.13	100	100	0
	100			

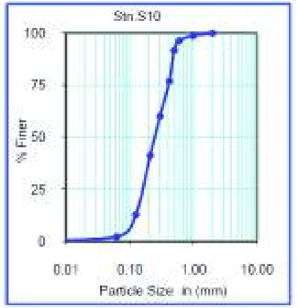


Table 13.7. Percentage composition of various parameters in sediment samples

Station	Total Organic Carbon (%)	Total Nitrogen (mg/g)	Total Phosphorus (mg/g)	Calcium Carbonate (%)
S1	0.64	1.49	0.22	6.42
S2	2.86	2.67	0.38	10.66
S3	0.50	2.35	0.46	9.70
S4	2.71	2.78	0.40	9.80
S5	1.50	1.79	0.05	7.06
S6	1.14	2.72	0.09	9.86
S7	0.93	2.11	0.48	9.04
S8	2.43	1.70	0.41	6.86
S9	2.64	1.53	0.19	8.70
S10	0.57	1.72	0.09	5.04

Table 13.8. Concentration of heavy metals, phenol and total petroleum hydrocarbons in seabed sediments

Stations	Heavy metals (mg/kg)				Phenols (mg/kg)	Total Petroleum Hydrocarbons (mg/kg)
	Cadmium as Cd	Mercury as Hg	Lead as Pb	Total Chromium as Cr	C_6H_5OH	
S1	0.125	<0.1	3.0	10.53	<1.0	<0.5
S2	0.126	<0.1	3.4	10.59	<1.0	<0.5
S3	0.123	<0.1	2.95	10.42	<1.0	<0.5
S4	0.118	<0.1	2.58	9.56	<1.0	<0.5
S5	0.120	<0.1	2.62	9.81	<1.0	<0.5
S6	0.137	<0.1	2.71	89.06	<1.0	<0.5
S7	0.215	<0.1	<0.30	40.14	<1.0	<0.5
S8	0.152	<0.1	2.10	15.12	<1.0	<0.5
S9	0.219	<0.1	1.85	22.18	<1.0	<0.5
S10	<0.300	<0.1	0.45	24.63	<1.0	<0.5

Table 13.9. Primary productivity in coastal waters

Station	Gross Photosynthetic activity	Net Photosynthetic activity	Photosynthetic quotient (PQ)	Primary production ($mgC/m^3/day$)
S1	1.12	0.64	1.0	480
S2	1.12	0.48	1.0	360
S3	1.76	0.64	1.0	480
S4	1.44	0.80	1.0	600
S5	1.12	0.48	1.0	360
S6	1.12	0.64	1.0	480
S7	1.44	0.48	1.0	360
S8	1.76	0.80	1.0	600
S9	1.92	0.64	1.0	480
S10	1.12	0.64	1.0	480
Average				**468**

Table 13.10. Comparative Statement of Primary Production along the East Coast of India

SL.No	Location	Date	Average PP ($mgC/m^3/day$)
1	**Karaikal (T.N) (10^{0}50’0.69”N 79^{0}50’49.51”E)**	**11.08.2013**	**468**
2	Krishnapatnam (A.P) (14^{0}10’47”N 80^{0}07’38”E)	21.08.2011	566
3	Vishakapatnam (A.P) (17^{0}33’17”N;83^{0}08’27”E)	25.04.2010	417
4	Vishakapatnam (A.P) (17^{0}33’17”N;83^{0}08’27”E)	26.08.2011	463
5	Kovvada (A.P) (18^0 06’71”N 83^{0}43’10”E) South West monsoon	28.05.2012	380
6	Kovvada (A.P) (18^0 06’71”N 83^{0}43’10”E) Fair weather	06.02.2013	460
7	Bhavanapadu (A.P) (18^{0}29’31”N 84^{0}17’46”E)	02.10.2007	666
8	Gopalpur (Orissa) (19^{0}17’28”N 84^{0}58’37”E)	14.02.2011	590
9	Paradip (Orissa) (20^{0}16’07”N 86^{0}40’57”E)	19.01.2010	465
10	Chudamani (Orissa) (21^{0}2’5.16”N 86^{0}52’55.68”E)	11.09.2010	590

Table 13.11. Phytoplankton species composition

Sl. No.	Genus / Species	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
1	*Asteromphalus* sp.	-	-	-	-	-	-	+	-	-	-
2	*Bacteriastrum hyallinum*	-	-	-	-	-	-	-	+	+	+
3	*Cerataulina bergonii*	+	+	+	+	+	+	+	+	-	+
4	*Chaetoceros affinis*	+	+	+	+	+	+	+	+	+	+
5	*Chaetoceros curvisetus*	-	-	-	-	-	-	-	-	+	+
6	*Chaetoceros* sp.	+	+	+	+	+	+	+	+	+	+
7	*Climacodium frauenfeldianum*	-	-	-	-	-	-	+	+	-	-
8	*Coscinodiscus excentricus*	+	+	+	+	+	-	-	-	+	+
9	*C. gigas*	+	-	-	-	-	-	-	-	-	+
10	*C. lineatus*	+	-	-	-	+	-	-	-	+	-
11	*C. marginatus*	+	+	+	+	+	+	+	+	+	+
12	*C. radiatus*	+	+	+	+	+	+	-	+	+	+
13	*Corethron* sp.	-	-	-	-	+	-	-	-	-	-
14	*Cyclotella striata*	-	-	-	+	+	-	-	-	-	-
15	*Ditylum brightwellii*	-	-	-	-	-	+	+	+	+	+
16	*Guinardia* sp.	+	-	+	-	+	+	+	+	-	+
17	*Eucampia* sp.	-	-	-	-	-	-	+	-	+	-
18	*Hemiaulus sinensis*	+	+	+	+	+	+	+	+	+	+
19	*Hemidiscus hardmannianus*	+	+	-	-	+	-	-	-	-	-
20	*Lauderia annulata*	-	+	+	+	+	+	+	+	-	+
21	*Leptocylindrus danicus*	+	+	+	+	+	-	+	+	-	+
22	*Odentella mobiiliensis*	+	+	+	+	+	+	+	+	+	-
23	*O. sinensis*	+	-	+	+	+	+	+	+	+	+
24	*Rhizosolenia alata*	+	+	+	+	+	+	+	+	+	+
25	*R. castracanei*	-	-	+	+	-	+	+	-	-	-
26	*R. crassispina*	-	-	-	-	+	+	-	-	-	-
27	*R. robusta*	+	+	+	-	-	-	+	-	-	-
28	*R. setigera*	+	+	+	+	-	-	+	+	+	+
29	*R. styliformis*	+	+	+	+	-	+	+	-	-	+
30	*R. stolterfothii*	+	+	+	+	+	+	-	+	+	+
31	*Skeletonema costatum*	+	+	+	+	+	+	-	-	-	+
32	*Stephanophyxix palmeriana*	+	-	+	+	+	+	+	+	-	+
33	*Streptotheca indica*	-	-	-	-	-	+	+	+	-	+
34	*Striatella* sp.	-	-	-	-	-	-	+	-	-	-
35	*Synedra* sp.	+	-	-	-	-	-	-	-	-	-
36	*Thalassiosira subtilis*	+	+	+	+	-	+	+	+	+	+

Centrales		**23**	**18**	**21**	**20**	**21**	**20**	**23**	**20**	**17**	**23**
37	*Amphiprora* sp.	+	+	+	+	+	+	+	+	-	-
38	*Amphora* sp.	-	+	+	+	+	+	-	-	+	+
39	*Asterionella* sp.	+	+	-	-	-	-	-	+	+	-
40	*Bacillaria paradoxa*	+	+	+	-	+	-	-	-	+	-
41	*Gyrosigma* sp.	+	-	+	+	+	-	-	+	+	-
42	*Navicula henneydii*	+	+	+	+	+	-	+	+	+	-
43	*Mastagolia* sp.	-	-	-	+	-	-	-	-	-	-
44	*Nitzschia closterium*	-	+	+	-	+	-	-	+	+	-
45	*N. migrans*	-	-	-	-	-	-	-	+	-	-
46	*Pseudonitzschia* sp.	+	+	+	+	+	+	+	+	+	+
47	*Pleurosigma dirrectum*	-	-	+	+	+	-	-	-	+	+
48	*P. elongatum*	-	-	+	+	+	-	-	+	+	-
49	*P. normanii*	-	+	-	+	+	+	+	+	-	+
50	*Thalassionema nitzschioides*	+	+	+	+	+	+	+	+	+	+
51	*Thalassiothrix frauenfeldii*	+	+	+	+	+	+	+	+	+	+
Pennales		**8**	**10**	**11**	**11**	**12**	**6**	**6**	**11**	**11**	**6**
52	*Ceratium fusus*	+	+	+	+	-	-	+	+	+	-
53	*C. furca*	+	-	+	+	+	+	+	+	+	+
54	*C. macroceros*	+	-	-	+	+	+	+	+	-	-
55	*C. tripos*	+	-	+	+	-	+	+	+	+	+
56	*C. trichoceres*	-	-	-	-	-	-	-	+	-	-
57	*Dinophysis caudate*	+	+	+	-	+	+	+	-	+	+
58	*Dinophysis* sp.	-	-	-	-	-	+	+	-	-	-
59	*Gymnodinium* sp.	-	-	-	-	-	-	-	+	-	-
60	*Noctiluca* sp.	+	+	+	-	+	+	+	+	+	-
61	*Peridinium depressum*	+	+	+	+	+	+	+	+	+	+
62	*Peridinium* sp.	-	-	+	+	+	+	+	+	+	+
63	*Prorocentrum micans*	+	+	+	+	+	+	+	+	+	+
Dinophyceae (Dinoflagellates)		**8**	**5**	**8**	**7**	**7**	**9**	**10**	**10**	**8**	**6**
64	*Trichodesmium erythraeum*	-	-	-	-	+	+	+	+	+	+
Cyanophyceae (Blue-greens)		**-**	**-**	**-**	**-**	**1**	**-**	**1**	**1**	**1**	**1**
Total		**39**	**33**	**40**	**38**	**41**	**35**	**40**	**42**	**37**	**36**

Table 13.12. Phytoplankton numerical abundance (nos/l)

Sl. No.	Genus / Species	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total	(%)
1	*Bacteriastrum hyallinum*	-	-	-	-	-	-	-	167	167	167	500	0.23
2	*Cerataulina bergonii*	167	167	333	167	167	167	167	333	-	-	1665	0.77
3	*Chaetoceros affinis*	333	167	333	167	167	167	333	167	0	333	2165	1.00
4	*Chaetoceros* sp.	-	-	333	-	-	-	-	-	-	-	333	0.15
5	*Coscinodiscus excentricus*	167	167	-	-	-	-	-	-	-	-	333	0.15
6	*C. marginatus*	167	500	167	500	500	333	-	-	500	167	2831	1.30
7	*C. radiatus*	167	1332	167	666	666	333	-	666	833	-	4829	2.22
8	*Guinardia* sp.	167	-	-	-	-	-	-	-	-	-	167	0.08
9	*Hemialusus sinensis*	-	-	-	-	167	-	167	-	-	-	333	0.15
10	*Lauderia annulata*	-	-	333	-	-	-	-	-	-	-	333	0.15
11	*Leptocylindrus danicus*	167	-	-	-	-	-	-	-	-	-	167	0.08
12	*Odentella mobiiliensis*	-	-	167	-	333	-	-	-	1332	-	1832	0.84
13	*O. sinensis*	167	-	-	500	167	500	167	-	500	167	2165	1.00
14	*Rhizosolenia alata*	1499	1832	3330	2498	1832	1832	2165	1499	833	1332	18648	8.58
15	*R. setigera*	333	333	500	167	-	-	333	-	333	167	2165	1.00
16	*R. styliformis*	500	167	1332	167	-	333	333	500	-	167	3497	1.61
17	*Skeletonema costatum*	-	-	-	333	-	-	-	-	-	333	666	0.31
18	*Stephanophyxix palmeriana*	167	-	-	-	-	-	-	333	-	333	833	0.38
19	*Streptotheca indica*	-	-	-	-	-	167	-	333	-	-	500	0.23
20	*Thalassiosira subtilis*	333	167	1665	500	333	167	666	-	167	167	4163	1.92
Centrales		**4329**	**4829**	**8658**	**5661**	**4329**	**3996**	**4329**	**3996**	**4662**	**3330**	**48119**	**22.15**
21	*Amphiprora* sp.	333	666	333	666	167	333	167	167	-	-	2831	1.30
22	*Bacillaria paradoxa*	-	-	-	-	333	-	-	-	167	-	502	0.23
23	*Gyrosigma* sp.	167	-	500	167	666	-	-	167	167	-	1832	0.84
24	*Mastagolia* sp.	-	-	-	333	-	-	-	-	-	-	333	0.15
25	*Navicula henneydii*	333	500	1332	999	333	-	666	333	167	-	4662	2.15
26	*Nitzschia closterium*	-	167	333	-	-	-	-	-	333	-	833	0.38
27	*Pseudonitzschia* sp.	58109	24809	15152	5328	1166	333	500	333	167	666	106560	49.04
28	*N. Clostorium*	-	-	-	500	-	167	-	-	-	167	833	0.38
29	*Pleurosigma dirrectum*	-	-	167	1499	333	167	-	-	167	-	2331	1.07
30	*P. elongatum*	-	333	500	1166	167	-	-	333	500	167	3164	1.46
31	*P. normanii*	666	1332	833	1665	1332	167	167	666	1332	333	8492	3.91
32	*Thalassionema nitzschioides*	500	333	500	1332	167	-	500	1998	-	833	6161	2.84
33	*Thalassiothrix frauenfeldii*	500	666	666	666	999	500	999	1665	500	500	7659	3.52

Pennales		**60606**	**28805**	**20315**	**14319**	**5661**	**1665**	**2997**	**5661**	**3497**	**2664**	**146189**	**67.28**
34	*Ceratium fusus*	167	-	-	-	-	167	-	-	-	-	333	0.15
35	*C. furca*	333	-	167	-	666	2165	999	500	500	-	5328	2.45
36	*C. tripos*	167	-	-	-	-	167	-	-	-	167	500	0.23
37	*C. trichoceres*	-	-	-	-	167	-	-	-	-	-	167	0.08
38	*Dinophysis caudate*	-	-	-	-	-	167	-	-	333	167	666	0.31
39	*Noctiluca* sp.	666	167	666	-	167	-	-	-	-	-	1665	0.77
40	*Peridinium depressum*	333	-	666	167	-	666	1166	666	500	167	4329	1.99
41	*Peridinium* sp.	-	-	167	-	167	500	-	-	-	-	833	0.38
42	*Prorocentrum micans*	2331	833	999	167	666	500	666	833	666	333	7992	3.68
Dinophyceae (Dinoflagellates)		**3996**	**999**	**2664**	**333**	**1832**	**4329**	**2831**	**1998**	**1998**	**833**	**21812**	**10.04**
43	*Trichodesmium erythraeum*	-	-	-	-	-	-	167	333	333	333	1166	0.54
Cyanophyceae (Blue-greens)		**-**	**-**	**-**	**-**	**-**	**-**	**167**	**333**	**333**	**333**	**1166**	**0.54**
Total		**68939**	**34638**	**31643**	**20320**	**11828**	**9998**	**10328**	**11992**	**10497**	**7166**	**217349**	**100.00**

Table 13.13. Station wise numerical abundance of Zooplankton (nos/100m^3)

Sl. No.	Genus / Species	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	(Total)	(%)
PHYLUM: PROTOZOA													
Order: Tintinnids (Ciliate groups)													
1	*Tintinnopsis* sp.	2577	2611	1390	3516	3762	2396	1112	1774	2904	1018	23060	1.76
2	*Favella* sp.	859	1958	927	2110	-	958	-	709	968	2037	10526	0.81
3	*Eutintinnus tenuis*	-	1305	-	2813	2257	1437	667	-	1936	509	10924	0.84
4	*Dictyocysta* sp.	-	653	1390	1406	-	-	445	-	968	-	4862	0.37
PHYLUM: CNIDARIA													
5	*Diphysis* sp.	430	-	463	703	3010	958	889	1064	1452	1018	9987	0.76
6	Smaller medusa larvae	859	-	463	2110	1505	-	445	709	-	1527	7618	0.58
PHYLUM: CHAETOGNATHA													
7	*Sagitta* sp.	1289	1958	1854	2110	752	1917	889	1419	2420	1527	16135	1.23
PHYLUM: ANNELIDA													
Class: Polychaeta													
8	Polychaete larvae	430	2611	463	2813	752	958	445	2128	1936	1018	13554	1.04
PHYLUM: MOLLUSCA													
9	*Creseis* sp.	-	-	-	-	-	-	222	-	-	-	222	0.02
10	Bivalve veliger larvae	1289	3264	463	703	2257	1437	889	709	968	1527	13506	1.03
11	Gastropods veliger larvae	430	1305	-	1406	-	479	445	-	484	509	5058	0.39
12	Molluscan eggs	430	653	463	2110	6020	958	667	1774	-	1527	14602	1.12
PHYLUM: ATHROPODA													
Class: Crustacea													
Order: Copepoda													
Sub- order: Calanoida													
13	*Acartia erythraea*	4725	6527	10658	14065	18059	10062	13787	2128	4356	11711	96078	7.35
14	*Acartia* sp.	430	1958	927	2813	3010	958	1334	-	-	-	11430	0.87
15	*Acrocalanus gracilis*	3007	5875	2317	9845	6020	2396	1779	709	1452	4073	37473	2.87
16	*Centropages furcatus*	1718	-	463	2110	752	958	889	1419	2420	1018	11747	0.90
17	*Calanopia* sp.	1289	-	463	-	-	-	667	-	-	1527	3946	0.30
18	*Centropages typicus*	430	653	1854	703	-	479	222	-	-	-	4341	0.33
19	*Eucalanus attenuatus*	2577	1958	927	703	1505	4312	4225	4612	1452	6110	28381	2.17
20	*Labidocera acuta*	-	-	-	703	-	1437	667	-	484	1018	4309	0.33
21	*Metacalanus* sp.	859	-	463	1406	-	-	-	-	-	-	2728	0.21

22	*Paracalanus parvus*	3436	8486	1390	1406	9029	3833	7338	6031	3872	10692	55513	4.25
23	*Pontella* sp.	430	-	927	703	-	958	222	-	-	-	3240	0.25
24	*Pseudodiaptomus serricaudatus*	1289	-	1854	3516	-	1917	1779	355	1452	2037	14199	1.09
25	*Temora turbinata*	10309	12402	11121	2813	1505	25395	36691	14544	6292	68737	189809	14.52
26	*Temora discaudata*	-	-	1390	-	-	2396	-	-	-	-	3786	0.29
27	Copepod nauplii	1718	1958	2780	2110	2257	1437	1112	1774	1452	1527	18125	1.39
Sub- order: Cyclopoida													
28	*Corycaeus danae*	430	1305	1854	1406	2257	479	667	1419	1452	509	11778	0.90
29	*Corycaeus catus*	-	-	463	703	-	1437	-	-	484	-	3087	0.24
30	*Oithona brevicornis*	-	1305	1390	-	1505	479	667	1064	1452	1018	8880	0.68
31	*Oithona* sp.	-	-	927	-	-	-	445	-	-	-	1372	0.10
Sub- order: Harpacticoida													
32	*Microsetella* sp.	-	-	463	1406	-	-	1112	-	484	-	3465	0.27
Other Crustaceans													
33	Brachyuran zoea	430	2611	1390	2813	2257	479	667	709	-	1527	12883	0.99
34	*Evadne* sp.	23196	33943	56997	80872	164033	74269	15788	76268	33882	17821	577069	44.16
35	Crustacean nauplii	2148	1305	-	2110	752	1917	889	1419	1936	509	12985	0.99
36	Mysid larvae	1289	2611	1854	2110	5267	1437	1779	2483	1452	2037	22319	1.71
37	*Lucifer* sp.	1289	1958	927	703	752	958	222	1064	968	509	9350	0.72
PHYLUM: CHORDATA													
38	Oikopleura larvae	1289	1305	2780	2110	2257	1437	445	1064	484	2037	15208	1.16
39	Fish eggs	859	1305	1390	1406	1505	958	445	355	484	509	9216	0.71
40	Fish larvae	-	653	463	703	752	479	222	355	-	509	4136	0.32
	Total	**71740**	**104436**	**116308**	**161038**	**243789**	**152365**	**101175**	**128058**	**80346**	**147652**	**1306907**	**100.00**

Table 13.14. Zooplankton biomass and population in different sampling stations

Station	No of genera or species	Population (nos/100 m^3)	Biomass (ml/100 m^3)
S1	30	71740	30.1
S2	27	104436	71.8
S3	35	116308	41.7
S4	35	161038	49.2
S5	26	243789	67.7
S6	33	152365	43.1
S7	36	101175	31.1
S8	26	128058	46.1
S9	28	80346	31.5
S10	30	147652	61.1

Table 13.15. Sub tidal and Inter tidal benthic population

Sl. No.	Groups	Sub tidal benthos (nos./m^2)										Inter tidal benthos (nos./m^2)			
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	IB1	IB2	IB3	IB4
Phylum: ANNELIDA **Class: Polychaeta**															
1	Polychaetes	200	80	200	180	150	140	590	80	110	420	30	15	15	30
Phylum: ARTHROPODA **Class: Crustacea**															
2	Amphipods	130	10	10	-	20	20	20	10	20	150	120	15	315	60
3	**Family: Hippidae** *Emerita* sp.	-	-	-	-	-	-	-	-	-	-	105	60	30	-
	Order: Mysidacea														
4	Mysids	-	-	-	-	-	-	10	-	-	30	-	-	-	-
5	Cumacea	-	-	10	-	-	-	-	-	-	10	-	-	-	-
Phylum: MOLLUSCA **Class: Gastropoda**															
6	**Family: Nassaridae** *Bullia* sp.	-	-	-	-	-	10	-	-	-		-	-	-	-
7	**Family: Naticidae** *Polinices* sp.	-	-	-	10	-	-	-	-	-		-	-	-	-
Class: Bivalvia															
8	**Family: Cultellidae** *Siliqua* sp.	-	-	-	30	-	-	-	-	10	-	-	-	-	-
9	**Family: Donacidae** *Donax* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	30
10	**Family: Veneridae** *Sunetta* sp.	10	10	-	-	10	-	-	-	-	-	-	-	-	-
11	*Meretrix* sp.	10	-	-	-	-	-	-	-	-	-	-	-	-	-
12	**Family: Mytilidae** *Modiolus* sp.	-	-	-	-	-	-	10	40	-	-	-	-	-	-

13	**Family: Pholadidae** *Pholas* sp.	-	10	-	-	-	-	-	-	-	-	-	-	-	-
Phylum: ECHINODERMATA **Class: Stelleroidea**															
14	**Family: Ophiactidae** *Ophioncnemus* sp.	-	-	-	-	-	-	-	-	-	10	-	-	-	-
Phylum: CHORDATA															
15	Fish larvae	-	10	-	-	-	-	-	-	-	-	-	-	-	-
Subphylum: Cephalochordata															
16	*Amphioxis* sp.	-	-	-	-	-	-	-	-	-	40	-	-	-	-
Total		350	120	220	220	180	170	630	130	140	660	255	90	360	120

Table 13.16. Bacterial population of coastal waters (nosx10^3/ml)

Media	Type of Bacteria	Stations									
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nut Agar	TVC	5.45	5.62	5.27	5.87	5.92	5.78	6.08	5.77	5.92	5.59
Mac Agar	TC	0.70	0.65	0.60	0.75	0.83	0.59	0.78	0.91	0.69	0.63
Mac Agar	ECLO	0.48	0.47	0.30	0.43	0.57	0.45	0.35	0.55	0.30	0.44
XLD Agar	SHLO	0.28	0.22	0.16	0.19	0.21	0.17	0.21	0.27	0.12	0.13
XLD Agar	PKLO	-	-	-	-	-	-	-	-	-	-
TCBS Agar	VLO	0.61	0.56	0.48	0.57	0.50	0.42	0.65	0.45	0.49	0.50
TCBS Agar	VPLO	0.29	0.18	0.21	0.35	0.31	0.27	0.32	0.27	0.26	0.22
TCBS Agar	VCLO	0.10	0.10	0.18	0.23	0.19	0.09	0.24	0.18	0.15	0.10
CET Agar	PALO	0.02	-	0.03	0.02	0.01	-	-	0.03	0.02	-

- Not Detectable

TVC -Total Viable Counts; TC- Total Coliforms; ECLO-*Escherichia coli* like organisms; SHLO-*Shigella* like organisms; SLO-*Salmonella* like organisms; PKLO-*Proteus klebsiella*; VLO-*Vibrio* like organisms; VPLO- *Vibrio parahaemolyticus* like organisms; VCLO-*Vibrio cholera* like organisms; PALO-*Pseudomonas aerugenosa* like organism.

Table 13.17. Bacterial population of seabed sediments (nosx10^4 nos./g)

Media	Type of Bacteria	Stations									
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Nut Agar	TVC	5.62	5.65	5.43	5.63	5.86	5.69	6.18	6.04	5.80	5.71
Mac Agar	TC	0.79	0.59	0.80	0.85	0.81	0.78	0.86	0.82	0.72	0.77
Mac Agar	ECLO	0.55	0.38	0.46	0.38	0.47	0.40	0.55	0.43	0.42	0.39
XLD Agar	SHLO	0.22	0.19	0.17	0.12	0.19	0.13	0.24	0.14	0.17	0.15
XLD Agar	PKLO	-	-	-	-	-	-	-	-	-	-
TCBS Agar	VLO	0.55	0.46	0.40	0.44	0.39	0.42	0.72	0.56	0.37	0.45
TCBS Agar	VPLO	0.15	0.28	0.19	0.30	0.26	0.20	0.38	0.22	0.21	0.24
TCBS Agar	VCLO	0.10	0.17	0.10	0.20	0.15	0.11	0.20	0.11	0.09	0.13
CET Agar	PALO	0.05	-	0.03	0.01	0.02	-	-	0.04	0.02	-

\- Not Detectable

TVC -Total Viable Counts; TC- Total Coliforms; ECLO-Escherichia coli like organisms; SHLO-Shigella like organisms; SLO-Salmonella like organisms; PKLO-Proteus klebsiella; VLO-Vibrio like organisms; VPLO- Vibrio parahaemolyticus like organisms; VCLO-Vibrio cholera like organisms; PALO- Pseudomonas aerugenosa like organisms.

Table 13.18. Details of fishing village and fishermen families in Karaikal

Sl. No.	Name of the village	No. of families
1	Mandapathur	115
2	Kalikuppam	180
3	Akkampettai	118
4	Kottucherrymedu	229
5	Keezhakasakudymedu	257
6	Kilinjalmedu	684
7	Karaikalmedu	827
8	Karukalacherry	360
9	Pattinacherry	479
10	North Vanjure	215
Total		**3464**

Source- Department of fisheries & fishermen welfare, Karaikal

Table 13.19. Details of vessel type operation in Karaikal (as on 18.03.2013)

SLNo.	Villages	Wooden MFB	Steel MFB	FRP catamaran with OBM	Wooden catamaran with OBM	FRP catamaran without OBM	Wooden catamaran without OBM
1	Mandapathur	1	3	28	2	0	12
2	Kalikuppam	2	2	39	0	0	8
3	Akkampettai	2	2	16	0	0	0
4	Kottucherrymedu	8	30	11	0	1	23
5	Keezhakasakudymedu	2	26	27	1	0	0
6	Kilinjalmedu	24	77	31	0	0	0
7	Karaikalmedu	11	34	120	2	0	0
8	Karukalacherry	0	0	2	0	0	0
9	Pattinacherry	6	21	110	16	0	2
10	North Vanjure	0	0	5	5	0	0
Total		56	195	389	26	1	45

** Source- Department of fisheries & fishermen welfare, Karaikal*

Table 13.20. Seasonal landings/commercially important fishes of Karaikal

Month	Type of Fishes	Throughout the year
January	Ribbon Fish and Anchovies (Nethili)	Cuttle fish, Squid,Shirmp, Cat fish, Ray fish, Groupers and Sciaenids
February	Yellow fin tuna and Anchovies	
March	Yellow fin tuna and Anchovies	
April	Yellow fin tuna, Anchovies, Flying fish, Seer fish, Oil sardine and Mackerels	
May	Yellow fin tuna, Anchovies, Flying fish, Seer fish, Oil sardine and Mackerels	
June	Yellow fin tuna , Anchovies, Flying fish, Eel fish, Bombay Duck and Snappers	
July	Flying fish, Eel fish, Bombay Duck and Snappers	
August	Pomfrets and Snappers	
September	Pomfrets, Skip Jack tuna, Snappers and Seerfish	
October	Skip Jack tuna, Crab and Seerfish	
November	Ribbon Fish, Skip Jack tuna, Seerfish and Crab	
December	Ribbon Fish, Seerfish and Crab	

** Source- Department of fisheries & fishermen welfare, Karaikal*

Table 13.21. Classification of experimental bottom trawl fishes

Phylum	Class	Order	Family	Species	Haul-1 (kg)	Haul-2 (kg)
Chordata	Osteichthyes	Clupeiformes	Clupeidae	*Sardinella longiceps*	17.0	12.0
			Engraulidae	*Stolephorus commersonii*	-	0.5
		Myctophiformes	Synodidae	*Saurida tumbil*	0.5	-
		Perciformes	Mullidae	*Upeneus* sp.	5.0	3.0
			Leiognathidae	*Leiognathus* sp.	6.0	7.0
			Centropomidae	*Lates calcarifer*	0.5	-
			Sciaenidae	*Johnius* sp.	1.0	0.5
			Sphyraenidae	*Sphyraena* sp.	0.5	1.0
			Lethrinidae	*Lethrinus sp.*	1.0	2.0
			Mugilidae	*Mugil* sp.	0.5	-
		Scorpaeniformes	Platcephalidae	*Platycephalus* sp.	-	0.5
		Gonorynchiformes	Ariidae	*Arius* sp.	-	0.5
Arthropoda	Crustacea	Decapoda	Penaeidae	*Penaeus monodon*	0.5	-
			Portunidae	*Portunus sanguinolentus*	1.0	0.5
		Stomatopoda	Squillidae	*Oratosquilla nepa*	0.5	1.0
Mollusca	Cephalopoda	Teuthida	Loliginidae	*Loligo* sp.	0.5	0.5
Trash					5.5	7.0
Total					**40 kg/hr**	**36 kg/hr**
Average of two hauls					**38 kg/hr**	

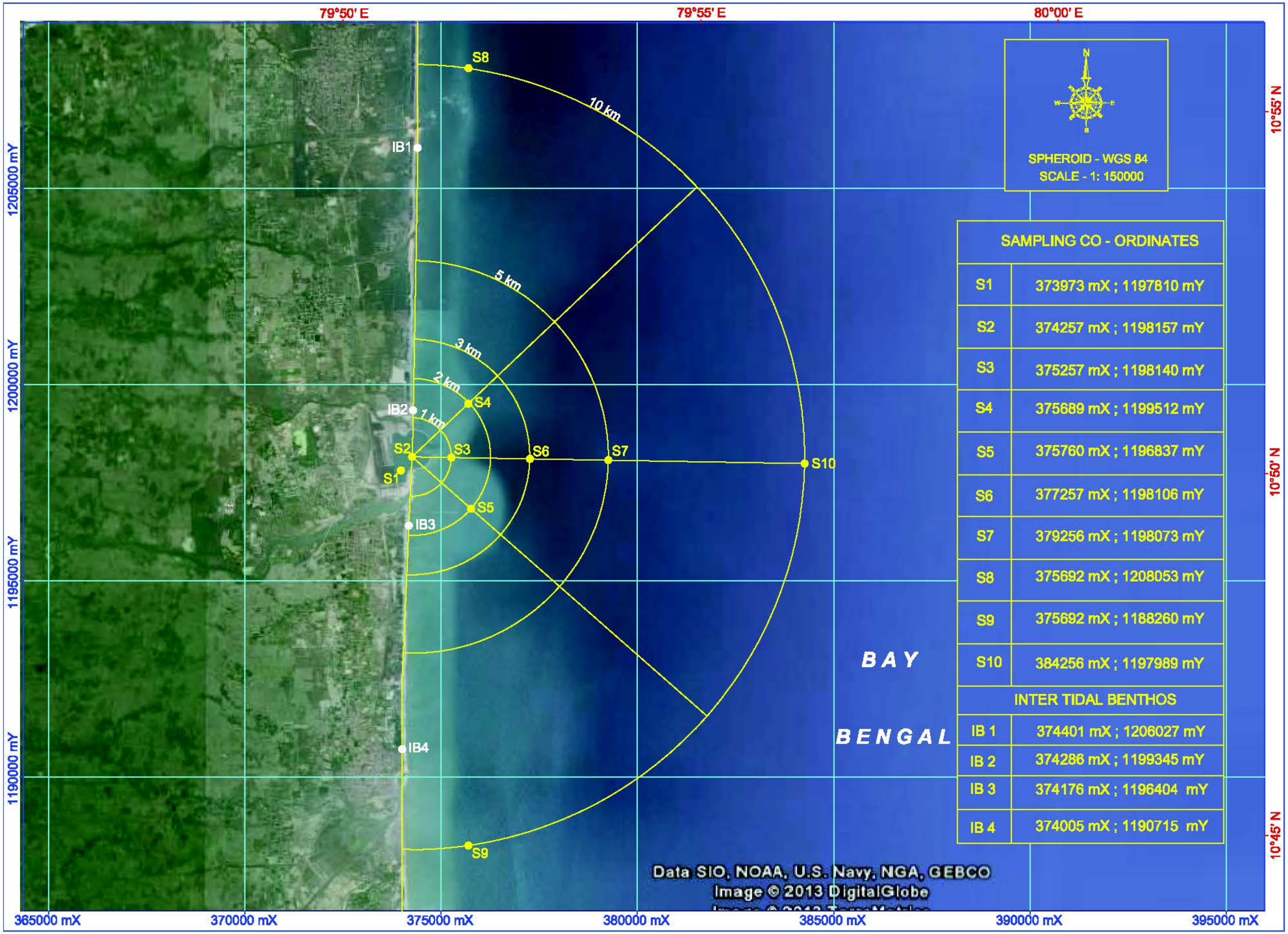
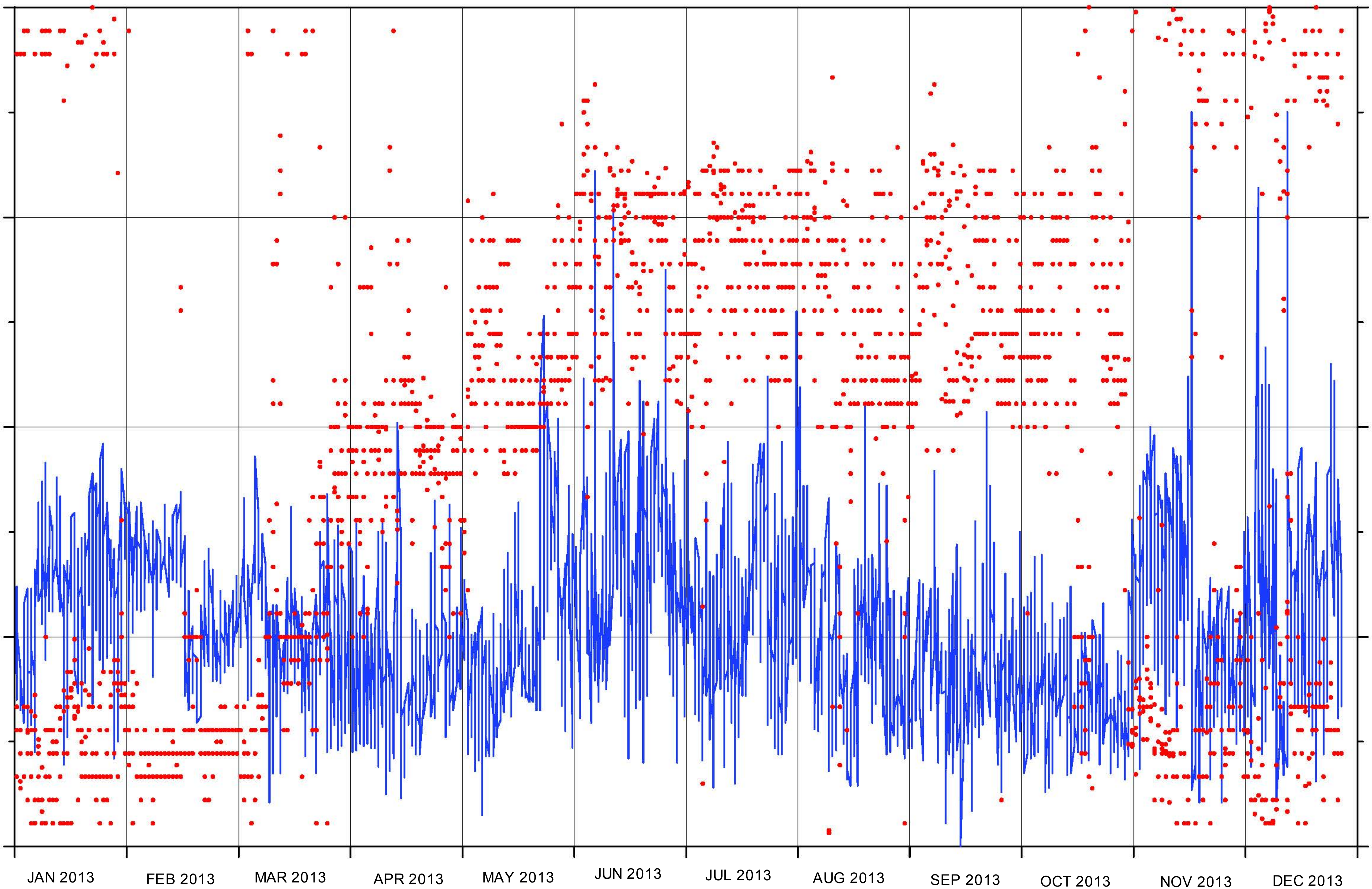


FIG. 13.1. OFFSHORE SAMPLING LOCATIONS


JAN 2013
FEB 2013
MAR 2013
APR 2013
MAY 2013
JUN 2013
JUL 2013
AUG 2013
SEP 2013
OCT 2013
NOV 2013
DEC 2013

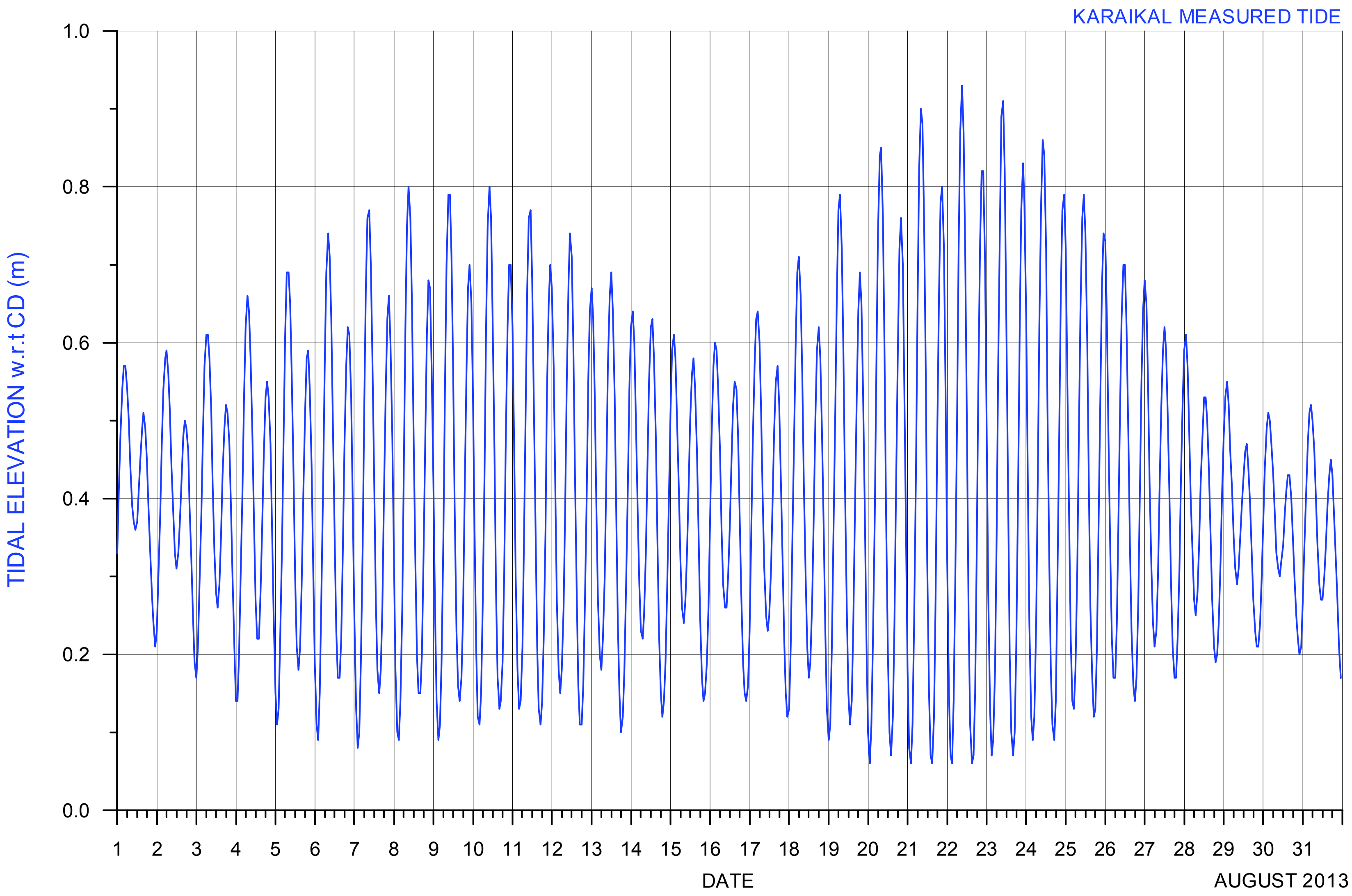


FIG. 13.3. VARIATION OF MEASURED TIDES AT KARAIKAL

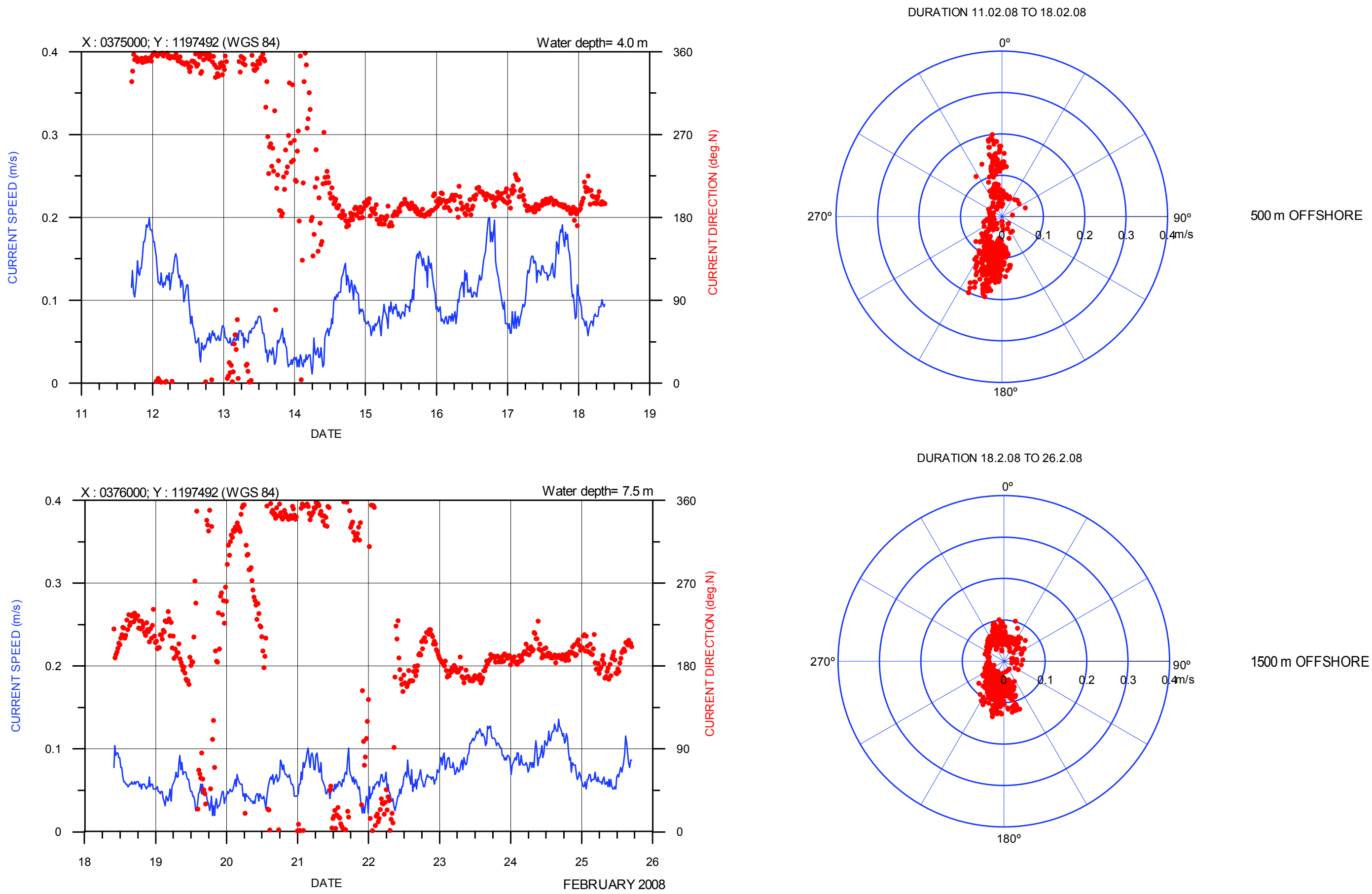


FIG. 13.4. VARIATION OF MEASURED CURRENT SPEED AND DIRECTION

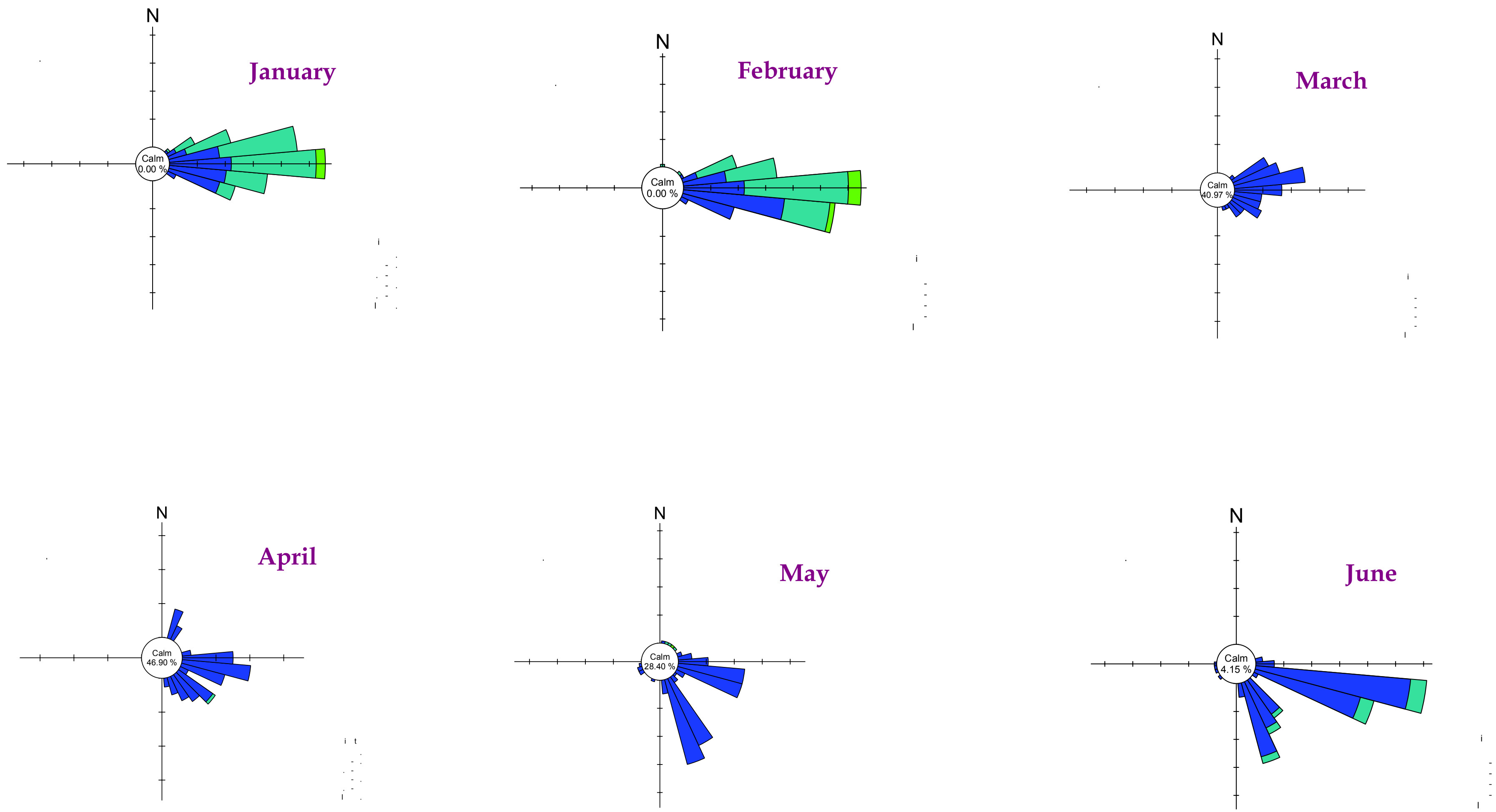


Fig. 13.5. Wave rose diagram for wave height

Fig. 13.5. Contd...

Fig. 13.5. Contn...

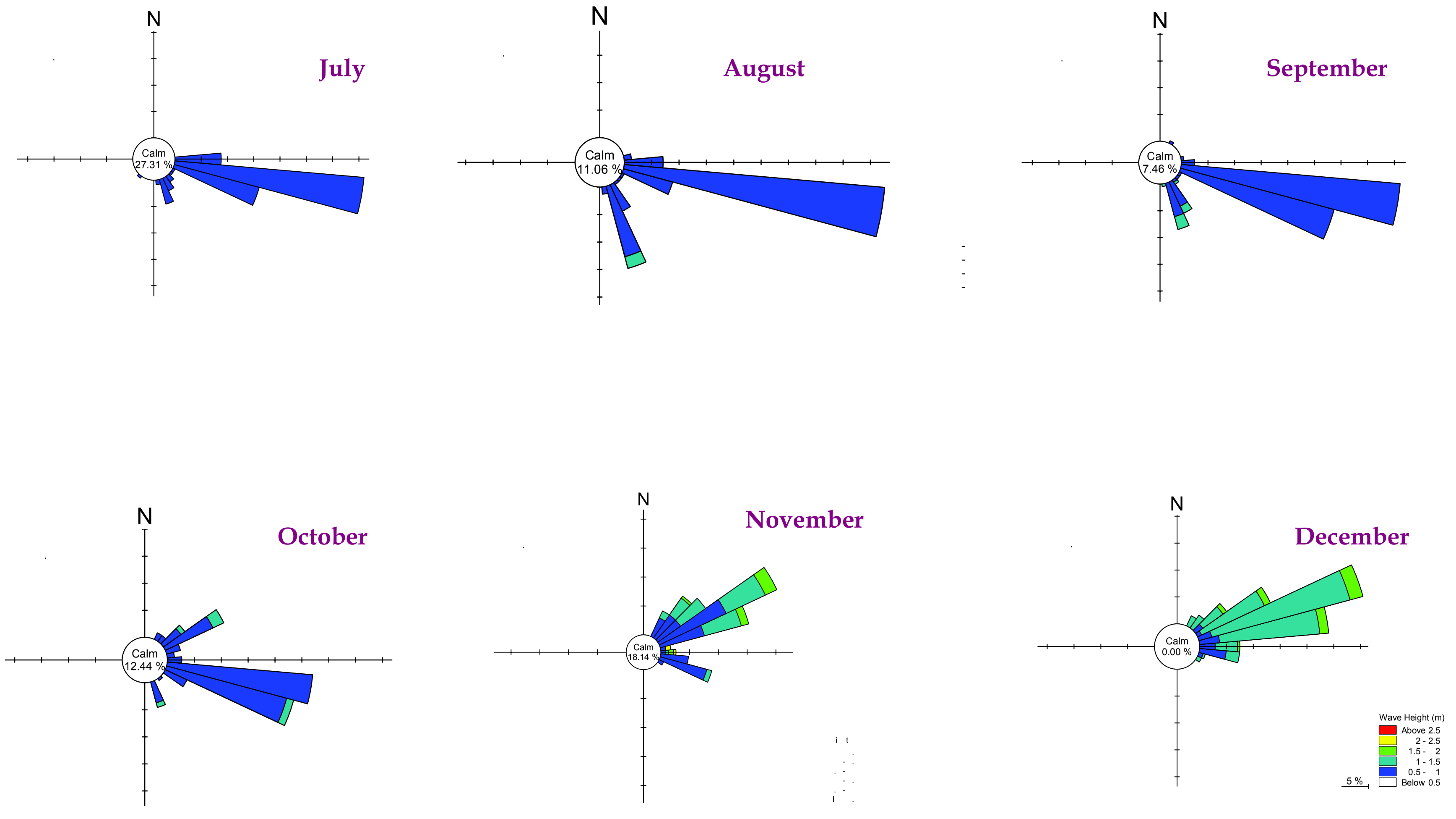


Fig. 13.5. Wave rose diagram for wave height

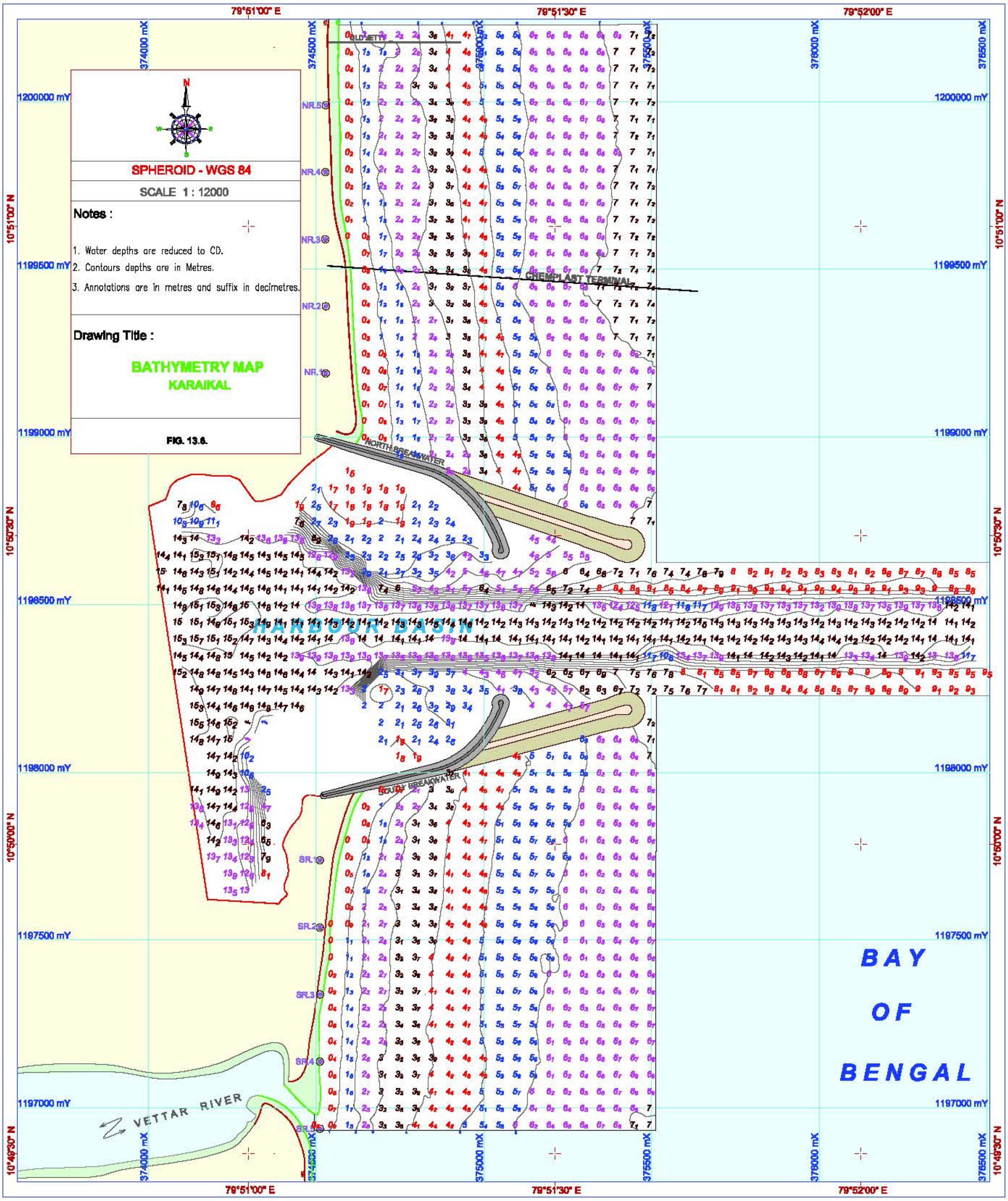


FIG. 13.6. BATHYMETRY MAP - KARAIKAL PORT

14. MATHEMATICAL MODELLING FOR MARINE ENVIRONMENT

14.1. Diffuser design - CORMIX model

The dilution of any return water released in a natural water body 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 return water jet plume is designed and estimated using **CORMIX** model. Once the return 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.

The Cornell Mixing Zone Expert System (CORMIX) is a software module for the analysis, prediction and design of aqueous toxic or conventional pollutant discharges into diverse water bodies. It is a widely accepted and recommended analysis tool in US on granting permission for industrial, municipal, thermal and other point source discharges to receiving waters. It is used to predict the geometry and dilution characteristics of the initial mixing zone and also the behaviour of the discharge plume at larger distances.

14.1.1. Methodology

The highly user-interactive CORMIX system is organized with three subsystems: (i) CORMIX1- for the analysis of submerged single port discharges, (ii) CORMIX2- for the analysis of submerged multiport diffuser discharges and (iii) CORMIX3- for the analysis of buoyant surface discharges. Several post-processing options are available like, CORJET (the Cornell Buoyant Jet Integral Model) for the detailed analysis of the near-field behaviour of buoyant jets, FFLOCATR (the Far-Field Plume Locator) for the far-field delineation of discharge plumes in non-uniform river or estuary environments, and CMXGRAPH, a graphics package for plume plotting.

Hydrodynamic Mixing Processes: The mixing behaviour of any effluent discharge is governed by the interplay of ambient conditions in the receiving water body and by the discharge characteristics. The **ambient conditions** in the receiving water body are described by the water body's geometric and dynamic characteristics such as: plan shape, vertical cross-sections and bathymetry, especially in the discharge vicinity. Dynamic characteristics are given by the velocity and density distribution in the water body, again primarily in the discharge vicinity. The **discharge conditions** relate to the geometric and flux characteristics of the submerged outfall installation. For a single port discharge the port diameter, its elevation above the bottom and its orientation provide the geometry; for multiport diffuser installations the arrangement of the individual ports along the diffuser line, the orientation of the diffuser line, and construction details represent additional geometric features; and for surface discharges the cross-section and orientation of the flow entering the ambient watercourse are important. *The distinction between near-field and far-field is made purely on hydrodynamic grounds and it is unrelated to any regulatory mixing zone definitions.*

14.1.2. Design details

The total volume of cooling water that would be discharged into the sea is 6500 m^3/hour with 8° C and it will be mixed with 6500 m^3/hour of seawater with ambient temperature. The resultant water will have a temperature of 18 °C. The outfall diffuser will have the multi ports of 300 nos.x 150 mm diameter placed along the south breakwater for a distance of 450 m. All the ports will be oriented 45° to the horizontal. The arrangement of the coldwater discharge diffuser along the breakwater and the cross section of the breakwater with diffuser is shown in Fig. 14.1 & 14.2. The design cooling water volume is taken as 13000 m^3/hour (3.61 m^3/s). The various input parameters for the CORMIX models are given below.

Volume of cooling water	=	13000 m^3/hour (3.61 m^3/s)
No. of Ports	=	300 nos. x 150 mm dia.
Inclination of ports	=	45° to horizontal

CORMIX SESSION REPORT:

****

CORMIX MIXING ZONE EXPERT SYSTEM
CORMIX Version 9.0GTH
HYDRO2: Version-9.0.0.0 September,2014

****

SITE NAME/LABEL	:	KARAIKAL PORT
DESIGN CASE	:	KARAIKAL PORT COLD WATER
FILE NAME	:	C:\Program Files (x86)\CORMIX 9.0\KPPL COLD WATER.prd
Using subsystem CORMIX2	:	Multiport Diffuser Discharges
Start of session	:	07/28/2015--11:24:10

****

SUMMARY OF INPUT DATA:

AMBIENT PARAMETERS:

Ambient velocity	UA	= 0.1 m/s
Darcy-Weisbach friction factor	F	= 0.3644
Calculated from Manning's	n	= 0.1
Wind velocity	UW	= 1 m/s
Stratification Type	STRCND	= U
Surface temperature		= 28 degC
Bottom temperature		= 28 degC
Surface density	RHOAS	= 1012 kg/m^3
Bottom density	RHOAB	= 1012 kg/m^3

DISCHARGE PARAMETERS		: Surface Multiport Diffuser Discharge
Diffuser type	DITYPE	= unidirectional perpendicular
Diffuser length	LD	= 500 m
Diffuser endpoints	YB1	= 0 m; YB2 = 450 m
Number of openings	NOPEN	= 300
Number of Risers	NRISER	= 300
Ports/Nozzles per Riser	NPPERR	= 1
Spacing between risers/openings	SPAC	= 1.50 m
Port/Nozzle diameter	D0	= 0.15 m
Contraction ratio	Co	= 1
Equivalent slot width	B0	= 0.0106 m
Total area of openings	TA0	= 5.3014 m^2
Discharge velocity	U0	= 0.68 m/s
Total discharge flowrate	Q0	= 3.6 m^3/s
Discharge port height	H0	= 1 m
Nozzle arrangement	BETYPE	= unidirectional without fanning
Diffuser alignment angle	GAMMA	= 90 deg
Vertical discharge angle	THETA	= 0 deg
Actual Vertical discharge angle	THEAC	= 0 deg
Horizontal discharge angle	SIGMA	= 0 deg

Relative orientation angle	BETA	= 90 deg
Discharge density	RHO0	= 1012 kg/m^3
Density difference	DRHO	= -15.7662 kg/m^3
Buoyant acceleration	GP0	= -0.1552 m/s^2
Discharge concentration	C0	= 10 deg.C

NON-DIMENSIONAL PARAMETERS:

Slot Froude number	FR0	= 16.74
Port/nozzle Froude number	FRD0	= 4.45
Velocity ratio	R	= 6.79

CORMIX2 PREDICTION FILE:

****

CORMIX MIXING ZONE EXPERT SYSTEM

Subsystem CORMIX2: Multiport Diffuser Discharges

CORMIX Version 9.0GTH

HYDRO2 Version 9.0.0.0 September 2014

****

CASE DESCRIPTION

Site name/label	: KARAIKAL PORT
Design case	: KARAIKAL PORT COLD WATER
FILE NAME	: C:\Program Files (x86)\CORMIX 9.0\KPPL COLD WATER.prd
Time stamp	: Tue Jul 28 11:24:10 2015

****

X-Y-Z COORDINATE SYSTEM:

Because of bank/shore proximity, the ORIGIN is located directly at the LEFT bank of theshore. The bank/shore acts as a plane of symmetry for the predicted plume geometry. X-axis points downstream, Y-axis points to left, Z-axis points upward.

NSTEP =50 display intervals per module

BEGIN MOD201: DIFFUSER DISCHARGE MODULE

Profile definitions:

BV = layer depth (vertically mixed)
BH = top-hat half-width, in horizontal plane normal to trajectory
S = hydrodynamic average (bulk) dilution

X	Y	Z	S	BV	BH
0.00	0.00	1.00	1.0	0.01	500.00

** WATER QUALITY STANDARD OR CCC HAS BEEN FOUND **

The pollutant concentration in the plume falls below water quality standard or CCC value of 0.500E+01 in the current prediction interval.

This is the spatial extent of concentrations exceeding the water quality standard or CCC value.

X	Y	Z	S	BV	BH
10	0.00	1.78	43	2.01	499.27
20	0.00	2.56	61	4.01	498.58
30	0.00	3.33	75	6.01	497.93
40	0.00	4.11	86	8.01	497.32
50	0.00	4.50	96	9.00	496.74
60	0.00	4.50	100	9.00	496.20
70	0.00	4.50	110	9.00	495.68
80	0.00	4.50	120	9.00	495.19
90	0.00	4.50	125	9.00	494.73
100	0.00	4.50	130	9.00	494.30

Discussion on Initial dilution

The study on CORMIX model shows the mixing zone will extend for 60 m to achieve a dilution of 100 times and extending further till 100 m distance to achieve to dilution of 130 times from the disposal location. Thereafter the initial dilution, the secondary dispersion take place due to convection currents and undergoes further dilution.

14.2. Modelling on currents inside port basin

MIKE 21-HD model is the application suite for calculating *combined current and wave induced* non-cohesive sediment transport in the nearshore region. These models have been developed by Danish Hydraulic Institute (DHI), Denmark and are being used worldwide for many coastal engineering applications.

MIKE 21 Flow module - HD is a multi-dimensional 2D hydrodynamic flow simulation model, which solves shallow-water equations for given boundary conditions to compute non-steady free-surface flow fields that result from a variety of environmental forcing and processes in natural water bodies. The MIKE 21-Flow model can be used to model: Tide and wind-driven flows, Stratified and density driven flows, Thermal stratification in lakes, seas and reservoirs, Cooling water recirculation, Transport of dissolved material and pollutants and Wave-driven currents. This module uses an Alternate Direction Implicit (ADI) Finite Difference Method on staggered orthogonal grids and also has the option to use Finite Element Method. The basic shallow water equations in the Cartesian co-ordinate system used in the MIKE 21 HD flow module are:

<u>Continuity equation:</u>

$$\frac{\partial \zeta}{\partial t} + \frac{\partial p}{\partial X} + \frac{\partial q}{\partial Y} = S - e$$

<u>Momentum equations in x- and y- directions:</u>

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial X}\left[\frac{p^2}{h}\right] + \frac{\partial}{\partial Y}\left[\frac{p\,q}{h}\right] + gh\frac{\partial \zeta}{\partial X} + F_{bx} - K_a W W_X - \frac{h}{\rho_W}\frac{\partial p_a}{\partial X} - \Omega\, q - F_{EX} = S_{iX}$$

$$\frac{\partial q}{\partial t} + \frac{\partial}{\partial X}\left[\frac{p\,q}{h}\right] + \frac{\partial}{\partial Y}\left[\frac{q^2}{h}\right] + gh\frac{\partial \zeta}{\partial Y} + F_{by} - K_a W W_Y - \frac{h}{\rho_W}\frac{\partial p_a}{\partial Y} + \Omega\, p - F_{EY} = S_{iY}$$

<u>Symbol list</u>

$$F_{EX} = \left[\frac{\partial}{\partial X}\left[\varepsilon_X\, h\frac{\partial u}{\partial X}\right] + \frac{\partial}{\partial Y}\left[\varepsilon_Y\, h\frac{\partial u}{\partial Y}\right]\right] \qquad F_{EY} = \left[\frac{\partial}{\partial X}\left[\varepsilon_X\, h\frac{\partial u}{\partial X}\right] + \frac{\partial}{\partial Y}\left[\varepsilon_Y\, h\frac{\partial u}{\partial Y}\right]\right]$$

$$F_{bx} = \frac{g}{C^2}\sqrt{\frac{p^2}{h^2} + \frac{q^2}{h^2}}\,\frac{p}{h}$$

$$F_{by} = \frac{g}{C^2}\sqrt{\frac{p^2}{h^2}+\frac{q^2}{h^2}}\,\frac{q}{h}$$

ζ (x, y, t)	-	Water surface level above datum (m)
p(x, y, t)	-	flux density in the x-direction ($m^3/s/m$)
q(x, y, t)	-	flux density in the y-direction ($m^3/s/m$)
h(x, y, t)	-	water depth (m)
S	-	Source magnitude per unit horizontal area ($m^3/s/m^2$)
S_{iX}, S_{iY}	-	source impulse in x and y-directions ($m^3/s/m^2.m/s$)
e	-	Evaporation rate (m/s)
g	-	Gravitational acceleration (m/s^2)
C	-	Chezy resistance No. ($m^{1/2}/s$)
K_a	-	$C_w \frac{\rho_{air}}{\rho_{Water}}$
C_w	-	wind friction factor
W, W_X, W_Y(x, y, t)	-	wind speed and components in x- and Y-directions (m/s)
p_a (x, y, t)	-	barometric pressure ($Kg/m/s^2$)
ρ_w	-	density of water (kg/m^3)
Ω	-	Coriolis coefficient (latitude dependent) (s^{-1})
ε(x, y)	-	eddy or momentum dispersion coefficient (m^2/s)
x, y	-	space coordinates (m)
t	-	Time (s)

14.2.1. Units and Conventions used

Units: Units of all parameters and variables in the model study are according to international SI conventions. Coordinate system: The coordinate system used for model grid generation and other horizontal positioning was UTM based on WGS 84 spheroid. Vertical reference level: The depth information used in the tidal flow models is relative to Mean Sea Level (MSL); depths below MSL are defined negative. ***Directions:*** Current – Ocean current directions refer to the direction towards which the flow is taking place. Directions of the flow are always given clockwise with respect to North. The Unit is degrees, where 360 degrees cover the circle. Wind - Wind directions refer to the direction from which the wind is approaching. Directions of the wind are always given clockwise with respect to North. The Unit is degrees, where 360 degrees cover the circle.

14.2.2. Depth Schematization

The bathymetry in the study region is extracted from: i) Indian Naval Hydrographic Charts, and ii) actual data on bathymetry as surveyed by Indomer.

14.2.3. Boundary conditions

In ocean flow modelling, we always encounter with open sea boundaries. To simulate tide induced flow fields inside the study area, tidal water level variations along the open boundaries of the model are prescribed as time series. For the generation of these boundary conditions, the KMS data base is used. If the tidal constituents along the boundaries of the study area are available, then the boundary conditions are represented by:

$$h_t = A_0 + \sum_{i=1}^{n} f_i A_i \cos(\omega_i t + (v_0 + u)_i - g_i)$$

With:

h_t	-	water level at time t
A_o	-	mean value of the signal
A_i	-	amplitude of component i
f_i	-	nodal amplitude factor of component i
ω_i	-	angular frequency of component i
$(v_0+u)_i$	-	astronomic argument of component i
g_i	-	phase lag of component i

More details on MIKE 21- HD model are presented in the modelling report prepared for Phase II development *'Mathematical Model Study for Development of All Weather Port at Karaikal, Indomer Coastal Hydraulics, August 2009'*.

Results: The tide induced flow field for the flood and ebb phases, of spring *and neap tidal days, for the scenarios in the harbour basin, with and without LNG terminal is* shown in Figs. 14.3 and 14.4 respectively. The variation in current speed and direction over one lunar cycle near the LNG terminal location with and without terminal are shown and compared in Fig. 14.5. The comparison shows that there is no alteration in current speed and direction due to the construction of the LNG terminal as the berthing wharf will be abutted with shore and the FRSU is a floating system without causing any interference to the prevailing flow. The current speed prevails around 0.04 m/s both during pre and post construction of LNG terminal. The model study shows that by constructing LNG terminal in the existing port basin, there will not be any significant change in flow field at port basin.

14.3. Modelling on sediment transport inside port basin

MIKE 21 ST module in the MIKE 21 application suite is used for calculating *combined current and wave induced* non-cohesive sediment transport rate in the nearshore region. The MIKE 21 ST module can simulate sand transport rates in a wide array of natural environment, e.g. tidal inlets, estuaries, coastal regions etc.

Approach: The Bijker's method for the total-load sediment transport is chosen in the MIKE 21 ST model. According to Bijker, the total-load sediment transport, q_t, is the sum of bed-load transport, q_b, and suspended load transport, q_s.

$$q_t = q_b + q_s = q_b(1 + 1.83Q)$$

Q is a dimensionless factor defined as,

$$Q = \left[I_1 \ln\left(\frac{33h}{r}\right) + I_2 \right]$$

Where, *h* is the water depth, *r* is the bed roughness and I_1 and $I_2$are Einstein's integrals, which must be evaluated numerically on the basis of the dimensionless reference level A = r/h and z*, defined as:

$$z^* = \frac{w}{kU_{f,wc}}$$

W = the settling velocity of the suspended sediment,

K = von Karman's constant,

$U_{f,\,wc}$ = the shear velocity under combined waves and current.

The influence of the waves on the suspended-load transport is therefore taken into account through the shear velocity, $U_{f,\ wc}$. The roughness, *r*, is related to the Chezy number, *C*, through,

$$C = 18\log\left(\frac{12\,h}{r}\right)$$

Following Bijker, the shear velocity in combined waves and current $U_{f,wc}$is found as:

$$U_{f,wc} = U_{f,c}\sqrt{1+\frac{1}{2}\left(\zeta\frac{\hat{u}_b}{V}\right)} = \frac{\sqrt{g}V}{C}\sqrt{1+\frac{1}{2}\left(\zeta\frac{\hat{u}_b}{V}\right)^2}$$

Where, $U_{f,c}$ is the current-related shear velocity, *V* is the depth-averaged current velocity, *ûb*is the amplitude of the wave-induced oscillatory velocity at the bottom, and ξ is a dimensionless factor that can be expressed in terms of the wave friction factor f_w and Chezy's number *C*.

$$\zeta = C\sqrt{\frac{f_w}{2g}}$$

The wave friction factor *fw* is calculated according to Swart as

f_w = wave friction factor

a_b = the amplitude of the wave motion at the bottom

The bed load transport, *qb*, and suspended load transport, *qs*, are calculated according to,

$$q_b = B d_{50} U_{f,c} \exp\left(-\frac{0.27\Delta d_{50}\, g}{\mu U^2{}_{f,wc}}\right)$$

B is a dimensionless bed load transport coefficient, Δ is the relative density of sediments and µ is the so-called "ripple factor".

More details on MIKE 21- ST model are presented in the modelling report prepared for Phase II development *'Mathematical Model Study for Development of All Weather Port at Karaikal, Indomer Coastal Hydraulics, August 2009'*.

Model input: The spatial discritization and bathymetry prepared for MIKE21 HD model and the bathymetry survey conducted inside the port basin are used in the ST model. The flow results obtained for different scenarios in MIKE 21 HD flow model were used as input for this model.

Model output: The simulations were carried out for one lunar cycle for two scenarios, i) existing port basin and ii) with LNG terminal. The outputs from these simulations give the average sediment transport flux and rate of bed level changes in the nearshore area.

Results: The sediment transport rate and the change in bed level for the present port basin and after the construction of LNG terminal are shown in Fig. 14.6. The exiting sediment flux near the proposed terminal is less than $1m^3$/year per meter width, and it remains the same value even after the construction of the LNG terminal. Thus the modelling result shows that, there is no significant change in sediment flux and there is no change in seafloor level due to the construction of the LNG terminal.

14.4. Modelling on dredge disposal

The present turning circle and the inner and outer channels exist with a navigable depth of (-) 15.5 m CD to (-) 16.5 m CD. Dredging has to be carried out to achieve a depth of (-) 19.8 m CD and (-) 19.0 CD in the outer and inner channel respectively. The dredging quantity is estimated as 14×10^6 m^3. Out of which, 1.0×10^6 m^3 is proposed for the backup area and the rest will be disposed off in the MoEFCC designated disposal point in the deep sea.

The dumping sites approved by MoEF vide letter No.10-2/2006-IA-III dt 15.10.08 are Lat. 10°52.8' N Long. 80° 0.5' E, Lat. 10°50.4' N Long. 80° 0.5' E and Lat. 10°48.0' N Long. 80° 0.5' E. and shall be used as per the conditions specified in the letter.

Disposal of the dredge spoil

Karaikal Port has demarcated a dredge spoil disposal ground at 30 m water depth located at 14 km offshore. The demarcated dredge disposal area extends around 3500 m x 3500 m as shown in Fig. 14.7. Port is disposing the annual maintenance dredging of around 2.0 x 10^6 m^3/year in this disposal ground. The disposal is being planned at 16 nodal points and the barges would dispose the sediments at different nodes in a sequential order. The quantity of sediment dredged during the development of LNG terminal can be disposed in this existing disposal ground.

> More details on MIKE 21-PA model are presented in the modelling report prepared for Phase II development *'Mathematical Model Study for Development of All Weather Port at Karaikal, Indomer Coastal Hydraulics, August 2009*'.

14.5. Modelling on oil spill analysis

The MIKE 21- Spill Analysis (SA) module was used to understand the dispersion pattern of oil spill. MIKE 21 Spill Analysis (SA) module is based on the Lagrangian discrete parcels method in which an ensemble of particles is followed. The Lagrangian discrete parcel scheme calculates the displacement of each particle as the sum of an advective deterministic component and an independent, random Markovian component, which statistically approximates the random and/or chaotic nature of time-averaged tidal mixing.

The advective velocities are (usually) obtained from hydrodynamic simulations (MIKE 21 HD), whereas the turbulent contributions are controlled by the dispersion coefficients. In this SA module, the discrete path of the pollutant parcels released in the water body are followed and recorded as a function of time relative to the reference grid system fixed in space. Then the density distributions of the ensemble are interpreted as the concentration of the spoil/waste/pollutant.

14.5.1. Model Input

- Bathymetry of the study area
- Flow field obtained from MIKE 21 HD module
- Wind Conditions, Air & Water Properties
- Pollutant Properties - Ratio between oil fractions, densities, vapour pressures, pour point etc.
- Pollutant Source: Position & Source flux
- Dispersion coefficients

14.5.2. Model Output

The SA module gives the following outputs,

- Instantaneous and averaged oil slick thickness [mm]
- Instantaneous and averaged oil components (up to eight) [mm]
- Instantaneous and averaged Emulsification rate [percentage]
- Instant and averaged oil evaporation [mm]
- Instant and averaged oil dissolution [mm]
- Instant and averaged vertical dispersion [mm]
- Exceeding concentrations [percentage]
- Time exposition [seconds]

Results: For the modelling study, the general LNG tanker of size 260000 m^3 having Heavy Fuel oil storage of 950 tonnes was considered. The spreading of oil slick during fair weather, southwest monsoon and northeast monsoon are shown in Figs. 14.8 to 14.10 respectively. The spread of the oil slick on the sea surface during fair weather in the absence of wind influence shows that the total oil slick thickness above 100 mm extends to 2200 m along the coast and slick thickness of 5 mm extends over 3500 m along the coast. Finally the oil slick decays after 5 days. The simulation shows that the spill travels nearly parallel to the shore.

In the presence of wind and turbulent sea, in case of southwest monsoon period and northeast monsoon period, the simulations show that the decay of oil fractions gets accelerated and they dissolve considerably within a period of 12 hours.

Therefore appropriate oil containment procedure should be evolved particularly during fair weather between February and May.

14.6. Modelling on storm surge

The storm/cyclone induced water level variations (storm surges) along the east coast of India near the project site are simulated using the MIKE21-HD module. In order to estimate the surge height, the distribution of the wind and pressure fields induced by the cyclone have to be specified over the Bay of Bengal near the study area. As the wind and pressure fields induced by a moving cyclone are nearly circular, they are described in terms of a smaller number of storm parameters in the MIKE21 module. The parameters used to describe the wind field associated with a cyclone are:

- Radius to maximum wind, R_m,
- Maximum wind speed, W_{max},
- Cyclone track, forward speed V_f and direction,
- Central pressure, P_c and
- The ambient pressure, P_a.

At a distance R from the center of the cyclone, the rotational wind speed W_r is given by,

$$W_r = W_{max} (R/R_m)^7 \exp[7(1 - R/R_m)] \qquad \text{for } R < R_m$$

$$= W_{max} \exp[(0.0025R_m + 0.005)(1 - R/R_m)] \qquad \text{for } R \geq R_m$$

where R and R_m are in km. Cyclone induced wind rotates anti-clockwise in the northern hemisphere and clockwise in the Southern hemisphere. The direction of the wind at a distance R from the centre of the cyclone is deflected towards its centre by friction at the air-sea interface. The deflection angle θ with respect to the tangent to the circle at a particular location R from the centre of the cyclone is given by,

$$\theta = 10^\circ \qquad \text{for } 0 < R \leq R_m$$

$$= 10^\circ + (R - R_m)/(0.2\ R_m)15^\circ \qquad \text{for } R_m < R \leq 1.2R_m$$

$$= 25^\circ \qquad \text{for } 1.2R_m < R$$

Finally, the pressure, P, at a particular location is given by,

$$P = P_c + (P_a - P_c)\ \exp(-R_m/R)$$

14.6.1. Model Input

- Bathymetry of the study area
- Wind Conditions (For available data base)
- Flow field obtained from MIKE 21 HD module

14.6.2. Model Output

- Surge height (m)
- Storm induced current in X- direction (m)
- Storm induced Current in Y-direction (m)

More details on MIKE 21- HD model are presented in the modelling report prepared for Phase II development *'Mathematical Model Study for Development of All Weather Port at Karaikal, Indomer Coastal Hydraulics, August 2009'*.

Results: The extreme values of the storm parameters, W_{max}, are determined by fitting Weibull distribution to the available data on *estimated maximum wind speeds* during cyclones that have crossed the Tamil Nadu coast since 1893. It shows a design extreme wind speed of 197 kmph, 226 kmph and 254 kmph for the return period of 50, 100 and 200 year respectively. The MIKE 21 HD Module has been used to simulate the storm surge for the different cyclonic conditions. The storm surge simulation has been carried out for different cyclonic wind speeds and corresponding to a return periods. It predicts a storm surge of about 1.71 m for 200 kmph wind.

14.7. Modelling on littoral drift, shoreline erosion and beach nourishment

In the present case the LNG terminal will be built inside the port basin as shown in the Fig. 3.5. Therefore the construction of LNG terminal will not alter or change the existing littoral drift pattern outside the port and will not disturb the present equilibrium of the shoreline.

The Karaikal port has conducted various studies including model study on littoral drift and shoreline changes and thereby evaluated shoreline stabilization procedure. The estimation of littoral drift for Karaikal port was then made by Indomer using the DHI- LITPACK- LITDRIFT model. The changes in shoreline on either side of the port breakwaters were studied by Indomer using the DHI - LITPACK- LITLINE module.

The details of the studies and the present mechanism of shoreline stabilization are presented in detail in the report prepared for Phase II development 'Mathematical Model Study for Development of All Weather Port at Karaikal, Indomer Coastal Hydraulics, August 2009'.

14.7.1. Littoral Drift

The monthly volume of littoral drift is presented in Table 14.1. It is observed that the highest northerly transport of 0.69 x 10^5 m^3/month occurs in the month of June. In the months of August and September also the northerly transport was relatively high around 0.5 x 10^5 m^3/month. The highest southerly transport was observed in the month of December (1.22 x 10^5 m^3/month) followed by November (0.88 x 10^5 m^3). The net monthly transport is northerly from March to October and southerly during the remaining months. The net transport in the month of March appears to be insignificant. The annual gross littoral transport is estimated as 0.63 x 10^6 m^3/year and the annual net transport is 0.03 x 10^6 m^3/year (towards north).

It shows that this coastal region selected for port development has very small annual net transport tending close to a nodal drift zone.

14.7.2. Changes in shoreline based on monitoring survey

The breakwaters construction started in June 2008 and completed in February 2009. Port operation commenced in April 2009. In order to preserve the marine environment, KPPL initiated the shoreline monitoring surveys along the northern and southern sides of the breakwaters.

Monitoring plan: The neighbouring coastline and the location of 10 reference stations at 200 m spacing covering on either side of the breakwaters are shown in Fig. 14.11. The monitoring area has been divided into 2 zones namely: i) South zone, 1000 m long, lying south of the southern breakwater and ii) North zone, 1000 m long, lying on the north of the northern breakwater.

In order to monitor the impact on the shoreline, KPPL had carried out bi-monthly shoreline survey during June 2008 to June 2009 and continued the monitoring program on monthly basis from September 2009 to August 2010.

The details of the studies and the shoreline changes are presented in the report *'Monthly Shoreline monitoring survey south of Karaikal Port'*

Beach nourishment was taken up in May and June, 2010. The material dredged at approach channel was pumped to the shore on the northern side of the northern breakwater. The quantity of sediment placed for beach nourishment was 16000 m^3 in May 2010 and 24000 m^3 in June 2010. The shoreline formed in June 2009 and October 2013 are shown in Fig. 14.11.

Dredging offshore

North of NBW

Placement of sediments for beach nourishment

The details of the studies and the present mechanism of shoreline changes are presented in detail in the report *'Shoreline Monitoring at Karaikal Port, Indomer Coastal Hydraulics, November 2013'*.

The change in sediment volume was estimated using HYPACK-DREDGE package based on the bathymetry conducted in October 2013.

The shoreline observation done during October 2013 indicates that the seabed, north of port area has become marginally shallower indicating a depositional trend. The region south of port area has become deeper indicating erosional trend.

It is important to note that the shoreline will undergo seasonal shifting i.e. about 10 m recession during monsoon and about 10 m accretion during fair weather. Taking into account of the seasonal changes of about 20 m, it is observed that the shoreline changes measured on either side of the breakwaters remain almost stable without any significant erosion or deposition. The beach nourishment carried out in May 2010 and June 2010 helped to stabilize the shoreline particularly about 600 m distance from the northern breakwater. It is suggested that the same amount of beach nourishment can be carried out from May to July every year.

Table 14.1. Monthly volume of littoral drift

Month	Quantity (m^3/month)	
	Northerly	Southerly
January	-23200	38500
February	-12300	22500
March	-11100	10000
April	-27500	3800
May	-33500	11800
June	-69050	280
July	-27850	100
August	-47900	400
September	-48850	980
October	-24950	1800
November	-2800	87500
December	-4800	121800
ANNUAL	**-333800**	**299460**
ANNUAL GROSS	**$0.63 x 10^6$ m^3/year**	
ANNUAL NET	**-0.03 $x10^6 m^3$/year (Northerly)**	

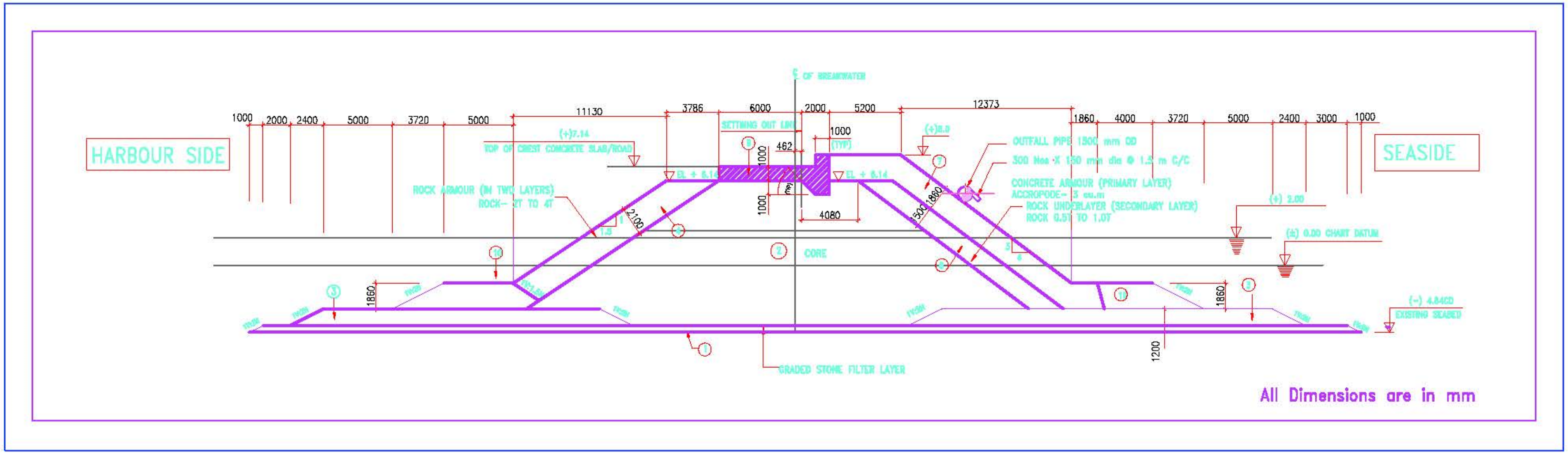


Fig. 14.1. C/S of breakwater showing arrangement of cold water discharge diffuser

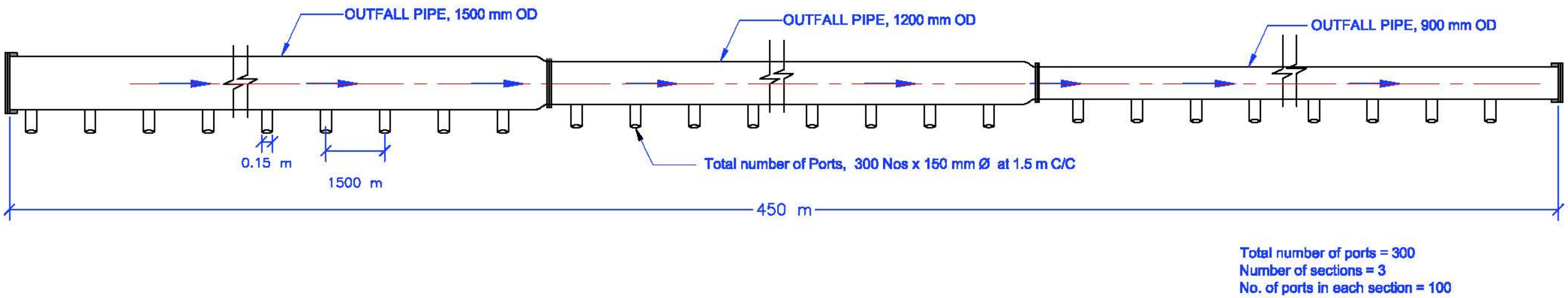


Fig. 14.2. Arrangement of coldwater discharge diffuser along the breakwater

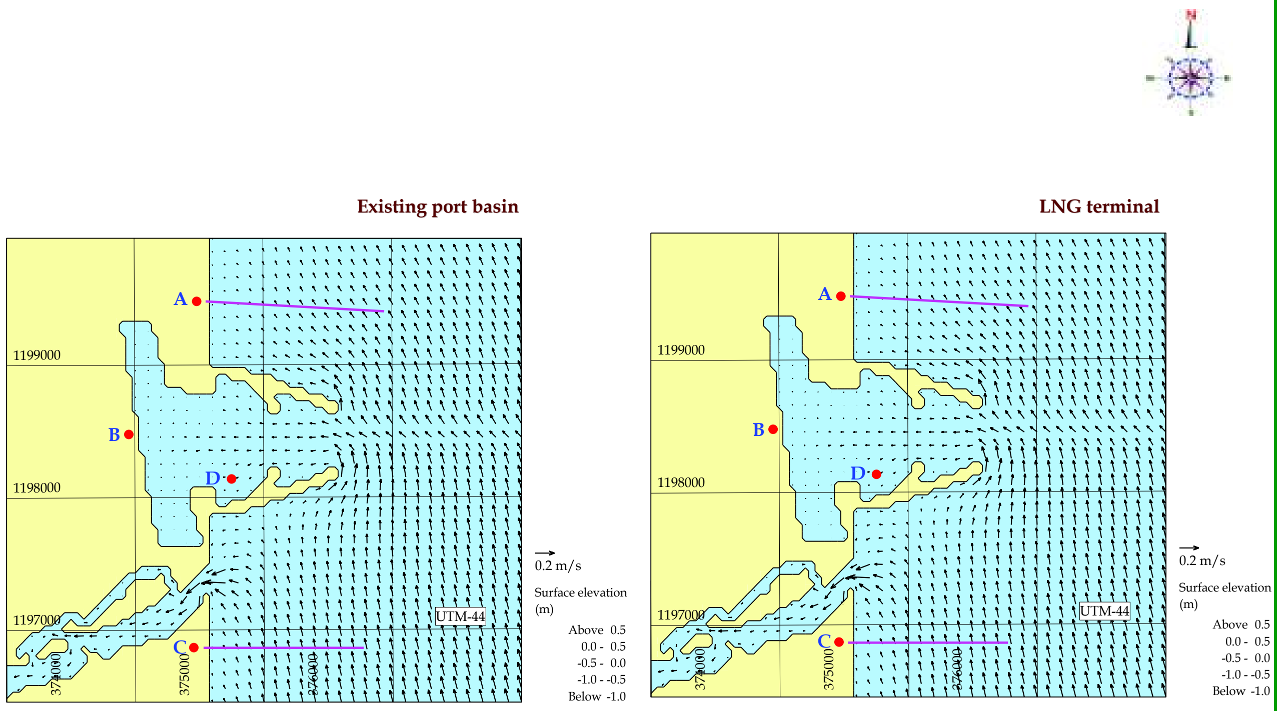


Fig. 14.3. Flow field – Fair weather - Spring tide

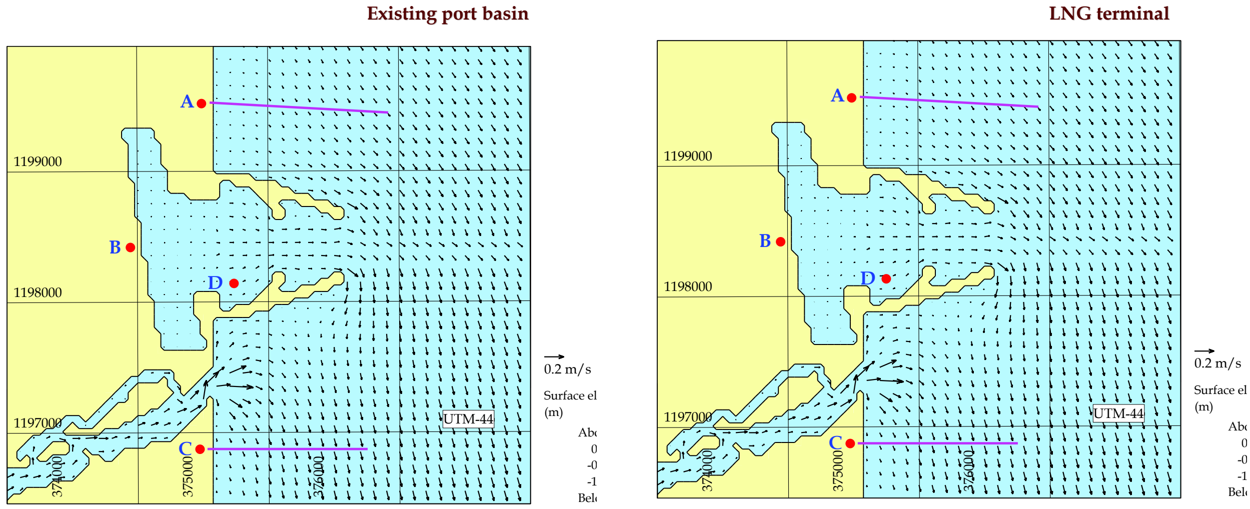


Fig. 14.4. Flow field – Fair weather - Neap tide

A – CHEMPLAST JETTY

B – KARAIKAL PORT

C – CPCL JETTY

D – LNG TERMINAL

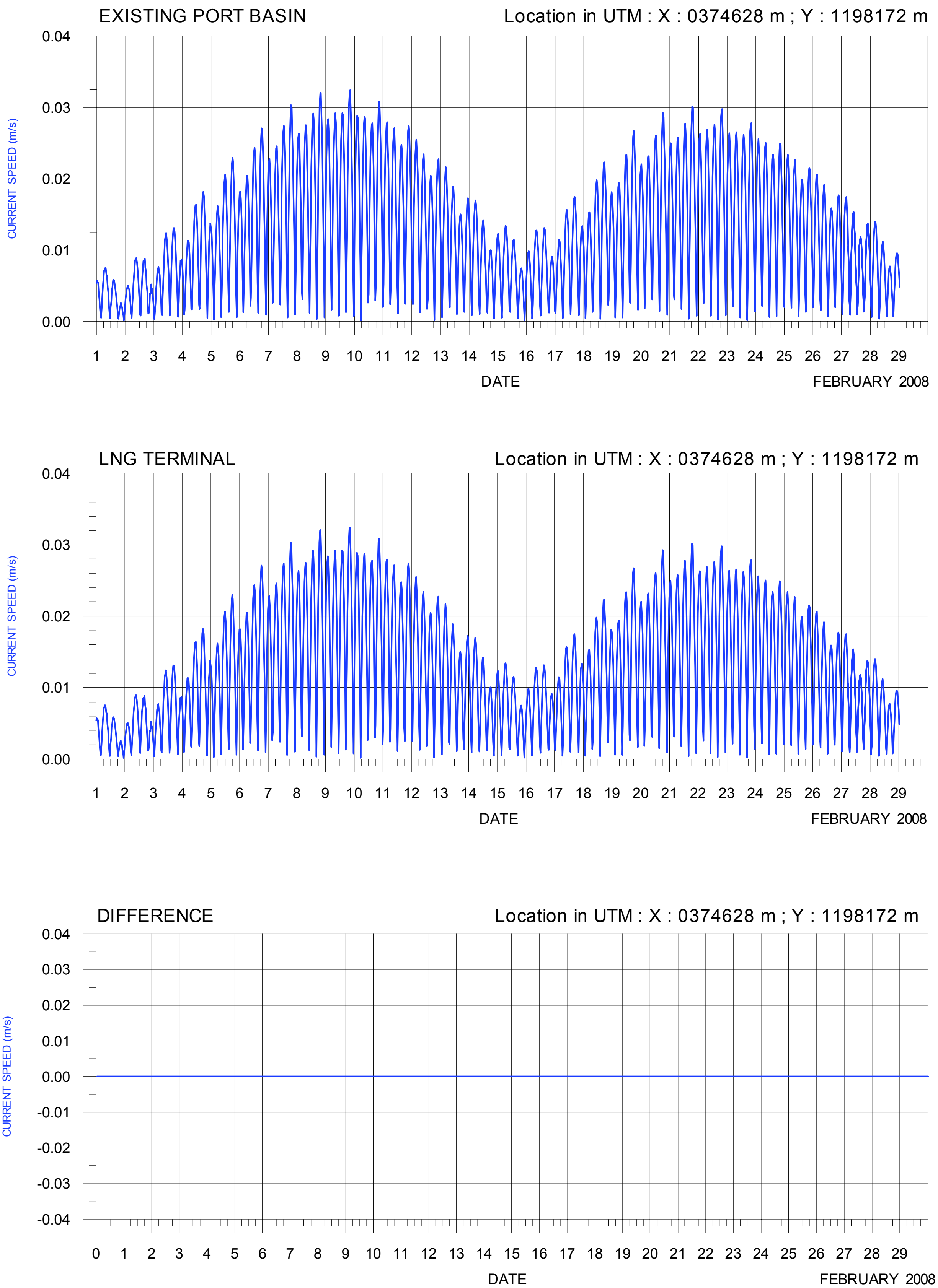


FIG. 14.5. VARIATION OF CURRENT SPEED AT KARAIKAL PORT

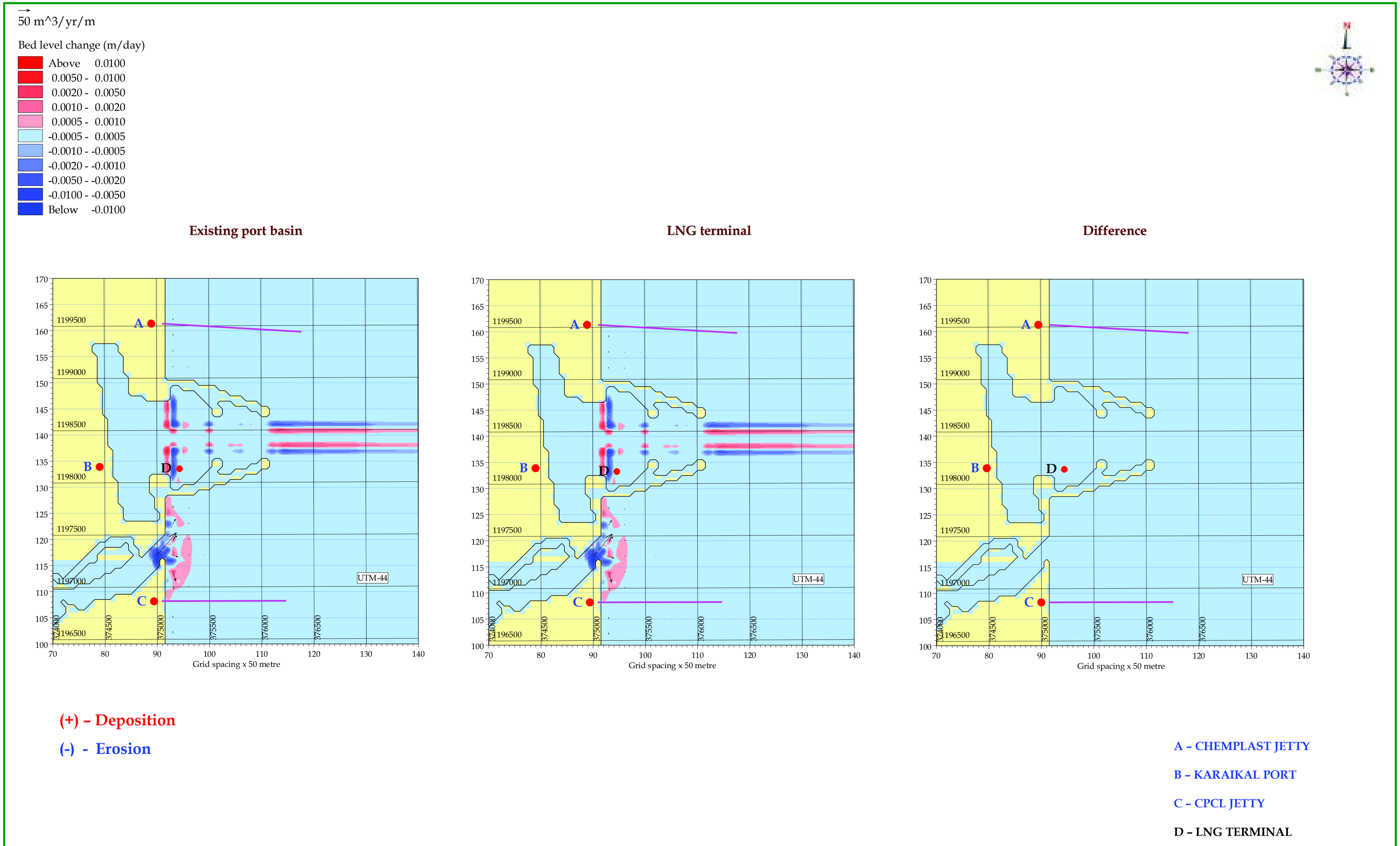
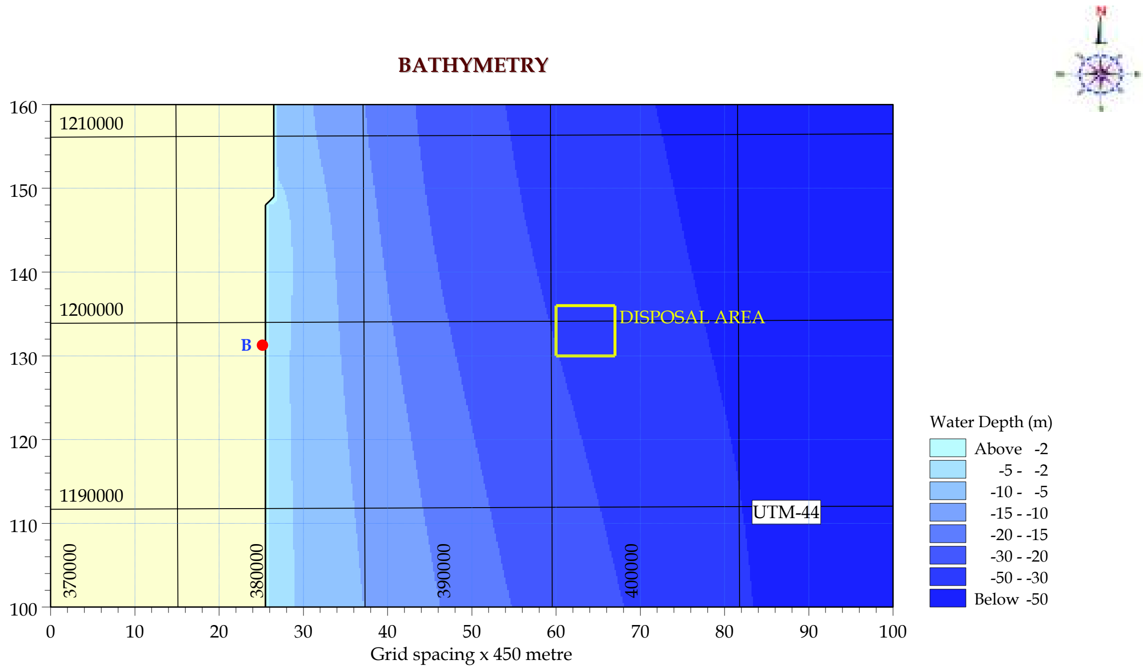


Fig. 14.6. Sediment transport and bed level changes – combined waves and current

BATHYMETRY



COORDINATES OF DISPOSAL LOCATION

Sl.No	Spheroid : WGS 84		Volume of disposal (m^3)
	UTM – X (m)	UTM – Y (m)	
1	390300	1198000	$1.25x10^6$
2	391200	1198000	$1.25x10^6$
3	392100	1198000	$1.25x10^6$
4	393000	1198000	$1.25x10^6$
5	390300	1198900	$1.25x10^6$
6	391200	1198900	$1.25x10^6$
7	392100	1198900	$1.25x10^6$
8	393000	1198900	$1.25x10^6$
9	390300	1199800	$1.25x10^6$
10	391200	1199800	$1.25x10^6$
11	392100	1199800	$1.25x10^6$
12	393000	1199800	$1.25x10^6$
13	390300	1200700	$1.25x10^6$
14	391200	1200700	$1.25x10^6$
15	392100	1200700	$1.25x10^6$
16	393000	1200700	$1.25x10^6$

NODAL POINTS

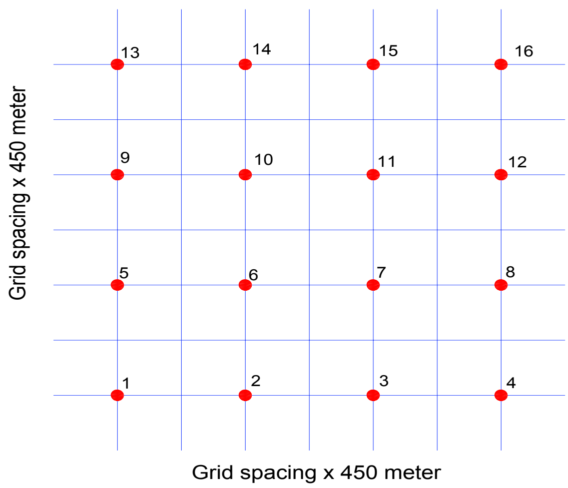


Fig. 14.7. Proposed configuration for dredge spoil disposal

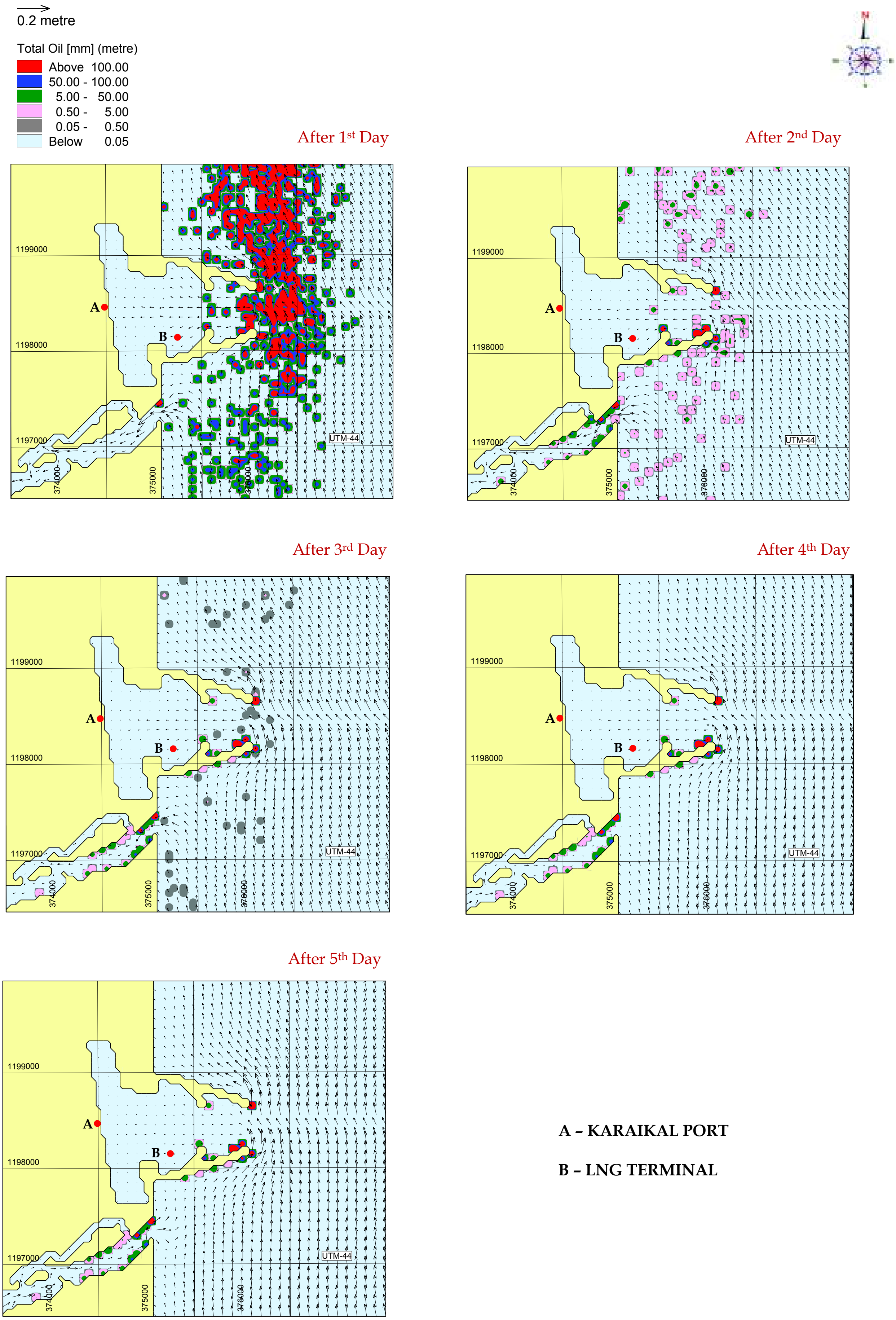


Fig. 14.8. Scenarios of oil spill in Fair weather

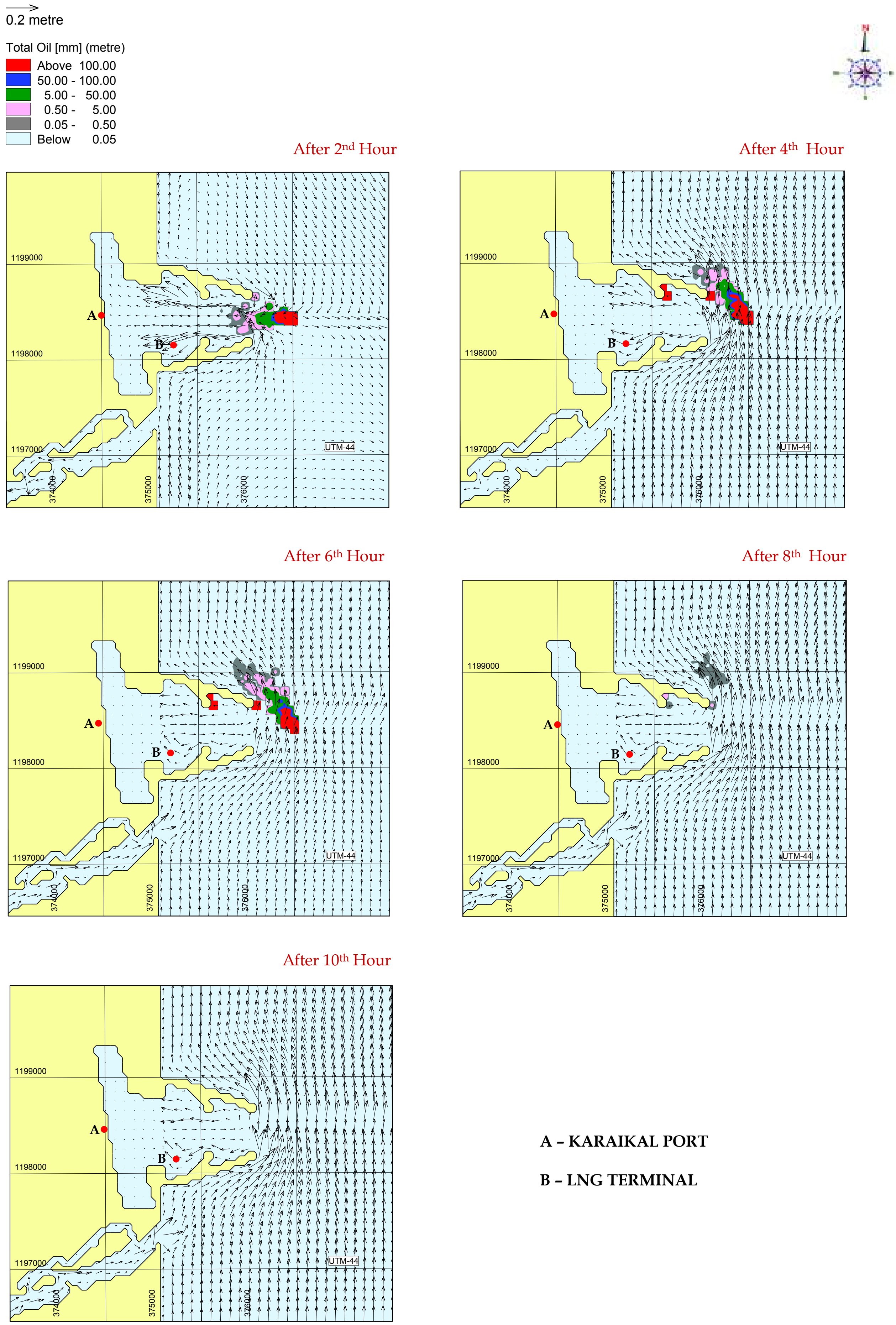


Fig. 14.9. Scenarios of oil spill in SW Monsoon

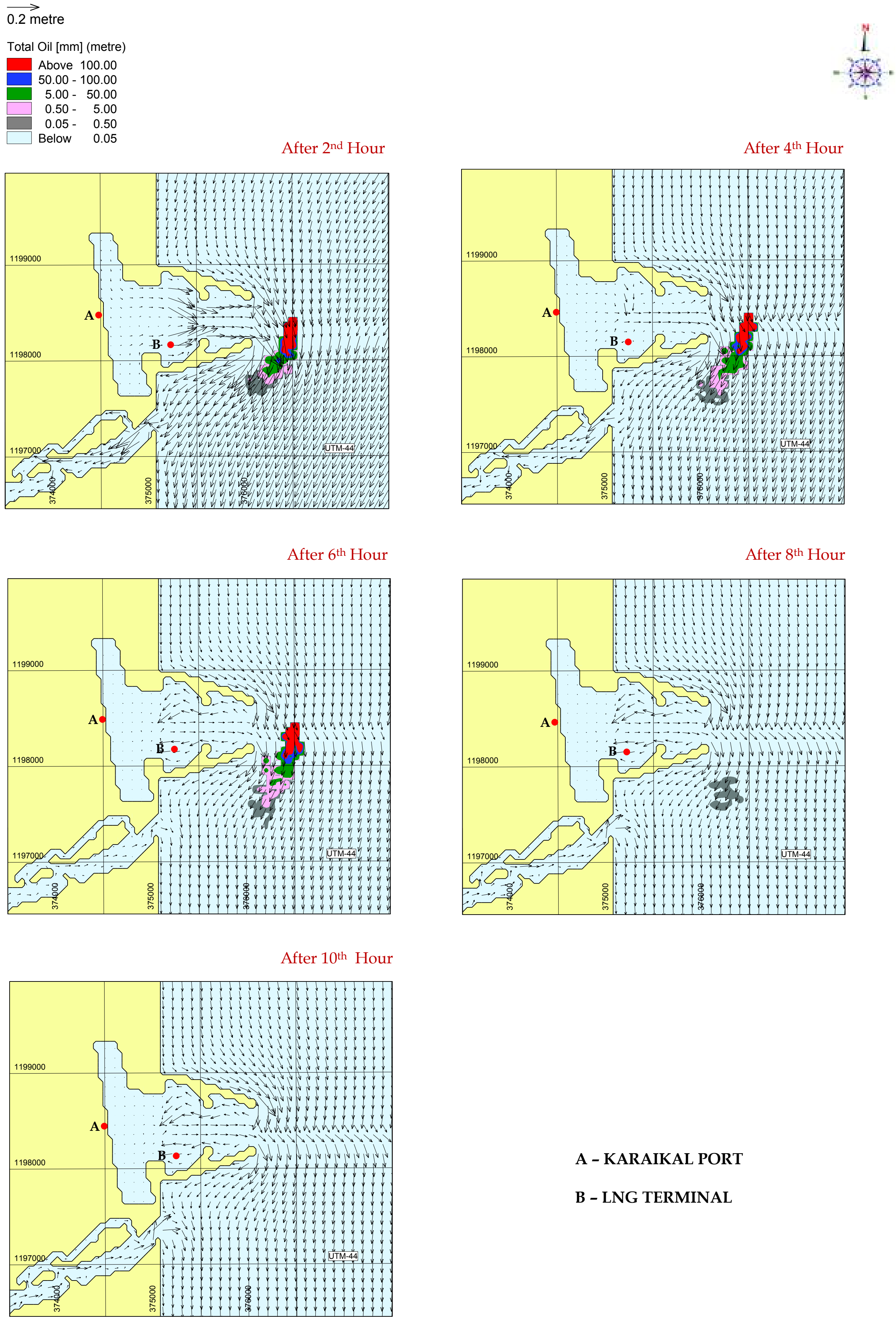


Fig. 14.10. Scenarios of oil spill in NE Monsoon

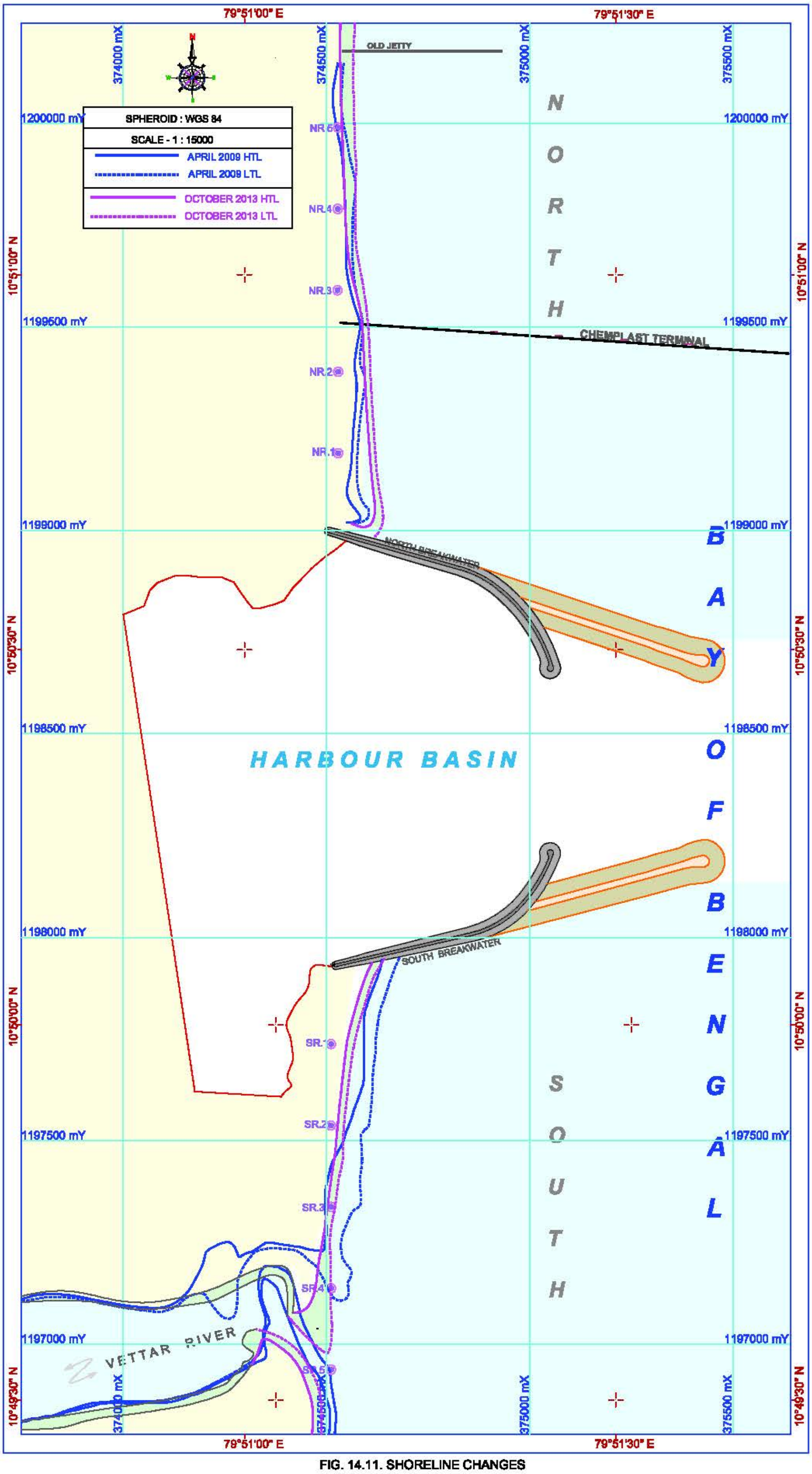


FIG. 14.11. SHORELINE CHANGES

15. DESCRIPTION OF MARINE ENVIRONMENT

The coastline remains relatively low with scattered bushes and it borders the East Coast Road. The CPCL oil terminal is located immediately at south around 500 m and the Nagapattinam port is located at 7 km south of the project site. The Chemplast offshore terminal is located at 500 m north of northern breakwater. The tidal influence in Vettar river and Paravanar river is restricted due to the formation of sand bar at the mouth and the absence of fresh water flow from upstream.

The morphology of this region is influenced by the 3 climatic conditions, viz., southwest monsoon (June to September), northeast monsoon (Mid October to February) and fair weather period from Mid March to May. The occurrence of depression and cyclones are more common during northeast monsoon period, which keeps the wave climate very high and brings large rain water discharge into the sea through the Vettar River. The wave action is relatively higher during northeast monsoon. The coastal currents are in general dominated by seasonal wind, showing northerly during southwest monsoon and southerly during northeast monsoon. The nearshore remains very dynamic due to persistent action of seasonal wind, waves, tides and coastal currents. The distribution of temperature and salinity indicates that the nearshore water is well mixed without stratification. The seabed in nearshore primarily comprises of sandy silty with uniform bathymetric features. The magnitude of littoral drift close to the project region is relatively low and it remains close to a nodal drift zone.

This coastal region selected for port development has very small annual net transport tending close to a nodal drift zone. It is observed that the shoreline changes measured on either side of the breakwaters remain almost stable without any significant erosion or deposition. The beach nourishment carried out in May 2010 and June 2010 helped to stabilize the shoreline particularly along the 600 m stretch from the northern breakwater. The storm surge upto 1 m to 2 m is normally expected during severe cyclone.

Examination of water quality of this region indicated that they do not differ substantially both 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 compare to the Inter tidal benthic fauna.

The marine flora and fauna also indicate the existence of diverse population. The area is rich in both pelagic and demersal fisheries. The presence of mangroves at open beach is absent and they are sparsely present inside the river mouth.

The study on various oceanographic parameters and the information on adjacent region indicate that the coastal water relatively clean and moderately productive.

16. IMPACT ASSESSMENT FOR MARINE ENVIRONMENT

16.1. Identification of impacts

The expansion of the existing project has been planned to develop a LNG terminal adopting FSRU with LNG vessel berthed alongside and connected to the shore by means of an approach jetty system. The proposed development is only within the existing basin and the cargo transfer takes place straight from the FSRU to the nearby GAIL network by means of pipeline system except a small quantity for supply to small time consumers. As such the impact due to construction of the marine facility to the marine environment will be very minimal.

16.2. 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 the environment. Based on the prediction, mitigation measures can be evaluated to minimize the impact on the environment. The activities which need the prediction of impacts are:

- i) Construction of LNG terminal
- ii) Dredging & Disposal
- iii) Shoreline changes
- iv) Discharge of cold water
- v) Oil spill
- vi) Storms and Tsunami
- vii) Fisheries, Turtles and Mangroves

i) Construction of LNG terminal

During the construction of berth, the bottom living communities like intertidal and sub-tidal benthos present in berth region will get temporarily disturbed. The turbidity induced during the process of construction would alter the water quality and inturn affect the fishes during the construction period and thereafter the system will slowly return to its normal status.

Potential impacts on water quality: Pile driving and other associated tasks water will cause re-suspension of sediments and turbid water. Re-suspension of sediments in water leads to an increase in the level of suspended solids and in the concentration of organic matter, possibly to toxic or harmful levels. It also reduces sunlight penetration.

Potential impacts on marine/coastal ecology: Settlement of suspended sediments on fragile marine fauna and flora damages the ecosystem. The organisms attached to submerged structures need dissolved oxygen for respiration and the plants need sunlight for photosynthesis.

Noise and vibration: One of the major impacts of underwater construction/pile driving on the marine organisms especially on fishes is the underwater sound pressure waves generated during hammering of the piles. The effect includes haemorrhage and rupture of internal organs, including the swim bladder and kidneys in fish. Pile driving may result in "agitation" of fish indicated by a change in swimming behaviour. They may exhibit "startle response" to the first few strokes of the pile. The startle response is a quick burst of swimming that may be involved in avoidance of predators.

ii) Dredging and Disposal

The development of LNG Terminal involves very minimal dredging of < 0.1 x10^6 m^3. The seabed along dredging areas primarily consists of fine sand and silt. Identified dredging effects include (i) entrainment and removal of organisms, (ii) increased turbidity at the dredging site, (iii) organic matter enrichment, (iv) fish injury associated with exposure to suspended sediments, (v) decreased dissolved oxygen and (vi) fish behavioural effects due to the effects of noise. Increased turbidity can affect the filter feeding organisms, such as shellfish, through clogging and damaging feeding and breathing equipment (gills). Similarly, young fish can be damaged if suspended sediments become trapped in their gills and increased fatalities of young fish have been observed in heavily turbid water. Adult fishes are likely to move away from or avoid areas of high suspended solids, such as dredging sites, unless food supplies are increased as a result of increases in organic material. Increases in turbidity results in a decrease in the depth that light is able to penetrate the water column which may affect submerged seaweeds, sea grasses and phytoplankton, the major primary producer in the coastal waters. During all dredging operations, the removal of material from the seabed also removes the animals living on and in the sediments (benthic animals). With 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 recovery of disturbed habitats following dredging ultimately, depends upon the nature of the new sediment at the dredge site, sources and types of re-colonizing animals and the extent of disturbance. In soft sediment environment recovery of animal communities generally occurs relatively quickly and a more rapid recovery of communities has been observed. The studies conducted elsewhere indicate that the dredging impacts are relatively short term in areas of high sediment mobility. If any heavy metals are present beneath the seafloor, then they may get exposed during dredging and increase in the concentration level in the water column. The disposal of dredged material at improper locations may lead to pollution and undesired accumulation of pollutants, if any, in the biota.

When the dredged material, are disposed of at sea they will have a blanketing and smothering effect on the benthic organisms in the immediate disposal site. This blanketing or smothering of benthic animals and plants, may cause stress, reduced rates of growth or reproduction and in the worse case the effects may be fatal.

However, in the present case, the dredged material has been proposed to be placed on shore as beach fill and therefore the impact on disposal will be avoided. Addition of dredged material to the intertidal area for shore stabilization (also known as intertidal recharge/sand bank) can provide long-term benefits of environmental protection. The act of placing material over existing intertidal habitats can cause short-term impacts of disposal at sea (suspended sediments and smothering), bringing them into often more environmentally sensitive environments along the shore.

However, despite the short-term problems, intertidal recharge (beach nourishment) is often the only practical means of attempting to combat coastal erosion. Beach nourishment of intertidal habitats with dredged materials that are coarser than the present intertidal sediments, such as a mixture of sand, gravel and rock can be used to protect the coast from erosion. However, the use of coarse sediments to recharge intertidal areas changes their nature considerably in terms of sediment processes and animal and plant communities.

The recharged material may be transported from the recharged site over a period of time. Redistribution of sediments may potentially cause increased suspended sediments and smothering of nearby sensitive communities such as shellfish beds, if available. When smothering of intertidal areas occurs, there may be subsequent effects on the availability of animals and plants in bird/fish feeding areas.

iii) Shoreline changes

The coastal region in the vicinity of the port has low annual net littoral drift behaving close to a nodal drift. However there will be a localized adjustment of shoreline geometry with marginal accretion on the south and erosion on the north. This effect will be solely due to the existing port breakwaters. Nevertheless, the construction of bulk liquid berth primarily for LNG terminal inside the port basin will not have any impact on the shoreline stability. The proposed development inside the existing port basin will not have any influence on the shoreline changes and the system which is already in place for the port as a whole will be adequate and continued.

iv) Discharge of Coldwater

Karaikal Port intends to use seawater as heat source for vaporizing LNG. The quantity of seawater required is 710 m^3/hour by a 170,000 m^3 LNG carrier (and upto 850 m^3/hr for a 267,000 m^3 LNG carrier) This seawater intake system will consist of various filters to remove debris and hypo chlorination plant to reduce bio accumulation. The intake well with sea pumps will be located within the harbour basin to provide lower sediment laden water. Seawater taken from sea will have temperature ranges from 20° C to 32° C.

The LNG is vaporized by heat from the seawater through a shell and tube heat exchanger or open rack. Seawater temperature will drop to 5° to 10° C and will require disposal for the once through system. The cooled seawater will be discharged in the sea.

However for the purposes of the EIA, the impacts are estimated in worst case scenario. USEPA's Cornell Mixing Zone Expert system (CORMIX) has been used to carry out the dispersion analysis. CORMIX is a software system for the analysis, prediction and design of aqueous toxic or conventional pollutant discharges into diverse water bodies. The system's major emphasis is on predicting the geometry and dilution characteristics of the initial mixing zone so that compliance with water quality regulatory requirements may be judged.

The coldwater at 8° C will be negatively buoyant due to the higher density and will sink to lower depths unless effectively dispersed through a diffuser. The disposal can be done through an appropriate diameter pipe in order to ensure a velocity of 0.68 m/s in the diffuser. This reduces the opportunity for bio fouling organisms to attach to the pipe, while also ensuring that reverse flow of seawater does not occur.

CORMIX has been run for a surface shore disposal for a location on the southern breakwater. This can be constructed as surface discharge of the cold water over cascade/steps on the breakwater which will allow the temperature to increase due to contact with air as well as creates sufficient diffusion to minimize the sinking of more dense cold water discharged. The model prediction shows that the cold water will attain ambient temperature within 60 m of discharge location. It needs to be kept in mind that this is a conservative estimate as the turbulence from waves on the breakwater will disperse the effluent further and thus the ambient temperatures will be achieved in a shorter distance.

v) Oil Spill

The detailed oil spill contingency plan has already been in operation at Karaikal Port. A separate report on *Oil spill contingency plan*, *Karaikal Port* has also been prepared in April 2010.

During towing and berthing of the ships, owing to natural calamity or piloting errors, there can be remote possibility of mishap of one to one ship collusion or ship hitting against the wharf or ship getting grounded. During such events, the ship may sink/break and lead to oil spill inside the port basin or in the vicinity.

It is difficult to assess the effect of oil in the marine environment because of the large variation in sources, quantities, and nature of the oil, also the physical, chemical and biological conditions of the environments involved. The majority of research relating to the effects of the oil on the marine environment relates to major oil spill events, usually from shipping accidents and groundings, the environmental effects of which are well known by all, particularly the associations with oiled birds and mammals. However, limited literature describes the effects of chronic discharges from run off or numerous small discharges of oil which are common in port and harbour areas.

Some of the potential effects of oil pollution are as follows:

- Marine animals and plants tend to be tolerant of low level concentrations of oil in sediments from chronic or small discharge; however this is not always the case.
- Prolonged exposure to major or minor oil spills can lead to mass mortality of benthic communities, fish, mammals and birds.
- Contamination of sediments with oil may modify chemical, physical and biological processes. Contaminants can be trapped in the sediments and later released as a result of disturbance such as erosion or dredging.

- In sediments, as it is organic, oil will be broken down relatively quickly by microorganisms which may result in the localized removal of oxygen from the sediments and surrounding water with possible effects on marine life.

- The persistent toxic constituents of oil, such as heavy metals, can become stored in the sediments, and taken up into the food chain. Therefore following large oil spills, even where animals recover in diversity and density, they may continue to suffer physiological and behavioural disorders which can result in reduction in growth and reproduction and in the worst cases, death.

- The breakdown of oil tends to be slowest in intertidal areas, which leads to the highest concentration and longest residence times.

vi) Storms and Tsunami and other manmade hazards

Storm: 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 wind followed by tides and show northerly during southwest monsoon/ fair weather and southerly during northeast monsoon. They will also affect the port installations structure and subsequently damage the marine living organism. In the vicinity of the Karaikal region, totally 58 cyclones had occurred in 114 years, out of which 23 storms had occurred in November followed by 19 storms in October. Totally 5 cyclones had crossed the coastline within the vicinity of 150 km from this region. The storm surge of 2.4 m height has been predicted for a cyclonic wind speed of 252 kmph.

Tsunami: Occurrence of Tsunami is an extremely rare phenomenon along the Indian coast. The past history shows that the periodicity of occurrence may range from 300 to 500 years. The recent Tsunami occurred on 26.12.04 had a dreadful devastation effect along the port region. The Tsunami run up along the stretch of Karaikal port was around 2.5 m – 3.5 m. The backshore in the project region was low with low and flat and hence the run up of Tsunami has intruded to a longer distance till the East Coast Road. In case of the port, the breakwaters are expected to protect the harbour basin from the impact of run up. However, the rise in sea level may over topple on the wharfs and wash away the shore installations. More details on storm and Tsunami are presented in Chapter 22.

vii) Impact on the fisheries, turtles and mangroves

Fisheries: In general, the dominant species of the Karaikal region are fishes such as sharks, skates, oil sardines, lesser sardines, *Thrissocles*, Perches, *Caranx*, *Chirocentrus*, anchovies, silver bellies, seerfish, eels, ribbon fish, clupeides, *Sphyraena* sp., mullets, *Leiognathus*, mackerels, tunnies, Pomfrets, sciaenids, Trichiuridae, crabs (*Portunus sanguinolentus*) and penaeid prawns represented by *Penaeus monodon, P. indicus, Metapenaeus monoceros* and *M. dobsoni.* Karaikal has a total number of 10 fishing villages with a coastline of 20 km. The fishery of the region is assessed based on the data obtained from the Department of Fisheries & Fishermen Welfare, Karaikal. The intensity of fishing operation using stake net, cast and gill nets in the area harvest shows significant fish catch. Negligible quantity of fish catches were reported around the neighbouring villages. It has also been reported that the fishermen from Karaikal port do not engage in nearshore fishing but travel deep inside the sea about 8-10 km offshore for fishing. As there is no significant fishing zones reported in the vicinity of the Karaikal port area, the traditional fishermen generally follow depth contours and change routes depending on seasons. Hence, the impact in the port area will be nominal and the proposed new facility of *LNG terminal* is not expected to create any impact on fisheries as it will be located inside the port basin.

Olive Ridley turtles: Olive Ridley turtles (*Lepidochellys olivaceae*) nest along the east and west coasts of India, with major mass nesting beaches in the state of Odisha. The coast of Tamilnadu (Nagapattinam coast), has sporadic nesting of Olive Ridley turtles and is believed to form part of the migratory route of the turtles that nest in Odisha. Based on the studies conducted earlier by various authors and institutions, it has been concluded that, as the project location falls on the southeast part of Tamilnadu coastline, no active nesting of Olive turtle is indicated. The proposed LNG terminal will not cause any impact on the life of turtles as it is going to be located inside the port basin.

Mangroves: Species diversity of mangroves is very much limited in Karaikal region. It is present in the riverine sides of Vettar river. *Avicennia* and *Clerodendrum* are present in all the deltaic regions of Karaikal region. The common fauna in mangroves include insects, molluscs, fishes, amphibians and reptiles. Salt marsh plants like *Spinifex littoreus, Salicornia sp*, *Suaeda monoica, Sesuvium sp* and *Suaeda maritima* were found to be sparsely distributed along the coastline. Since the proposed *LNG terminal* is to be located inside the port basin, there will not be any impact on the mangrove plants occurring in the region.

17. MITIGATION PLAN FOR MARINE ENVIRONMENT

i) Construction of LNG terminal

During the construction of LNG terminal, the benthic organisms will get temporarily disturbed, but they are expected to colonize again once the construction is completed. In order to limit the damage at initial stage, the bed should not be disturbed much. Explosives should not be used. The construction materials should be placed one above another by using proper hoisting machineries and should not be dropped on the seafloor. Once the berth is built, the honey comb voids in it would serve as a suitable substratum for marine flora and fauna.

ii) Disposal of dredge spoil

The quantity of dredged sediments is expected to be around 14 x 10^6 m^3 out of which 13 x 10^6 m^3 will be disposed off at the MoEFCC designated areas in the deep sea. Some quantity will be used in the back up area for the LNG development. The remaining quantity will be placed on the northern shore as beach fill which will form as a part of shore stabilization programme and will help to stabilize the shoreline.

iii) Shoreline stability

Even though the proposed *LNG terminal* does not have any direct impact on shoreline stability, it is advisable to continue shoreline monitoring program. The Karaikal Port has got a regular monthly monitoring programme for assessing the shoreline changes. It is observed that the shoreline changes measured on either side of the breakwaters remain almost stable without any significant erosion or deposition. The beach nourishment carried out in May and June, 2010 helped to stabilize the shoreline on the northern side. It is suggested that same monitoring programme may be continued after the implementation of construction of the LNG terminal.

iv) Oil spill

Oil spill contingency plan should be evaluated to handle accidental spill. Karaikal Port has already evaluated and implemented an effective oil spill contingent plan. This is being successfully monitored over the last 2 years. The same plan and the facilities have to be followed after the construction of LNG terminal.

The list of Oil Spill Pollution Response Trained personnel in Karaikal Port Private Limited is given below.

S. No.	Name	IMO Level	Designation	Department	Trained Year
1	Sekhar Mahabhashyam	Level - 1	GM	EHS	2011
2	Mr.K.D.Gopinathan	Level - 2	AGM	Marine Operations	2013
3	Suresh Singh Bogal	Level - 2	Sr.Manager	Marine Operations	2014
4	Karuna Murthy U	Level - 1	AGM	Cargo Operations	2011
5	Narayana Swamy L	Level - 1	Sr. Manager	Mechanical	2011
6	Ramachandran M	Level - 1	Sr.Manager	Marine Operations	2014
7	Mr.P.Karthikeyan,	Level - 1	Asst. Manager	Fire & Safety	2010
8	Sivakumar.SB	Level - 1	Asst. Manager	Marine Operations	2012
9	Jayakannan	Level - 1	Asst. Manager	Fire & Safety	2012
10	Landa Naresh	Level - 1	Sr. Officer	Fire & Safety	2011
11	Jegan R	Level - 1	Executive	Cargo Operations	2011
12	Mr.Rajapandian,	Level - 1	Fire Man	Fire & Safety	2010
13	Arockiaraj A	Level - 1	Supervisor	Fire & Safety	2011
14	Perumal	Level - 1	Supervisor	Fire & Safety	2012
15	Tamilselvan A	Level - 1	Jr.Supervisor- F & S	Fire & Safety	2013
16	Rajendiran K	Level - 1	Asst. Manager	EHS	2014
17	Amalraj A	Level - 1	Raido Officer	Marine Operations	2014
18	Anandaraj M	Level - 1	Sr.Supervisor	Marine Operations	2014
19	Detchanamurthy P	Level - 1	Leading Fireman	Fire & Safety	2014
20	Jeevanathan S	Level - 1	Supervisor	Marine Operations	2014
21	Silambarasu C	Level - 1	Radio Officer	Marine Operations	2015
22	Panjanathan S	Level - 1	Executive	Marine Operations	2015

OFFSHORE OIL SPILL RESPONSE EQUIPMENT

Sl. No.	Description	Quantity
1.	Air filled Light Oil Boom	1000 meters
2.	Skimmer 2 Nos	30 TPH
3.	Boom reels with power packs	02
4.	Anchors & accessories for booms	as per set
5.	Oil Spill Dispersant	500 liters
6.	Reusable Adsorbents	For up to 1000 ltr absorption
7.	Bio-Product developed by NMRL	500 Ltrs

The following authorities have to be kept informed in case of any oil spill incident without delay:

i) Indian Coast Guard at Nagapattinam giving the details of the quantity and type of oil, exact location with coordinates,

ii) Ministry of Environment at Poducherry Union Territory, Tamilnadu State and Centre at Delhi,

iii) Nagapattinam Port,

iv) Poducherry Pollution Control Board,

v) Tamilnadu Pollution Control Board,

vi) Departments of State Fisheries in Poducherry and Tamilnadu,

vii) Departments of Tourism in Poducherry and Tamilnadu,

viii) State CRZ Committees in Poducherry and Tamilnadu,

ix) State Port Departments in Poducherry and Tamilnadu,

x) National Institute of Oceanography, Goa,

xi) Indomer Coastal Hydraulics (P) Ltd., Chennai,

xii) Local Fishing Hamlets,

xiii) State Forest Departments, and

xiv) State Blue Cross Societies.

v) Storms and Tsunami and manmade hazards

Cyclonic shelter may be constructed within the port and in the nearby villages. A Tsunami protection mound with native sand of 5 m height may be constructed on the seaside on either side of the breakwaters within the port area in order to protect from any event of Tsunami run up. Cyclone and Tsunami warning systems may be established in coordination with Indian National Centre for Ocean Information Services (INCOIS), Hyderabad and Department of Disaster Management.

The ships berthed on the wharf have to be taken offshore immediately on receiving the Tsunami warning. The port has to establish appropriate warning system in co-ordination with INCOIS and Department of Disaster Management. Online monitoring system with appropriate prediction system in the control room should be established.

For manmade emergencies, Port has already implemented a Disaster management plan which includes Emergency Response Action Plan to tackle any type of manmade contingencies such as Grounding of Vessels, Breaking up of mooring ropes and collision of vessels, fire incidents etc where in procedures and action plan has been elaborated.

More details on EMP and Disaster Management Plan are described in Chapter 17 and 22.

vi) Protection of Turtles and Fisheries

As there are no nesting grounds in the project area, the problem of protecting turtle nests does not exist. However proper lighting in the port area has to be installed to prevent the attraction of these animals. The Karaikal Port can also conduct training program to local fishermen to use TED in their nets. No fishing activity exists inside the port and hence requires no special mitigation measures.

vii) Port installations

All port installations on the shore in connection with handling, stacking, offices and other facilities may be located and constructed as per the CRZ regulations.

The list of various impacts and the possible mitigations are given below

Activity	Impact	Duration of Impact	Mitigation
Construction of LNG Terminal	Noise, turbidity are the main impacts	Temporary	The impact will be quite minimal in view of its size, small size piles, and limited operational requirements and short construction period.
	Piling will disturb the seabed resulting in loss of benthic communities.	Temporary	Use of good engineering tools for installation of the piles and construction of the berth.
	Increased turbidity affecting the photosynthetic process of the water column.	Temporary	No waste disposal into the sea from the construction materials.
	Suspended particles will affect the filter feeders and adult fish will migrate from the site of impact	Temporary	To minimize the spread of suspended particles, silt screens may be deployed. Installation of proper marker lights on the jetty and marker buoys in the channel
Dredging	Removal of benthic animals at the dredge site	Temporary	Selection of good cutter suction dredger to minimize re-suspension of sediment.
	Increased turbidity resulting in low light penetration and disturbance of benthic animals (filter feeders).	Temporary	Use of silt curtains where practicable Timing to avoid sensitive periods (breeding) for marine animals
Disposal of dredge spoil	Physical damage (siltation & smothering) to the benthic organisms in intertidal zone. benthic organisms)	Temporary	Careful selection of disposal site and restrict the area of dumping. Sequential dumping with proper timing to avoid overloading of a particular dump.

Shoreline stability	Boat movements and fishing activity will be restricted	Temporary	Laying operation may be done in shortest duration. Barricading the water has to be avoided. Install proper marker lights indicating if any obstructions.
Oil Spill	Water contaminated with oil.	Temporary	Proper contingency plan; Readily available oil handling equipment like booms, skimmer and chemicals for dispersion; Establish coordination with National Oil Spill Committee (Indian Navy).
Storm and Tsunami and manmade hazards	Physical damage	Temporary	Disaster management plan which includes Emergency Response Action Plan to tackle any type of manmade contingencies such as Grounding of Vessels, Breaking up of mooring ropes and collision of vessels, fire incidents etc where in procedures and action plan has been elaborated.
Port installation	-	-	All installations as per CRZ regulations.
Cold water Discharge	Damage to Benthic communities and fishes	Continuous	Use of good engineering tools for installation of the outfall pipeline with multiple ports for jet mixing. The temperature of cold water discharge to be monitored. A alarm will actuate if temperature goes below 18˚.

18. MANAGEMENT PLAN FOR MARINE ENVIRONMENT

18.1. Introduction

The Karaikal Port has a well documented Marine Environmental Management Plan (EMP). This plan is in place since commencement of operation of the port facilities in April 2009 and improved/modified suitably to suit the requirements arising out of enhanced port facilities from a 2-berth system initially to the present level of ten berths. It is suggested to implement the same EMP with suitable adjustments to take care of the specific requirement of LNG handling aspects.

18.2. Identified mitigation and compensation measures

Though the proposed port activities involving construction of bulk liquid berth primary to LNG terminal, leading to certain adverse impacts initially on marine environment, there is sufficient scope for mitigation measures.

a) Activity: Construction and operation

Mitigation: During the construction work, the subtidal benthos will get temporarily disturbed. In order to limit the damage to benthos at initial stage, the bed should not be disturbed much. Explosives should not be used. The construction materials should be placed above one another by using proper hoisting machineries and should not be dropped on the seafloor. There should not be any sudden increase in flow velocity within the port basin.

Compensation: The activities are related directly to the port and there are no stakeholders and hence no compensation is considered necessary.

b) Shoreline erosion

Mitigation: The Port authorities have to make necessary beach nourishment scheme for stabilizing the downdrift coastline. Regular monitoring of the shoreline is essential in order to design a suitable shore protection method if needed.

Compensation: The activities are related directly on the shore and beach users/coastal dwellers/coastal property owners are involved in the impact caused by this activity. The affected persons may be engaged for any marine related works.

c) Activity: Accidental collusion of ships and oil spill

Mitigation: Oil spill contingency plan should be evaluated to handle any accidental spill. Oil spill contingency equipments like boom, skimmer and dispersant chemicals should be stored. Oil Contingency Team established at Port may be strengthened. They should coordinate with National Oil spill Committee headed by Indian Navy.

Compensation: The activities are related directly in the sea at offshore and no shareholders are involved in any impact caused by this activity.

d) Activity: Port installations

Mitigation: All port installations on the shore in connection with handling, stacking, offices and other facilities may be developed beyond the CRZ line.

Compensation: The activities are related directly in the sea at offshore and no shareholders are involved in any impact caused by this activity.

19. POST PROJECT MONITORING OF MARINE ENVIRONMENT

The post project monitoring is an important aspect in Environmental Management Plan. The Karaikal Port is already having a well established and documented post monitoring programme to assess the marine parameters on a regular basis. The same system will continue for the proposed expansion i.e. LNG facilities. This is summarized as under:

i) Monitoring marine water and sediment quality:

ii) Habitat and ecosystem integrity

iii) Plan survey programme for assessing ecosystem integrity.

iv) Coastal processes

Prepare and implement a monitoring programme to determine the effects of the proposal at the project site.

i) Siltation
ii) Shoreline erosion
iii) Marine fauna
iv) Non-indigenous marine species (NIMS)
v) Research

Monitoring, Review and Reporting

Purpose	Parameter	Frequency
Seawater & Sediment quality		
To monitor impacts on seawater and sediment quality	Measurements of levels of turbidity, nutrients and heavy metals in water and sediment samples collected from sites at risk of pollution	Quarterly 3 seasons (SW Monsoon, NE Monsoon and Fair weather)
Habitat and Ecosystem integrity		
To determine whether the community structure, habitat has been altered	Measurements of various parameters: phytoplankton, zooplankton, benthic population, primary	Quarterly 3 seasons (SW Monsoon, NE Monsoon and Fair weather)

Purpose	Parameter	Frequency
	production, bacteria of health significance, nutrients and heavy metals. Subjecting them to statistical analyses to assess the change (if any) in species diversity, richness, evenness etc.	
Coastal Processes		
To determine if the project changes the quality and quantity of water entering the ecosystem	Sediment transport and nutrient flows into offshore areas	Quarterly 3 seasons (SW Monsoon, NE Monsoon and Fair weather)
To determine any shoreline change on either side of the port	Shoreline monitoring for 1 km on either side of the port	Quarterly for the entire operational period of the port. 3 seasons (SW Monsoon, NE Monsoon and Fair weather)
	Satellite imagery – comparison of photos used to establish any trends or changes in the morphology of shore in the vicinity	Annually
Marine Benthic Fauna		
To determine the composition and distribution of major groups of fauna	Benthic faunal composition in the water and sediment of the port basin and channel.	Quarterly 3 seasons (SW Monsoon, NE Monsoon and Fair weather)
Non-Indigenous Marine Species (NIMS)		
To determine if they, especially fouling organisms, have been introduced.	Temporal and spatial changes in species composition in port basin and anchoring areas.	Annually

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

- Ministry of Environment and Forests, Zonal office, Bangalore
- State Department of Environment
- State Pollution Control Board
- National Biodiversity Authority for NIMS

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.

Regions to be monitored

Port basin, navigational channel and outer anchorage as per the ongoing monitoring locations around the port (Fig. 14.11).

a) ***Water quality:*** Sampling can be carried out atleast at 3 locations in areas mentioned above. The parameters which are to be analyzed are: temperature, salinity, pH, dissolved oxygen, BOD, nutrients like ammonia, nitrite, nitrate and inorganic phosphate.

b) ***Biological parameters:*** Phytoplankton population, zooplankton population, benthic fauna, and the nature of fisheries in the area (by experimental trawling once on three months).

c) ***Shoreline:*** The shoreline for 5 km on either side of the breakwater has to be monitored.

d) Bathymetry in the vicinity covering 1 km on either side of the breakwater and 1 km into the sea.

CRZ

20. CRZ study

On the request of the M/s Karaikal Port Private Limited, Chettinad business chambers, 3rd floor, Dr.Radhakrishnan Salai, 5th Street (Near AVM Rajeshwari Marriage hall), Mylapore, Chennai – 600004, a survey was carried out to demarcate the High Tide Line (HTL), Low Tide Line (LTL) and Coastal Regulation Zone (CRZ) for the proposed activities of M/s Karaikal Port Private Limited, at Vanjoor Village, Karaikkal, Puducherry State. The satellite imagery of the project area was interpreted for topographic and geomorphic features in the vicinity of the proposed project site. The proposed site falls in the vicinity of Bay of Bengal and River carrying tidal water during high tide. The proposed project site falls within administrative boundary of Vanjoor Village as well as Bay of Bengal.

The cadastral map of the Villages in and around the project area, provided by the client was used as the Base Map. IRS, an agency authorized by MoEFCC, Government of India for demarcation of HTL and CRZ has conducted required field surveys and measurements for demarcation of CRZ during September 2013. Based on the geomorphology and topography in the vicinity of project area, HTL has been identified and traced in the field by Kinematic GNSS survey. HTL, ecologically sensitive areas, if any, along with setback lines as per CRZ Notification 2011 were superimposed on to georeferenced cadastral map to prepare a local level CRZ map at 1:4,000. The boundary of project area is superimposed on the CRZ map and Landuse map. Detailed report on “Demarcation of HTL, LTL and CRZ for the proposed activities of Karaikal Port, Karaikal, Puducherry state” is attached as Annexure III.

RISK ASSESSMENT

21. RISK ASSESSMENT

21.1. Introduction

Risk Assessment (RA) is a method that has proven its value as an all-round tool for improving the safety standards prevalent in every hazardous industry. With advancements in in-built and inherent safety systems, accidents rates have come down, but still persist at unacceptable levels for newer technology, new plants and chemical handling facilities. RA is a structured safety assessment tools designed for high hazard industries such as chemical, petrochemical, pesticides, pharmaceuticals, sea ports, etc., supplementing other safety systems tools such as HAZOP, safety audit, and regular incident analysis to identify the potential for incidents (near-misses, unsafe conditions) and to evaluate the necessary control measures.

21.2. Objectives of Risk Assessment

The objectives of RA can be summarized as follows:

- Assessing risk levels due to the operations of the facility
- Identification of the risk mitigation measures to bring the potential risk within acceptable range
- To suggest general safety improvement measures.
- To help generate maximum accident free mandays.
- To identify emergency scenarios and suggest mitigation measures.

The underlying basis of RA is simple in concept. It offers methods to answer the following five questions:

1. What are the risks?
2. What are the causes of risks?
3. What are the consequences of risks?
4. What is the probability of the risk causing events?
5. Whether the risk is at acceptable level ?

21.3. Philosophy behind Risk Assessment

Risk is the unwanted consequence of an event or series of events. Risk occurs when multiple risk causing factors occur at the same time causing an accident manifesting in an event like a fire or explosion. Certain risks are generally accepted as part of the industrial operations, while other low-frequency, high consequence risks attract statutory attention and are regarded unacceptable to local public.

The influence of various factors on the public perception of risk are summarised below.

Sr.	Factors influencing public perception	Description
1	Control	People are more willing to accept risks they impose upon themselves than to have risks imposed upon them.
2	Dread and scale of impact	Fear is greatest where the consequences of risks are likely to be catastrophic rather than spread over time.
3	Familiarity	People appear to be far more willing to accept risks that are familiar rather than new risks
4	Timing	Risks are more acceptable if the risk consequences are immediate or short-term, rather than delayed consequences.
5	Social amplification & attenuation	Concerns are increased if media coverage or graphic depiction of events is there, reduced if there is economic hardship
6	Trust	If public trusts policy makers, public trusts regulators or industry as being honest, admit mistakes and limitations and one who take into account different views, then public is more likely to place credibility in them.

Source: British Parliamentary Office of Science and Technology – "Safety in Numbers - Risk Assessment and Environment Protection"

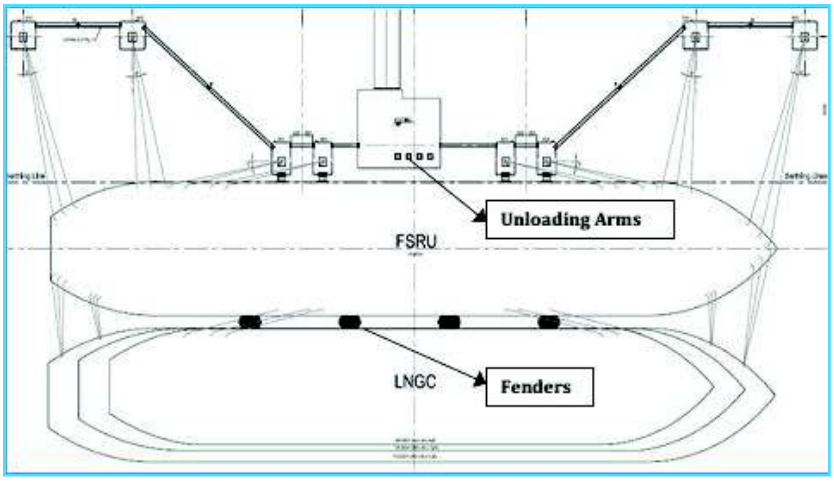
The need for communicating acceptable risks is very important. Though setting acceptable criterion for use in Quantitative Risk Assessments may often lead to disagreement between parties, nevertheless sound techniques and methods have led to the definition of acceptable levels of risks taking into account the need of people to feel safe in their day-to-day activities.

A RA should therefore, be seen as an important component of any or all on-going preventive actions aimed at minimising and thus hopefully, avoiding accidents. Re-assessments should therefore follow at regular intervals, and/or after any changes that could alter the hazard, so contributing to the overall prevention programme and disaster management plan of the project.

21.4. Statutory Requirement, Coverage of the Risk Assessment

An LNG Terminal of 05 MMTPA capacity has been considered for the RA, with a Floating and Storage Unit and jetty deck based Regassification and Sendout Unit (FS-R-U). The RA covers operations of the Port within the battery limit of the proposed LNG terminal. As Loss of containment scenarios of LNG/natural gas and consequent hazards are possible only on the above-ground segment of the pipeline carrying NG within the Port battery limit, the RA includes the above-ground, Port-ward side of NG pipelines up to the Sectionalizing and Metering Station in the battery limit for the RA.

Schematic arrangement of the proposed jetty/FSU



and NG qualify as '*Hazardous*' by virtue of listing in the Schedule 1, Part I and/or II of the Manufacturing Storage and Handling of Hazardous Chemicals Rules, 1989 (amended 2000), (MSIHC Rules) therefore have been considered for consequence analysis for RA.

The Project *inter alia* attracts application and compliances under following statutes relevant to port and personnel safety:

- **i)** Manufacture, Storage and Import of Hazardous Chemicals (Amended) Rules, 2000
- **ii)** Chemical Accidents (Emergency Planning, Preparedness and Response) Rules, 1996
- **iii)** Petroleum Act, 1934, Petroleum Rules, 2002

The RA also discusses risks due to vessel collision and grounding and risks due to fire and explosion of hazardous cargo in the vessels within the notified Port limit/administrative limit of the proposed Port.

The DMP covers emergency response of the Port during natural hazards and hazards due to release and compound consequences of hazardous chemicals. The RA is prepared to address the following two ToR points as issued by EAC:

- i) ToR No. 4 – "Submit details of Risk Assessment, Disaster Management Plan including emergency evacuation during natural and man-made disaster like floods, cyclone, tsunami and earth quakes, etc.", and
- ii) ToR No. 5 – "Submit details of safety aspects associated with handling of LNG vis-a-vis other cargo in other facilities within the port", and
- iii) ToR No. 6 – "Submit details of storage and regasification, distribution network, etc. and vulnerability of human habitation vis-a-vis LNG associated risks"

21.5. Methodology of Risk Assessment

The risk is measured usually by various screening techniques that vary from one technique to another. No single risk measure is sufficient for conveying all the possibilities and combinations in process risks. The basic methodology adopted for risk assessment is generally based upon the nature of the hazard, the basic need for conduct of risk assessment and the information and resources available for such risk assessment.

Table 21.1. Possibility and severity of Risk

Probability of Occurrence	Severity of Occurrences			
	Major	**Significant**	**Minor**	**Incidental**
Frequent (Incident may occur on annual basis or more)				
Occasional (Incident may occur several times during facility life)				
Seldom (Incident may occur once during facility life)				
Unlikely (Given current practices and procedures, incident is not likely to occur at this facility)				

SEVERE	HIGH	MODERATE	LOW

The following illustrates the detailed philosophy of the classification of incidence severity.

MAJOR INCIDENTS:

- Personnel: Fatality or permanently disabling injury
- Community: One or more severe injuries
- Environmental: Event having serious on-site or off-site impact, results in off-site agency involvement and a major fine, serious negative public health or financial impacts, major local negative media coverage, international negative media coverage.
- Facility: Major or total destruction to process area(s)

SIGNIFICANT INCIDENTS:

- Personnel: One or more severe injury
- Community: One or more minor injuries
- Environmental: Event having significant on-site or off-site impact and requiring prompt agency and corporate notification, serious negative public impact or perception, significant local negative media coverage, a fire is likely.
- Facility: Major damage to process area(s)

MINOR INCIDENTS:

- Personnel: Single injury, not severe, possible lost time.
- Community: Odour or noise complaint from public
- Environmental: Event results in agency reporting or consent violation, minor negative public impact or perception, little or no local media coverage, a fire is not likely
- Facility: Some equipment damage

INCIDENTAL INCIDENTS:

- Personnel: Minor or no injury, no lost time
- Community: No hazard to public, no public complaint
- Environmental: Environmental event with no agency involvement or consent violation, no negative public impact or perception.
- Facility: Minimal equipment damage

Another RA method generally used for the classification of incidence and used for Risk Analysis is the NIOSH method. The NIOSH method gives in brief the methodology and the Hazard Risk Matrix to assess the risks posed by use of hazardous substances and operations.

Methodology of the NIOSH method is summarized as follows:

- List of all possible hazards that exist in the study area.
- Assessment of all the possible hazards that exist in the study area.
- Selection of the identified hazards for consequence analysis.
- Consequence analysis of the identified areas.

The Hazard Risk Matrix is a useful tool to accord a risk rating for each hazard identified in terms high, medium or low. The Hazard Risk Matrix is illustrated below.

The terms *Hazard* refers to a situation that has damage potential, *Probability* is the likelihood that the particular hazard will lead to damage, *Severity* is an estimation of how serious will be the manifestation of the damage.

Hazard Risk Matrix

1. Hazard : ______________________________

2. Potential Location : ______________________________

____

____

____

Probability	Severity		
	Low	**Medium**	**High**
Low			
Medium			
High			

Notes (if any)

3. Area in which potential location(s) exists:

4. Date:

22. VULNERABILITY PROFILE OF THE PORT

22.1. Project Site

The Port is located near Keezha Vanjore village, Karaikal, UT of Puducherry, about 10 km south from the Karaikal City. The Port site is bordered by Kaveri river in the south. Siting features of the Port are given below. General siting features within 10 km of the Port site is shown below.

Siting Features of the Port

Sr.	Feature	Distance, approx, (Km)	Direction
1.	Karaikal City (Approx. centre of city to approx. centre of the Port)	9.8	N
2.	Karaikal City (Approx. margin of city to margin of the Port)	7.7	N
3.	Nagore Railway Station (Southern Railway – Chennai Madurai trunk route)	2.0	S
4.	Tiruchirappali Civil Airport	138	W
5.	Channai International Airport	298	N
6.	NH 45A (Villupuram to Nagapattinam)	3.9	NW
7.	NH 49 (Chennai to Nagapattinam)	1.5	W
8.	NH 67 (Nagapattinam to Gundlupet)	2.1	W
9.	SH 148 (Nagore to Vettur)	2.4	SW
10.	Nagore town	2.6	S
11.	Boothangudi village	4.4	SW
12.	Panangudi village	3.5	W
13.	Neravy village	7.3	NW
14.	Pravadenar river	4.5	N
15.	Vettar river	1.4	S
16.	Abhirami Amman temple, Thirukadaiyur,	25	N
17.	Lord Singaravelavar Temple, Sikkal	14	S
18.	The Church of Basilica of Our Lady of Good Health, Velankanni	18 km	S
19.	Nagore Dhargah	3.1	S
20.	Indira Gandhi National Park and Wildlife Sanctuary	303	SW
21.	Guindy National Park, Chennai	243	N
22.	Vedanthangal Bird Sanctuary	186	N

General Siting Features of the Port

22.2. Site Meteorology

Meteorology of a site plays an important part in its natural hazard vulnerability and dispersal characteristics in case of loss of containment of any hazardous material. The consequences of released toxic or flammable material are largely dependent on the prevailing weather conditions. For the consequence analysis of major scenarios the most important meteorological parameters are wind speed, atmospheric stability and temperature as they directly affect the atmospheric dispersion of the escaping material. Rainfall does not have any direct bearing on the results of the consequence analysis; however, it can have beneficial effects by absorption/washout of released materials. Actual behaviour of any release would largely depend on prevailing weather condition at the time of release.

Climate

Karaikal has Tropical Dry and Wet climate according to Köppen-Geiger climate classification system. Karaikal experiences small daily range of temperature and moderate rainfall.

Rainfall

Karaikal has an annual average rainfall of about 126 cm, 68 percent of which occurs during October to December. The amount of rainfall during the south-west monsoon period is small, being less than 20 per cent of the annual. November is the rainiest month, accounting for about a third of the annual total.

Temperature

The level of temperatures in Karaikal is about the same as in Poducherry. December and January are the coolest months with the maximum temperature at about 28° C and the minimum at about 23°C. However, minimum temperature as low as 16°C have been recorded.

Humidity

The level of humidity and the pattern of cloudiness and surface winds are the same as in Poducherry. Although slight variations in the month wise occurrence of depressions and storms are noticeable, thunder-storms generally occur during April to November, particularly in April, September and October.

Wind

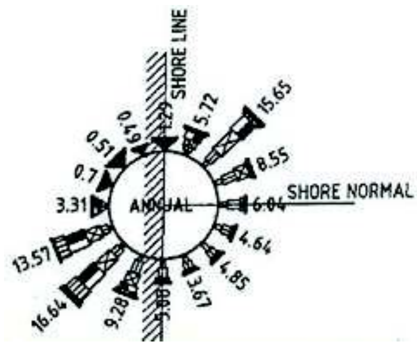
Average wind conditions at the Port are shown below.

Average Wind Conditions at Karaikal

Month	Direction	Avg. Speed (Km/hr)
January	N, NE	18.3
February	NE, E, SE	15.9
March	NE, E, SE	14.2
April	E, SE	13.8
May	S, SW, W	12.7
June	S, SW, W	12.8
July	S, SW	11.7
August	SE, S, SW, W	10.6
September	SE, S, SW, W	9.9
October	SW, W, NW, NE	8.9
November	N, NE, NW	13.8
December	N, NE	14.0

Wind direction is predominant from the West South-West direction during the south west monsoon and North-East direction during North East monsoon. Windrose of Karaikal is given below.

Annual Windrose of Karaikal



Karaikal experiences average wind velocity between 2.7 m/s to 4.2 m/s.

Atmospheric Stability

Stability of atmosphere is its tendency to resist vertical motion or to suppress existing turbulence. This tendency directly influences the ability of atmosphere to disperse pollutants emitted into it from the facilities. In most dispersion scenarios, the relevant atmospheric layer is that nearest to the ground, varying in thickness from a few meters to a few thousand meters. Turbulence induced by buoyancy forces in the atmosphere is closely related to the vertical temperature gradient.

Temperature normally decreases with increasing height in the atmosphere. The rate at which the temperature of air decreases with height is called Environmental Lapse Rate (ELR). It will vary from time to time and from place to place. The atmosphere is said to be stable, neutral or unstable according to ELR is less than, equal to or greater than Dry Adiabatic Lapse Rate (DALR), which is a constant value of 0.98°C/100 meters.

Pasquill stability parameter, based on Pasquill – Gifford categorization, is such a meteorological parameter, which describes the stability of atmosphere, i.e., the degree of convective turbulence. Pasquill has defined six stability classes ranging from `A' (extremely unstable) to `F' (stable). Wind speeds, intensity of solar radiation (daytime insulation) and nighttime sky cover have been identified as prime factors defining these stability categories. Table presented below indicates the various Pasquill stability classes.

Pasquill Stability Classes

Surface Wind Speed (m/s)	Day time Solar Radiation			Night time Cloud Cover		
	Strong	Medium	Slight	Thin <3/8	Medium 3/8	Overcast >4/5
< 2	A	A – B	B	-	-	D
2 - 3	A - B	B	C	E	F	D
3 – 5	B	B – C	C	D	E	D
5 – 6	C	C - D	D	D	D	D
> 6	C	D	D	D	E	D

Legend: A = Very unstable, B = Unstable, C = Moderately unstable, D = Neutral,
E = Moderately stable, F = stable

As the D Neutral and F Stable states of the atmospheres pose greatest hindrance to dispersal of any chemical by advection by natural atmospheric dynamic processes, these stability classes are assumed for consequence analysis for the purpose of conservativeness. Possibility of occurrence of stability class D Neutral, E Moderately stable and F Stable are rare at Karaikal owing to wind speeds generally being lesser than in 5-6 km/hr during day time. Neutral to Stable atmospheric condition may be possible during night time in the monsoon months with overcast skies.

22.3. Vulnerability Profile of the Port

Following aspects of the Port may create threat to safety and wellbeing of the Port infrastructure and life of the people working in the Port and those residing in the vicinity of the Port. A qualitative scoping assessment of the hazards has been presented in Table below.

Vulnerability Profile of the Port

S. No.	Hazard	Cause	Effect	Mitigation
1	Earthquake	Geo-tectonic	Building and marine structure failures - Onsite effects, low casualty potential	a. Construction in accordance with applicable Codes b. DMP
2	Wildfire	Causative factor not present		
3	Tsunami	Geo-tectonic, Oceanographic	Marine structure failures, inundations, loss of hazardous cargo, offsite impacts, high casualty potential	a. Construction in accordance with applicable Codes b. DMP
4	Mud/landslide	Causative factor not present		
5	Dam failure	Causative factor not present		
6	Riverine Floods	Possibility of high flow in the rivers on north and south of the Port possible only in conjunction with Cyclone induced rainfall		
7	Cyclone	Meteorological	Blow away of structures, cargoes and secondary losses, low casualty potential	a. Construction in accordance with applicable Codes b. DMP
8	Flash Floods	Not likely		
9	Thunderstorm and lightening	Not likely		
10	Volcano	Causative factor not present		
11	Extreme weather conditions	Out of purview of Port Intervention		
12	Major Industrial accident/industrial disaster/nuclear disaster	Causative factor not present , out of purview of Port Intervention		
13	Fires (Casue and effect limited and localized to solid cargo handling sections of the existing Port operations)	Spot fire in coal stockpile	Localized effect, economic loss, no casualty potential	a. Sprinkling of water b. Fire fighting system c. SOP d. DMP

S. No.	Hazard	Cause	Effect	Mitigation
		Fire in POL/Hazardous cargo (due to pipeline failures)	Localized effect, economic loss, no casualty potential	a. Design engineering b. Fire fighting system c. SOP d. DMP
		Fire in bulker fuel	Localized effect, no casualty potential	a. SOP b. DMP
		Fire in Fertilizer/FRM	Localized effect, economic loss, no casualty potential	a. SOP b. DMP
14	Explosion	Dust explosion in coal	Localized effect	a. Design engineering b. SOP
15	Toxic release	Liquid Chemical cargo	Localized to medium spread (onsite) effect, casualty potential low	a. Design engineering b. SOP c. DMP
16	Terrorist/disruptive activity	Low likelihood		Port security

22.4. Vulnerability Profile of the Site with respect to Natural Disasters

Sea ports are vulnerable to natural hazards of ocean geo-tectonic and meteorological origins by being the first to bear their brunt. Ports absorb the forces of nature and act as shield for population immediately in their landward shadow, though facing losses due to damage of infrastructure and cargo, disrupted operations and other commercial losses.

Natural Hazard classification of the Project has been carried out in accordance with the Munich Re database of natural hazards. Munich Reinsurance Company Limited (Munich Re) is a leading International Reinsurer which has collected and analysed precise natural disaster data of about two centuries in addition to credible historic records of natural disasters for classification of the world into hazard proneness and exposure ratings. The authoritative database is used by insurance companies worldwide to assess natural hazard risks of projects in specific geographical locations and decide upon the insurance premium amount.

Following natural hazards relevant to the proposed Port have been ranked on the scale of respective severity for the Karaikal region:

A. Earthquake
B. Storm/Cyclone
C. Lightening
D. Flood
E. Tsunami

A. Earthquake

According to Munich Re Earthquake classification, Karaikal falls in the Zone 2 – MM VII which is rated medium. The location falls in earthquake zone II as per IS 1893.

The Port construction will take into account structural stability of the onshore and offshore structures so that they may withstand a high intensity earthquake during construction phase. Port structures will be designed in accordance with IS 1893: Part 1 2002 - Criteria for Earthquake Resistance Design of Structures. Construction activities will be based on technically evaluated and certified plans by established and authorised consultants. Action to be taken during an earthquake has been spelt out in Disaster Management Plan.

22.5. Disaster Management Plan for Storm and Tsunami

This section describes the possibility of occurrence of Cyclone and the related high wind speed, the expected storm surge along the coastal region due to the passage of Cyclone and also the impact in case of occurrence of Tsunami. The possible intensity of occurrence, impact on the coastal form and people, the risk assessment and the Disaster management plan are enumerated.

22.5.1. Storm surge

Occurrence of storm is a common phenomenon in Bay of Bengal during Northeast monsoon particularly in October and November. The region selected for the development is prone to cyclone and storm surges. Based on the data published by IMD in, '*The tracks of Storms and Depressions in the Bay of Bengal and the Arabian Sea-1877 to 2013*', ninety nine storms had occurred in the vicinity. The occurrence of cyclones is more frequent in the month of November followed by October (Table 11.3). If a cyclone with an intensity of 180 kmph develops near the project region it will be followed by heavy wind and continuous rain, in such case the storm surge will be around 1.5 m. The rise in water level combined with high tide period and flood discharge due to heavy rain fall will flood the areas having elevation < 3 m MSL.

Storm surge and the associated effect during the storm

If a cyclone approaches the project region, it will be followed by heavy wind, incessant rain, coinciding with the high tide time, flooding from catchments and the storm surge causing the rise in water level on low lying areas and draining basins.

In addition, during the event of storm, high waves approach the coast and break. The heavy rainfall causing huge flood in the river as well as the opening of inland dams/reservoirs will cause stagnation of flow and inundation leading to killing people and damaging the coastal properties. For e.g., during the disastrous Cyclones like Andhra Pradesh Cyclone (November, 1977), Odisha Cyclone (November, 1999) and Rameswaram Cyclone (December, 1964), thousands of people were killed and there was a huge damage to the coastal properties.

The characteristics of tropical disturbances and the maximum surge heights recorded along the east coast of India are given below:

Characteristics of Tropical disturbances

Tropical disturbances	Wind Speed	
	knots	kmph
Low pressure	< 17	< 31
Depression	17 – 27	32 – 50
Deep depression	28 – 33	51 – 60
Cyclonic storm	34 – 47	61 – 89
Severe cyclonic storm	48 – 63	90 – 119
Severe cyclonic storm with a core of hurricane winds	64 – 119	120 – 221
Super cyclones	≥ 120	≥ 222

Source: IMD, Pune.

22.5.2. Tsunami

Tsunami is a series of wave train generated in the ocean by a hydraulic impulsive force that vertically displaces the water column. Earthquakes, landslides, volcanic eruptions, explosions and even the impact of cosmic bodies taking place in the ocean can generate Tsunami waves with long periods (≈30 min), long wave length (≈ 100 km) with a high velocity of propagation (≈700 km/hr).

Tsunamis are shallow water waves which propagate with phase velocity equal to the square root of the product of the acceleration due to gravity and the water depth. For example, in the Pacific Ocean, where the typical water depth is about 4000 m, the Tsunami wave travels at about 700 km/hr. Because the rate at which the wave loses its energy is inversely related to its wave length, Tsunami not only propagates at high speed, but it can also travel great transoceanic distances with limited energy losses and reach different continents in shorter time i.e., the energy propagating with a Tsunami waves remain nearly constant.

Among the various factors causing the occurrence of Tsunami, the large vertical movements of the earth's crust is more predominant and it can occur at tectonic plate boundaries. The plates that interact along these boundaries are called faults. Around the margins of the faults, the denser oceanic plates slip under the continental plates in a process known as subduction. Such subduction earthquakes are particularly very effective in generating the devastating Tsunamis.

The energy flux due to Tsunami is proportional to its velocity of propagation and height and it remains nearly constant till it reaches the coast. Consequently, the velocity of propagation gets retarded when it enters shallower water and its height gets amplified. Because of this shoaling effect, the Tsunami that is imperceptible at deep ocean close to centimetre height may rise up to several metres near the coast called run up.

When Tsunami finally reaches the coast, the crest of the wave appears as rapidly risen water mass gushing into the coastline as a bore with a crashing velocity of 50 km/hr for more than 10 - 30 min. The trough of the wave will appear as the withdrawal of water mass with same speed back into the ocean swallowing everything on the land and dragging back into the ocean.

Possible intensity of Tsunami: In worst case, if a Tsunami occurs due to the movement of Andaman and Indonesian plate then there will be surging of Tsunami waves with a speed of > 60 kmph into the shore and the run-up will be > 4 m. The gushing of water will sweep and flood the areas having elevation < 3 m MSL.

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 event was witnessed on 26th December 2004 along the Tamilnadu coast, and the water level rise due to this Tsunami along the coast near the project region was around 2.5 m. The backshore in the project region was low and flat and hence the runup of Tsunami has intruded to a longer distance till the East Coast Road.

From the records of tide gauge data during the 2004 tsunami event, the number of high tsunami waves at different places along the coast was observed to vary between 3 to 5 waves with an average period of nearly 2 hours. 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 only for a short duration of nearly 30 minutes.

22.6. Disaster Management Plan

Cyclone, Tsunami and Storm surge are the most destructive forces among the natural devastations. It causes instant disaster and burial of lives and destruction to entire coastal properties. The damage and loss can be minimized if appropriate preparedness plan is formulated. The following statutory guidelines are recommended by National Disaster Management Authority (NDMA) to minimize the impact due to Cyclone, Tsunami and storm.

- Developing sand dunes along the coast with shrubs or Casuarina trees for stabilization of the sand dunes (Tsunami Mound).
- Raising the ground level (above the design water level) with natural beach sand so as to rehabilitate the coastal region.
- Development of coastal forest (green belt) by planting casuarinas and coconut trees along the coastline to cover minimum of about 500 m width of the beach.
- Adopting natural beach nourishment to create steep beach face.
- Creation of sandy ramps at close intervals along the coast.

In addition to the guidelines by NDMA, it is also necessary to adopt various preventive actions in the coastal region of the project site.

Preparedness Plan

The preparedness plan shall contain details about: i) warning that should be given ii) Protective measures to contain the effect of surging water level and iii) Other precautionary measures to be taken. The following measures are the key aspects in the preparedness plan.

i) Coordination with International and National Agencies
ii) Vigilant online monitoring
iii) Emergency Evacuation

22.6.1. Coordination with International and National Agencies

International: Following a series of Tsunamis that hit Japan and North America, an international Tsunami warning network was put in place in 1960s in regions around the Pacific Ocean. This network is administered by National Oceanic and Atmospheric Administration (NOAA), USA. NOAA comprises of hundreds of seismic stations worldwide, which can detect earthquakes that are precursors to Tsunami. This network also includes coastal tide gauges that detect local changes in sea level and sophisticated **DART Buoys** (Deep Sea Assessment and Reporting of Tsunamis buoys) in the Pacific basin, capable of detecting even a centimetre change in water depths in ocean. DART was introduced in 2003. This system consists of a pressure sensor anchored to the sea floor and a surface transmitter. When potentially dangerous seismic activity is detected, the network of DART buoys will detect the small change in the sea level.

Tsunami waves do not induce high surface elevation in Deep Ocean and hence their presence is not felt in Deep Ocean until they reach the shallow water close to coast. If any small yet potentially significant sea level change is noted following a seismic activity, the data are transmitted acoustically to the surface buoys and relayed by satellites to the warning stations. Computer modelling converts the data into a prediction of potential damages for the use of the members of the network.

National: After the 2004 Tsunami affected the Indian sub continent, the following organizations are involved on watch and cautioning the government and public in the event of possibility of occurrence of Tsunami. As a part of Tsunami hazard mitigation, warning systems have been established in India by the coordination of the following organizations.

i) Indian National Centre for Ocean Information Services (INCOIS), Hyderabad.
ii) National Disaster Management Authority (NDMA), New Delhi.
iii) Indian Meteorological Department (IMD), New Delhi.
iv) National Institute of Ocean Technology (NIOT), Chennai.

The contact details of International and National agencies are given below:

Organization	Address	Email ID	Contact Number
INCOIS	Ocean Valley, Pragathi Nagar (BO), Nizampet (SO), Hyderabad - 500090	www.incois.gov.in	+91 - 40 - 23895002
NDMA	NDMA Bhavan, A-1 Satdarjang Enclave, New Delhi, DL 110029.	www.ndma.gov.in	+91 - 11 - 26701700
IMD	Mausam Bhavan, Lodi road, New Delhi, DL 110033.	www.imd.gov.in	+91- 11 - 24699216
NIOT	Velachery – Thambaram main Road, Narayanapuram, Pallikaranai, Chennai 600100.	www.niot.res.in	+91 - 44 - 66783300
NOAA	1401, Constitution Avenue, NW. Room 5128, Washington,USA. DC 20230	www.noaa.gov	-
Andaman Nicobar Administration	Andaman & Nicobar Administration o/o secretary (GA), Secretariat, Port Blair.	webmaster.and@nic.in	+91- 3192 - 236572

INCOIS in collaboration with NIOT has deployed DART buoys at 3 locations in the deep ocean along the fault plane of Andaman plate and Indonesian plate. The data transmission system has been effectively linked through satellite with 24 hours online monitoring at NIOT, Chennai.

The online monitoring is capable of raising alarm in case of instantaneous change in surface elevation exceeding centimetre which can be caused by the generation of Tsunami. IMD interacts with the above institutions and takes the responsibility of broadcasting the disaster through various Medias. In case of a Tsunami, the warning is usually broadcast based on the earthquake occurred in the nearby ocean. Irrespective of *definite occurrence* of Tsunami, the *possibility to occur* is also considered as equally vulnerable and accordingly the warning news is instantly flashed through Radios and TVs. The notification is followed by orders from the local Government Authorities on reinforcing evacuation, prohibition to enter the demarcated risky zone and mobilizing facilities for easier evacuation and augmenting medical facilities.

There are a variety of evacuation notification systems in case of Cyclone, Tsunami and Storm surge. They include sirens, weather radio, Emergency Alert System, Telephones, Emergency Weather Information Network etc. In each system, it should be noted that the application and message is consistent as well as continuous with repetition of messages with periodicity at short time interval. It should be ensured that the warning reaches immediately to all people prone to the devastation.

22.6.2. Vigilant online monitoring

The time at which the cyclone, storm surge or Tsunami may reach the coast can be predicted with sufficient lead time. The destruction can be minimized if the coastal populations are warned and evacuated to elevated place and inland in time. Therefore keeping vigil on the warning is the very important aspect in protecting the lives.

PPGC should have an agreement with NIOT/INCOIS/IMD by enrolling themselves as the potential users. Live contact should be kept with the organizations indicated above to transmit the instant warning on occurrence of cyclone, Tsunami and storm surge. A vigilant team must be created and they should be deputed to the above organizations to attend the training programs and to understand the method of monitoring and the kind of emergency preparedness. The vigilant team must monitor the warning systems around the clock.

The vigilant team should have proper knowledge about the warning systems and should have attended the training programs conducted by the Tsunami warning centres. The training should be given periodically to update the system and methods of warning. The team should take the responsibility of giving immediate warning to the people in and around the power plant in case of Tsunami and they have to undertake the Emergency Preparedness Action. Safety drills should be conducted periodically.

Operational and emergency preparedness procedures should be planned meticulously in order to act on the warning and to disseminate it rapidly and effectively to the public.

22.6.3. Emergency Evacuation

Evacuation of people from risk areas is the first priority when early warning is received or the natural warning sign indicates the immediate arrival of cyclone, Tsunami wave or rise of storm surge.

Evacuation plan describes the time span available before and during the Tsunami or storm surge event. When facing local threat, evacuation procedures most possibly will have the character of a ‘runaway effort’ and people should not expect to receive much institutional support. The primary objective should be bringing as many people as possible out of the reach of the wave’s impact to safe or ‘relatively safe’ areas. Therefore necessary steps have to be taken in advance to enable and support the community at risk to protect themselves at any time.

22.6.4. Mitigation against Tsunami and storm

Although the impact of Tsunami and storm is disastrous, the impact can be minimized by adopting the key components of mitigation measures. It was noticed during December 2004 Tsunami that the places located behind the highly elevated dunes, forest department planted Casuarina tress, dense plantations, Mangrove forests, offshore coral reefs, long salt pan heaps etc., were considerably protected. These areas experienced very low damage without causing death of the people. The kinematic energy of the Tsunami waves riding into the land gets dissipated due to these natural barriers. Thus the nature gives the scientific understanding of preparing the energy dissipating obstruction on the shore that can greatly protect the people and property against Tsunami.

The mitigation measures to be taken normally vary according to the local site conditions. Accordingly, in general case, the following mitigation measures are seen to be effective for the proposed project:

i) Bio Shield
ii) Construction of Tsunami mound
iii) Construction of Tsunami/Cyclone Shelter

Bio Shield

It is a general belief that natural formations such as coral reefs, grass beds, coastal vegetations such as mangroves, estuaries and deltas of river mouths and flood plains play an important role in dissipating the forces of Tsunami waves.

A bio-shield formed by planting a vegetation belt along coastlines would protect the region against coastal storms, cyclones and Tsunamis. The plantations could absorb the force of severe storms and Tsunamis, and it could act as a 'carbon sink' by absorbing emissions of the greenhouse gas. The coastal front comprises beaches, sand dunes, head lands, creeks/river, rocky cliffs. The coastal vegetation also has a very important role in stabilizing and trapping marine sediments and forming a protective buffer between the land and the sea.

Mangroves: Mangroves are often recognized as the best defenses against wind, waves and erosion by deflecting and absorbing much of the energy of winds hence, Forest department encourages afforestation of Mangroves. Because of planting suitable species of mangroves along the coastline, during 2004 Tsunami, the fishing hamlets located on the leeward side of the Pitchavaram were totally safe without any traces of Tsunami. Therefore, Karaikal Port may explore the suitability of their location to plant mangroves in consultation with Forest department.

Planting of Casuarinas: *Casuarina equisetifolia* is the most popular farm forestry tree in the coastal lands of Mainland India. The Casuarinas planted along the east-coast protected the region from Cyclone in November, 1999. Planting Casuarinas along the coastal front would provide substantial protection to the project region from the impacts of storm surges and Tsunami. Hence the water level rise during a Tsunami or storm will not have any major impact in this region.

Transplanting vegetation will not prevent the natural process of erosion, but it will accelerate natural recovery after damage. Additional works are often necessary to increase the potential for success. Thatching and beach recycling will assist in the accretion of sand, and will provide minor protection from Tsunami waves and will reduce damage due to trampling. Once grasses are well established they may well become self-sustaining, although any storm erosion damage will need to be rapidly made good.

Construction of Tsunami Mounds

One of the natural methods of protecting the shore from the natural disasters like Tsunami and Storm surge is to construct Tsunami Mounds which will effectively help to dissipate the energy of Tsunami surge and protect the leeward side.

In order to protect the project region against Tsunami destruction, it is proposed to construct Tsunami Mounds along the low lying coastal belt of < 3 m MSL. The top level of the mound can be raised to 5 m above the existing ground level. The mound can be constructed as 75 m long with 50 m gap in between. The mounds can be constructed 100 m on the landward side from the HTL.

The mounds can be constructed with beach sand or any inland native sediments/rocks. The mounds should be erected without felling trees if they exist in this region. It is very important that the Tsunami Mounds are constructed in a way that will not affect the existing trees along the coastal front.

The faces of the mounds can be planted with dune creeper like *Ipomea pes-caprae, Avicennia sp*. Also Casuarina trees can be planted in between and within the mounds. Coconut trees can also be planted which will add protection against Tsunami and also cyclone. Planting the dune creeper is very essential to minimize the wind drift of the sand from the mounds.

Tsunami/Cyclone shelter

The warning and disaster evacuation system is the most important element in ensuring the public's safety. Suitable shelter must be constructed in order to evacuate the people in case of emergency.

The time of arrival provides only a limited time for people to move safely to the shelter. Two Cyclone shelters per cluster must be provided along the region of port. After the warning/siren is given, the government authorities will start the evacuation and the people living in the interior area will have to be moved to the Cyclone shelter built along the coastal stretch.

The location of the shelter must be chosen such that it is easily accessible for workers in industries and for the public living in the vicinity. Maintenance of these shelters and the access roads and keeping them in good condition throughout the year to its functional requirements is very important.

The shelter should be equipped with water supply, toilets, first aid centre, Generators, ration storing rooms and minimum cooking facility**.** The shelters should be designed to bear the workers in the industry and the people living in the vicinity. The stairway should be wide enough (>3 m) for the rushing people to climb the top without confusion and struggle. It should have an elevated handrail with proper light and ventilation. There should not be any windows on the seaward side to avoid the entry of water due to rising Tsunami wave. But enough windows and other ventilation measures must be provided on the leeward side of shelters.

Escape routes: The availability of safety zones that can be used as evacuation sites within walking distance must be inspected. People can be evacuated to hills over ten metres in elevation or the deep inland (>1 km) out of coastal inundation. Good elevated roads should be laid along the escape route to safe places which can be waded even during flooding.

Emergency alarm from Government Institutions

Karaikal Port should jointly make understanding with NIOT/INCOIS/NDMA and a communication link should be established through satellite or GPRS. In case of emergency if warning is given at the above mentioned institutions, they can instantly activate the alarm at the industries through satellite/GPRS and give caution to the vigilant team so that they can immediately start the rescue operation.

23. ASSESSMENT OF RISKS IN HANDLING LNG

23.1. Risks due to Handling of LNG

A 05 MMTPA LNG import terminal is proposed in the Phase III development of the Port. The Terminal will have mandate comprising LNG unloading, LNG storage, LNG re-gassification into natural gas, and natural gas send out into country's gas grid. Salient features of the Terminal are discussed in **Chapter 4**. The Terminal will be a jetty-moored FSU based LNG import facility driven by the following considerations:

- low capital investment,
- very low land requirement,
- quick set up in event of early joining of gas JV partner and favourable gas procurement contract

23.2. Identification of Hazards – Loss of Containment of LNG

LNG as pure material and under confinement is non-combustible due to low temperatures and being too rich to support combustion. All fire related risks of LNG are associated with natural gas produced due to vaporization of LNG.

23.2.1. Property of LNG

LNG is imported and stored as a cryogenic liquid. LNG contains methane between 80% ? 95%, remaining ethane, less than 1% of propane, with helium, nitrogen and carbon dioxide in traces (relative composition varying depending on the gas field of origin). Properties of LNG are as follows.

- LNG Density: 424.49 kg/m^3 (lighter than water)
- LNG boiling point: -161^0 C
- Natural gas has a density of 0.8 kg/m^3, at 20^0 C under one bar pressure
- Flammability limits

- Lower Flammability Limit (LFL): 5%,
- Upper Flammability Limit (UFL): 15%
- 1 m^3 LNG = 600 m^3 of gas at 20°C

LNG as a cryogenic liquid is a relatively safe material to handle under insulated containment. LNG when in open and under conditions of heat ingress from ambient or conductive sources vaporises into natural gas which is flammable in a narrow range of concentration. Properties of LNG that have safety implications include auto-ignition temperature, low temperature, heat of vaporisation, flammability limits, heat transfer rate of boiling liquid and specific gravity. The average auto ignition temperature of pure methane at atmospheric pressure is 537 ^{0}C, which is quite high, and rare to be encountered in typical normal storage and handling conditions. The lower and upper flammability limit of methane in air is 5% & 15% by volume. Methane being a light and buoyant gas disperses (both by advection and diffusion) rapidly under normal atmospheric conditions and dilutes beyond 5% within few meters of the point of release with a vapour cloud incapable to sustain ignition. LNG under confinement cannot ignite.

23.2.2 Handling of LNG in the Terminal

LNG will be unloaded from the LNG carrier to the FSRU at the rate of 710 m^3/hour by a 170,000 m^3 LNG carrier (and upto 850 m^3/hr for a 267,000 m^3 LNG carrier) and will depending on the vessel size and distance of the vessel to the shore. In order to maintain a positive pressure, some of the vapour generated in the storage tank will be returned to the LNG vessel during unloading operations. The boil-off gas generated due to heat leak will be passed through BOG compressor (used to increase the pressure of boil off gas) and recondensor where LNG will be injected to liquefy the boiloff gas. If there is not enough LNG send-out to absorb the boil off vapour then the vapour will be compressed to pipeline pressure, or flared or vented.

The submerged pumps provided in each tank will pump will the LNG to the recondensor and from recondensor, a high pressure (HP) pump will boost the pressure to send to the vapourisers. The regasification process includes several vapourisers laid out in parallel to gradually increase the temperature to convert from the liquid to gas.

The regasified natural gas will be metered at a metering station at the terminal. The gas will be delivered to the national gas grid pipeline operated by GAIL through high pressure feed pipelines; the pressure in the feed pipeline will be achieved through multi-staged high head send out pumps.

23.2.3. Identification of Hazard Scenarios and Consequence Analysis

The RA of the FS-R-U is based on the following identified release scenarios from possible hazardous sources listed below.

The consequence analysis has been carried out for Pasquill and Gifford atmospheric stability class ‘D – neutral’ and ‘F – stable’.

Identification of Hazard Scenarios

Sr.	Failure Case	Failure Mode Type	Consequence
1	25 mm leak in 16” DCMA LNG unloading arm or LNG STS Cryogenic Hose of the FSU	Loss of holdup of one arm, LNG drained into concrete impoundment basin, evaporative dissemination, vapour cloud meeting with a source of ignition after one minute	Pool fire (**Scenario 01** - stability class D, **Scenario 02** - stability class F). As the site of release is not a congested area, formation of ignitable vapour cloud followed by UVCE is not possible.
2	25 mm leak (flange or pipeline length) on 48’ diameter insulated LNG berth-to-tank transfer pipeline operating at 08 Bar-g.	Loss of 40% holdup of pipeline for the first 10 minutes until intervened, LNG drained on ground/water, evaporative dissemination, vapour cloud meeting with a source of ignition after five minutes	Pool fire (**Scenario 3** - stability class D, **Scenario 04** - stability class F). UVCE is not supported for typical, open-to-air FS-R-U setup – not congested setting. Application override – congested setting assumed. UVCE (**Scenario 5**, - Stability class D, **Scenario 6**, - Stability class F)

Sr.	Failure Case	Failure Mode Type	Consequence
3	25 mm leak on LNG LP pump header (flange or pipeline length) 20" diameter LNG pipeline operating at 12 Bar-g.	Loss of holdup of 80 m line, LNG drained into concrete impoundment basin, evaporative dissemination, vapour cloud meeting with a source of ignition after five minute	Pool fire (**Scenario 07** - stability class D, **Scenario 08** - stability class F).
			UVCE is not supported for typical, open-to-air LNG terminal – not congested setting. Application override – congested setting assumed. UVCE (**Scenario 09**, - Stability class D, **Scenario 10**, - Stability class F)
4	5 mm leak on exposed 26" NG send out pipeline (pipeline length) operating at 90 Bar-g.	NG jet leak meeting a source of ignition,	Jet fire (**Scenario 11**, - Stability class D, **Scenario 12**, - Stability class F)

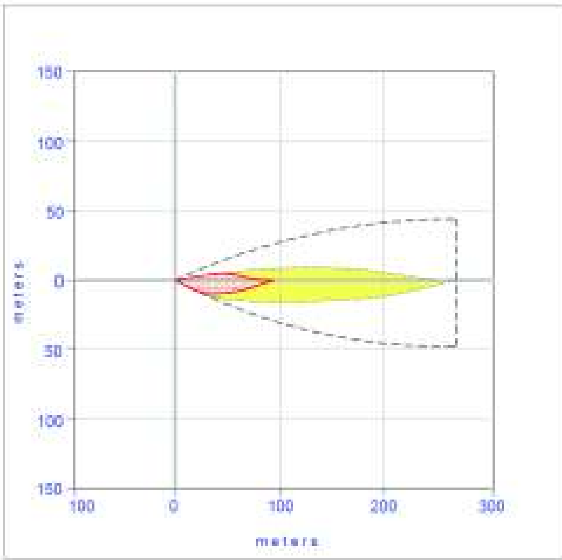
Quantity of LNG spill leaked from the terminal pipelines will comprise be full or part holdup of the pipeline. This may range from about 15 kl (from a 16" DCMA/LNG STS cryogenic hose collected in an impoundment basin/over concrete deck of the unloading platform or on the steel deck of the FSU) to several hundred kl (from the 48' diameter insulated LNG berth-to tank transfer pipeline). Spill of such size will generate NG vapours in quantities larger than what can sustain flash fire.

As the terminal will be an open-to-air facility with lack of congestion and high air exchange rates (owing of large wind fetch of the sea), possibility of concentration of NG vapours in pockets leading to a UVCE is not likely. However congested conditions have been assumed in the model and UVCE scenario have been run.

Since the LNG tanks on the FSU will store LNG under normal pressure under refrigerated condition, BLEVE on the tanks is ruled out.

Scenarios of Jet fire are possible on pipelines/sections under high pressure, which have been modelled for NG send out pipeline.

Scenario 01 – 25 mm leak in 16” DCMA unloading arm/LNG STS Cryogenic hose of the FSU, pool fire, Stability Class D

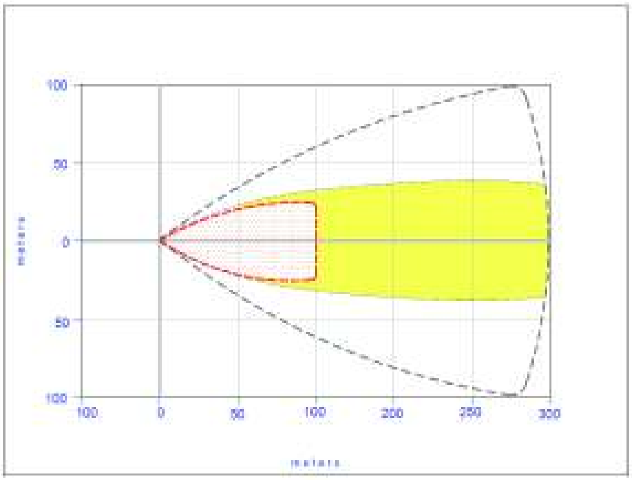


Thermal radiation from pool fire

Red : 83 meters --- (30000 ppm = 60% LEL = Flame Pockets)

Yellow: 274 meters --- (5000 ppm = 10% LEL)

Scenario 02 – 25 mm leak in 16” DCMA unloading arm, pool fire, Stability Class F

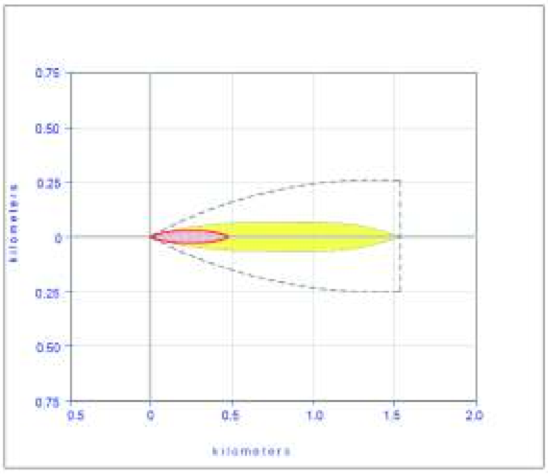


Thermal radiation from pool fire

Red : 101 meters --- (30000 ppm = 60% LEL = Flame Pockets)

Yellow: 299 meters --- (5000 ppm = 10% LEL)

Scenario 03 – 25 mm leak in 48" LNG Ship to Tank pipeline, pool fire, Stability Class D

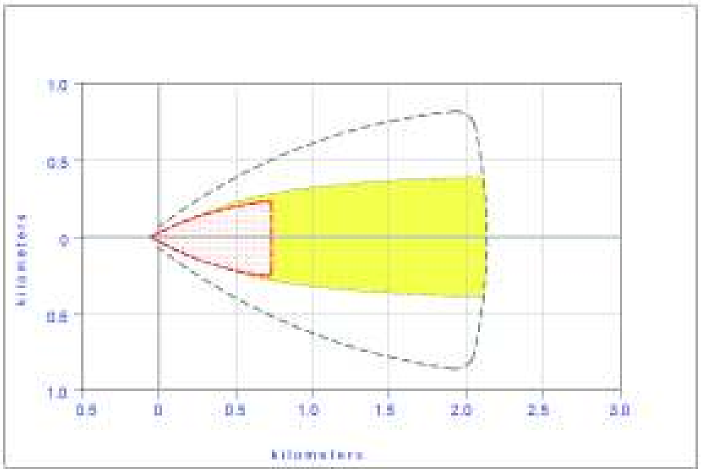


Thermal radiation from pool fire

Red : 453 meters --- (30000 ppm = 60% LEL = Flame Pockets)

Yellow: 1.6 kilometers --- (5000 ppm = 10% LEL)

Scenario 04 – 25 mm leak in 48" LNG Ship to Tank pipeline, pool fire, Stability Class F

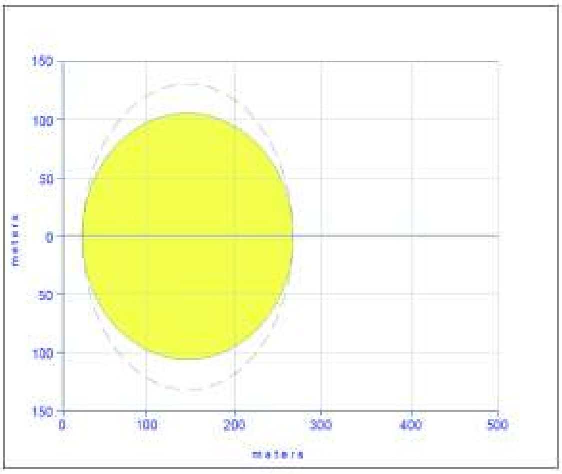


Thermal radiation from pool fire

Red : 730 meters --- (30000 ppm = 60% LEL = Flame Pockets)

Yellow: 2.1 kilometers --- (5000 ppm = 10% LEL)

Scenario 05 – 25 mm leak in 48” LNG Ship to Tank pipeline, UVCE, Stability Class D



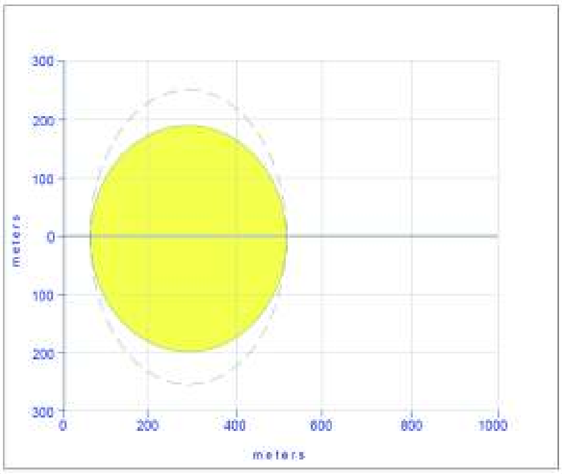
Blast overpressure

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: LOC was never exceeded --- (3.5 psi = serious injury likely)

Yellow: 257 meters --- (1.0 psi = shatters glass)

Scenario 06 – 25 mm leak in 48” LNG Ship to Tank pipeline, UVCE, Stability Class F



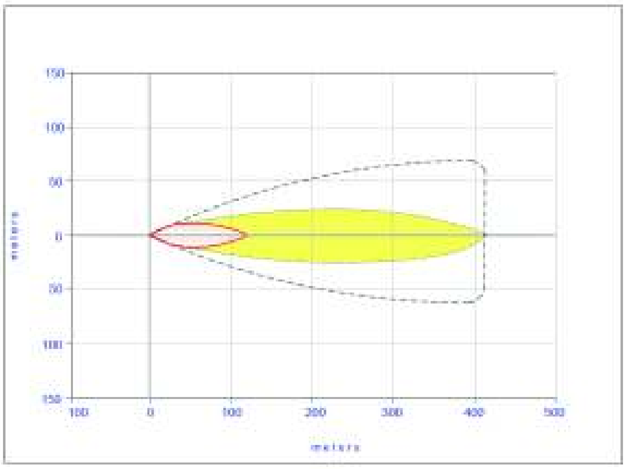
Blast overpressure

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: LOC was never exceeded --- (3.5 psi = serious injury likely)

Yellow: 455 meters --- (1.0 psi = shatters glass)

Scenario 07 – 25 mm leak in 20” LNG LP Pump line, pool fire, Stability Class D

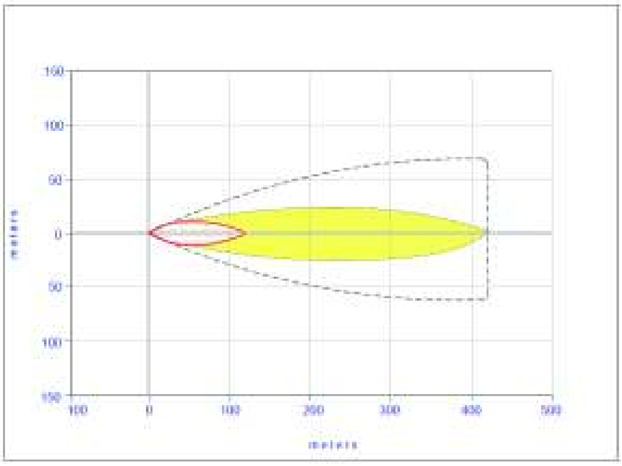


Thermal radiation from pool fire

Red : 125 meters --- (30000 ppm = 60% LEL = Flame Pockets)

Yellow: 434 meters --- (5000 ppm = 10% LEL)

Scenario 08 – 25 mm leak in 20” LNG LP Pump line, pool fire, Stability Class F

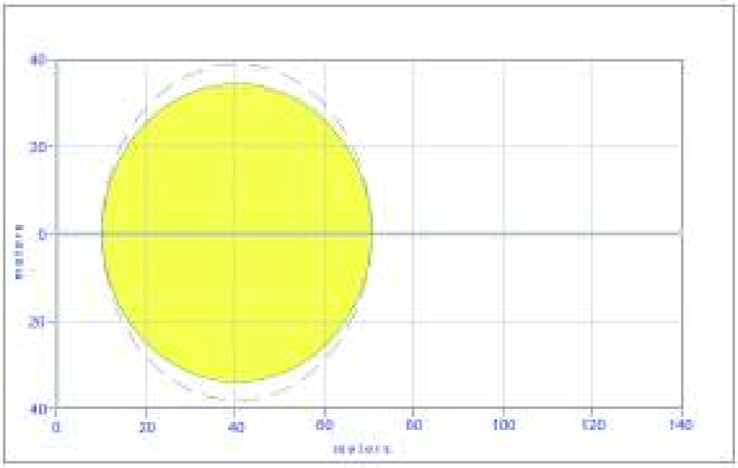


Thermal radiation from pool fire

Red : 167 meters --- (30000 ppm = 60% LEL = Flame Pockets)

Yellow: 522 meters --- (5000 ppm = 10% LEL)

Scenario 09 – 25 mm leak in 20" LNG LP Pump line, UVCE, Stability Class D



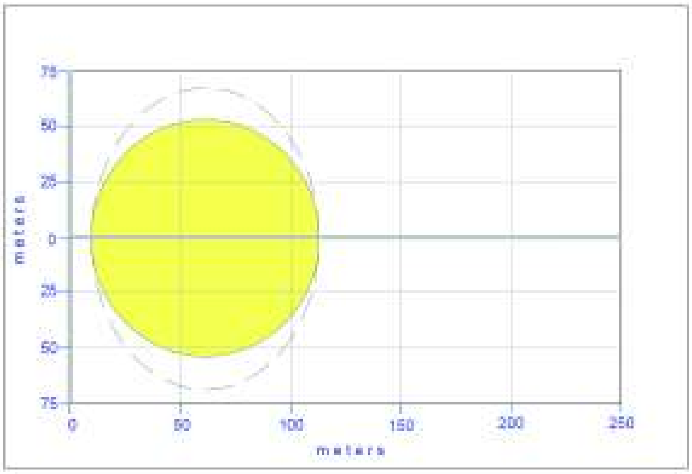
Blast overpressure

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: LOC was never exceeded --- (3.5 psi = serious injury likely)

Yellow: 72 meters --- (1.0 psi = shatters glass)

Scenario 10 – 25 mm leak in 20" LNG LP Pump line, UVCE, Stability Class F



Blast overpressure

Red : LOC was never exceeded --- (8.0 psi = destruction of buildings)

Orange: LOC was never exceeded --- (3.5 psi = serious injury likely)

Yellow: 111 meters --- (1.0 psi = shatters glass)

Scenario 11 – 1 cm leak in 26” NG send out line, jet fire, Stability Class D

Max Flame Length: 1 meter

Max Burn Rate: 69.6 kilograms/min

Total Amount Burned: 230 kilograms

Thermal radiation from jet fire

Red : less than 10 meters (10.9 yards) -- (10.0 kW/(sq m) = potentially lethal within 60 sec)

Orange: less than 10 meters (10.9 yards) -- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)

Yellow: less than 10 meters (10.9 yards) -- (2.0 kW/(sq m) = pain within 60 sec)

Scenario 12 – 1 cm leak in 26” NG send out line, jet fire, Stability Class F

Max Flame Length: 1 meter

Max Burn Rate: 71.4 kilograms/min

Total Amount Burned: 236 kilograms

Thermal radiation from jet fire

Red : less than 10 meters (10.9 yards) -- (10.0 kW/(sq m) = potentially lethal within 60 sec)

Orange: less than 10 meters (10.9 yards) -- (5.0 kW/(sq m) = 2nd degree burns within 60 sec)

Yellow: less than 10 meters (10.9 yards) -- (2.0 kW/(sq m) = pain within 60 sec)

Consequence distances for the scenarios for Stability Class D and F are given below.

Sr.	Scenario	Consequence	Stability Class D	Stability Class F
1	01 and 02 – 25 mm leak in 16” DCMA unloading arm/LNG unloading arm or LNG STS Cryogenic Hose of the FSU	Pool fire	60% of LEL = Flame pocket – 83 m	60% of LEL = Flame pocket – 101 m
2	03 and 04 – 25 mm leak in 48” LNG Ship to Tank pipeline	Poo, fire	60% of LEL = Flame pocket – 453 m	60% of LEL = Flame pocket – 730 m
3	05 and 06 – 25 mm leak in 48” LNG Ship to Tank pipeline	UVCE	Blast overpressure 1.0 psi = shatters glass – 275 m	Blast overpressure 1.0 psi = shatters glass – 455 m
4	07 and 08 – 25 mm leak in 20” LP LNG line	Pool fire	60% of LEL = Flame pocket – 125 m	60% of LEL = Flame pocket – 167 m
5	09 and 10 – 25 mm leak in 20” LP LNG line	UVCE	Blast overpressure 1.0 psi = shatters glass – 72 m	Blast overpressure 1.0 psi = shatters glass – 111 m

23.3. Failure Frequency associated with Loss of Containment

Quantitative risk is a product of failure frequency and consequence of the scenario. Failure frequencies of plant elements in the LNG terminal are given below.

Sr.	Plant component	Failure Frequency per year
1.	16”unoading arm, 25 mm hole	5.0 E -7
2.	48” unloading header, 25 mm hole	2.5 E -7
3.	20” LP Pump header, 25 mm hole	6.0 E -7
4	26” send out heder, 25 mm hole	5.0 E -7

It may be observed from the above failure frequency data that the likelihood of an incidence occurring in the 40 years assumed lifetime of the LNG terminal is extremely rare.

23.4. Risks due to Vessel Collision and Grounding

Vessel collision or grounding, onboard fire, explosion etc. are the consequences which may threaten integrity of the vessel, can endanger cargos on the vessel involved in the incident and may result in release of cargo in the sea. Vessel collision and grounding are more frequent and often result from out of control vessel movement.

The frequency of vessel collision is governed by the frequency of vessel encounter and the probability of collision given an encounter. From the records of accidents maintained at several major ports worldwide it has been considered that collision frequency is proportional to the square of the traffic density and is directly proportional to the number of encounters. Casualty statistics maintained at UK ports indicate that collisions involving vessels account for 7% of all accidents and represent 0.024 for every 1000 vessel movements. Accident figures for India would be still lower considering lack of congestion in Indian ports.

The proposed all weather Port at Karaikal has a channel extending from the fairway from natural depths of 20.0 m or more so that the vessels of any other Port do not intermingle, thus eliminating ship interactions. The channel has been designed following PIANK Guideline (which considers safety as the primary requirement for selection of the channel width. Tug assistance will be provided in the channel and basin for safe manoeuvring and berthing.

Not all ship accidents result in spills. International Tank Owners Pollution Federation Limited (ITOPFL) has maintained a database of oil spills from tankers and other ships. Spills are categorized by size (< 7 t, 7 -700 t and> 700 t). Information is held for about 10000 accidents. Their data-base indicates that the vast majority of spills (83%) fall in the smallest category (< 7 t) and < 3% of accidents result in large spills. Hence, the probability of a large spill occurring along this coastal area is low.

Bulk release of liquid/refrigerated cargo can also result if a tanker goes aground rupturing cargo holds. The data-base of ITOPFL reveals that 34.4% and 28.9% of large spills (> 700 t) have occurred due to groundings and collisions respectively. Channel length and its width are the major factors controlling grounding in inshore waters. The ships are vulnerable to grounding in long and narrow channels particularly those which have several bends. From grounding incidents at several ports it has been considered that the channel length to width ratio gives a good indicting probability of encountering a grounding obstruction. Thus, the grounding frequency increases with increasing length of the channel and decreases with increasing width for a given length. The grounding frequency may therefore be expressed as:

$$GF = K \times L/W$$

Where G = grounding frequency

L = channel length

W = effective channel width

K = constant (normally taken as 1×10^{-5} per movement).

Hence, depending on frequency of ship movement the grounding probability increases or decreases. In case of the Karikal Port, there will be no bends in the navigation channel and it will be dredged and maintained at (-) 19.0 m CD, practically eliminating grounding incidences inside the Port waters. In addition – “no movement of any other ship in the channel while LNG vessel is moving in the channel” - will be observe as an operational protocol thus practically eliminating LNG vessel interaction with any other vessel in the Port. All LNG transfer will be carried out under a tug at disposal.

24. DISASTER MANAGEMENT PLAN

24.1. Introduction

Emergency/disaster is an undesirable occurrence of events of such magnitude and nature that adversely affect operations, cause loss of human lives and property as well as damage to the environment. Coastal infrastructure is vulnerable to various kinds of natural and manmade disasters. Examples of natural disaster are flood, cyclone, tsunami, earthquake, lightning, etc., and manmade disasters are like major fire, explosion, sudden heavy leakage of toxic/poisonous gases, civil war, nuclear attacks, terrorist activities, sabotage, etc. It is impossible to forecast the time and nature of disaster, which might strike a common user infrastructure. An effective disaster management plan helps to minimize the losses in terms of human lives, assets and environmental damage and resumes working condition as soon as possible.

Disaster Management Plan (DMP) forms an integral part of any risk assessment and management exercise; any realistic DMP can only be made after proper risk assessment study of the activities and the facilities provided in the installation. Correct assessment and evaluation of the potential hazards, advance meticulous planning for prevention and control, training of personnel, mock drills and liaison with outside services available can minimize losses to the facility's assets, rapidly contain the damage effects and effectively rehabilitate the damage areas.

24.2. Location of the Port, Surrounding Areas and Population

The LNG FS-R-U berth is proposed beyond 1.5 km from the boundary of Port, separated by the Port basin and southern breakwater. In an event of fire on the berth or on the pipeline corridor between the Pump House and the liquid berths only Port personnel present within 50 to 100 m of the of the point of release will be effected. These persons will be trained to quick leave the site of incidence and let the Port Fire and Safety Department personnel take charge of the situation. No incidence in the Port has likelihood of offsite consequences.

24.3. Approaches to Disaster Management Plan

Modern approach to disaster management involves the following two steps:

- Risk Identification
- Risk Evaluation

Risk identification entails:

- Identification of hazardous events in the installation, which can cause loss of capital equipment, loss of operation, threatens health and safety of employees, threatens public health and damage to the environment
- Identification of risk important processes and areas to determine effective risk reduction measures

Risk evaluation involves calculation of damage potential of the identified hazards with damage distances, which is then termed as consequence analysis as well as estimation of frequencies of the events.

A hazardous area with different hazard scenarios and their damage potential with respect to fire has already been mentioned in Consequence Analysis chapter. However, failure rate of different hazard scenarios has been discussed broadly based on data available for similar incidents outside India.

Probability of any hazardous incident and the consequent damage also depends on:

- Wind speed
- Wind direction
- Atmospheric stability
- Source of ignition and also
- Presence of Port assets & population exposed in the direction of wind.

Action plan depends largely on results of risk assessment data and may include one or more of the following:

- Plan for preventive as well as predictive maintenance
- Augment facilities for safety, fire fighting, medical (both equipment and manpower) as per requirements of risk analysis
- Evolve emergency handling procedure both onsite and offsite
- Practice mock drill for ascertaining preparedness for tackling hazards/emergencies at any time of the day

24.4. General Nature of the Hazard

Operation of the Port involves two types of cargoes which may pose operational hazards: bulk solid cargo, mainly coal and Fertilizer/FRM, and liquid cargoes including POLs and chemicals.

Coal and Fertilizer/FRM cargoes have moderate to low fire hazard potential localized to the site of storage. Incidences of fires in these cargoes can be easily avoided and controlled if recommended practice for their handling is followed.

Incidences of pool fire are possible in events of loss of inventory from the Port pipeline which is laid above grade. While vapors evaporating from a pool of low-vapor pressure hydrocarbons and chemicals may be explosive under conditions of congestion, owing to low level of ambient confinement and high wind conditions, explosions are not possible in the Port.

Any small fire in the Port near the POL and chemical pipelines, if not extinguished immediately, can cause large scale damage and may have a cascading effect. Hence, liquid berths and pipelines require:

- A quick responsive containment and control system requiring well planned safety and fire fighting system
- Well organized trained manpower to handle the process equipment & systems safely
- Well trained personnel to handle safety and fire fighting equipment to extinguish fire inside the installation promptly as well as tackle any type of emergency

24.5. Designated Hazardous Areas of the Port

Depending on the kind of operation, hazardous area within the battery limit of the Port may be subdivided into the following sections:

Activities	Place
a) Pumping of POL and chemical	Pump house
b) Pipeline conveying above grade	Pipeline corridor
c) Ship shore transfer	Liquid berths

Since some of the POL products are highly inflammable and explosive, fire hazard exists in all these areas. However, risk varies due to varying inventory of the material and operations involved.

The risk potential of the above areas has been discussed in the **Chapter 19** as in Consequence Analysis. The maximum credible hazard scenarios are found to be gasket failure, mechanical seal failure of pumps, loading arm failure on the liquid berths and small bore pipe line failure, etc.

Apart from the above, fire cannot be ruled out in substation & MCC as well as in other places from short circuiting and also secondary fire from nearby industries.

However, major accident may occur in the Port and call for emergency/disaster.

24.6. Disaster Preventive and Pre-Emptive Measures

After identification and assessment of disaster potential the next step in disaster management plan is to formulate and practice the preventive measures. Proper preventive and pre-emptive measures can reduce the disaster potential to a minimum.

Preventive and pre-emptive measures are taken from the design stage itself. Preventive measures which are to be taken during design stage:

- Layout of the Pump House, pipeline corridor and liquid berths with sufficient safety distances
- Avoidance of low lying areas, which facilitate accumulation vapors of flammable material
- Use of proper material of construction for equipment and piping
- Use of SRVs & Pop-off valves of proper size and capacity
- Use of automatic as well as manual isolation valves at proper places
- Proper instrumentation with interlock, trip and alarm system
- Installation of vapor and heat detectors, and fire water system (sprinkler, hydrants, deluge valves, etc.) at proper places to detect release of flammable inventory and taking necessary automatic/manual action

Apart from the above precautions in the design stage, procurement of equipment are to be done strictly as per specification/code and fabrication/erection of the equipment are to be done under supervision of competent and experienced personnel. Some of the preventive & pre-emptive measures, which are to be taken during operational life are as follows:

a) Safety Measures

Following safety tips should always be borne in mind while working in the Port to avoid emergency & hazardous situation.

- Follow specified procedures and instructions for start-up, shut down and any maintenance work
- Follow permit to work system
- Identify correctly the part of the pipeline in which work is to be done
- Isolate the part, machine properly on which work is to be done
- Release pressure from the part of the pipeline on which work is to be done
- Remove flammable liquid/gases thoroughly on which work is to be done
- Use non sparking tools

b) Port Inspection

Apart from planned inspection, checks and tests should be carried out to reduce failure probability of containments.

- Pump house and pipeline during both their construction and operational life
- Pressure relief valves to avoid fail danger situation. The safety relief valves connected with pumps and piping should be checked and calibrated at regular intervals according to specification
- Critical trips, interlocks, & other instruments should be checked regularly to avoid fail danger situation
- Vapor detection, heat detection & fire fighting system should be checked regularly to ensure proper functioning for avoiding emergency situation
- Lightning protection system

c) Performance or Condition Monitoring

A systematic monitoring of performance or condition should be carried out especially for pumps and associated equipment, which may be responsible for serious accidents/disaster in case the defined limits are crossed.

- Vibration, speed & torque measurements for pumps, etc.
- Thickness and other flaw measurements in metals of pipelines, etc.

Many types of non-destructive testing/condition monitoring techniques are available. X-ray radiography, acoustic emission testing, magnetic particle testing, eddy current inspection techniques etc. are used for detection of flaws and progression of cracks in metals. The above condition monitoring techniques should be applied regularly by internal/external agencies. Immediate corrective measures should be taken if any flaws are detected.

d) Preventive Maintenance

A schedule for preventive maintenance for moving machineries like pumps, compressors, etc. should be prepared based on experience in other similar operations as well as instruction of the suppliers. The schedule should be followed strictly during operation as well as planned shut down period.

e) Entry of Personnel

Entry of unauthorized personnel will be strictly prohibited inside the Port liquid cargo battery limit. The persons entering the liquid cargo area will not carry matches, lighters, Mobiles, Cameras etc. and hot work will not be permitted except in designated areas with utmost precaution.

24.7. Disaster Control/Response Plan

Disaster may arrive without any warning, unexpectedly in spite of all precautions & preventive measures taken. However, an efficient control/response plan can minimize the losses in terms of property, human lives and damage to the environment can be the minimum.

24.7.1. Objectives of the Plan

The plan should be developed to make best possible use of the resources at the command of the Port as well as outside resources available like State Fire Services, Police, Civil Defence, Hospitals, Civil Administration, neighbouring institution and industries.

It is not possible for the Port to face a disaster single handed and calls for use of all available resources in the surrounding area. Advance meticulous planning minimizes chaos and confusion, which normally occur in such a situation and reduce the response time of Disaster Management Organization.

The objectives of Disaster Management Plan are:

- To contain and control the incident
- To rescue the victim and treat them suitably in quickest possible time
- To safeguard other personnel and evacuate them to safer places
- To identify personnel affected/dead
- To give immediate warning signal to the people in the surrounding areas in case such situation arising
- To inform relatives of the casualties
- To provide authoritative information to news media and others
- To safeguard important records & information about the organization
- To preserve damaged records & equipment needed as evidence for any subsequent enquiry
- To rehabilitate the affected areas
- To restore the facilities to normal working condition at the earliest

24.7.2. Components of the DMP

An onsite emergency is one, which is having negligible effects outside the Port premises and can primarily be controlled by internal facilities and resources available. Some help may be required from external agencies or local authorities. All the consequence footprint of the scenarios identified in the Consequence Analysis chapter indicates that the effects of the incidences will be well within the boundary, which can be mitigated by following the Onsite DMP.

An offsite emergency will affect the neighbouring areas and population outside the Port premises and would require substantial contribution from local authorities and institutions like police, civil defence, state hospital and civil administration in addition to state fire services. Offsite DMP will be needed in case of natural disaster of large magnitude such as tsunami and cyclone.

24.7.3. Onsite Emergency as Statutory Requirement

The requirement of an Onsite DMP with detailed disaster control measures was embodied for the first time in section 41B (4) of the Factories (Amendment) Act, 1987. The requirement is applicable to Ports handling flammable cargo per the First Schedule of the Act, item 29 entitled "Highly Flammable Liquids and Gases".

Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989, (amended) under Sections 6, 8 and 25 of the Environment (Protection) Act, 1986 concurrently provides the requirement of an Onsite Emergency Plan by the occupier of accident hazard site, under rule 13, sub-rule 1.

24.7.4. Emergency Control Philosophy

The principal strategy of emergency control at the proposed Port is prevention of the identified major hazards. Since hazards can occur only in the event of loss of containment, one of the key objectives of detail engineering, construction, commissioning and operating of the Port is total and consistent quality assurance.

The second control strategy adopted for potential emergencies is surveillance of handling and storage of hazardous substances.

Yet another control measure adopted is early detection of any accidental leak of hydrocarbon and other flammable vapors by gas detectors and by trained and vigilant operating staff and activation of well-structured, resourced and rehearsed emergency plan to intercept the incident with speed and ensure safety of employees, assets, public and environment as a matter of priority.

24.7.5 Content of the Onsite DMP

Information to be provided by any MAH installation or an Isolated Storage has been prescribed in schedule 11 of the MSIHC Rules. This DMP has been prepared, in so far as is practicable, in accordance with the guidelines stipulated in the Rules.

Details that need to be furnished in the Onsite DMP per schedule 11 of MSIHC Rule, 1989 are:

- Name and address of the person furnishing the information
- Key personnel of the Organization and responsibilities assigned to them in case of an emergency
- Outside Organization if involved in assisting during an onsite emergency:
  - Type of accidents
  - Responsibility assigned.
- Details of liaison arrangement between the Organizations
- Information on the preliminary hazard analysis:
  - Type of accidents
  - System elements or events that can lead to a major accident.
  - Hazards
  - Safety relevant components
- Details about the site:
  - Location of dangerous substances
  - Seat of key personnel
  - Emergency control room
- Description of hazardous chemicals at Port site:
  - Chemicals (quantities and toxicological data)
  - Transformation if any, which could occur
  - Purity of hazardous chemicals
- Likely dangers to the Port
- Enumerate effects of -
  - Stress and strain caused during normal operation

- Fire and explosion inside the Port and effect, if any, of fire and explosion out side

- Details regarding
  - Warning, alarm, safety and security systems
  - Alarm and hazard control plans in the line with disaster control and hazard control planning, ensuring the necessary technical and organizational precautions
  - Reliable measuring instruments, control units and servicing of such equipments
  - Precautions in designing of the foundations and load bearing parts of the building
  - Continuous surveillance of operations
  - Maintenance and repair work according to the generally recognized rules of good engineering practices
- Details of communication facilities available during emergency and those required for an offsite emergency
- Details of fire fighting and other facilities available and those required for an offsite emergency
- Details of first aid and hospital services available and its adequacy

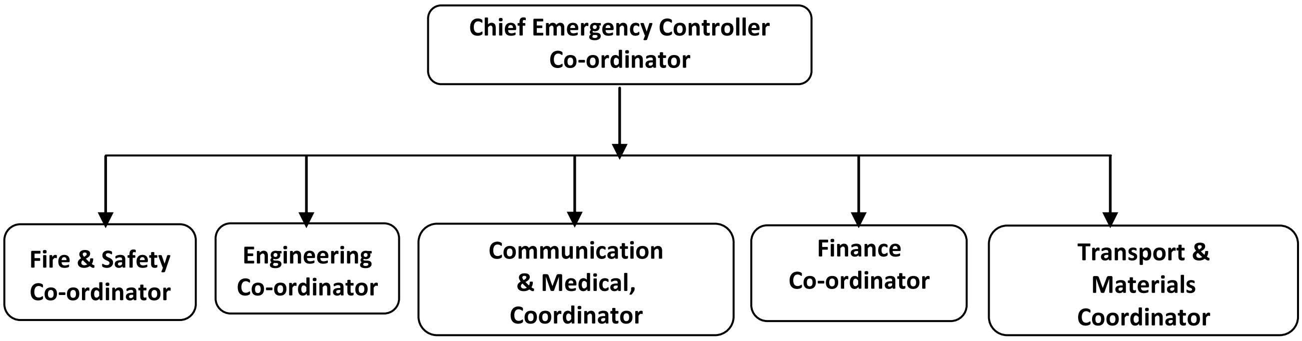
An outline of these details is provided in the pages following under the headings stated above, in so far as the headings apply to the proposed Port.

24.7.6. Key Personnel of the Port and Responsibilities in the Event of an Emergency

It is to be understood that the first few minutes after the start of an incident are most vital in prevention of escalation. Therefore the personnel available at the site on round-the-clock basis will play an important role. Some of them will be the identified “Key Persons”. Since the liquid berths and Pump House are to be operated by highly skilled officers/operators with the help of “Port In-Charge/Dy. Port Manager”, in the emergency he will also act as “Chief Controller” for incidence and he will nominate different “Emergency Coordinators” to control emergency situation.

The role of various coordinators is to assess the situation from time-to-time, take appropriate decisions in consultation with the “Chief Controller” and to provide timely resources to the “Key Persons” to fight the emergency. “Key Persons” as far as is possible are available during shift on a round the clock basis. An organogram of the officers at the liquid cargo operations during emergency is presented below.

Organization Chart for Onsite Emergency Management Team



Key Personnel

The senior most officer present in the Port at the time of the incident will be the designated the “Chief Emergency Controller”. Duties and responsibilities of “Chief Controller: and other “Coordinators” are as follows:

A. Chief Emergency Controller

He will report at the “Emergency Control Centre” and will assume overall responsibility of the works and its personnel. His duties will be:

- **i)** To assess the magnitude of the situation and decide whether a major emergency exists or is likely to develop, requiring external assistance. To inform District Emergency Chief (i.e. District Collector)
- **ii)** To exercise direct operational control over areas in the Port other than those affected

iii) Assess the magnitude of the situation and decide if staff needs to be evacuated from the assembly points to identified safe places

iv) To continuously review and direct shutting down of Port sections and operations in consultation with the other key personnel

v) To liaise with senior officials of Police, Fire Brigade, Medical and local administration, and pass on information on possible effects on the surrounding areas, outside the factory premises

vi) To liaise with various coordinators to ensure casualties are receiving adequate attention and traffic control movement within the work is well regulated

vii) To arrange for a log of the emergency to be maintained in the Emergency Control Centre

viii) To release authorized information to press through the Media Coordinator

ix) To control rehabilitation of the affected persons and the effected areas after the emergency

a. Fire and Safety Coordinator

The main responsibilities of Fire and Safety Coordinator will be:

i) To immediately take charge of all fire fighting operations upon sounding of the alarm

ii) To guide the fire fighting team and provide logistics support for effectively combating the fire

iii) To barricade the area at appropriate locations in order to prevent the movement of vehicular traffic

iv) To operate the Mutual Aid Scheme and call for additional external help in fire fighting

v) To organize relieving groups for fire fighting

vi) To inform the Chief controller and give “All Clear” signal when the fire emergency is over

b. Engineering Coordinator

Responsibilities of Engineering Coordinator will be:

i) To liaise with Chief Controller and various other Coordinators

ii) To stop/regulate all operations within the Port

iii) To switch off main Instrument Control Panel

iv) To stop all engineering works and instruct contractors and their employees to leave the area

v) To assess the water level in the fire water reservoir and supply engineering tools, fire-fighting materials and equipments to various Coordinators

vi) To start all pumps to replenish water and switch on the fire engine for hot standby

vii) To liaise with transport Coordinator to arrange for external water supply and fuel for generators/engines

viii) To attend mechanical fault/failure of fire water pump and facilities

ix) To assess situation in consultation with Chief Controller and if required, start/provide electric supply to certain areas/points

c. Communication and Medical Coordinator

Duties and responsibilities of the Communication and Medical Coordinator will be:

i) To liaise with Chief Controller and various other Coordinator

ii) To take over entire communication system (external as well as internal)

iii) To arrange to distribute Walky-Talkie/ VHF sets to various other Coordinator

iv) To inform police, fire brigade, civil authorities, hospitals & request for speedy help

v) To arrange for vehicles/ambulance for evacuation and causalities

vi) To set and activate first aid centre and arrange to mobilize medical team

vii) Arrange to procure required drugs & appliances

viii) Arrange to transfer causalities to other hospitals/first aid centre

ix) To maintain a register for causalities (type of injury, number, hospitalization, etc)

x) To inform families of the causalities

d. Finance Coordinator

The Asst. Manager (Finance) or his nominee:

- **i)** Release finances (Cash/Cheques, etc.) as directed by the Chief Controller
- **ii)** Assist Material Coordinator in enactment of emergency procurement procedures and by deputing his staff
- **iii)** To liaise with Insurance Company personnel

e. Transport and Materials Coordinator

Duties & Responsibilities will be:

- **i)** To liaise with Chief Controller and other Coordinators
- **ii)** To arrange issue of materials from warehouse round-the-clock during the emergency period
- **iii)** To arrange emergency procurements from local dealers or from neighbouring industries
- **iv)** To arrange transportation of materials from warehouse to the site in consultation with other Coordinators
- **v)** To arrange for police help for control of traffic & public outside the affected area of the Port
- **vi)** To arrange for entry for authorized personnel/vehicles only
- **vii)** To mobilise necessary vehicles as required by various Coordinators
- **viii)** To arrange for regulating the traffic inside the Port area
- **ix)** To arrange to evacuate all unnecessary personnel from the Port and arrange for vehicles/ambulance for evacuation and casualties
- **x)** To control and disperse crowd from the scene of fire
- **xi)** To mobilize all the fire fighting spare equipment/ refills/hosepipes/trolleys etc. form the neighbouring units, if required
- **xii)** To monitor stock of all fire fighting equipments and replenish them as and when required

24.7.7. Safety Hardware recommended in the Port

The designated hazardous areas of the liquid cargo handling facility in the Port will be served by a number of sensitive flammable gas detectors, hooked to alarm in the Marine Control Room. The detectors will be strategically located to detect presence of flammable vapor cloud. The detectors will be supplemented by manually operated break-glass type fire alarm call points linked to electric sirens and a centralized and manned alarm annunciator panel.

All strategic areas, especially the Pump House shall be fitted with 'quartz heat-bulb' actuated medium velocity water sprinkler systems supported by fire fighting water pumps. An extensive network of pressurized fire hydrant system set up in accordance with OISD 144 standard shall been installed to fight fire anywhere within Port and to cool pipelines and structures to ensure their safety during an incident, involving incidence of dangerous heat flux. Adequate onsite manpower shall be suitably trained and equipped to carry out fire fighting operation efficiently.

A number of diverse fire fighting media such as DCP, CO_2 Fire extinguishers, etc. will be strategically located in various parts of the Port in suitable dispenser sizes.

Foam or any other equivalent substance will be used in adequate measure to cut down evaporation from a flammable liquid pool and thus inhibit fire and formation of a flammable gas cloud.

The design of the complete fire protection system is as per OISD norms.

a. Emergency Annunciation

Warning alarm, safety and security systems will be installed in the Port. One 3 km range Electric Siren will be installed on the roof of the Marine Control Room to announce the onset of an emergency.

The alarm will have facility to be triggered manually after activation of anyone of the break-in glass type fire-alarm call points, geographically located throughout the plant both in hazardous as well as in non-hazardous areas. Sirens can also be energized as and when a gas leak is detected.

Flammable vapor alarm will be set to activate by scanning network of vapor detectors spread near the liquid handling area in the Port site to detect presence of flammable vapor at 50 % of the LEL level. The audio-visual alarm will come on in control room alarm annunciator panel. Auto-sprinkler alarm will be provided in the Pump Room as well as in the MCR if any auto-sprinkler is activated through operation of heat fuse by a fire.

b. Communication Facilities to be provided for Emergency

- One 3.0 km range Electric Siren to announce nature of emergency
- An Interport paging system in non-flame proof areas and as well as in flame proof areas will be provided for normal and emergency announcements and communication with master control in the MCR
- For inter-location communications requisite number of P&T telephones will be provided including tie lines and hot lines for communication with district emergency services, authorities, hospitals, etc.
- The interport paging and public address system will have the following features-
    - All call with answer back
    - Group call with answer back
    - Interfacing with walkie talkies
    - Field call stations
- Walkie Talkies and mobile phones will be deployed for mobile-to-mobile and mobile-to-stationary communication
- A broad communication diagram outlining interactions between various role players will be set up and rehearsed

24.8. Details of First Aid and Hospital services available

Fully stocked first aid boxes shall be placed in the Port at strategic locations. A visiting medical practitioner will be made available on a part time basis during day. He will be available on call and round-the-clock for emergency duty. The onsite medical center will be equipped with facilities for treatment of mechanical injuries, burn injuries and electric shock. An ambulance will be available in the Port round-the-clock. Details of important/prominent medical facilities available in Karaikal with their contact numbers is given below.

Emergency Contact

Numbers INTERNAL CONTACT No	
FIRE & SAFETY OFFICE	04365 256614/95000 94245
DSS PUMP HOUSE	87545 96257
MEDICAL CENTER	04365 256534/95001 21771
PORT SECURITY OFFICE	04365 256617/9566680077
VECHILE RETRIEVAL	9600192851
PORT OPERATION CENTER	04365 256612 / 9566000700
CARGO OPERATION – 24 X 7 Hrs	96770 52433/9566159588
MECHNICAL – 24 X 7 Hrs	95001 25252
ELECTERICAL - 24 X 7 Hrs	95001 25244
RAILWAY -24 X 7 Hrs	95000 93414
PFSO	97909 60448
DY.PFSO	96000 45039
HEAD FIRE & SAFETY	98409 02445
HEAD SECURITY	87545 96248

HOSPITALS / CASUALTY POLICE STATIONS

G.H KARAIKAL	04368 222593	COASTALPOLICE	04368 224750
SUGAM PRIYA Hospital	04368 224040	KARAIKAL POLICE	04368 222437/2224O2
ANSARI HOSPITAL – NGT	04368 224349	T.R.PATTINAM P.S	04368 233014/233480

FIRE STATIONS

KARAIKAL 230101/227112 NAGAPATTINAM 04365 242101/221101

ONGC – NERAVY 04368 238890 CPCL 04365 256420

ONGC – NARIMANAM 04365 235167

COAST GUARD		***INDIAN NAVY***
KARAIKAL	04368 226500	NAGAPATTINAM 04365242534
PUDUCHERRY	04132 602498	
CHENNAI	044 23460403	

BOMB SQUAD (To be contacted through Karaikal police station)

KARAIKAL POLICE 04368 222437/222402

24.9. Personal Protective Equipment

The following PPEs and other emergency handling equipment will be stocked in the MCR to be issued to the trained Key Personnel during an emergency.

- Fire proximity suit
- Fire entry suit
- Self contained Breathing Apparatus with one spare cylinder (30 minutes)
- Water gel blanket
- Safety helmet.
- Rubber hand gloves for use in electrical jobs
- Power tool
- Resuscitator

The quantities available will be sufficient to meet the needs of emergency handling personnel.

24.10. Rehearsal and Testing

'Fire Drills' will be arranged periodically to test out the laid down system and facilities. The emergency handlers will also "act out" their individual roles in accordance with the emergency procedures laid down to demonstrate that the entire emergency response system can perform efficiently and accurately. Mock drills for emergency will be conducted twice a year.

24.11. Emergency Plan for Natural Disasters

Due to its location, the Port is exposed to natural disasters of cyclones and tsunami in greater measures than any other natural disaster. Both the disasters give a short to very short notice, have potential to cause sudden and widespread damage to the Port infrastructure and the population beyond it, and make recover efforts difficult due to total collapse of administrative and welfare machinery.

It is essential for DMPs of a Port to have special provision for meeting with the challenges of cyclones and tsunamis. Since they do not give a long lead warning, pre-meditate and pre-rehersed action between the first intimation and the onset of the event becomes crucial for effectiveness. Since both events involve mass evacuation and widespread public notice, DMPs for cyclone and tsunami can ill-afford to be complicated.

a. Emergency measures during a Cyclone

IMD usually gives a 24 to 36 hours early warning on the onset of cyclone right from the time a depression starts forming in the Bay of Bengal. Aided by weather satellite, path of a cyclone can be traced almost in real time. The path of the cyclone can be reliably predicted and early warning/alerts can be given 10 to 12 hours prior to the hit of the cyclone. The details of actions to be taken before, during and after a cyclone by the Port authorities are given below.

Sr.	Action	Responsibility
	A. Actions before the Cyclone	
1	The MCR will depute a Nodal Person to be on standby for receiving cyclone alert messages from the DG Shipping, DG Lighthouse and Lightships, Maritime Department of the state and Distt. Collector, as also from AIR and DD news telecasts and keep the MCR In-charge abreast of the situation.	MCR In-charge
2	The Port In-charge will start taking Cyclone Action 12 hours before the forecast time of hit. He will issue cyclone warning in the Port by asking the Nodal Person to play out warning on the Port paging channel, and individual call to all the HODs including Port security at the gate complex to be on high alert for further instructions.	Port In-charge Nodal Person in MCR.
3	The Port In-charge will order implementation of Port shutdown and evacuation 8 hours before the time of hit. Following actions will be taken: a. Entry to the Port will be stopped. All cargo trucks will be told to leave the Port premises in a coordinated manner assisted by the Traffic In-charge of the Port. b. Cargo handling operation on the Port backup (bulk cargo area and on the berths) will be stopped. All machinery will be folded back, retracted, fixed, moored and close-secured.	Port In-charge Transport and Materials Coordinator, Port Security Dry Cargo Department

Sr.	Action	Responsibility
	c. All material handling on the berths will be stopped. Outriggers of the cranes will be lifted and secured, booms and hoists retracted and secured in position, and the cranes to be locked and tide down with tie down hooks provided on the berths.	Dry Cargo Department
	d. All vessels berthed on the Port will be unmoored and set to sail to the anchorage area assisted by tugs.	MCR Traffic and VTMS Incharge, Tug masters
	e. All liquid cargo transfer on the liquid berths will be stopped. The loading arms will be unclamped, drained, folded and secured into vertical position. Liquid vessels will be given first right to sail.	Dry Cargo Department
	f. All tugs and other Port flotilla will be securely moored to the berths in the best wave shadow part of the berths.	Tug masters. Harbour masters.
	g. All loose material stored on the Port will be covered by tarpaulin and secured on the ground through grommets to the hooks provided on the edges of the hard stands.	Transport and Materials Coordinator
	h. All vehicles and material movers will be parked on the landward side of wind obstructing structures such as ware houses and buildings. Vehicles will be closed, locked down with their parking breaks on.	Transport and Materials Coordinator
	i. The ventilators of the covered godowns will be opened to provide cross movement of cyclonic winds.	Transport and Materials Coordinator
	j. Port In-charge will ask the HOD through the Nodal Person to relieve all the employees on duty except few who will be needed for final shutdown.	Port In-charge, Nodal Person, HODs.
	k. A jeep with battery power loudspeakers will be pressed to announce Cyclone Warning in local language on the nearby area.	Transport and Materials Coordinator
4	The Port In-charge will order complete evacuation of Port including the HODs 4 hours before the time of hit.	Port In-charge, Nodal Person
	Following actions will be taken:	
	a. Security patrol party will announce evacuation in all the buildings by megaphone announcements.	Port security
	b. The MCR will be closed down systematically with all antennae lowered and secured, all equipment closed and powered off. All vessels at the anchorage will be asked to switch to VHS and UVHS channels as primary communication and maintain radio silence unless absolutely essential. MCR Communication will be put to roving mode. Communications will be handed over to the radio officer in the City office outside and away form the Port.	Port In-charge, MCR In-charge
	c. Port closure and security arrangements will be briefly	

Sr.	Action	Responsibility
	communicated to the District Crisis Group Centre by the Port In-charge through the hotline.	Port In-charge
	B. Actions during the Cyclone	
1	Port In-charge will be in contact with the Port personnel and District Crisis Group Centre on need basis through his VHS radio set from his residence or City office.	Port In-charge
	C. Actions after the Cyclone	
1	Port In-charge will order assembly of all HODs at his residence or in the Port city office after winds velocities have come down below 50 km/hr.	Port In-charge, HODs
2	Port In-charge will inspect damage in the Port personally along with relevant HODs and verbally instruct corrective and remedial measures to be taken. Following actions will be taken:	Port In-charge, HODs
	a. The MCR will be reopened and all communication and navigation equipment restarted, calibrated and synchronised.	MCR In-charge
	b. Vessel stationed at anchored will be supplied with necessary supplies and spared if required by Port supply and pilot boats. Any medical causality will be rescued and hospitalized if necessary.	Harbour master
	c. All debris and wasted material spilled due to wind and rain will be collected, checked for contamination, and disposed off in a well designed pit in the Port premises.	Transport and Materials Coordinator
	d. Damage to structural work of the Port, namely the cranes and other tall material handling structures (conveyor galleries, watch towers, building glasses) will be inspected and necessary repairs and cleaning will be undertaken. Structures whose stability is under question will be cordoned off till they are inspected in detail and cleared for general use.	Engineering department
	e. Water supply will be tested for portability, and other sanitary services resumed after suitable inspection. Water accumulated due to heavy rains will be drained and area dried, sprayed with disinfectant, etc.	Communications and Medical Coordinator
	f. Status of Port will be communicated to the District Crisis Group Centre by the Port In-charge through the hotline	Port In-charge.
1	After the Port housekeeping has been brought to order, all machineries will be sequentially tested. Port operations will be resumed with dry cargo handling vessels to be berthed first, followed by containers and liquid cargoes vessels.	Port In-charge.
2	Port medical, logistics, communication and personnel facilities will be suitably extended to the Crisis Group Centre Team the leadership of the Distt. Collector for any further relief work as desired by the local and distt. administration.	Port In-charge.

b. Emergency measures during a Tsunami

Early warning for a tsunami can be as short as one hour. Tsunami can be predicted by a network of seismic detection centers installed by the bordering nations after the December 2004 tsunami, as well as deep sea telemeterd buoys placed by the MoES. Tsunami warning will be communicated to the Port MCR by the District Crisis Group Centre by telephone/emergency hotline.

Rapid action after the alert is critical to effective tsunami response. Unlike cyclone, tsunami is not accompanied by tell-tale disturbed weather and high winds, therefore Port must effectively communicate and elicit urgent action in this regard. The actions to be taken before, during and after a cyclone by the Port authorities are presented below.

Sr.	Action	Responsibility
	A. Actions before the Tsunami	
1	The MCR will initiate high–intensity emergency tsunami warning through all communications channel including Port paging channel, and individual call to all the HODs, including Port security at the gate complex with clear instruction to shut down all operations possible within 20 minutes, and move as far as possible from the sea front using any means of transportation available, including running away.	MCR In-charge
2	The MCR In-charge will carry out the following under standing authorization of the Port In-charge. Following actions will be taken:	MCR In-charge
	a. Entry to the Port will be stopped. All trucks and visitors will be driven away from the Port using one empty truck without creating any unnecessary traffic and congesting the roads/Port gate(s).	Port Security
	b. All cargo handling operation on the Port and backup will be stopped immediately. All machinery will be folded back, retracted, fixed, moored and close-secured. Outriggers of the cranes will be lifted and secured, booms and hoists retracted and secured in position, and the cranes to be locked and tide down with tie down hooks provided on the berths.	Dry Cargo Department
	c. Mooring ropes of all vessels berthed on the Port will be slackened. Vessels will be asked to be on full power for any during-tsunami power assists. Tugs will be pressed to turn and send off any inbound vessel in the channel. All vessels in the anchorage will be communicated tsunami alert. All tugs and other Port flotilla will be securely moored to the berths in the best wave shadow part of the berths.	MCR Traffic and VTMS In-charge, Harbour master, Tug masters
	d. All vehicles and material movers will be parked on the landward side of wave obstructing structures such as ware houses and	

Sr.	Action	Responsibility
	buildings. Vehicles will be closed, locked down with their parking breaks on. e. All HODs will ensure rapid and complete evacuation of the Port. f. MCR will be manned and operational with essential staff for communication and coordination. g. Decision on electrical shut down will be taken by the MCR In-charge after consultation with the Port In-charge depending on the size of the Tsunami waves predicted and communicated.	Dry Cargo Department HODs.

	B. Actions after Tsunami	
1	Port In-charge will resume office within minutes of waves subsiding to below deck height. He will inspect damage in the Port personally along with relevant HODs and verbally instruct corrective and remedial measures to be taken. Following actions will be taken: a. Vessels at the berths will be immediately attended for evacuation of any medical emergency. b. All debris and wasted material floated over dye to wave hit will be collected, checked for contamination, and disposed off in a well designed pit in the Port premises. c. Damage to civil and structural work of the Port, namely the berths, cranes, etc. will be inspected and necessary repairs and cleaning will be undertaken. Structures whose stability is under question will be cordoned off till they are inspected in detail and cleared for general use. d. Water supply will be tested for portability, and other sanitary services resumed after suitable inspection. Water accumulated due to wave hit will be drained and area dried, sprayed with disinfectant, etc. e. Status of Port will be communicated to the District Crisis Group Centre by the Port In-charge through the hotline	Port In-charge, HODs MCR In-charge, Harbour master, Tug masters, Communication and Medical Coordinator Dry Cargo Department Engineering department Communications and Medical Coordinator Port In-charge
2	After the Port housekeeping has been brought to order, all machineries will be sequentially tested. Port operations will be resumed after starting the unloading and stacking equipment.	Port In-charge.
3	Port medical, logistics, communication and personnel facilities will be suitably extended to the Crisis Group Centre Team the leadership of the Distt. Collector for any further relief work as desired by the local and distt. Administration.	Port In-charge.

Offsite action will be carried out in coordination with external agencies, whose responsibilities are listed as follows:

- Police
- Fire Brigade
- Medical Services
- Technical Agencies
- Rehabilitation Agencies
- Electricity Board

Responsibilities of the Services

I. Police

- To control traffic & mob by cordoning off the area
- Arrange for evacuation of people on advice from the Site Controller/District Collector
- Broadcast/communicate through public address systems to the community on advise from the District/Sub Collector
- Inform relatives about details of injured and casualties

II. Fire Brigade

- Fighting fire & preventing its spread
- Rescue & salvage operation

III. Medical/Ambulance

- First Aid to the injured persons
- Shifting critically injured patients to the hospitals
- Providing medical treatment

IV. Technical/Statutory Bodies

(Constitutes Factory Inspectorate, Pollution Control Board, Technical Experts from Industries)

- Provide all technical information to the emergency services, as required
- Investigate the cause of the disaster

V. Rehabilitation

- Arrange for evacuation of persons to nominated rescue centre and arrange for their food, medical and hygienic requirements
- Coordinating with the Insurance Companies for prompt disbursement of compensation to the affected persons
- Maintain communication channels of nearby industries like telephone, telex etc. in perfect working condition

VI. Electricity Board

- To regulate/re-connect the power supply to the Port if specifically asked for by the Port

24.12. Conclusion

24.12.1. Failure Frequency associated with Loss of Containment

Quantitative risk is a function of failure frequency of an equipment and consequence of the scenario. A moderate consequence with extremely rare frequency of occurrence may pose only minor risk to the facility in its operative lifetime. Failure frequencies of plant elements in the LNG terminal are given below.

Sr.	Plant component	Failure Frequency per year
1	16”unoading arm, 25 mm hole	5.0 E -7
2	48” unloading header, 25 mm hole	2.5 E -7
3	20” LP Pump header, 25 mm hole	6.0 E -7
4	26” send out heder, 25 mm hole	5.0 E -7

It may be observed from the above failure frequency data that the likelihood of an incidence occurring in the 40 years assumed lifetime of the LNG terminal is extremely rare.

24.12.2. Consequence Analysis findings – interpretation in the context of the proposed LNG Terminal

LNG industry has been among the safest in the petroleum and chemical sector with comparatively miniscule number of incidences in comparison with the total number of operational LNG facilities, number of shipments through seas, on roads and by pipelines. The strong safety record of the LNG industry is a result of several factors.

The industry has technically and operationally matured to ensure safe and secure operation.

Physical and chemical properties of LNG are such that risks and hazards are well understood and incorporated into technology and operations.

Standards, codes and regulations that apply to the LNG industry further ensure safety.

Safety in the LNG industry is ensured by four elements that provide multiple layers of protection both for the safety of LNG industry workers and the safety of communities that surround LNG facilities.

Primary containment is the first and most important requirement for containing the LNG product. This first layer of protection involves the use of appropriate materials for LNG facilities as well as proper engineering design of storage tanks onshore and on LNG ships and elsewhere.

Secondary containment ensures that if leak or spills occur at the onshore LNG facility, the LNG can be fully contained and isolated from the public.

Safeguard system offers a third layer of protection. The goal is to minimize the frequency and size of LNG releases both onshore and offshore and prevent harm from potential associated hazards, such as fire. For this level of safety protection, LNG operations use technologies such as high level alarms and multiple back-up safety systems which include Emergency Shutdown (ESD) systems. ESD systems can identify problems and shut off operations in the event certain specified fault conditions or equipment failures occur, and which are designed to prevent or limit significantly the amount of LNG and LNG vapour that could be released. Fire and gas detection and fire fighting systems all combine to limit effects if there is a release. The LNG facility or ship operator then takes action by establishing necessary operating procedures, training, emergency response systems and regular maintenance to protect people, property and the environment from any release.

Finally, LNG facility designs are required by regulation to maintain separation distance to separate land-based facilities from communities and other public areas. Safety zones are also required around LNG ships.

The physical and chemical properties of LNG necessitate these safety measures. LNG is odourless, non-toxic, non-corrosive and less dense than water. LNG vapours (primarily methane) are harder to ignite than other types of flammable liquid fuels. Above approximately -1100C LNG vapour is lighter than air. If LNG spills on the ground or on water and the resulting flammable mixture of vapour and air does not encounter an ignition source, it will warm, rise and dissipate into the atmosphere.

There is a very low probability of release of LNG during normal industry operations due to the safety systems that are in place.

Shore based installations are characterized with high wind speeds and warm climate due to the land and sea breeze, and heat sink phenomenon of the ocean. This type of climate will ensure quick dispersion of any LNG spillage beyond its LFL of 5%.

Being in the temperate region, due to generally strong solar insolation, atmospheric stability is generally from A to D which ensures greater ambient mixing and rapid dispersion of flammable vapours. Stability Class F occurs for short duration in overcast skies with less than 2 m/s wind speed, which is an unlikely condition for Karaikal. However, consequence analysis is carried out for conservative dispersion scenarios under atmospheric dispersion condition of 'D – Neutral' and 'F – Stable'.

Intervention time upon any release, chance of the flammable cloud meeting with a source of ignition and total quantity under burn are equally important while perception of risk of the proposed terminal. In the modelled release scenarios serious risk may arise only due to escalation of the incidence, which is taken care in the operation philosophy and design of the facility per most stringent design codes for the industry.

Annexure I: Aditya Accreditation Letter

National Accreditation Board
for Education and Training

NABET

NABET/ EIA/ 01/ 12/006

The Director

January 31, 2012

Aditya Environmental Services Pvt. Ltd.
107, Hiren Light Industrial Estate
Mogul Lan, Mahim, Mumbai - 400016
(Kind Attention: **Mr. Rajiv Vasudeo Aundhe**)

Dear Sir,

QCI – NABET Scheme for Accreditation of EIA Consultant Organization

This is with reference to your application for QCI – NABET Accreditation as EIA Consultant Organization.

We are pleased to inform you that based on Document & Office Assessment, the Accreditation Committee has recommended the conditional accreditation of **Aditya Environmental Services Pvt. Ltd.** as per the scope given in Annexure I (A & B).

Please confirm the correctness of spellings of the names of the experts mentioned in Annexure I B. The detailed terms and conditions are mentioned in Annexure II. You are also advised to check the QCI website for the Minutes of the Accreditation Committee Meeting held on December 27, 2011 for observations related to your application or any decisions with respect to Scheme/ assessment process and take necessary action for compliance.

The accreditation of your organization will be for three year period starting November 24, 2011. The annual renewal of the accreditation will be confirmed after surveillance assessment every year. Surveillance assessments will be conducted to ensure compliance with NABET Scheme and the details mentioned in your Quality Manual.

May we request you for an early payment of the annual fees and your confirmation of acceptance of the terms and conditions attached. This will enable us to issue you the requisite accreditation letter & certificate which will be valid for one year duration.

We thank you for your esteemed support in making this scheme successful and for your participation in this national cause.

Thanks and best regards,

Yours sincerely,

(Vipin Sahni)
Director

Institution of Engineers Building, 2nd Floor, Bahadur Shah Zafar Marg, New Delhi – 110 002, India
Tel : +91-11-2337 9321, 2337 8057 Fax : +91-11-2337 9621 email: nabet@qcin.org Website: www.qcin.org

Creative Engineers Accreditation Certificates

Certificate of Registration

This certificate has been awarded to

Creative Engineers & Consultants

No. 9B/4, Bharathwajar Street, East Tambaram, Chennai, Tamilnadu, 600059, India

in recognition of the organization's Quality Management System which complies with

ISO 9001:2008

The scope of activities covered by this certificate is defined below

Preparation of Environmental Impact Assessment (EIA)/ Environmental Management Plan (EMP) Reports, Environmental Sampling and Laboratory Analysis

Certificate Number:	Date of Issue: (Original)	Date of Issue:
[illegible]	28 May 2010	28 May 2013
Issue No:	**Expiry Date:**	
2	27 May 2016	

Issued by: *On behalf of the Schemes Manager*

Cert. IU Iss 0408

NABL

National Accreditation Board for Testing and Calibration Laboratories

Department of Science & Technology, India

CERTIFICATE OF ACCREDITATION

CREATIVE ENGINEERS & CONSULTANTS

has been assessed and accredited in accordance with the standard

ISO/IEC 17025:2005

"General Requirements for the Competence of Testing & Calibration Laboratories"

for its facilities at

9 B/4 Bharathwajar Street, East Tambaram, Chennai

in the discipline of

CHEMICAL TESTING

(To see the scope of accreditation of this laboratory, you may also visit NABL website www.nabl-india.org)

Certificate Number T-1838

Issue Date 19/03/2013

Valid Until 18/03/2015

This certificate remains valid for the Scope of Accreditation as specified in the annexure subject to continued satisfactory compliance to the above standard & the additional requirements of NABL.

Signed for and on behalf of NABL

Anand Deep Gupta	Anil Relia	Dr. T. Ramasami
Convenor	Director	Chairman

F. No. J-11013/77/2004- IA II (I)
Government of India
Ministry of Environment and Forests
(I.A. Division)

Paryavaran Bhawan
CGO Complex, Lodhi Road
New Delhi – 110 003
E-mail : pb.rastogi@nic.in
Telefax : 011: 2436 7668
Dated 30th September, 2011

OFFICE MEMORANDUM

Subject: Accreditation of the EIA Consultants with Quality Council of India (QCI) National Accreditation Board of Education and Training (NABET)

In continuation of the Ministry's O.M. No. J-11013/77/2004- IA II (I) dated 30th June, 2011regarding above mentioned subject and after a review of the progress of the accreditation process, following decision will come into force w.e.f. 1st October, 2011:

I. Only accredited consultants as per List 'A' will be allowed to appear before the Expert Appraisal Committee (EAC) for Category 'A' projects and State Level Expert Appraisal Committee/State Environmental Impact Assessment Authority (SEAC/SEIAA) for Category 'B' projects. Registration of QCI accredited consultants will be valid for the period of accreditation/not exceeding three years and these approved EIA consultants and EIA coordinators will engage themselves only in the approved sectors as approved by the QCI.

II. The consultants who have applied to NABET/QCI before 30th June, 2010 (within S.N.265) and whose applications are still in process, ***last date for accreditation/ registration is extended upto 31st December, 2011***. Consultants whose applications are in process are listed under List 'B'.

III. The Consultants who have withdrawn their applications or rejected on various grounds are listed in List 'C' and will not be eligible to appear for presentation. They will be free to apply to QCI/NABET, and if accredited, will be eligible for appearance in EAC/SEAC/SEIAA from the date of accreditation.

IV. The Consultants who have applied after 30th June, 2010 will continue to be considered by the NABET/QCI for accreditation on first-cum-first serve basis.

This issues with the approval of the Competent Authority.

PRastogi
(Dr. P. B. Rastogi)
Director

Copy to:
1. All the Officers of IA Division
2. Chairman/Secretaries of SEIAA/SEACs
3. Website of MoEF.
4. Guard File

QMS Certificates of Karaikal Port

QS

QUALITY SERVICE

CERTIFICATE

Certificate no. 6394

karaikal port

Karaikal Port (P) Limited

Kheezhavanjoor Village, T.R.Pattinam, P.B.No.33,
Karaikal - 609 606, Puducherry (India)

QS Zürich AG certifies that the management system of the above mentioned company has been assessed and meets the requirements established by the following rules:

ISO 9001: 2008

The management system includes:

Operation, Management and Maintenance of Modern Port, Consisting of Berths, Material Handling Equipment & Systems, Support facilities, Storage and Delivery of Bulk, Break-bulk, Project & Liquid Cargoes

EA Sector 35

In the course of the validity of the present certificate the enterprise management system must permanently satisfy the requirements of the international regulations.
The fulfilment of these regulations will be regularly controlled by QS Zürich AG.

For precise and updated information concerning possible changes occurred in the certification object of the present certificate, please contact info@qszurichcertification.com

SWISS

First certification date: 18.08.2010
Date of issue: 15.11.2013
Expiration date: 28.10.2016
Subject to successful surveillance audit

QS Zürich AG
P.O. Box 6335
CH-8050 Zürich
qs-zuerich@quality-service.ch

SCESm 047
www.sas.ch

Direction

QS
QUALITY SERVICE

CERTIFICATE

Certificate no. 6781

MARG karaikal port

Karaikal Port (P) Limited

Kheezhavanjoor Village, T.R.Pattinam, P.B.No.33,
Karaikal - 609 606, Puducherry (India)

QS Zürich AG certifies that the management system of the above mentioned company has been assessed and meets the requirements established by the following rules:

ISO 14001: 2004

The management system includes:

Operation, Management and Maintenance of Modern Port, Consisting of Berths, Material Handling Equipment & Systems, Support facilities, Storage and Delivery of Bulk, Break-bulk, Project & Liquid Cargoes

EA Sector 35

In the course of the validity of the present certificate the enterprise management system must permanently satisfy the requirements of the international regulations.
The fulfilment of these regulations will be regulary controlled by QS Zürich AG.

For precise and updated information concerning possible changes occurred in the certification object of the present certificate, please contact info@qszurichcertification.com

SWISS

First certification date: 28.01.2011
Date of issue: 15.11.2013
Expiration date: 28.10.2016
Subject to successful surveillance audit

QS Zürich AG
P.O. Box 6335
CH-8050 Zürich
qs-zuerich@quality-service.ch

SCESm 047
www.sas.ch

Direction

CERTIFICATE

Certificate no. 6782

Karaikal Port (P) Limited

Kheezhavanjoor Village, T.R.Pattinam, P.B.No.33,
Karaikal - 609 606, Puducherry (India)

QS Zürich AG certifies that the management system of the above mentioned company has been assessed and meets the requirements established by the following rules:

OHSAS 18001: 2007

The management system includes:

Operation, Management and Maintenance of Modern Port, Consisting of Berths, Material Handling Equipment & Systems, Support facilities, Storage and Delivery of Bulk, Break-bulk, Project & Liquid Cargoes

EA Sector 35

In the course of the validity of the present certificate the enterprise management system must permanently satisfy the requirements of the international regulations.
The fulfilment of these regulations will be regularly controlled by QS Zürich AG.

For precise and updated information concerning possible changes occurred in the certification object of the present certificate, please contact info@qszurichcertification.com

First certification date: 28.01.2011
Date of issue: 15.11.2013
Expiration date: 28.10.2016
Subject to successful surveillance audit

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Direction

NABET Accreditation letter – Indomer

NATIONAL ACCREDITATION BOARD FOR EDUCATION & TRAINING

QUALITY COUNCIL OF INDIA

QCI Office, 6th Floor, ITPI Building, Ring Road, I.P. Estate, New Delhi

Scheme for Accreditation of EIA Consultant Organizations

Minutes of 130th Accreditation Committee Meeting for Initial Accreditation held on October 10, 2014

Present

1. Sh. R. K. Bansal - Member
2. Prof. A. K. Maitra - Member
3. Sh. Bharat Bhushan - Member

Leave of absence was granted to Shri Paritosh C. Tyagi, Dr. A. N. Jha, Sh. N.S. Tiwana, Prof. J. K. Garg, and Dr. Asha Rajvanshi.

NABET Secretariat was represented by:

Mr. A. K. Ghose – Principal Advisor and Ms. Meenakshi Arora– E.O.T

1. The minutes of 129th IA AC meeting dated October 1, 2014 were considered and approved

2. Applications for Initial Accreditation

2.1 Indomer Coastal Hydraulics (P) Ltd, Chennai

The organization has scored more than 60% overall marks, therefore, qualifies for Cat. A.

2.1.1 Scope of Accreditation

Sl. No.	Sector No. as NABET Scheme	Name of Sector	Cat.	Project or Activity as per Schedule of MoEF Notification dated September 14, 2006 and subsequent amendments
1	27	Oil & gas transportation pipeline (crude and refinery/ petrochemical products), passing through national parks/ sanctuaries/coral reefs /ecologically sensitive Areas including LNG terminal.	A	6 (a)
2	33	Ports, harbours, jetties, marine terminals, break waters and dredging	A	7 (e)

S. No.	Consultant Organization	Scope of Accreditation: As per NABET Scheme – Sector Number	Name of Sector	Category	Project or Activity as per Schedule of MoEF Notification dated September 14, 2006 and subsequent amendments
	Barakhamba Road Connaught Place New Delhi 110001,India Tel: + 91-11-49691000, +91-9212393934 E mail: shivam.kaushik@ifsenv.com *Conditions apply*	27	Oil & gas transportation pipeline (crude and refinery/ petrochemical products), passing through national parks/ sanctuaries/coral reefs /ecologically sensitive Areas including LNG terminal	A	6 (a)
		37	Common municipal solid waste management facility (CMSWMF)	B	7 (i)
		38	Building and large construction projects including shopping malls, multiplexes, commercial complexes, housing estates, hospitals, institutions	B	8 (a)
		39	Townships and Area Development	B	8 (b)
81	**Indomer Coastal Hydraulics (P) Ltd *** **Address:** 63, Gandhi Road Alwar Thirunagar, Chennai 600 087 Tel:+91-44-2486 2482 to 84	27	Oil & gas transportation pipeline (crude and refinery/ petrochemical products), passing through national parks/ sanctuaries/coral reefs /ecologically sensitive Areas including LNG terminal.	A	6 (a)

S. No.	Consultant Organization	Scope of Accreditation – As per NABET Scheme – Sector Number	Name of Sector	Category	Project or Activity as per Schedule of MoEF Notification dated September 14, 2006 and subsequent amendments
	099401 41650 **E mail:** indomercoastalhydraulics@gmail.com *Conditions apply*	33	Ports, harbours, jetties, marine terminals, break waters and dredging	A	7 (e)
82	**In Situ Enviro Care *** **Address:** F-1, II Floor, Gomti Apartments, Plot No. 69-A, Zone II, M. P. Nagar, Bhopal- 462011 **E-mail:** admin@insituenvirocare.com ajay.mohan@insituenvirocare.com **Tel.:** 07555- 2577143/ 3914807 09425012465, 08878698002 *Conditions apply*	4	Thermal power plants	B	1 (d)
		38	Building and large construction projects including shopping malls, multiplexes, commercial complexes, housing estates, hospitals, institutions	B	8 (a)
83	**Ind Tech House Consult *** **Address:** G-8/6, Ground Floor, Sector 11, Rohini, Delhi – 110 085 **E-mail:** suman.ithc@gmail.com, ithconsult@hotmail.com	1	Mining of minerals including Open cast/ Underground mining	A*	1 (a) (i)
		4	Thermal power plants	B	1 (d)
		21	Synthetic organic chemicals industry (dyes & dye intermediates; bulk drugs and intermediates excluding drug	B	5 (f)

Annexure II: Design details for proposed 50 KLD Sewage treatment plant

Quantities of waste water generated from the Port premises 45,000ltr/ day or say 50,000 ltr/day. Assuming 16hrs is the average flow period so flow will be 3.125m^1/ hr

BAR SCREEN:

Flow : 50 M^1 / day □~ 3.125 M^1 /hr

Function :To separate coarse matter from the Raw sewage

Peaking Factor= 3

Flow (Max) = 3.125 x 3 = 9.375m ^{1}/hr

Desired Velocity through Screen (v) = 0.8 m/sec (for gravity flow)

Net area of screen = $\dfrac{9.375 \text{ m}^1/\text{hrs}}{3600 \times 0.8 \text{ m / sec}}$ = 0.0033 m / sec

Adopting screen with flats of 5mm thick and 8mm opening

Gross area = $\dfrac{0.0033 \times 13}{8}$ = 0.0053 m^1

Assuming that the inclination of screen to horizontal is at 60 degree,

The gross area of screen needed = $\dfrac{0.0053 \text{ m}^1}{\sin 60}$

= 0.0061 m^1

Hence area of screen 0.0782 x 0.0782 M

However, Provide the bar screen of size 0.5 M x 0.5 M to be fitted in the bar Screen Chamber.

EQUALISATION TANK

Average BOD of sewage at the inlet of the Pre-aeration tank.	:250 mg/lit.
Total organic load with 20% BOD reduction considered.	:50 mg/lit
Total oxygen required assuming 2 kgs of O_2/kg of BOD removed	:5Kgs/day
Air required for pre aeration	:118 m^1/hr.
Type of aeration	: Coarse bubble diffused aeration system.
Size of the unit	: 2.5 m x 2.5m x 2.0 m SWD
Volume of the unit	: 12.5 m^1
Detention time available	: 4.0 Hours during Average flow.

RAW SEWAGE PUMP

Volume of sewage : 50 m^3 /day – 3.125 m^3 /hr

Discharge rate : 3.125 m^3 /hr @ 8-10 m head.

Function To transfer Raw Sewage from pre-aeration /equalization tank to aeration tank.

FIRST STAGE AERATION TANK

Flow : 50 m^3 /day or 3.125 m^3 /hr

F/M : 0.2

MLSS : 3500 mg /litre

BOD entering to the aeration tank: 200 mg/litre

Since 20% of the BOD has been removed in the equalization tank,

% of BOD removal in 1st Stage
aeration tank : 65% of the total inlet BOD to aeration tank

Total organic load with 65% BOD
reduction considered. : 130 mg/lit.

Calculation of volume of aeration tank:

$$\text{Volume} = \frac{\text{BOD x Flow rate}}{\text{F/M x MLSS}}$$

Assume F/M = 0.2, & MLSS = 3500 mg/l

Therefore volume of the tank required : $\frac{200}{0.2 \times 3500}$

= 14.28 m^3

Considering 30% extra volume for sludge recirculation

Volume of Aeration tank required : 4.28 m^3

Therefore total volume of aeration tank required = 14.28 + 4.28

= 18.56 m^3

Assume SWD to be 2.0 m

Therefore plan area required = 18.56/2.0 = 9.2 m^2

Size of Aeration Tank Required = 3.1 m x 3.1 m x 2.0 m SWD

Calculation of total organic load:

Average BOD of sewage at the inlet of the aeration tank : 200mg/lit.

BOD x Flow rate

Organic load = $\dfrac{\qquad\qquad}{1000}$

Total organic load in the system : 200 x 50 x /1000

= 10 kgs/day

Total oxygen required assuming that 2 kgs of O_2/kg of BOD removed

: 2 x 10 = 20 Kgs/day.

Calculation of air requirement:

Assume alpha = 0.6 and ß = 0.7

Consider oxygen transfer at 0.25 m depth =25%

Density of air : 1.2 kg/m^3

Percentage of Oxygen in Atmospheric air 21

Therefore Actual Air required for pre aeration : $\dfrac{20}{1.2 \times 0.21 \times 0.6 \times 0.7 \times 0.25}$

= 755.85 m^3/hr

Assuming duration of air supply as 16 hours per day Air required

= 47.24 m^3/hr

iv)Calculation of diffuser required:

Considering 6m^3 /hour diffusion of air through the diffuser /m length

Number of diffusers required = 47.24/6

= 7.87 diffusers

Type of aeration : Membrane Fine pore diffused aeration system .

FIRST STAGE SETTLING TANK

Average flow – 50 cum/day

Consider the overflow rate of 10-12 cum/sqm/day

Surface area = 50/10 = 5 sqm

Therefore Dimension of the settling tank is 2.3x2.3x1.5 SWD with 0.5 FB

SECOND STAGE AERATION TANK

Flow	: 50m^3 /day or 3.125m^3/Hr
F/M	: 0.2
MLSS	:3500 mg/litre

BOD entering to the second stage aeration tank

: 70 mg/litre

Calculation of volume of aeration tank:

$$\text{Volume} = \frac{\text{BOD x Flow rate}}{\text{F/M x MLSS}}$$

Assume F/M = 0.2, & MLSS=3500 mg/l

Therefore volume of the tank required : $\frac{70 \times 50}{0.2 \times 3500}$

= 5 m^3

Considering 30% extra volume for Sludge Recirculation

Volume of Aeration tank required : 1.5 m^3

Therefore total volume of aeration tank required = 5 + 1.5

= 6.5 m^3

Assume SWD to be 2.0 m

Therefore plan area required = 6.5/2.0 = 3.25 m^2

Size of Aeration Tank Required = 2.0 m x 2.0 m x 2.0 m SWD

ii) Calculation of total organic load:

Average BOD of sewage at the inlet of the Secondary aeration tank: 70mg/lit.

$$\text{Organic load} = \frac{\text{BOD x Flow rate}}{1000}$$

Total organic load in the system : 70 x 50 x/1000

= 3.5 kgs/day

Total oxygen required assuming that 2 Kgs of O_2/kg of BOD removed

: 2 x 3.5= 7 Kgs/day.

Calculation of air requirement:

Assume alpha = 0.6 and ß = 0.7

Consider oxygen transfer at 0.25 m depth =25%

Density of air : 1.2 kg/m^3

Percentage of Oxygen in Atmospheric air 21

Therefore Actual Air required for pre aeration : 70/

1.2 x 0.21 x 0.6 x 0.7x0.25

= 264.55 m^3/day

Assuming duration of air supply as 16 hours per day Air required

= 16.5 m^3/hr per tank

iv)Calculation of diffuser required:

Considering 6m^3 /hour diffusion of air through the diffuser /m length

Number of diffusers required = 16.5/6

= 2.7 diffusers

Type of aeration : Membrane Fine pore diffused aeration system.

SECOND STAGE SETTLING TANK

Average flow – 50 cum/day

Consider the overflow rate of 10-12 cum/sq.m/day

Surface area = 50/10 = 5 sq.m

Therefore Dimension of the settling tank is 2.3x2.3x1.5 SWD with 0.5 free Board

SLUDGE RECYCLE PUMP

Volume of Sludge : 15 m^3/day

Discharge rate : 1.875/Hr @ 10-12 m head.

Type of pump : Horizontal centrifugal with CI, open impeller self-priming type coupled to motor of required speed with B Class insulation and IP 55 protection hood.

Function : To re-circulate the return sludge to aeration tank to maintain the required MLSS and transfer excess sludge to sludge drying beds or Aerobic Digester.

PLATE & FRAME FILTER PRESS

Assumed Type of Sludge : Secondary Biological

Design Liquid Sludge Flow : 1500 Lts/day

Concentration of solids : 1%

Specific Gravity : 1.2

Minimum Dry Solids allowable in the sludge solid cake : 25-30%

Sludge Cake characteristics :

Cake thickness : 32 mm

Wet Cake Density : 1280 Kgs/m^3

Operating time

10 Hrs/day : 6 days /week

Cycle time

Feed : 20 Minutes

Compression : 15 Minutes

Cake Discharge : 25 Minutes

Total : 60 Minutes

Daily Sludge Solid Generation

Rate :1500 x 0.01x1.2 = 18 Kgs/Day

Quantity of sludge solids load

on filter press : 18x 3(Three days in a week operation)

: 54 Kgs /for 3 days

Assuming the sludge holding capacity as 40 Kgs/m^1

The size of Filterpress required = 54/40 = 1.35 m^1

Let the size of the each Plate be (0.61 X 0.61 m) = 0.37 m^1

Therefore the number of such chambers required will be

= 1.35/0.37 = 3.64 Nos

Note: However provide 5 chambered filter press of size 0.61 X 0.61 m with

Collection tray, Filtrate line with Hydraulic /Power packed mechanism.

SREW PUMP

Capacity : 3 m^1/hr.

Type : Single Screw Type with shaft mounted gear box.

Working Pressure : 4-6 kg/cm^1

SLUDGE HOLDING TANK

Anticipated quantity of secondary sludge

From the STP : 1500 liters per day

Capacity of the Aerobic digester

required : 1500 liters

Size of aerobic digester required : 1.2 x 1.2 x 1.2 m SWD

Air Required for Aerobic digestion : 5 m^1 /hr

PREFILTERATION TANK

Size of the unit : 2.5 m x 2.5m x 2.0 m SWD

Volume of the unit : 12.5 m^1

Detention time available : 4.0 Hours.

Air required : 0.5 x Volume of the tank

0.5 x 12.5 = 6.25m^3/hour

Function : to collect & store the settled supernatant/ treated sewage from the Settling unit

FILTER FEED PUMP – 2 No.s (1 w + 1 SB)

Pumping Rate : 3.125 m 3/Hr

Pumping Head : 10 - 12 m

Type of pump : Horizontal centrifugal with C I open impeller self Priming type coupled to motor of required speed with B class insulation and IP 55 protection hood.

Function : To pump the clarified sewage through Pressure Sand and Carbon Filters

PRESSURE SAND AND CARBON FILTERS

Total flow : 50 m^3/day

Duration of Pumping considered : 10 hr/day

Pumping Rate : 5 m^3/Hr

Surface loading considered : 10 m^3/m^2/hr

Area of Filter required : 0.5 m^2

Dia of filter required : 0.79 m

Number of Sand Filters : 01

Number of Carbon Filters : 01

Height of Shell : 1.8 m

Media for Sand filter : Pebbles, Grit, Silt, Gravel, Coarse & Fine Sand.

Media for Carbon filter : Pebbles, Gravel & Activated Carbon

DISINFECTION UNIT

Objective: It is generally done to disinfect the biologically treated sewage to kill the bacteria and to oxidize the remaining organics present in the Treated water.

Q Max = 50 cum/day

Hypo dosage recommended = 5-10 mg/hr

Total hypo required = 10gm/cum X 50 cum/day

= 500 gms/day

Commercial grade available =5%= 5gm /100 ml= 50gms/day

To dose 1000 gms per day we need approx 20 L of 5% solution

Dosing pump capacity required : 2lph

Dosing pump capacity provided : 4 lph.

FINAL TREATED WATER SUMP:

Size of the unit : 3.2 m x 3.2m x 2.5 m SWD

Volume of the unit : 25 m^3

Detention time available : 8.0 Hours

Function : To collect & store the filtered water to pump to either garden or toilet flushing within the premises.

COMMON TREATED WATER TRANSFER PUMP

Volume of Treated Water : 50 m^3/day

Discharge rate : 3.125m^3/ Hr @ 10 - 12 m Head

Type of pump : Horizontal centrifugal with C I opens Impeller self Priming type coupled to Motor of required speed with B class Insulation and IP 55 protection hood.

BLOWER CAPACITY

Blower capacity require : Air for pre- aeration + AT 1 + AT 2 + Pre- filtration + Aerobic Digester + 10% extra

= 11.8 + 47.24 + 16.5 + 5 + 6.25 + 10%

= 86.79 +8.69 = 95.46 m^3/hr

Note: The capacity of Common Twin Lobe Roots Air blower suitable to discharge about 100m^3/hr @ 0.5 KSC – 2 Nos (1W + 1 SB). The common blower shall supply the air required for the Aeration System (Aeration Tank & Aerobic Digester) and other primary, intermittent and final storage units of the treatment plant (Equalization Tank, Pre- filtration and Filtered Water Tank)