DETAILED PROJECT REPORT

Inland Water Transport In Vasai Creek – Ulhas River

NW-53

Vasai To Kalyan

SUBMITTED TO: THANE MUNICIPAL CORPORATION

MAY 2018

PREPARED BY:

C-Borne Services

KASHEC

Disclaimer

C-Borne Services (CBS) having registered office in Navi Mumbai Maharashtra, Medula Soft Technologies having its registered office in NOIDA and Kashec Engg Pvt Ltd having its registered office in Pune have been engaged by Thane Municpial Corporation for preparing the Detailed Project Report on Inland Water Transport in Vasai Creek – Ulhas River (NW-53) Thane, Maharashtra.

The statements of fact, opinions and conclusions expressed in this report are correct to the best of our knowledge and belief and are based on information, collected in the field, provided by promoters of the project, and that available in the public domain.

This Report should be used in its entirety only and shall not be reproduced in any form without prior permission from the consortium of Consultants.

Neither the consortium of Consultants nor any Partner, representative or employee of consortium of Consultants accepts any liability for any direct, consequential or perceived loss arising from the use of this report or its contents.

Consortium of Consultants has no financial liability whatsoever to the promoters of the project or any other user(s) of this report.

CONTENTS

TABLES

ANNEXURE

FIGURES

SYMBOLS AND ABBREVIATIONS

Symbols and abbreviations used are generally in accordance with the following list.

1 Proper names and organisations - India

BIS....................Bureau of Indian Standards

GAIL ....Gas Authority of India

IAPH ....The International Association of Ports and Harbours

MLDB ....Main Lighting Distribution Board

MMB……………Maharashtra Maritime Board

MoEF&CC ....Ministry of Environment, Forests & Climate Change

MoS ....Ministry of Shipping

MPCB ....Maharashtra Pollution Control Board

MSCDCL ....Maharashtra State Electricity Distribution Company Limited

NHO ....National Hydro graphic Office, Dehra Dun

OCIMF ....The Oil Companies International Marine Forum

PIANC .... Permanent International Association of Navigation Congress

SIGTTO ....Society of International Gas Tankers & Terminal Operators Ltd.

SoI ....Survey of India

SOLAS ....Safety of Life at Sea

TMC..................Thane Municipal Corporation

2 Proper names and organisations – Other

BA.....................British Admiralty

BS.....................British Standard

IALA..................International Association of Marine Aids and Lighthouse Authorities

IMO...................International Maritime Organization

ISPS ....International Ship and Port facility Security code

UTM..................Universal Transverse Mercator (map projection)

WGS.................World Geodetic System (ellipsoid for map projection)

3 Other abbreviations

Approx. ....approximately

cif......................cost, insurance, freight

dia.....................diameter

feu ....forty foot equivalent unit (container)

fob ....free on board

max...................maximum

min....................minimum

No.....................number (order) as in No 6 nr ....number (units) as in 6 nr

Panamax ....ship of max permissible beam of 32.2m for transiting the Panama Canal

ppt ....parts per thousand

teu ....twenty-foot equivalent unit (container)

BOOT ....Build – Own - Operate – Transfer

CCTV................Closed Circuit Television

CD ....Chart DatumCSR Corporate Social Responsibility

CBRM……………...Coal bearing raw material

DPR..................Detailed Project Report

EIA....................Environmental Impact Assessment

HAT ....Highest Astronomical Tide

ICD ....Inland Container Depot

IBRM………..…..Iron bearing raw material

IT ....Information Technology

LAT...................Lowest Astronomical Tide

LOA ....Length overall (of a ship)

LCL...................Less Than Container Load / Consolidation Containers

M ....“mega” or one million (10^6)

MHWS ....Mean High Water Spring tides

MHS………………..Material Handling System

MLWS...............Mean Low Water Spring tides

MSL ....Mean Sea Level

MoU..................Memorandum of Understanding

MVA………………..Mega volt ampere

SEZ ....Special Economic Zone

ToR...................Terms of Reference

VTMS ....Vessel Traffic Management System

4 Units of measurement

Length, area and volume

mm ....millimetre(s)

m ....metre(s)

km.....................kilometre(s)

n. mile...............nautical mile(s)

mm^2 ....square millimetre(s)

m^2 ....square metre(s)

km^2 ....square kilometre(s)

ha ....hectare(s)

m^3 ....cubic metre(s)

Time and time derived units

s........................second(s)

min....................minute(s)

h ....hour(s)

d ....day(s)

wk ....week(s)

mth ....month(s)

yr ....year(s)

mm/s.................millimetres per second

km/h..................kilometres per hour

m/s....................metres per second

knot...................nautical mile per hour

Mass, force and derived units

kg......................kilogram(s)

g ....gram = kg x 10^{-3}

t ....tonne = kg x 10^3

displacement ....the total mass of the vessel and its contents. (This is equal to the volume of water displaced by the vessel multiplied by the density of the water.)

DWT ....dead weight tonne, the total mass of cargo, stores, fuels, crew and reserves with which a vessel is laden when submerged to the summer loading line. (Although this represents the load carrying capacity of the vessel it is not an exact measure of the cargo load).

Mt ....million tonnes = t x 10^6

TPD................... …Tonnes per day

TPH/tph............. …Tonnes per hour

Other units

°C ....degrees Celsius (temperature)

Mtpa ....million tonnes per annum

0 Executive Summary

0.1 Project Back Ground

Water transport is the cheapest and the oldest mode of transport, which operates on a natural track and hence does not require huge capital investment in the construction and maintenance of its track except in case of canals. The cost of operation of water transport is also very less, which is evident from the fact that 1 litre of fuel can take 1 ton of cargo up to 180 km over waterways as compared to 25 km by road or 75 km by rail[1]. It has the largest carrying capacity and is most suitable for carrying bulky goods or ODC (Over Dimensional Cargo) over long distances. It has played a very significant role in bringing different parts of the world closer and is indispensable to foreign trade.

The water transport potential in India has been largely untapped and except for the Gogha-Dahej ferry service, there is no organized ferry movement for passenger and Ro-Ro vehicles. In this connection the Maharashtra Maritime Board (MMB), operates various ferry services all over the state and last reported figures suggest about 18 million[2] passengers use this mode annually. The waterway mode in the Mumbai region is developed fractionally compared to the potential. In fact, if correctly planned, the integrated waterway could give the other modes a run for their money. Figure 1.10 shows the existing and the proposed waterways that could be potentially developed in the Mumbai Metropolitan Region (MMR) area. In this context the initiatives of the TMC to develop about 50 km waterway between Vasai on the Arabian Sea and Kalyan is commendable. This report is the Detailed Project Report prepared in line with the requirements of IWAI, by a consortium of consultants, after collecting field data and examining existing facilities all over. The planning has been wholesome and live and would react to the development as it grows and is supported by scientific studies.

0.2 Waterway General Description / Detailed Hydrographic Survey

The Ulhas River originates in a valley north of the Rajmachi hills formed by mountain streams draining the northern slope of those hills, which are part of the Sahyadri range of the western Ghats in the Raigad district of Maharashtra. The district is the northernmost part of the Konkan lowlands of Maharashtra. It comprises the wide amphitheater like Ulhas basin on the south and hilly Vaitarna valley on the north together with plateaus and the slopes of Sahyadri. From the steep slopes of the Sahyadri in the east, the land falls through a succession of plateaus in the north and center of the

1 Source: http://www.yourarticlelibrary.com/Article by R.C.Agarwal

2 Web Site - MMB

district to the Ulhas valley in the south. These lowlands are separated from the coast by a fairly well-defined narrow ridge of hills that runs north-south to the east of the Thane creek, parallel to the sea, keeping a distance of about 6 to 10 km from the shores. Isolated hills and spurs dot the district area. The major tributaries meeting the Ulhas River are – The River Kalu (which is earlier joined by river Bhatsai) at 10 Km upstream of Kalyan, the River Mumbra at Mumbra, the Kamvadi River 12 Km downstream of Thane, the Kaman 7 Km upstream of Bassein and the Sopara Creek just upstream of western Railway Bridge. All the above tributaries except Mumbra meet Ulhas River on its right (Northern bank). The seaward end of the river is also known as Vasai (Bassein) creek.

At Kasheli near Thane, a distributary of Ulhas River known as Thane Creek branches out and flows southward. It passes the industrial areas of Thane-Belapur and Mumbai and finally falls into the north end of Mumbai Harbour, just near and east of Trombay. The distance from the offtake to Trombay along Thane creek is about 24 Km and from Trombay to Ballard Pier is about 20 Km. The Nhava Sheva Port (JNPT) is about 8 Km from Trombay.

To the south of the creek lies the Bhayander shore, which is developed on both sides of the railway track. 2 railway bridges connect Naigaon and other stations to the western suburbs. Old bridge was built during the British Raj and has been closed since it was declared dangerous to commute. The new bridge is functional and has 4 tracks. Bhayander sea shore sees a huge number of people in the evenings which have been developed recently with protective measures for over enthusiasts. It houses a children park, playing ground, pooja area, Idol immersion (visarjan) area on the east side. On the west there are small garden benches where people can sit and chat. Small paths lowering into the sea also exist where people can stand and watch the waves hitting the shoreline.

The minimum vertical clearance available under the old railway bridges near Bhayander is 3.43 m above Mean High Water Springs (MHWS). The horizontal clearance between the piers the same old railway bridge is 18.7 m. Hence, this bridge must be removed for permitting the proposed navigation in the National Waterway no. 53.

East of Panju Island, both the channels join in and the creek narrows. There are two power transmission lines crossing the Vasai Creek in line with Sansunavghar Village. The vertical clearance available near the transmission line is about 26.2 m above CD.

The outfall mouth is wide and spread narrowing down as one moves upstream. The creek or estuary is tidal dominated manifested by the formation of the shoals and occasional island. The Panju Island is one such physiological feature at the entrance. The banks of the creeks are mostly hilly and with steep banks. At locations the areas are undulated and plain with vegetation and swampy low-lying areas. Geologically it is part of the Gondwanaland Plateau. Upstream of the Ghodbunder Fort, the waterways narrow to the minimum and the velocities are higher. Though there is no fall, the creek bed is steep. Moving upstream as the tidal effects reduces the meandering starts and the river narrows. The entire waterway is under the influence of the tidal prism.

Table 0. 1: Hydrographic Survey Was Details As Per The Schedules Given In Table Below

Sl.no.	Particulars	Details	Remarks
1	Waterway Name – NW no	Vasai Creek/Ulhas River – National Waterway no.53	
2	Length of the Stretch	50 km – Approximately – between Vasai to Kalyan	Surveyed length 52.50 km
3	Duration of the Survey	30th April, 2017 to 15th September, 2017	
4	Datum	WGS 84	
5	Data collected Tide	5 Locations	Control Station - Panju
6	Data collected Current	6 Locations	
7	Data collected Wave	6 Locations	
8	Data collected TSS	6 Locations	
9	Data collected Bed Samples	6 Locations	

The cross structures except for the old as well as the new Bhayander bridge has low air draught which may be an impediment in vessel design. While the old bridge could be dismantled, the new bridge would have to be replaced with new ones as the waterway grows beyond a Level.

The bends in the waterway are adequate for the vessel that are likely to use the waterway up to chainage 46 km. Beyond this chainage and up to Kalyan there are 4 bends which are having bend radius between 257 m to 360 m, which need to be negotiated at slower speeds.

From the collected data it could be seen that the tidal range is about 4.5 m to 5 m and the maximum current is about 0.8 m/s at the Panju island station, in the narrow stretch. At other stations the speed is low and around 0.3 to 0.4 m/s. In addition, water samples and bed samples were collected and analysed for determining the dredgebility of the channel. It was noted that the Total Suspended Solid (TSS) values are low and the bed samples are mostly in the fine sand to sandy range.

0.3 Waterway Development

The Inland Water Authority of India (IWAI) classifies the waterway into various classes based on the requirements and the waterway condition, enabling navigation for majority of the time. The waterway is classified in the following categories for safe plying of self-propelled vessels up to 2000-ton Dead Weight Tonnage (DWT) and tug-barge formation in push-tow units of carrying capacity upto 8000 tons. The classification applicable to rivers is given as

Table 0. 2: Waterway Classification By IWAI Regulations, 2006 Notified In Part – III, Section 4 Of The Gazette Dated 20-26, January, 2007

Waterway Classification	Water Depth (m)	Bottom Width (m)	Bend Radius (m)	Vertical Clearance (m)	Horizontal Clearance (m)
Class - I	1.20	30.00	300.00	4.00	30.00
Class - II	1.40	40.00	500.00	5.00	40.00
Class - III	1.70	50.00	700.00	7.00	30.00
Class - IV	2.00	50.00	800.00	10.00	50.00
Class - V	2.00	80.00	800.00	10.00	80.00
Class - VI	2.75	80.00	900.00	10.00	80.00
Class - VII	2.75	≥ 100.00	900.00	10.00	100.00

In addition, the IWAI specifies, the vertical clearance for power cables or telephone lines or cables for any transmission purpose for all the classes of waterways mentioned above. However, this classification is mostly theoretical and adaptation would be required for the real-life situations. Accordingly, the waterway channel was designed using various other stipulations of U.S. Corps of Engineers and PIANC. Finally based on these requirements, a 100 m wide channel was found 'Good' for the present as well as the future requirements for optimally utilizing the capacity of the waterway. A design vessel size of LoA = 56 m and Beam 14 m with a loaded draft of 2.5 m was chosen as the maximum vessel size for the proposed NW 53 channel, with vertical clearances suiting the minimum available air draught of 4.43 m, with the lowered masts. However, a mix of different sizes of vessels will be required to operate in the waterway,in different stretches.

The waterway is free form bank erosions and requirements of erosion control and bank protection works are generally not required. The only conservancy measures to be adopted for the waterway is Dredging of the existing 6 to 9 shoals in the waterway. The total fairway development consisting of erosion control, old bridge dismantling and dredging would cumulatively cost about ₹ 418.00 Million and would require about ₹ 25.50 million for operation and maintenance cost annually. Adequate land for locating the waterway facilities like terminals and other associated activities shall be acquired, though efforts are made to locate terminals near lands owned by the Government.

0.4 Traffic Study

Maharashtra is one of the affluent maritime states which uses the waterways and the coastal shipping rather wisely. There are total 48 identified minor ports in Maharashtra. Out of them, 14 are currently active. These ports collectively handled an amount of 24.8 million tons in the year 2014. This includes the coastal movement as well as overseas. Bulk forms the major share of the traffic mainly – Iron ore, Cement and Coal. A large part of cargo is meant for the industries located within a radius of 50 km from the ports. This waterway for the present phase would deal with passenger transport and ro-ro service only, for which a different traffic study was carried out.

To carry out the analysis travel behavior data collection was employed through the traditional passenger interview survey. Travel behavior data has been collected through predesigned questionnaire which aimed at providing the data to meet the objectives of the present study. The questionnaire consisted of three sections namely household information, person information and trip information. Household information captured aspects like household income. Under personal information age and gender was sought for. Both household information and personal information were used to characterize the socio demographic attributes of the commuters. Travel distance (Home to work), travel time, access time, waiting time, transfer time, parking time, travel cost and preferred mode of travel was pursued under travel information. Rating questions regarding soft factors of travel information were also included in the questionnaire.

Survey samples were collected from different locations as per the need of the study; these include Bhiwandi, Bhayander, Diva, Dombivli, Kalwa, Kalyan, Mumbra, Naigaon, Nalasopara, Thane, Vasai and Virar. A total of 50,000 samples were collected from the survey locations.

The data was preprocessed for better assessment and simplified interpretation of the obtained results. Correlation analysis was carried out to find the correlation between the various parameters. Preprocessing of data also involves preparation of input data according to NLOGIT[4] format for mode choice analysis. Nlogit format consists of multiline format, one for each choice option. All the mentioned parameters were analyzed.

4 NLOGIT: Superior Statistical Analysis Software

The study is aimed to assess the potential shift of commuters presently travelling by local trains, bus, auto, two-wheeler and car within Mumbai where a new mode of transport i.e. Inland Water Transport is to be introduced. The primary survey conducted for the study included the existing mode choice behaviour of passengers for travel within Mumbai.

A certain base value for the proposed mode that is Inland Water Transport has been assumed from the secondary sources. In this case we have assumed that the proposed mode will be having lesser travel cost and the reduction in the time will be more from the existing modes. As per the stated preference survey data, passengers were allowed to choose one of the seven options towards their discrete choice.

The mode with the maximum probability has been chosen and hence the total samples with the probability of same mode are being added to estimate the total shift from the existing mode to the IWT.

It has been found from the model that about 17.4%, 16.3%, 14.15%, 47.10%, 19.02%, 7%, 19.9%, 52.75% of the people travelling from Bhayander, Mira Road, Mumbra, Nai Gaon, Nala Sopara, Thane, Vasai and Virar respectively shifted to IWT from the present modes in the realistic scenario.

Combining these model results with the OD survey data of each jetty location, OD expansion was carried out to get the actual values of traffic. For further analysis, these values were projected for future scenarios considering growth rate of 7.8% per year, according to the CMP-2016, Mumbai. The detailed calculations for Jetty capacity are given in Chapter 4.

To obtain detailed picture of travel pattern and for further analysis, data related to trip was obtained from OD survey. OD survey was done at 21 locations, and peak hour traffic volume in each direction was obtained from video graphic survey. Using these data Origin-Destination matrix was derived.

The modal shift values attained for each Jetty location from NLOGIT was applied to this OD matrix to obtain the base year traffic volume at each jetty location. The operation of the service is considered from the year 2018, therefore an estimation of the demands for the base year is important. Chapter 4 gives the peak hour traffic volume expected at each jetty location. Considering 15 hours of operation of jetty, per day volume count was calculated. Assuming 1 year of construction and 20 years as a period of economic evaluation, this data was forecasted at the growth rate of 7.8% per year according to CMP-2016, Mumbai.

The per day base year traffic at each Jetty location is shown in Figure below.

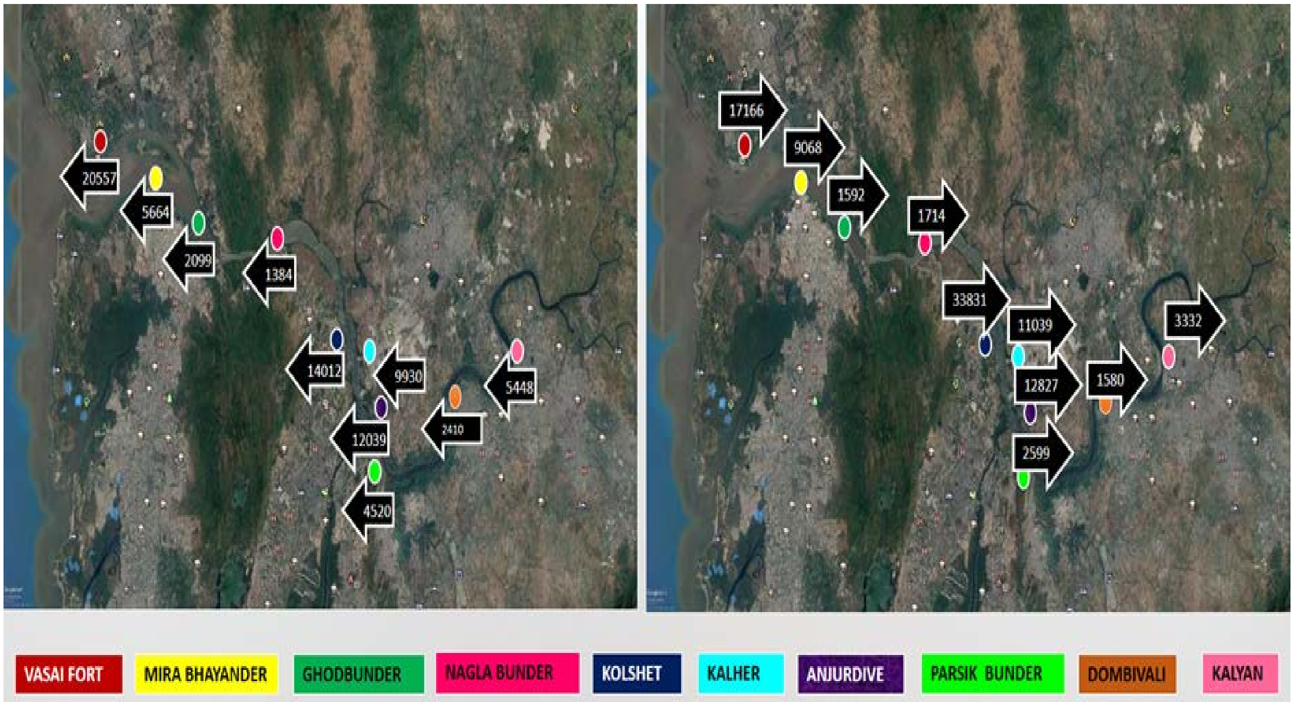


Table 0. 3: Jetty Traffic In The Base Year Of 2019.

Up Traffic (Up stream of the River)				Down Traffic (Down stream of the River)		
From	Traffic	Traffic 15hour		To	Traffic	Traffic 15hour
Vasai	1805	17167		Vasai	1765	20557
Mira-	697	9066.5		Mira-	462	5664
Ghodbunder	153	1592		Ghodbunder	175	2099
Naglabunder	153	1714		Naglabunder	119	1384
Kolshet	3163	33832		Kolshet	1144	14013
Kalher	1070	11039		Kalher	974	9931
Anjur Dive	1070	12827		Anjur Dive	966	12040
Parsik	229	2600		Parsik	434	4521
Dombivli	142	1580		Dombivli	194	2410
Kalyan	292	3332		Kalyan	504	5448

Table 0. 4:Jetty Traffic For The End Of The 30th Year Of Operation (2049)

Up Traffic (Up stream of the River)				Down Traffic (Down stream of the River)		
From	Traffic	Traffic		To	Traffic	Traffic 15hour
Vasai	17182	187349		Vasai	16797	196406
Mira-	6633	84480		Mira-	4397	43004
Ghodbunder	1455	18088		Ghodbunder	1666	17762
Naglabunder	1457	16936		Naglabunder	1133	12291
Kolshet	30109	322150		Kolshet	10889	119764
Kalher	10183	130553		Kalher	9272	116962
Anjur Dive	10184	116707		Anjur Dive	9198	115750
Parsik	2180	26169		Parsik	4134	47691
Dombivli	1347	15747		Dombivli	1843	18440
Kalyan	2779	29982		Kalyan	4797	58368

No cargo traffic is considered for the purpose of this study.

0.5 Terminal

The terminal locations in general depends on the following main factors,

1. Population Centers
2. Connectivity
3. Accessibility
4. Land availability
5. Depths availability
6. Saving in time
7. Environmental Impact

Based on the above requirements the following Terminal locations were selected along the water way. There are 7 terminals on the left and 3 on the right bank as shown in Figure 5.2.

1. Vasai Fort
2. Mira-Bhayander
3. Ghodbunder
4. Nagla Bunder
5. Kolshet
6. Kalher

7. Parsik
8. Anjur Dive
9. Dombivli
10. Kalyan

There will be three types of terminals as indicated below; 1. Main Terminals, 2. Secondary Terminals, 3. Special terminals

Main Terminals

Vasai, Mira-Bhayander, Kolshet, Kalher and Kalyan are the likely main terminals in the waterway. These terminals would have the following facilities;

1. Water Front

i. Dolphins for berthing of the Vessels up to 40 m length initially and progressively upto 100 m with addition of extra dolphins.
ii. Floating Pontoon and the Link Span
iii. Concrete platform for turning and handling up to 40' Containers trucks
iv. Approach adequate for passenger and container trucks

2. Foreshore

i. Passenger amenities like
   a. Waiting area
   b. Restaurants
   c. Children's' Play area
   d. Shopping areas
   e. Banks/ATMS
   f. Space for Parking facility for Commercial and Private vehicles/Motor Cycles
   g. Space for Passenger handling for Public Transport

ii. Terminal Amenities
   a. Terminal Office
   b. Ticketing Area
   c. Staff and others waiting area
   d. Baggage Storage Facility
   e. Public toilets

iii. Cargo Amenities (To be developed later)
   a. Container marshaling yard

b. Covered storage area
c. Cold Storages
d. Loading and unloading areas

iv. Other Facilities

a. Sewage Treatment Facility
b. Medical Facility/First Aid facility
c. Connectivity to the terminal
d. Protected waterfront for shoreline stability
e. Garbage, waste oil, grey water, bilge water recepetion facilities

Secondary Terminal

Ghodbunder, Nagla Bunder, Parsik Bunder, Anjur Dive, and Dombivli terminals are to be designed as secondary terminals with regard to facilities. The following amenities are proposed at the secondary areas;

1. Water Front

a. Dolphins for berthing of the Vessels up to 40 m length initially and progressively upto 100 m with addition of extra dolphins
b. Floating Pontoon and the Link Span
c. Concrete platform for turning and handling up to 40' Containers trucks
d. Approach adequate for passenger and container trucks

2. Foreshore

a. Passenger amenities like

i. Waiting area
ii. Restaurants
iii. Children's' Play area
iv. Shopping areas
v. Banks/ATMS
vi. Parking facilities for Public and Private vehicles
vii. Handling of Public transport passengers

b. Terminal Amenities

i. Terminal Office
ii. Ticketing Area
iii. Staff and others waiting area

iv. Baggage storage facility
v. Public toilets

c. Other Facilities

i. Sewage Treatment Plant
ii. Medical and First aid facility
iii. Connectivity to the terminal
iv. Protected waterfront for shoreline stability
v. Garbage, waste oil, grey water, bilge water recepetion facilities

Special Terminals

At the Kolshet terminal additionally the facilities for the ship repair and building for vessels up to 110 m would be provided.

The layout of the terminal at each of the locations is given in Chapter 5.
In addition to the facilities described above, the following facilities would be provided at some of the selected/all terminals.

A. Solar Panels on the Terminal Building for Green Energy
B. Restaurants, Resorts and Amusement areas for the Tourists
C. Parks and gardens
D. Electric car Charging Points

In all about 50 acres of land would be required for development of the 10 terminals.

Geotechnical studies were carried out for determining the nature of soil at the terminal. In general, it was found that the soil profile is mostly identical through the river and there is weak basalt overlain by medium to fine sand.

Various structural designs nomenclatures for the berthing structures were evaluated, before finally deciding on the piled structure, because piled structures are least intrusive to water flows and are more durable.

The total cost of developing the 10 terminals worked to about ₹ 3615.6 milions with a 1.5% maintenance cost annually.

0.6 Preliminary Engineering Designs

The terminal and the other facilities are designed based on the guidelines of the IS and BS codes of practice. The Various facilities provided under the contract will be designed for service life as listed below:

- Link Span & Pontoon: 25 Years.
- Concrete Structures: 50 Years.
- Mechanical Plants: 20 Years.
- Electrical Plants: 20 Years.
- Buried earth electrical system: 50 Years.
- Control Panels: 25 Years.
- External Instrumentation Systems: 15 Years.
- Transmission Main: 30 Years.

The main navigational aids for the present context are:

1. Channel marker Buoys
2. Leading lights for night navigation
3. Terminal location lights
4. Marking on the Cross structures
5. Shore beacons and radar Reflectors
6. Marking of the permanent structures such as electric towers
7. Marking along the bends
8. No navigation/Shallow area markings

0.7 Vessel Design

The specifications and requirements of a modern vessel has been discussed, including the construction, power and the maneuverability. Fuel Efficient vessels which operates in shallow water would be preferred. Most of the vessels would be Ro-Ro types except for some exclusive passenger buses earmarked for longer hauls.

In the context of the present waterway, starting a full service right away after creating the full infrastructure may be a little out of place. On the contrary, slowly but steadily increasing the service quality and frequency would be testing the viability and adaptability of the waterway, and make the service stable before the actual service with all infrastructure starts, may be 3 years down the line.

Accordingly, it is proposed to split the service in to three distinct segments namely,

1. Partial Service to start immediately with locally available vessels and sloping/pre-fabricated floating jetties
2. Limited service with some of the terminals readied and with better and leased vessels
3. Full service after the terminals are ready and the vessels are constructed.

The initial services would be mostly cross ferries and would be using Ro-Ro vessels available in the country. This would immediately position the waterway as a viable alternative mode to the existing modes, apart from taking care of the initial teething problems.

Since the waterway is not very wide, the turn around times are low and often times less than 30 mins. The cross movement turn around is about 11 to 14 mins.

After examining various designs and compatibility with the waterway, the following mix of vessels were selected for the waterway. These vessels would be owned by the SPV operating the waterway and the operation and maintenance would be outsourced.

For this, various Ro-Ro types of vessels available in the world were examined and the following vessels were selected.

1. Modular vessels: 2 numbers
    a. Length (m) 32
    b. Beam (m) 10
    c. Passengers 150
    d. Speed max (knots) 12
    e. Number of cars 14
    f. Engine size 250 HP x 2
    g. First in and First Out System
2. Passenger Ferry: 2 numbers
    a. Length (m) 34
    b. Beam (m) 10
    c. Passengers 160
    d. Speed max (knots) 12.0
    e. Number of cars 0
    f. Engine size 250 HP x 2
3. Water Buses: 2 numbers
    a. Length (meter) 32
    b. Beam (m) 8.1
    c. Passengers 86
    d. Speed max (knots) 12
    e. Engine 250 HP x 2
4. Ferry : 2 numbers
    a. Length (meter) 36

b.	Beam (m)	12
c.	Passengers	400
d.	Speed max (knots)	10
e.	Number of cars	40
f.	Engine	250 HP x 2
5.	Cross Ferries:	2 numbers
a.	Length (meter)	34
b.	Beam (m)	12
c.	Passengers	150
d.	Speed max (knots)	8
e.	Number of cars	25
f.	Engine	250 HP x 2

The cost to purchase the vessels, whether they are new or second-hand, represents a significant commitment for the ferry operating company. There are 5 types of vessels proposed for the waterway of different capacity and dimensions. For flexibility of service it has been assumed that ten ferries capable of making the longest journey on the network will be used, one assigned to each terminal. However, for the purpose of developing costs as input to this study the network will consist of vessels described above with approximate cost as indicated below;

A. Modular Vessels – 2 numbers

Capital cost per vessel: $ 1.75 Million[5] = ₹120 million

B. Passenger Ferry – 2 numbers

Based on approximate market price for the similar vessels = $ 2.0 Million = ₹140 million

C. Water Buses – 2 numbers

Based on approximate market price for the similar vessels = $ 2.15 Million = ₹150 million

D. Ferries – 2 numbers

Based on approximate market price for the similar vessels = $ 2.6 Million = ₹180 million

E. Cross Ferries – 2 numbers

Based on approximate market price for the similar vessels = $ 2.4 Million = ₹160 million

Total Capital cost from above = ₹120 x 2 + ₹140 x 2 + ₹150 x 2 + ₹180 x 2 + 160 x 2 = ₹1500 Million

5 Discussions with potential suppliers in the Western Europe/USA

The above prices of the vessels are based on preliminary enquiries with various manufacturers located in the Europe and USA. With placing of bulk orders, the prices may vary substantially. In the alternative, shipbuilders in India, especially Cochin Ship Yard, or Goa Shipyard, could be enabled to fabricate vessels to be designed for the waterway.

Total Operation cost is given in Table 0.5.

It is however advised that the operation be outsourced and only supervisory responsibility is retained with the waterway. Without investments in the vessel many experienced organisations would be available for the operation and maintenance.

Future requirement of vessels is proposed to be acquired in the PPP mode.

Table 0. 5: Operation And Maintenance Cost Of Vessels

Item	Operation Cost /Day ₹	Operation Days	Total Cost Million ₹
Crew	1,700,000	330	561
Fuel	4,500,000	330	785
Oil and Other Consumable	300,000	330	99
T O T A L			**1045**

0.8 Navigation And Communication Systems

In order to ensure safe navigation, it is imperative to implement an advanced navigational aid system as per the IALA and a communication system that is compatible with the international standard. The IWAI is implementing a RIS system that is akin to the ATC in aviation. The RIS is an integrated system which takes input form tide, current, wave, vessel details, passenger details, terminal facility details and occupancy, requirement of vessel at a location and provides a global platform for total control of the system. RIS is proposed to be implemented in the waterway.

The capital cost of the Navigation and communication system would be detailed below;

1. Channel Marker Buoys for 47.5 km waterway: ₹ 30 million
2. River Information system and leased line communications: ₹ 30 million
3. Terminal Control systems and navigation aid: ₹ 75 million
4. Survey boat and Equipment: ₹ 25 million

Total ₹ 160 million

The monthly operation and maintenance cost of the waterway is worked out and given below.

Staffing of the RIS in three shifts:	10 x 3 x 12 x ₹75000	=	₹ 27 million
Terminal Communication:	10 x 4 x 3 x 12 x ₹50000	=	₹ 72 million
Survey and channel safety:	2 x 8 x 12 x ₹70000	=	₹ 13.50 million
Consumables and Fuel:		=	₹ 41.50 million
Total			₹ 154 million

0.9 Environmental Impact Assessment

General

The Vasai Creek - Ulhas River has always been in existence and therefore unlike new highways, the land acquisition and consequential displacements leading to resettlement and rehabilitation issues are not there. As some of the proposed IWT terminals fall within 10 Km of Wild Life Sanctuaries the project falls in Category A for obtaining Environmental Clearance.

Environmental Studies

The environmental studies in general include finding the baseline status of the environmental settings consisting of various parameters listed below.

1. Terrestrial Ecology
2. Marine Ecology (in the present case, as it is a creek)
3. Water Environment
4. Air Environment
5. Noise Environment

The study involves:

1. Baseline Data collection
2. Analysis of Data
3. Study the stages of development and extent of construction involved
4. Likely impact during the construction and the operation phase
5. Prepare a Management Plan for both the phases
6. Identify the likely risks and devise a mitigation plan
7. Establish an Environmental Monitoring Programme for close watch on the day to day environmental impact

Objectives of Environmental Management

- Establish systems and procedures
- Ensure that the mitigation measures are implemented
- Monitor the effectiveness of mitigation measures
- Protect environmental resources where possible
- Enhance the value of environmental components

Environmental Legislation

- Environmental Impact Assessment Notification, 2006 and amendments
- Coastal Regulation Zone Notification, 2011 and subsequent amendments
- Air (Prevention and Control of Pollution) Act, 1981, 1987
- Water (Prevention and Control of Pollution) Act, 1974, 1988
- Noise Pollution (Regulation and Control Act) 2000 and amendment till date
- Hazardous Wastes (Management Handling and Trans boundary) Rules, 2008
- MSIHC Rules, 1989
- Biological Diversity Act, 2002
- Wild Life Protection Act, 1972, 1993
- Disaster Management Act, 2005
- The Wetland rules, 2010
- Inland Vessels (Prevention and control of pollution and Protection of Inland water) Rules 2016
- The Archaeological Sites and Remains Act, 1958

Social Legislations

- The RFCTLAR&R Land Acquisition, Rehabilitation and Resettlement Act, 2013
- Legal Provision related to Sexual Harassments of Women at workplace (Prevention, Prohibition and Redress) Act, 2013 etc.
- Payment of Wages Act, 1936
- Equal Remuneration Act, 1979
- Child Labour (Prohibition and Regulation) Act, 1986,
- Minimum Wages Act, 1948
- The Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996 and the Cess Act of 1996
- Workmen's Compensation Act 1923
- Contract Labour (Regulation and Abolition) Act, 1970

- Inter-State Migrant Workmen's (Regulation of Employment and Conditions of Service) Act, 1979 and Rules, 1996
- The Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act, 1995 and Rules, 1996
- Public Liability Insurance Act, 1991.

Generic Structure of the EIA Report

The following chapters have been included in this EIA report, which is in line with the Generic Structure of Environmental Impact Assessment and as per the EIA Notification 2006:

1. Introduction
2. Project description
3. Description of the Environment (includes Social Impacts)
4. Anticipated Environmental Impacts and Mitigation Measures
5. Analysis of Alternatives (Technology & Site)
6. Environmental Monitoring Program
7. Additional Studies
8. Project Benefits
9. Environmental Cost Benefit Analysis
10. Environmental Management Plan (EMP)
11. Summary and Conclusion
12. Disclosure of Consultants engaged

Environmental Setting in the Project Area

In order to assess the baseline environmental setting of the area a core area with in the 10 km radius of the project is considered as is the norm. The location of the data collection stations and the eco sensitive area vis-à-vis the project area is also examined.

Eco-Sensitive Area

The project area falls in the vicinity of the following eco-sensitive zones.

1. Tungareshwar Wild life Sanctuary
2. Sanjay Gandhi National Park
3. Thane Flamingo Wild Life Sanctuary
4. Dombivli Critically polluted area

Table 0. 6: Distance Of The Terminals From The Eco-Sensitive Zone

(in Kms)

Sr. No.	Site Name	SGNP	Thane Creek WLS	Tungareshwar WLS	Dombivli Critically Polluted Area
1	Vasai Jetty	8.67	> 10.00	7.22	> 10.00
2	Mira Bhayander (Jasal Park)	4.35	> 10.00	5.60	> 10.00
3	Ghodbunder	0.27	> 10.00	6.22	> 10.00
4	Nagla Bunder	1.27	> 10.00	2.54	> 10.00
5	Kolshet	2.38	8.67	6.31	> 10.00
6	Bhiwandi (Kalher)	3.03	8.90	6.39	> 10.00
7	Bhiwandi (Anjudrive)	5.41	6.70	9.45	8.575
8	Parsik Bunder	4.97	6.06	9.70	9.10
9	Dombivli (Thakurli Village)	> 10.00	> 10.00	> 10.00	3.55
10	Kalyan	> 10.00	> 10.00	> 10.00	2.29

Meteorology

The baseline data has been collected in respect of air quality, marine water quality, noise levels, Terrestrial Ecology, Marine Ecology and Fisheries in and around the project area and the details are included in EIA report.

Air Environment

In respect of air quality, the parameters analysed were Particulate Matter (PM10 and PM2.5), Sulphur dioxide (SO2) and Nitrogen Oxides (NOx). The average PM2.5 levels at all the stations was within the permissible limit specified for residential areas (100 µg/m3). Likewise, the ambient SO2 and NOx concentration at all the stations was within the permissible limit of 80 µg/m3 for the residential areas.

Marine Water Quality

Similar data was collected with regard to the ground and surface water and analysed. The analysis indicates that the base line status of this area does not show any pollution and the parameters are within the prescribed limits.

Other Water and Sediment quality data

Amongst, the trace metals, the concentration of zinc, copper and lead was quite low. The mercury and cadmium levels showed lesser concentration, considering the fact that there are no sources of these pollutants in the area. However, the concentration of mercury and cadmium is not alarming.

Terrestrial Ecology -The core area, falls inside the SGNP and the Wild Life Sanctuaries. Hence there is forest all around the creek. The major forest type in the core area are southern typical moist deciduous forest and moist teak forest. Satellite images of the area does show mangrove along the coastline. However, the terminal locations were carefully selected so that no mangrove gets damaged. There are limited wildlife observed during the survey in the core area.

Marine Ecology -To ascertain the biological productivity a few biological parameters like Chlorophyll pigments, primary productivity, pheophytin, particulate organic carbon, zooplanktons, phytoplanktons and benthic fauna at the sites were analysed. Based on the data of various parameters, the terminal sites can be termed as low to moderately productive.

Fisheries -Deep sea fishing activities are being practiced in the villages of the core area. Fishing continues throughout the year except during monsoon months, when the sea is choppy and boats cannot go to the high sea due to higher risk involved. During the monsoon months some of the fishermen families use the creek area for catching fish. The fish catch is not significant, but helps the locals to augment a part of their income during the monsoons.

Socio-Economic Aspects

According census 2011 and DSA 2012-13 data most of the people of the study area are depending on Industrial works, service sector, small business and fishing/fish culture for their livelihood. Business is also one of the major occupations of the people of coastal region. The average household size of the study area (4.3) is slightly lower than the state average (4.6 as per census 2011). The literacy rate in the study area is much higher than the national scenario in both sex male and female.

Stakeholder Consultation

A summary of issues raised by various stakeholders and how these issues are addressed and incorporated in the EIA report, are shown in below Table 0.7

Table 0. 7: Issues raised by Stakeholders

Stakeholders Type	List of Concerned Raised	Responses and mitigation measures under the project-summary
Shopkeepers	Shopkeepers opined in favour of the project, but they want to see the ferry ghat improved with more facilities such as toilets, sufficient space for shops on a designated area so that they will not be bound to shift their structure frequently. They expressed that the project will increase their business opportunities and new venture of business will be open after completion of the project.	Toilets and drinking water facilities will be included in the design of ferry ghats and river terminals. The designs of terminals will also include shops and while leasing out these shops, priority will be given to the affected communities.
Physically Disabled	There should be special facility for the disabled people in the ferry terminals and water vessels. They want separate place in ghat and ferry terminals for their easy movement. Wheel chair and bed facilities must be available in emergency situation. Disabled persons want proper safety and security in terminal and launch as well. Disabled persons do not know the facilities about river transports. Most of the people think that road transport is easier than river transport especially for the disabled persons as they cannot swim. They want separate space/seat for them in the launch/ferry and easy riding facility such as smooth way, wheel chairs, etc. If such facilities are provided for the disable people, then they may comfortably use the river transport.	Ramps will be provided at the terminals for embarkation and disembarkation of disabled people. Other aspects will be explored in full in the detailed EIA and design studies to be carried out during project implementation.
Fishermen	Fishermen communities are mostly living along the creek or within one km from the creek. They want modern signalling system and safety and security during fishing. Some time they are to face trouble from pirates or even some politically influenced persons who make them bound to pay money for fishing. They welcomed the project but requested to keep in mind about fish moving routes, season and fishing areas during	Navigational buoys/signals will be provided along the navigational channels. Spawning areas of fish, migratory routes and commercial areas for fishing will be avoided for dredge material placement.

Stakeholders Type	List of Concerned Raised	Responses and mitigation measures under the project-summary
	dredging so that their livelihoods will not be disturbed.	
Women	Safety and security, separate space for them in the launch terminals and vessels, separate ticket counter, etc. are their needs.	Separate ticket counters, waiting rooms and toilets will be provided for the women passengers near the terminals. Separate toilets will also be provided at the landing stations. Specific design features to maximize women's needs, comfort and safety in using, will be studied in more depth during the detailed design and EIA stage for river terminals and landings, as well as thorough study to develop a gender action plan and to be carried out during project implementation.

Socio- Economic Impacts

The following issues provide an overview of the impact that may be faced during construction and maintenance of the ferry terminals and other components of the project.

1. Demographic Impacts (Impacts of the project which may cause changes in the size and makeup of the population of the areas affected by the project)
2. Social Infrastructure (Impacts on the social characteristics of the community including housing, water and power supply, educational, health and recreation, transport and public safety)
3. Land Use
4. Social Relations and Impact
5. Cultural Property (Including religious, historic and archaeological sites)
6. Economic Activity (Primary and multiplier effects)
7. Human Rights and Regulation

Socio- Cultural impacts

According to proposed project component there is no physical or economic displacement of any schedule tribe community involved due to proposed project. Therefore, any socio-economic and cultural impacts that may occur as a result of the project would be in future and the overall severity of impact will be low.

Impact on Human Health & Occupational Safety

Safety issues associated with TMC's terminal activities involve improper handling, storing and disposing the waste material and some agricultural chemicals as well as accidents occurring with the operation of moving equipment. However, the project activities may not prove harmful to human health, but Workers on-site could be affected from different activities like noise emissions, cutting activities, improper electrical supply, slippery areas, improper movements of trucks, lack of protective gear/hygiene, uncontrolled access, lack of proper controls and signage around potentially hazardous areas,etc. However, these could be minimised by use of correct machinery and procedures.

Risk Analysis and Disaster Management

For any vessel to operate in this stretch of National Waterway 53, the likely impediments may be:

- Draft of the vessel
- Air draft of the vessel
- Width of the waterway (restrciting turning circle)
- Bends in the waterway
- Shallow areas
- Non availablity of suitable terminal/jetty

The modeling approach adopted for the quantitative assessment of the risks associated with runway operations involves several methodological steps which are defined as:

- Identification of hazardous conditions and accident scenarios
- Determination of probabilities of the accident identified
- Definition of consequences of such an accident (fatalities and vessel damages).

Hazards Identification

1. Engine Failure of RO-RO Vessel / accidental Ship/Hull, hull, propeller and rudder damages.
2. Vessel accidental collapse/capsize
3. Adverse Environmental condition of wind, waves and current. Natural Disaster such as Tsunami, Earthquake, Cyclone and Flood
4. Manmade threat such as fire,noise, sabotage, Terrorist activities along with likely stampede on narrow boarding/De boarding platform at heavy rush hours
5. Medical emergency to passenger on board.

6 Variation in interrelations between the safety domains and the interrelations between certain hydromechanics characteristics/parameters leads to accidents

Disaster Management Plan

Disaster Management Plan (DMP) effectively deals with all kinds of port/jetty related hazards during all shipping activities and also is in a state of preparedness to respond to such events and their adverse effects to the on-site as well as off-site population.

DMP caters to worst disaster scenario with reference to specific cases like Tsunami, fire, explosion, toxic gases dispersion, oil/chemical spills, including floods, cyclones, terrorist attacks etc. The plan should include early detection of emergencies (like fire explosion, toxic gas release, natural calamities like cyclones, earth quakes etc.). The details have been included in EIA report.

Environmental Management Plan

The aim of the Environmental Management Plan (EMP) is to ensure that the stress/load on the ecosystem is within its carrying capacity. Moreover, EMP also aims to maximize the beneficial impacts and minimize the anticipated adverse impacts likely to accrue as a result of the two proposed project alternatives. The EMP for the construction phase and operational phase are given in table no 9.14 and 9.15

Table 0. 8: Clearances Required For The Project

Sr. No.	Clearances Required
1.	CRZ clearance from the Maharashtra Coastal Zone Authority for the terminals and structures, under CRZ notification, 2011
2.	Consent to establish and Consent to Operate from Maharashtra Pollution Control Board
3.	Since this is a Category A project, the Environmental and CRZ clearance is from the MoEF& CC, under EIA notification, 2006.
4	Fire clearance for the Terminals
5	Classification society and DG Shipping for the Vessels
6	Maharashtra Maritime Board for the waterway channel and notification of the waterway
7	Requirement of Wildlife Clearance under Wildlife Protection Act, 1972

Cost Etimates

The cost estimates for implementing EMP for project shall be ₹ 25.00 million (Table 9.18) which includes ₹ 6 million for Equipment cost, ₹ 7.5 million for EMP and ₹ 11.5 million for Area development activities.

In addition to above, ₹ 21.50 millions/year (Table 9.19) is likely to be spent over EMP and Area Development Activities.

0.10 Institutional Requirements

The waterway is proposed to be run through a specially created SPV with a Board of Governers at the helm. The SPV will have majority participation of the TMC. The members of the SPV are;

1. Thane Municipal Coporation (TMC)
2. Inland Waterways Authority of India (IWAI)
3. Jawaharlal Nehru Port Trust (JNPT)
4. Maharashtra Maritime Board (MMB)
5. Mira-Bhayander Municipal Corporation (MBMC)
6. Vasai -Virar Municipal Corporation (VVMC)
7. Kalyan-Dombivli Municipal Corporation (KDMC)
8. Bhiwandi Nizampur Municipal Corporation (BNMC)

The SPV christened as Vasai Creek Waterway Authority (VCWA), would be responsible for day to day running of the waterway headed by a Chief Executive Officer (CEO).
There will be 4 departments namely, Waterway Operation, Engineering and Maintenance, Finance and administration and Shipyard Operation. The CEO would be assisted by one Chief Operating Operator (COO) for operation, Director Engineering for engineering and maintenance, Director Finance and Human Resources, and Director of the shipyard. The COO would be responsible for the operational aspects, Director Engineering for the engineering.

0.11 Project Costing

Table 0. 9: Capital Cost Estimates For The Project Including The Vessel Cost. (₹ Million)

Sr.no	Details	Amount in Million ₹
1	Terminal Development (10 nos)	3615.63
2	Land Acquisition	221.57
3	Road connectivity	60.00
4	Dredging (for 3.0 m CD)	363.00
5	Bridge dismantling (Old Rly Bridge at Vasai)	50.00
6	Erosion control	5.00
7	Fairway Development (Navigational Aids/RIS, etc)	160.00
8	Environmental issues	25.00
9	PDC/PMC charges (@ 6% including cost of vessels)	360.01
10	Contingencies (3%) including cost of vessels and except on Sr.no 1 above	82.34
	Total	4942.55

Table 0. 10: Operation Cost (O & M) Without The Dry Docking (₹ Million)

Sl.no	Details	Amount in Million ₹
1	Infrastructure at 1.5 %	54.23
2	Dredging	25.00
3	Erosion control	0.50
4	Navigation and Channel safety	154.00
5	Environment	21.50
6	Institutional (Terminal operations)	280.00
	Total	535.23

0.12 Implementation Schedule

The construction of the waterway development would consist of the following and the allotted time frame is as follows:

Dredging and Reclamation

About 0.71 million m3 of soft and hard material would be dredged for making the 100 m wide channel navigable for the proposed vessels giving a 3.0 m CD depth at all stages of tide. The dredged material especially the hard material shall be used for erosion control and bank protection works. The soft materials obtained from the dredging, could be used for bank protection, erosion prone area protection, use as construction material under licence as discussed in chapter 3, section 3.4.2.5.

The estimated quantity of the dredging can be completed in about 12 – 18 months' time, with majority of the times estimated for the removal of hard material. The waterways being ecologically sensitive water bodies are generally not permitted to have blasting as a mode of removal of hard strata. Therefore, with no blasting the removal of the hard materials would be limited to controlled drilling, chemical cracking and breaking, use of hammers and removal of broken rocks by back hoes. This process is time consuming and estimated to take about 8 months of time.

For the soft solid, crawl cat dredgers/cutter suction dredgers with less head room or/and dismantlable dredgers carried through land transport can be used for dregding. This would enable dredgers reaching the inner part of the creek without much difficulty. This must however, be remembered that these dredgers would be of low capacity with limited output and hence time taken shall be more. On the other hand, the good part is that the dredging requirement is mostly concentrated in the upstream stretches and partially functioning of the waterway covering almost 80-90% of the stretch could commence immediately.

Terminal Construction

Construction of berth approaches involves piling from the land side and subsequent development of turning platform and then the dolphins. Berth is located in shallow waters and therefore construction may not be arduous task. The superstructure construction would be mainly cast in situ and there will be no soffit shuttering. This would also enable the construction of superstructure on the piles already completed.

The superstructure shall be laid only after attachment of link span and other appurtenances. With deployment of multiple fronts and enough resources, it is possible to complete the terminals and the bank protection associated with it in a period of 12 to 16 months as detailed in Figure 12.1.

It is envisaged to complete the infrastructure for passenger operations quickly in a period not spanning more than 12 months. It is possible to give the passenger ferry operation a quick start at 4 sites namely, Parsik Bunder, Anjur Dive, Kolshet and Kalher by deploying prefabricated floating structures like link-span and turning platform with minimal civil works as adequate depths are already available as per costs and works discussed in sec 12.2. This would enable the passenger ferry operation stabilizing before the actual operation commences. Cost of summary for quick start of operations at these four sites is given in table 0.11

Table 0. 11: Cost Summary

Summary of costs for quick start of project at four selected sites		
1	Kolshet	279420071.90
2	Kalher	237216778.72
3	Parsikbunder	223340893.78
4	Anjurdive	241186166.36
	Total Cost	**981163910.75** **Say ₹ 981.16 Million**

Equipment and Onshore Development

It is envisaged that the delivery and installation of equipment as well as the onshore development can be done in synchronization with the execution of marine works. These works can be carried out to suit the complete commissioning of the facilities. Construction of the approach road to the terminals needs to be taken up on priority basis to aid the construction.

The ro-ro services destinations could be commenced with the passenger operation. The onshore construction including the approach roads could be completed in 12 months' time.

Procurement of Vessels

This is perhaps the most time consuming activity. Fabricating these vessels would not be less than 30 to 36 months', unless special arrangements with multiple agencies are made. However, from the date of laying of the keel, 18 to 24 months is generally assumed on the conservative side. Therefore, the following steps are recommended for quick start of the operation and sustenance of the operation,

1. Standardise the vessel design of various categories recommended for the waterway
2. Consider awarding the work to specialised and multiple agencies for vessel fabrication
3. Centralised procuring of engines and other vital vessel equipments for hastening the process and effecting economy
4. Construct the shipyard slipway at Kolshet and establish the shipyard, which could be used for fabricating the new vessels complementing the external efforts. This would also enable the shipyard to cope with the future demands.

5. In the interim, after the completion of the dredging of the channel in the downstream reaches, (about 4 to 6 months without the hard starta dredging) leased vessels from the markets could be requisitioned for commencing passenger ferry operation.

It is therefore possible to start the operation in about 6 months to 1 year's time from commencement of work, if the planning is adequate and methodical.

Navigational Aid and Fairway development

After completion of the dredging, the navigational buoys would be installed and the channel is notified before any commercial operation commences. This time also shall be utilised for installing and calibrating the River Information System and other communication systems.

Dismantling of the Cross Structures

As indicated in Chapter 2 and Chapter 3, the old railway bridge (made of iron) near Bhayander, is required to be dismantled for enabling ferry operations. Though complete dismantling would be desirable, dismantling of the middle span (navigation span) would be immediately carried out. This could be accomplished in a matter of 4 to 6 months time.

The proposed time schedule is given in Figure 12.1.

0.13 Economic And Financial Analysis

The financial evaluation indicates that the ferry services investment proposal is expected to be economically viable as:

1. It represents the most efficient option to achieve the intended project outcomes
2. It generates an economic surplus above its opportunity cost
3. It will have sufficient funds and the necessary institutional structure for successful operation and maintenance

The general criterion for accepting a project is achieving a positive ENPV discounted at the minimum required EIRR or achieving the minimum required EIRR. ADB's newly adopted minimum required EIRR is 9%. However, for social sector projects, selected poverty-targeting projects and projects that primarily generate environmental benefits (such as pollution control, protection of the ecosystem, flood control, and control of deforestation), the minimum required EIRR can be lowered to 6%.

The investments were evaluated using the economic internal rate of return (EIRR) and economic net present value (ENPV). For the ENPV, the discounted cash flow (DCF) was calculated using an economic opportunity cost of capital (EOCC) of 12%. This is the normal rate applied by ADB where capital is constrained. The EIRR must be compared with the economic opportunity cost of capital, when determining project feasibility.

The financial analysis included the following assumptions and criteria;

(i) The financial analysis was undertaken in accordance with ADB's Framework for the Economic and Financial Appraisal of Urban Development Sector Projects. Financial analysis was conducted to assess the financial viability of the various component of the investment proposal

(ii) The FIRR have been independently estimated for each of the investment proposal components at constant financial prices considering the incremental cost and benefit streams over the anticipated useful life of all direct revenue earning investments and tested with the sensitivity analysis under given variables. The proposal will be considered financially viable if the FIRR is more than the weighted average cost of capital (WACC).

(iii) The proposed fare levels were assessed to ascertain their affordability to the beneficiaries, in particular the low-income groups and poor households, i.e. those below the poverty line. Financial projections for the Corporation were also performed to determine the financial capability of Corporation to deliver and operate the investment proposal on a sustainable basis.

There are four broad steps in project economic analysis:

(i) Identify gross project benefits and costs;
(ii) Quantify and value the benefits and costs, initially in market or financial prices;
(iii) Adjust the costs and benefits to reflect their economic values; and
(iv) Compare gross economic benefits with economic costs.

The economic benefits considered include:

1. Value of Travel Time Savings:

For the passengers diverted from road to ferry services

2. Value of vehicle operating cost (VOC) savings:

For the passengers diverted from road to ferry services

The EIRR is calculated as 7.1% for the project. This rate compares favourably with the 6% benchmark for social sector projects that primarily generate environmental benefits, substantiating the economic viability of the project.

A financial analysis was carried out using a fare structure designed depending on the distance to be travelled. The fare structure considered for the analysis is given in Table 13.8. For analytical purpose, an increase of 15% every third year has been considered in respect to fees. The assumptions and approach used in the calculation of FIRR include:

i. All revenues and costs are stated at constant prices
ii. All revenues and costs are calculated on incremental basis

Both economic and financial analysis rely on the assumed patronage being achieved.

The results of consolidated FIRR calculations of entire project are summarized as follows in Table 13.9 as 4.1%. Details of EIRR for each Jetty location per direction of travel is also given in Chapter 13 for reference. This would help in establishing the viability of O-D pair terminals.

0.14 Conclusion And Recommendations

Conclusion

Vasai Creek-Ulhas river starting from the Arabian Ocean up to the Kalyan, a distance of about 50 km, declared as National Waterway no 53, is a developable proposition. About 80-90% of the existing waterway from the Arabian sea upstream is more or less navigable with little or no dredging. Most of the waterway has a depth of more than 2.5 to 3 m. Hence, the first ingredient for the waterway is in existence. The other ingredients, namely, low wave heights, milder current and ample area for development of Terminals do exist. The river is mostly bereft of erosion and bank instability issues.

Most of the cross structures are also having desirable air draught, for permitting passage of design vessels except for the singular Bhayander old railway bridge, which is abandoned and needs to be dismantled. In short, an ecosystem for providing an alternative mode of transportation does exist and require adequate planning for ensuring the same. In this scenario, it was proposed to develop a 3.0 m CD deep, 100 m wide, navigable waterway for providing a credible alternative mode.

Accordingly, 10 terminal locations were selected in the proximity of the Population centers. These terminals are so selected so as to provide not only seamless connectivity to the local population, but a cheap and environmentally acceptable mode of communication.

The terminals and the waterway would be provided with the latest and most advanced communication and navigational markings for ensuring safety of the vessels and the passengers. The communication network would be hooked on to the River Information System (RIS), for integrating to a global platform.

Five different vessel types were chosen for achieving the ultimate target of the passenger transport. In addition, vessels and the terminals would be equipped to handle Ro-Ro vehicles carrying vehicular traffic. The terminals at selected locations would be provided with fueling centers for the vehicles and charging centers for electric cars. In addition, they would be provided with restaurants, children play area and elaborate passenger waiting area for comfort of the passengers. The terminals will have recepetion facilities for garbage, waste oil, grey water, bilge water and disposal through authorized agencies.

All the vessels would have dual fuel engines and would be capable of running on natural gas in addition to MDO or IFO/Ethanol. In future vessels operating on electric power will be pressed into service as the technology becomes available.

The portion of the water way between the Nagla Bunder and the Kolshet terminal would be dedicated for water sports and floating restaurants, owing to its natural ambience and the water depths. Resorts and other amusement facilities already existing along this stretch, especially close to the Nagla Bunder area, because of the breathtaking and scenic backdrop it provides. Infrastructures at the terminals would be provided for supplementing the proposed facilities on water.

The waterway would be run by a SPV created with the participation of the TMC, IWAI, JNPT,MMB, MBMC, VVMC, KDMC and BNMC. Funds for developing the waterway will (could) be provided from the Government as a grant. Procurement of vessels also could be an arduous task and therefore should be taken up immediately. Indian shipyards should be approached to take this task of fabricating vessels for the waterway. In addition, the shipyard on the waterway would be enabled for the Job so that the inhouse expertise is also developed.

All the terminals would be provided with Solar panels and electric vehicle charging terminals for the benefit of the users. LNG/CNG filling station for bunkering of vessels also shall be provided.

Financially this is a viable project.

Recommendations

The following recommendations are made for making the development and facilitating smooth operations of the waterway.

1. Vessels designed for running on shallow water depths and air draft are recommended to help reduce the dredging cost.
2. A shipyard facility should be created nearby Kolshet jetty location by taking government land on lease for maintenance and manufacturing of vessels.
3. Integration of facilities like approach road, parking, commercial area etc. should be planned for Jetty and intermodal hub (at Kolshet).
4. Considering a higher level of environmental protection and conservation, for incremental benefits, use of Liquefied Natural Gas (LNG) or Ethanol/Methanol operated vessels instead of diesel operated vessels is recommended. As the technology for electrical propulsion becomes available for smaller vessels, electrically operated ferries should be pressed into service.
5. Facilities for seaplanes should be created to accommodate future requirements of takeoff and landing at Nagla Bunder jetty site

6. Last mile connectivity should be considered as priority. Charging stations for battery operated feeder vehicles should be provided at terminals to improve last-mile connectivity.
7. For safe movement of vessels in the river/creek, traffic systems like River Information System (RIS) should be installed.
8. Solar Panels for the vessels and the terminals must be made mandatory.
9. Green fuels should be used in the vessels as far as practicable.
10. Clearance from 3 Wildlife Sanctuaries/National Park, namely Sanjay National Park, Tungareshwar WLS and Thane Flamingo WLS should be obtained in addition, to the clearance from CRZ and MoEF&CC authorities, being a Category A project.
11. A quick start to the project should be given by providing pre-fabricated structure with minimal civil works at Kolshet, Kalher, Parsik Bunder and Anjur Dive at an estimated cost of ₹ 981.16 Million, as per details given in section 12.2.

1 Introduction

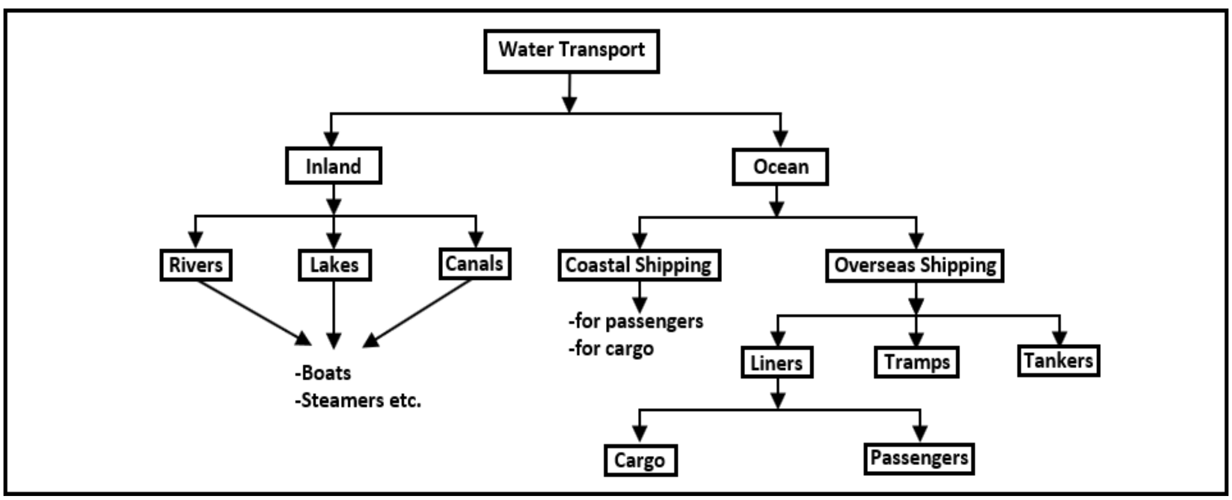
1.1 Project Background

1.1.1 General

Water transport is the cheapest and the oldest mode of transport. It operates on a natural track and hence does not require huge capital investment in the construction and maintenance of its track except in case of canals. The cost of operation of water transport is also very less, which is evident from the fact that 1 litre of fuel can take 1 ton of cargo up to 180 km over waterways as compared to 25 km by road or 75 km by rail[6]. It has the largest carrying capacity and is most suitable for carrying goods in bulk and large in size (Over dimensioned Cargo) over long distances. It has played a very significant role in bringing different parts of the world closer and is indispensable to foreign trade. The modes of water transport are as shown below:

1. Inland Transport
2. Ocean Trade

Figure 1. 1: Water Transport System



1.1.1.1 Inland Water Transport

As shown in the above chart, inland water transport consists of transport using rivers, canals and lakes by floating equipments or vessels which carries passenger, cargo, Ro-Ro traffic etc.

[6] Source: http://www.yourarticlelibrary.com/Article by R.C.Agarwal

A. Rivers:

Rivers are a natural waterway which can be used as a means of transport. They are suitable for small boats as well as big barges. River transport played a very important role prior to the development of modern means of land transport. Their importance has gradually declined on account of more reliable, faster and cheaper transport services offered by the railways.

B. Canals:

They are artificial waterways made for the purpose of irrigation or navigation or both. Canal transport requires a huge amount of capital investment in construction and maintenance of its track i.e., the artificial waterways. The cost of the canal transport is, therefore, higher than that of river transport. To add to it, the cost of providing adequate water for the canals is also a very big problem of canal transport.

C. Lakes:

Lakes can be either natural like rivers or artificial like canals.

1.1.1.2 Advantages

A. Low Cost:

Rivers are a natural highway which does not require any cost of construction and may require limited maintenance, for having a minimum navigable depth, often by dredging or by any other river training measures. Even the cost of construction and maintenance of canals is much less or they are used, not only for transport purposes but also for irrigation, etc. Moreover, the cost of operation of the inland water transport is very low. Thus, it is the cheapest mode of transport for carrying goods from one place to another.

B. Larger Capacity:

It can carry much larger quantities of heavy and bulky goods often known as Over Dimensioned Cargo (ODC) and bulk cargo such as coal, iron ore, cement, fertilizers, and, timber etc.

C. Flexible Service:

It provides much more flexible service than railways and can be adjusted to individual requirements.

D. Safety:

The risks of accidents and breakdowns, in this form of transport, are minimum as compared to any other form of transport.

1.1.1.3 Disadvantages

A. Slow:

Speed of Inland water transport is very slow and therefore this mode of transport is unsuitable where time is an important factor.

B. Limited Area of Operation:

It can be used only in a limited area which is served by deep canals and rivers.

C. Seasonal Character:

Rivers and canals cannot be operated for transportation throughout the year as water may freeze during winter or water level may go very much down during summer.

1.1.2 Waterway Potential Untapped

As indicated above, rivers have served as effective waterways, carrying people and goods over long distances. With opening of the Dahej - Ghogha terminal by the Honorable Prime Minister, on October 22nd, 2017, a new era in the water transport has started in the country. The facility currently in operation albeit not fully, would cut down a road distance of 310 km to mere 30 km. The details of the road and the water route along with the details of the facilities are shown in Figure 1.2 below.

Figure 1. 2: Dahej-Ghogha Ro-Ro Service In The State Of Gujarat

It is a ferry service between Ghogha in Bhavnagar district and Dahej in Bharuch in the Gulf of Cambay. The first phase of the service inaugurated by PM Modi is meant for passengers. In the second phase, cars can also be carried between the two towns. It is a complex project, which involves complicated marine structure of the Gulf of Cambay, on which it is built. The service reduces the distance between the two towns from 310 kilometers by road to 30 kilometers, which can be covered in one hour only. The main advantage of the project once it's fully operational would be as follows;

1. Reducing travel distance from 310 km to 30 km
2. Reduction in travel time from 7 hours to 1 hour
3. Ro-Ro service would bring the East and the West banks of the Gulf of Khambath, closer
4. Exchange of goods and services
5. Improvement in the economies of the regions
6. Saving of fuel and environmental pollution.

River Ganga and Brahmaputra in the northern India and west Coast Canal in the south is used as effective waterways for transport of man and material since very long. In recent years the Inland Waterways Authority of India (IWAI) has brought in scientific planning for a sustained effort for their development. India as a country is bestowed with many rivers, creeks and backwaters, which touches often times most important commercials and population centers. With the situation of the road and rail transport as it is, waterways seem to be the mode for the future, to maintain the speed of economic development at present or at an accelerated level. The immense potential of the waterways hitherto untapped needs to be recognised, in the light of shallower and more powerful vessels made available through better technology. The potential is slowly being recognised by the power that-be, and many waterways are being added to the already existing and recognised waterways.

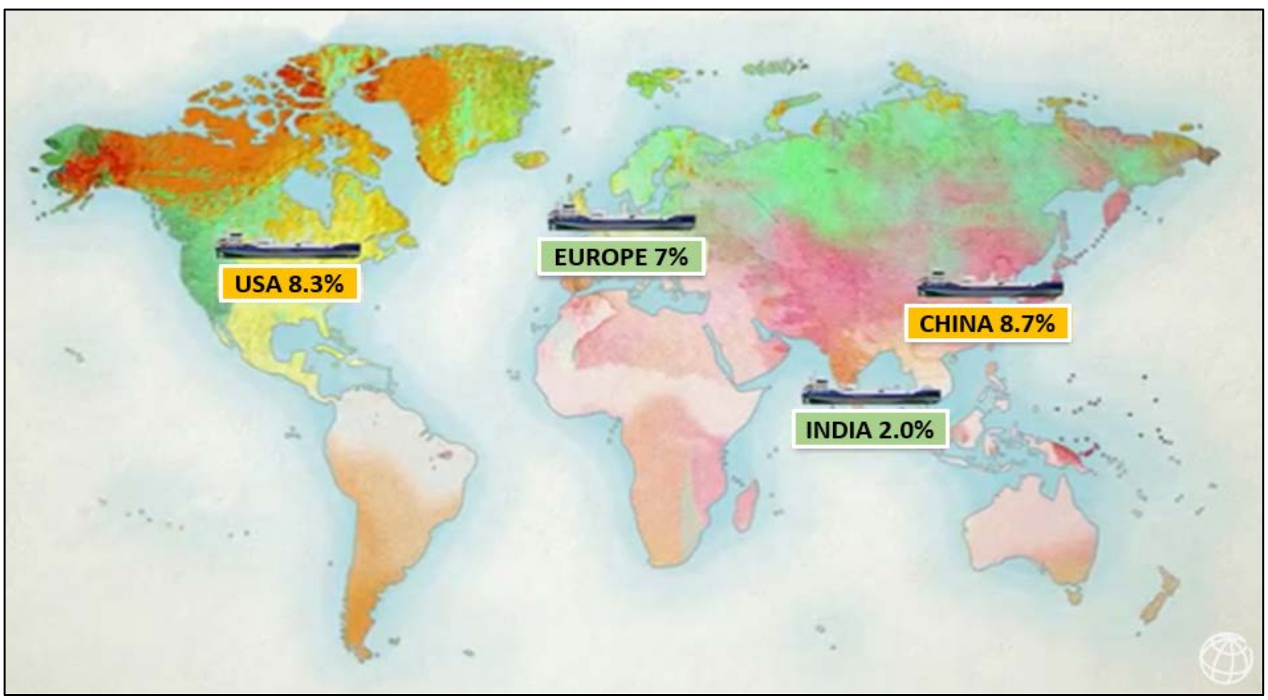
1.1.3 Waterway As An Effective Mode

While the development of the large-scale waterways, especially in the Inland areas, India is in the nascent stage development, many countries depend heavily on inland water transport, especially for passenger and large and bulky cargo, as it is cheaper, more reliable and less polluting than transporting goods by road or rail. India has yet to develop this cheaper and greener mode of transportation.

Goods still travel by congested road and rail networks, slowing the movement of cargo, adding to uncertainties, and increasing the costs of trade. So much so that logistics costs in India are estimated to account for as much as 14.48 percent of the country's GDP[7].

The illustration, Figure 1.3 below indicates the use of the waterway mode in different parts of the world painting a very dismal picture on the use of the waterways in India or lack of it.

Figure 1. 3: Freight Movement On Waterways Across Countries (World Bank)



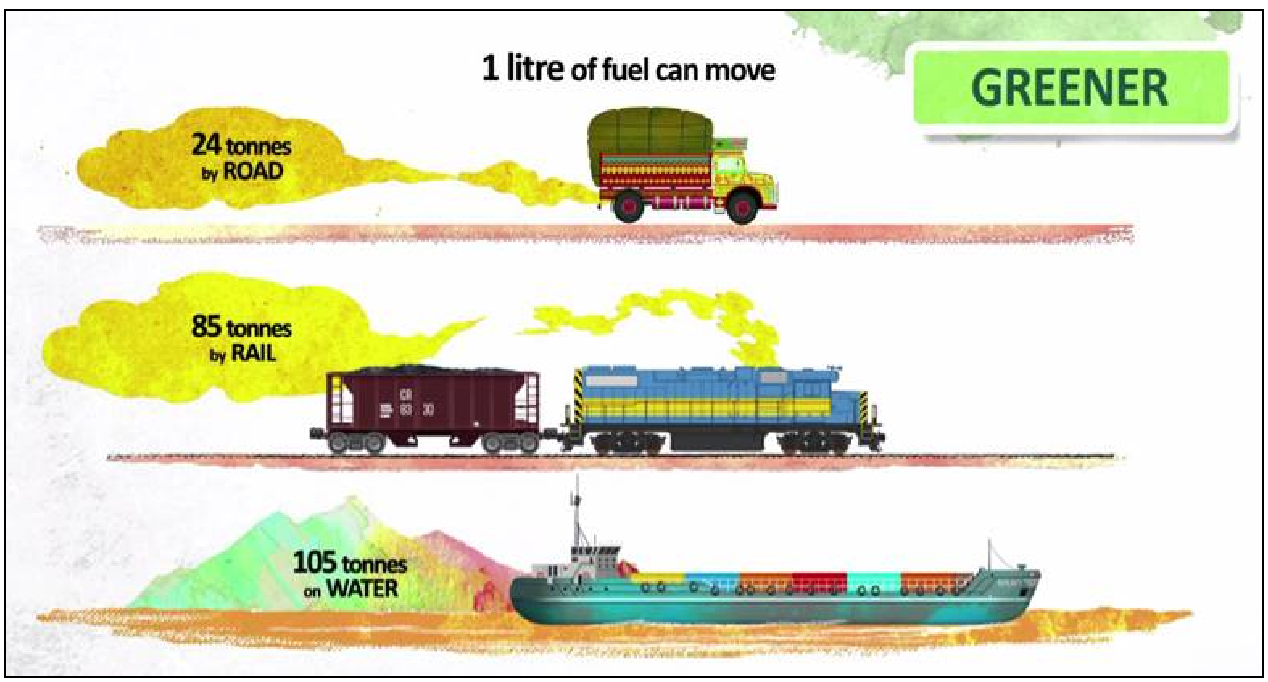
7 Budget 2017, January 25th, 2017, Financial Express

The waterways for transportation of passengers in the world are not as prevalent as their use for cargo movement. On the contrary, usefulness of the waterways for recreation and amusement has been more common. China has 110,000 kilometers of navigable rivers, streams, lakes, and canals, more than any country in the world. In 2015, the traffic on the inland waterways has grown to 3.459 billion tonnes, cargo turnover to 1.331 trillion t-km. It has trebled since 2006. Passenger traffic is 271 million people and 7.308 billion person-km (2015), as reported by the 2015 Transportation Industry Statistical bulletin.

The main navigable rivers are the Heilong Jiang; Yangtze River; Xiang River, a short branch of the Yangtze; Pearl River; Huangpu River; Lijiang River; and Xi Jiang.
Ships of up to 10,000 tons can navigate more than 1,000 km (621 mi) on the Yangtze as far as Wuhan. Ships of 1,000 tons can navigate from Wuhan to Chongqing, another 1,286 km (799 mi) upstream. The Grand Canal is the world's longest canal at 1,794 km (1,115 mi) and serves 17 cities between Beijing and Hangzhou. It links five major rivers: the Haihe, Huai River, Yellow River, Qiantang, and Yangtze.

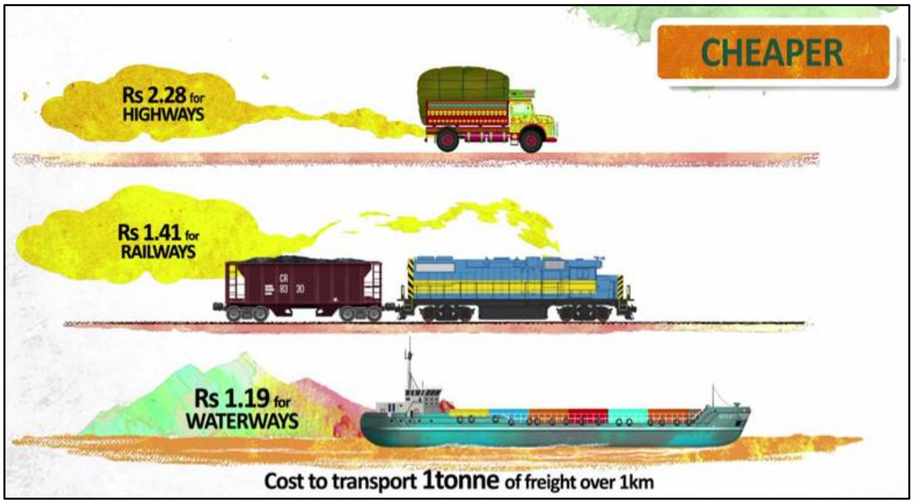
Studies by the World Bank validated for different regions of the world, stresses the greener aspect of the Waterways. While 1 litre of fuel can move about 24 tons of cargo on the road, same fuel could move about 85 tons of cargo by rail and 105 tons of cargo by waterway as illustrated in the Figure 1.4.

Figure 1. 4: Fuel Requirements For Different Modes Of Transport (World Bank)



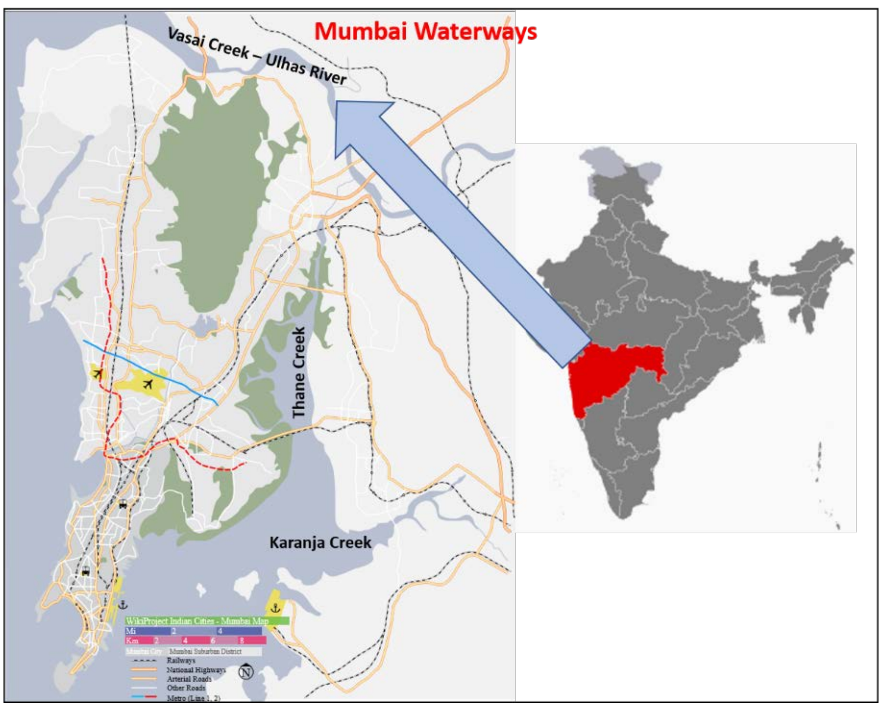
Similar studies by the World Bank indicated that the waterway is almost half of the cost of the road transport cost and about 65% of the rail cost.

Figure 1. 5: Logistics Cost Of Different Modes Of Transport (World Bank)



Vasai Creek is an estuarine creek, one of the two main distributaries of the Ulhas River in Maharashtra state of western India. The Ulhas splits at the north-east corner of Salsette Island into its two main distributaries, Vasai Creek and Thane Creek. Vasai Creek forms the northern boundary of Salsette Island, and empties west into the Arabian Sea; Thane creek empties southwards into Bombay Harbour.

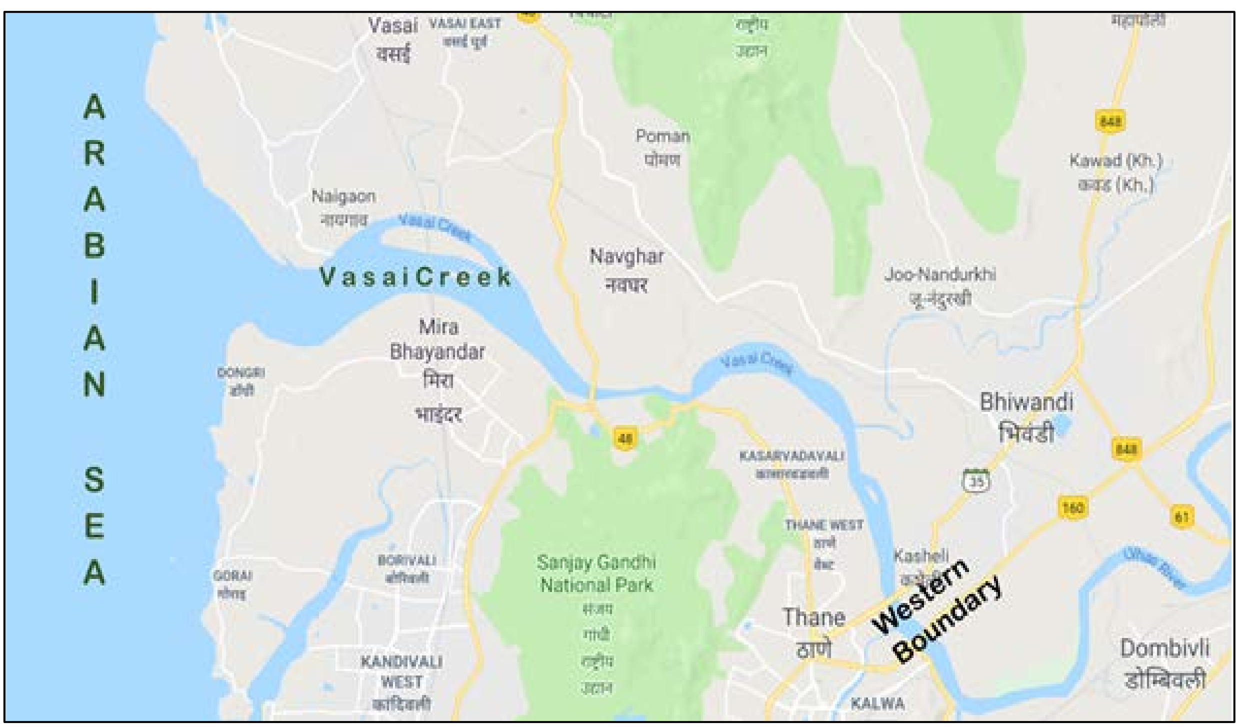
Figure 1. 6: Location Of The Proposed Waterway In The Map Of India



Though reason for development of these waterways are many, two main reasons are, Ro-Ro service to ferry trucks from Kasheli to Ghodbunder in Thane, on the way to Gujarat and Water transport along the east coast of Mumbai region will ease congestion on roads leading to Gujarat. With JNPT controlling part of the container cargo movement to the southern Gujarat, it is expedient to plan the waterway transport from the left bank of the Ulhas River to the Right, across the creek, alleviating the pressure on the roads.

However, the proposed waterway in the Vasai Creek/Ulhas River stretch, would not only make the life simpler for the users by saving in the time, but also go a long way in reducing the pollution due to the road, apart from the congestion. In fact, Dombivli, which forms part of the waterway, is a critically polluted area. The waterway's stretch between Vasai on the Sea on the west and the Kalyan (Kasheli) in the east passes through one of MMR's (Mumbai Metropolitan Region) most densely populated areas. A sizeable population is slowly getting themselves shifted to this region, due to the numerous residential and commercial properties in the region because of better affordability. Once operational, the waterway will form part of the larger multi-modal transport network planned along the river. It will link up with the southern part of the land mass to the northern Maharashtra and southern Gujarat. In this backdrop in order to harness the tremendous potential of the waterways in the region, the Thane Municipal Corporation (TMC), has taken up the Vasai (Bassein) creek-Ulhas River for development for cargo as well as passenger transit. The general plan of the waterway from the Arabian Sea to the Kasheli (Kalyan) upstream is in Figure 1.7 below.

Figure 1. 7: The Plan Of The Proposed Waterway



1.2 Earlier Studies Carried Out

1.2.1 Study Background

Several studies have been carried out for navigation across or in the Vasai-Ulhas River over the time. Most of them limiting the scope of the studies to certain portion of the waterway. M/s WAPCOS Limited recently carried out the study for waterway development for cargo movement, for Maharashtra Maritime board. The main findings of the reports are given in the following section. The report discusses the asymmetric cargo handling capabilities of the State of Maharashtra, near the greater Mumbai Region, at the Jawaharlal Nehru Port Trust (JNPT), (≈ 65 million tons of Cargo) and Mumbai Port Trust (≈ 62 million tons including 37 million tons of liquid cargo). Apart from the above Maharashtra has about 35 creeks where there are many captive/commercial jetties, which handles about 30 million tons of cargo in total. It is clear that the bulk of the cargo handling is currently happening in and around the Mumbai Metropolitan Region. Coupled with that JNPT handles about 55% of all the containers handled by all the major ports in India. Hence, in not only the State, but also cargo distribution is required all across the country. Accordingly, in order to decongest the roads and reduce the logistical costs, Maharashtra Maritime Board (MMB) has identified three most promising creeks for development with regard to cargo transport namely,

1. Vasai Creek
2. Rajapur Creek
3. Jaigarh Creek

The report then proceeds to discusses various aspects of development of the Vasai Creek.

1.2.2 Need For The Project

Creeks are that part of the water body, which is in emanating from the Sea/Ocean stretches up to a length of 10 to 150 km in to the hinterland. Majority of these creeks lie in the hilly region of Konkan division and is part of a river out fall. This region gets good rain in the monsoon season. Coupled with the good tidal heights the creeks have good draught throughout the year, especially near the sea. Fortunately, the coastal areas are very thickly populated and therefore are the main demand centers. Accordingly, creeks can play a vital role as an alternate mode for movement of cargo. Especially, since Vasai is hugely industrialized and roads are congested, the waterway mode can be a big boon and can serve as the best supplement for the existing modes. Therefore, there is a growing need for planned and proper development of the waterway to unveil the underutilized potential of waterways, which could potentially provide the cheapest, efficient, pollution free mode of transport.

1.2.3 Comments On Trade In Maharashtra Through Inland Waterways

The report discusses the trade activities in the state of Maharashtra through land and waterways including the import and the export cargo handled at the Ports. Maharashtra has been using its waterways for movement of its industrial cargo as well as passenger traffic. There are total 48 identified minor ports in Maharashtra. Out of them, 14 are currently active. These ports collectively handled an amount of 28.8 million tonnes in the year 2015-16[8]. This includes the coastal movement as well as overseas. Bulk forms the major share of the traffic mainly – Iron ore, Cement and Coal. A large part of cargo is meant for the industries located within a radius of 50 km from the ports.

1.2.4 Vessel Size Recommendation

With regard to the vessel size, in the Vasai Creek the report examines of suitability of the vessel system vis-á-vis creek characteristics and recommends to operate vessels (Class 5 Waterway Vessels) of capacity up to 1000 DWT for Self-propelled barges of Size (70 m x 12 m), Loaded draft 1.8 m and vessels of capacity up to 2000 DWT for 1 Tug + 2 barges combination with length 170m x breadth 24 m, loaded draft 1.8 m (moulded width 24 m).

1.2.5 Navigation Opportunity

The WAPCOS concludes the navigation opportunity as follows;
Project is commercially viable wherever the rivers of Maharashtra could be integrated into coastal shipping and cargo is available for the hinterland.

1. Coastal and river movement of Cement from Gujarat to Vasai Creek
2. Ro-Ro vessel operation across Vasai Creek

1.3 Project Location / Details of The Study Area

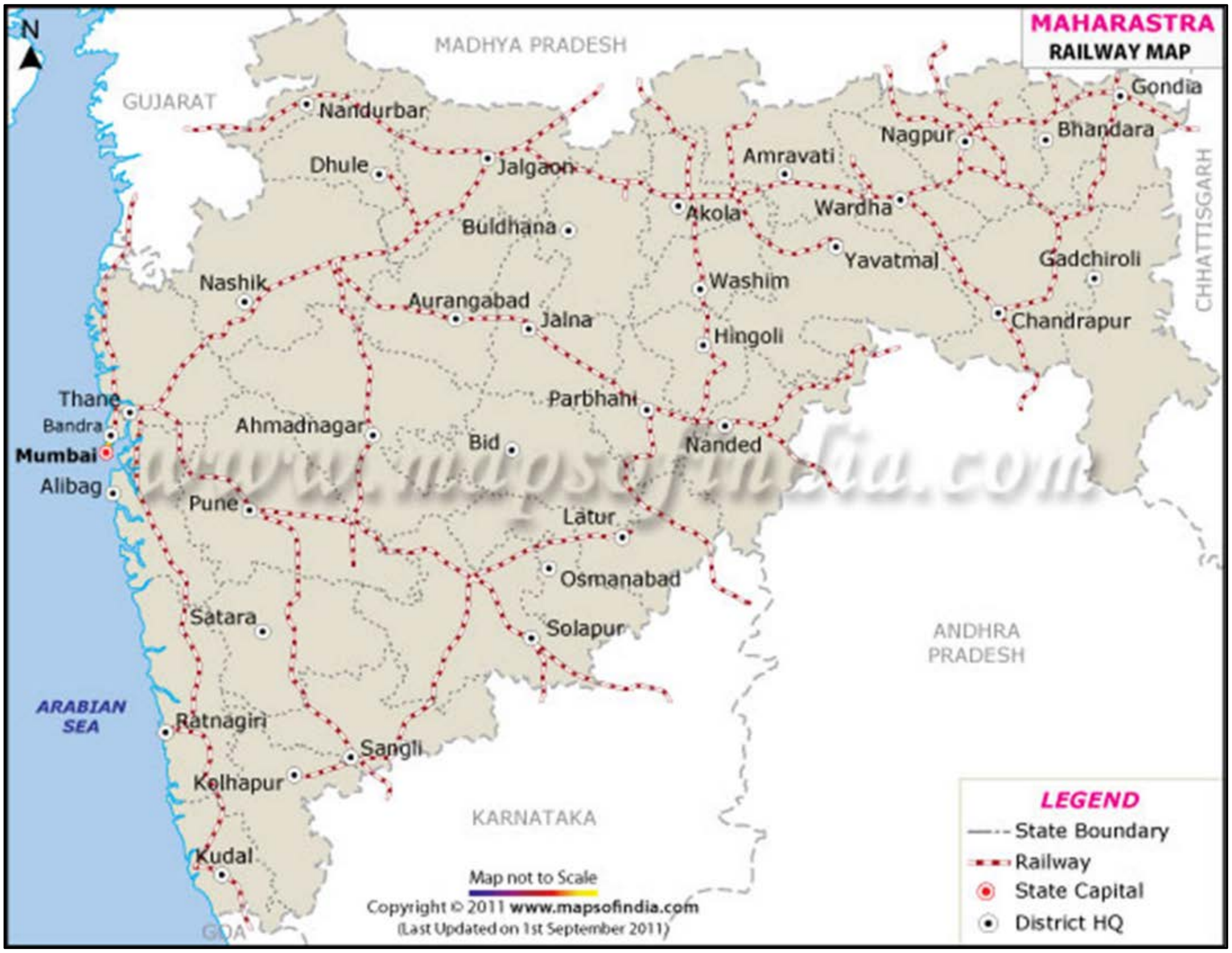
1.3.1 Maharashtra Coastline

The Maharashtra coastline spanning 720 km, consists of Sandy beaches (17%), Rocky Coast line (37%) and Mud flats (46%). The state has two Major ports, namely, Mumbai Port and Jawaharlal Nehru Port in the Mumbai Estuarine system. Networks of creeks, rivers, canals and other water bodies dots the coastline and are home to 48 non-major ports/jetties, majority of which are located in the protected water bodies. The six coastal districts facing the Arabian Ocean are shown in Figure

8 TEFR Study for Coastal Cargo in Maharashtra & Development of Vasai, Jaigarh and Rajpuri Creeks for Integrated Transport, by WAPCOS Limited, Gurgaon, India

1.8 are - Greater Mumbai, Thane, Palghar, Raigad, Ratnagiri and Sindhudurg. There are numerous creeks and creek-lets that dots the coastline, mostly as the out fall of natural drains or rivers. The creeks with bigger catchments are mostly small rivers and has adequate depths in combination with the tidal ingress.

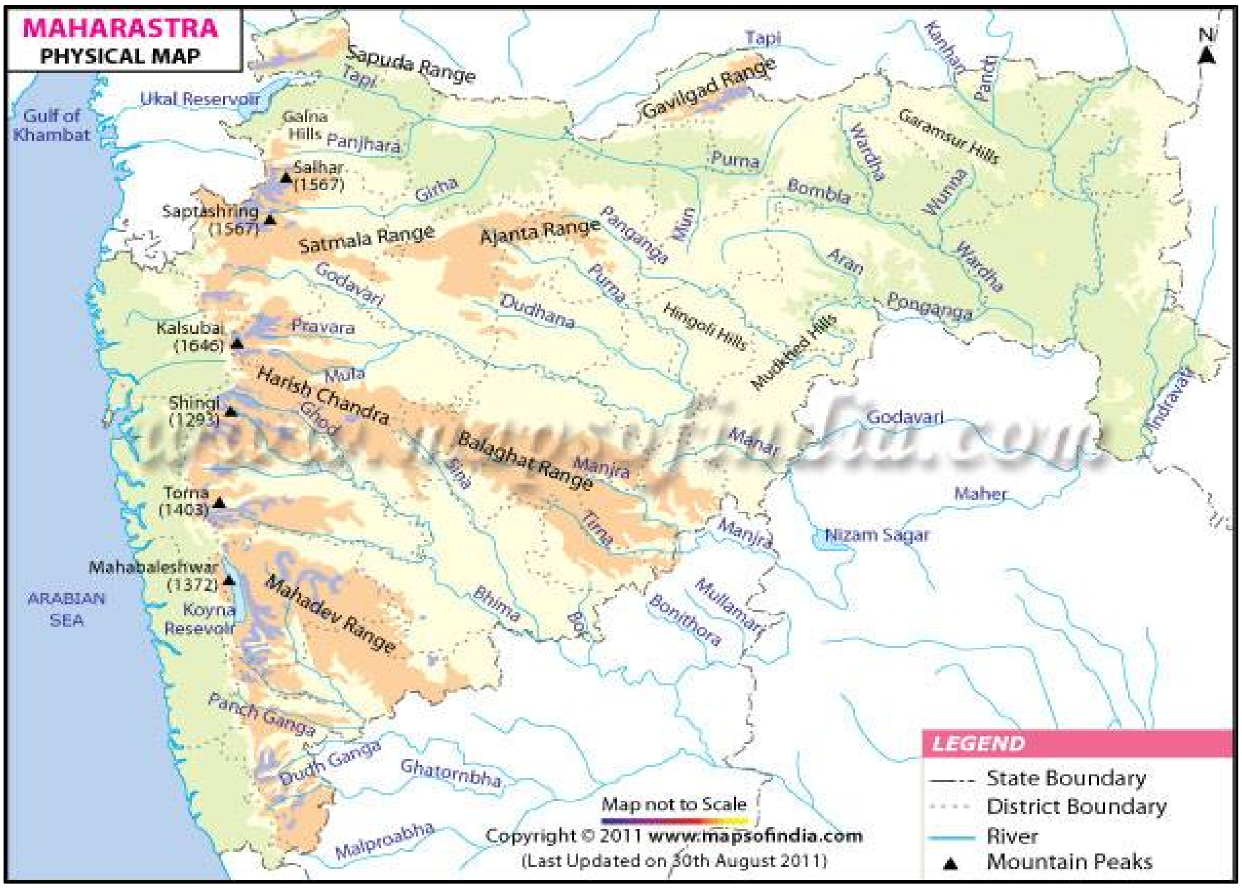
Figure 1. 8: District Map Of State Of Maharashtra



The existence of large number of rivers and creeks, along the coastline offers unlimited possibility of inland water transport and makes out a strong case for traffic sharing. In this the seaports both Major as well as Minor, can play a significant role in providing the pivotal nodes. In consonance with the existing transport capacity, the Government of Maharashtra (GoM) believes that there exists an ample scope for coastal cargo movement in the state. Even though the coastal movements are in vogue since ancient times, it is believed that there is a possibility of achieving greater growth, if right incentives are in place especially for the private operators. It is also believed that there would be quantum jump even in the passenger movements, which could alleviate the present day woes of the passengers due to over stretched and overcrowded surface infrastructure, like road and rail.

The importance of Inland Water Transport for transferring cargo volumes in bulk is well recognised and documented. However, the inherent weakness of not providing the last-mile connectivity like the road transport has been a major hurdle in its growth. The Mumbai Metropolitan Region (MMR) is blessed with an elaborate network of creeks and water bodies that could be used for the so-called last mile connectivity. In addition, this planning would bring in increased freight and passenger movement capability at much lower transport costs. The Figure 1.9 shows the major creeks and rivers in the Maharashtra coast.

Figure 1. 9: Rivers And Creeks In The Maharashtra Coast



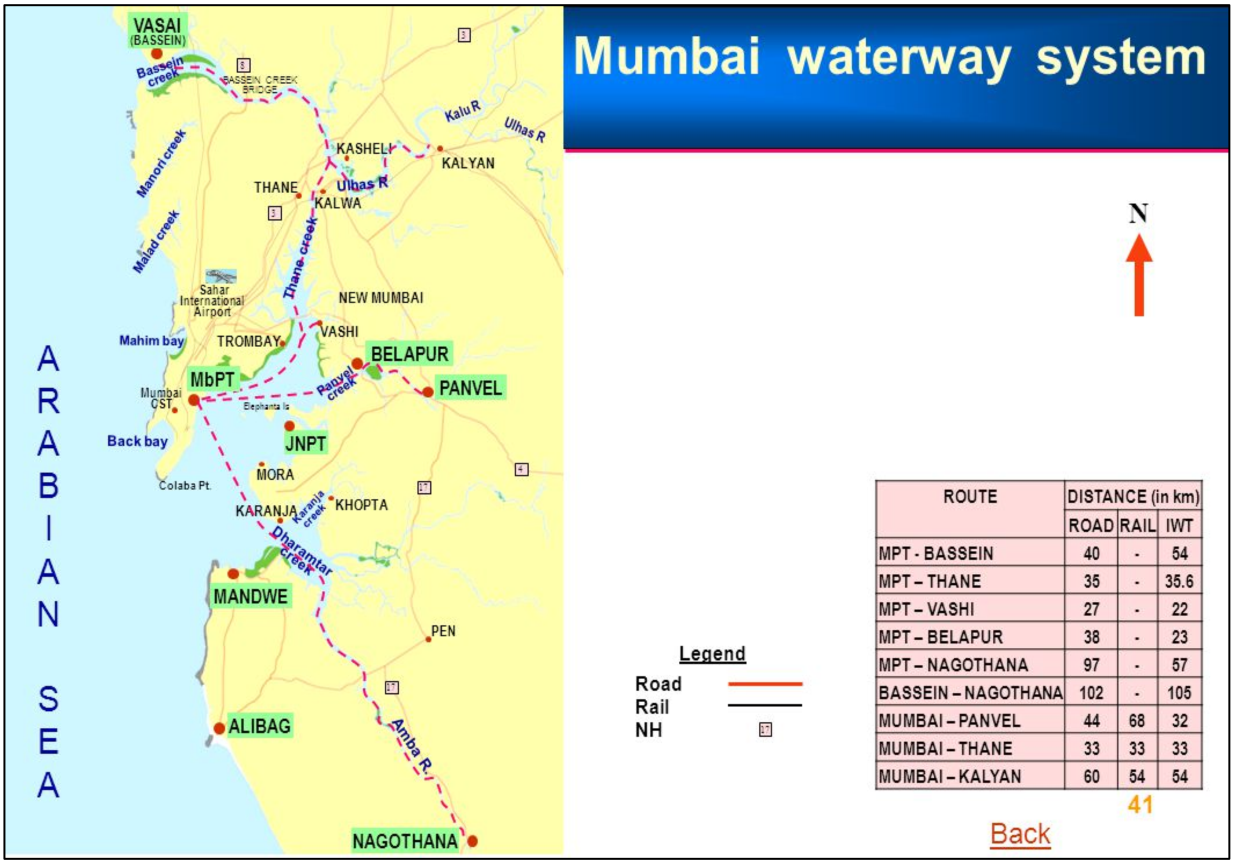
1.3.2 Mumbai Metropolitan Region (MMR)

Closer to the MMR, the nature has been kind to have an elaborate array of interconnected creeks and water bodies as shown in Figure 1.10. The figure is also illustrating the distance of the various consumer centers through various modes including waterways in the region.

Incidentally, MMR is the biggest trade center not only in the state of Maharashtra but for the entire nation. The two major ports in the state namely, the Jawaharlal Nehru Port Trust (JNPT) and Mumbai Port Trust (MbPT). Jawaharlal Nehru Port handled 62.17 million tons of cargo during Financial Year 2016-17, out of which, 54.40 million tons (87.74%) was containerized cargo, 6.78 million tons

(10.91%) liquid cargo & remaining 0.84 million tons (1.35%) was miscellaneous types of Dry Bulk Cargo (Cement) & Break Bulk. In the same period, Mumbai Port Trust handled 63.05 million tons of cargo during Financial Year 2016-17 out of which, POL traffic constituted about 34 million tons and Non-POL traffic constituted the rest.

Figure 1. 10: Waterways In And Around MMR



The distribution of the trade to the consumer centers are mostly achieved through the rails and road transport. The north bound containers either use rail for long hauls and road for short hauls.

Following are the main creeks that makes up the MMR waterways as indicated in the Figure 1.9.

1. Vaitarna River
2. Vasai(Bassein) Creek -Ulhas River
3. Thane Creek
4. Panvel Creek
5. Karanja Creek
6. Patalganga River
7. Dharamtar Creek- Amba River

As shown in Figure 1.11, Vaitarna River is the first creek as one travels from the north, southwards in the MMR. South of this creek lies Vasai (Bassein) creek, which merges in to the Ulhās River landwards. Further south, the major creeks are Thane Creek, Panvel Creek, Karanja Creek, Patalganga River, Dharamtar/Rewas Creek merging with the Amba River. Out of these creeks, Dharamtar creek is most active with the maximum cargo for the JSW steel plant.

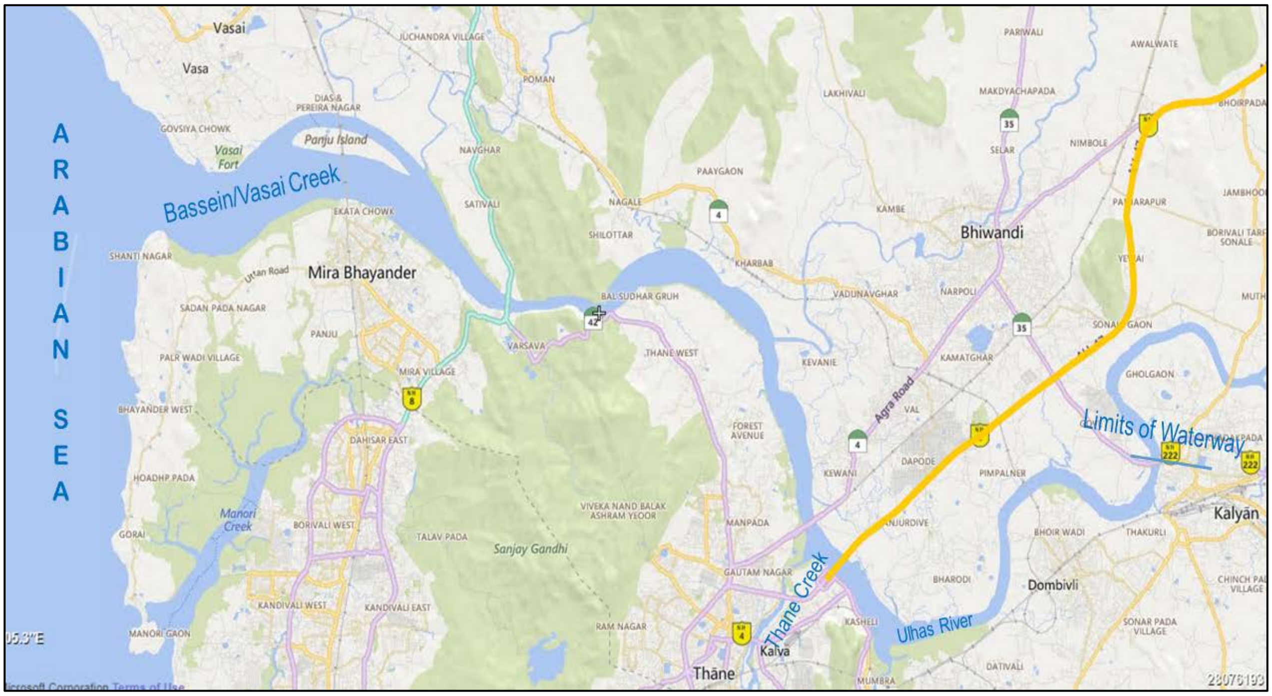
Figure 1. 11: Waterways In And Around MMR

The most heartwarming feature of these waterways is their interconnectivity and the fact that they run right through the city region with dense population right on the banks.

1.3.3 Coastal Movements & Creek Location

Thane Municipal Corporation (TMC) have chosen Vasai (Bassein) creek (which is believed to have abundant scope for coastal cargo movement) for development and eventually integrating it with coastal cargo movement of the Mumbai and JNPT ports through either the sea or the creek route. The congested roads and the thickly populated residential areas in and around the creek makes a good case for starting ferry services, with ro-ro ferries preferred, so that the men and the machines can move together in a short time and with much less effort avoiding the congested and circuitous roads. For example, a man moving from the Navi-Mumbai region and working in the south Mumbai area can reach his work place in about 2 hours in the least through the road. However, if he takes a ferry say, from the Belapur or Nerul terminal, he could reach his destination may be in 45 minutes and still have the comfort of his car near to his place of work. Similar examples can be emulated by the people who are travelling from northern extremities of the city say in Vasai or Bhayander to the city and vice versa.

Figure 1. 12: Location Of The Vasai Creek



The details of the waterway under consideration is given in the Table 1.1.

Table 1. 1: Details Of The Waterway Through The Vasai Creek

Sr. No.	Name of the	Details
1.	Vasai Creek	Creek entrance to Kalyan via Kasheli

To the south of the creek lies the Mira-Bhayander, which is located on both sides of the sub-urban railway track. Two railway bridges connect Naigaon station to the western suburbs. Old bridge was built during the British Raj and has been closed since it was declared dangerous to use. The new bridge is functional and has four tracks. Bhayander seashore attracts a huge number of people in the evenings. It houses a children park, playing ground, Pooja area, visarjan area for idol immersion on the east side. On the west, there is a small garden with sitting area for people to sit and chat. Small paths lowering into the sea also exist where people can stand and watch the waves hitting the shoreline. In this background, to unlock the seemingly untapped potentials of the waterway, for commercial, recreational and tourism perspective Thane Municipal Corporation (TMC) has engaged the JV partners' M/s Kashec Engineers Private Limited (KEPL) & Medulla Soft Technologies (MST) with an objective of preparing a technical report based on site collected data and identify the weakness and potential of the Vasai Creek. C-Borne Services (CBS) were appointed by the JV partners as sub-consultants for the study. The CBS would collect the data from the site, analyse and suggest the improvements for making the creek/river a world class waterway by implementing the best practices of the world and making planned waterway of world standards for passenger movement and tourism.

1.4 Brief Scope of Work & Compliance Statement

The Brief scope of the work as issued to the consultants by the TMC is placed at Annexure A:

1.4.1 Field Activities

Field activities shall include:

1. Detailed Hydrographic/Bathymetric Survey
2. Topographic Survey
3. Traffic Survey along the selected streams/creeks/tidal/stretches
4. Selection of terminal locations

1.4.2 Identification of Potential Routes

This shall include but not limited to the following:

Hydrographic & Hydro-morphological survey

A. Reference Bench Marks

The consultant shall obtain the details of existing benchmarks near the region from MMB or any other authority.

B. Water Level Measurements

Water level measurements shall be carried out for the non-tidal reaches of finalized streams. Scope shall include the fixing of water level gauges at every 10 km interval along the river and at upstream and downstream of any river structures, such as Dams, barrages, etc.

C. Bathymetric Survey

Bathymetric survey shall be carried out as per the prevailing International Standards for finding the potential of inland navigation. Major considerations shall be as follows:

a) The detailed hydrographic survey to WGS'84 datum would be carried out after establishing the horizontal and vertical control. Chart datum/sounding datum shall be determined from the following methods: -

i) For non-tidal reaches – Average minimum water level of last 5 years, as observed by Central Water Commission / State Irrigation Department at their gauge stations along the river.

ii) Minimum water level observed during water level measurements at installed gauges, with one control station and other 4-5 temporal stations which takes care of the tidal variations locally.

b) To select the potential navigation channel complete creek survey shall be carried out by conducting Bathymetric survey for minimum 100 m wide corridor at the center of the proposed waterways, i.e. 50 m width on both side from the center line of the channel.

c) Cross-section sounding lines / levelling shall run from bank to bank at spacing of 50 m., to identify the navigable channel.

d) Continuous soundings are to be taken by running the sounding boat at constant speed along the cross-section to get smooth contours. Intermediate line is to be run at bends if the line spacing is more than the specified above.

e) For cross-sectional bathymetric survey, more than 60 m in proposed Inland Waterways, spot levels at line spacing of 20 m. Spot levels should also cover 20 m. length grid on both banks. If any island or sandspur exist in the middle of the waterway, spot levels on the same at the same spacing should also be taken and indicated in the charts along the same cross-section line.

f) The soundings are to be reduced to the chart datum/ sounding datum established at every gauge stations.

D. Velocity & Discharge Measurement

Velocity & discharge measurement shall be done as per the following:

a) Velocity shall be measured by current meter at every 10 km interval, once in a day during the survey period.

b) Current meter observations should be taken at 1 m below water surface or 0.5d (if depth is less than 1 m), where d is measured depth of water.

c) Measurements at different depths may be taken by single equipment over three different time spans.

Current velocity at different depth is to be measured for at least 25 hours or as per listed calibration period of the equipment

a) Current velocity and discharge can also be measured with the help of ADCP (Acoustic Doppler Current Profilers) during survey, at every 10 km interval.

b) Discharge can be measured either by ADCP or standard formulas.

E. Water and Bottom Soil Tests

Water and soil samples are to be collected from bottom of the deepest route at every 10 km interval and are to be tested.

Soil sample can be collected by a grab and water sample at 0.5d (d-measured depth of water) by any approved systems.

The following tests are to be performed for Bottom soil samples:

a. Grain size distribution
b. Specific gravity,
c. PH value
d. C_u, C_c
e. Percentage Clay silt

Water samples should be tested for Sediment concentration.

F. Topographical Features

All topographical features located in the survey area to be captured and presented in the survey charts & report. Details of various features are as follows:

1. Photographs of the prominent features along with its position. Permanent structures located within this corridor are be indicated on the charts.
2. All prominent shore features (locks, bridges, aqueducts, survey pillars if available etc.) and other conspicuous objects to be fixed and location indicated on the chart
3. Cross structures, obstructing navigation to be identified.
4. Details (horizontal and vertical clearances above High Flood Level in non-tidal area and High Tide Level in tidal area) of bridges, aqueducts, electric lines, telephone lines, pipe lines, cables en-route to be included in the report along with their co-ordinates and location.
5. Details of water intake/ structures
6. Existing berthing place, jetty, ferry ghats, approach roads etc.
7. Detailed condition of the banks is also required to be collected along with protection details (pitched/protected or eroded). Estimated length of bank protection required for eroded banks to be included in the report.
8. Approachable roads / rails / places outside the corridor may be incorporated from Topo-sheets/Google Map/Google Earth.

G. Preparation of Survey Charts

Survey charts shall be prepared as per the following specifications:

a) Scale of the chart shall be as follows:

Table 1. 2: Scale Of The Survey Under Different Scenarios

Waterway width	Scale
Less than 100 m.	1:1000
From 100 m. – 300 m.	1:2000
From 300 m. – 500 m.	1:5000
Above 500 m.	1:10000

b) Contours of 0 m, 1 m, 2 m, 3 m, 5 m and 10 m are to be indicated on the charts with respect to Chart Datum / Sounding Datum.

c) Spot level values are to be given w.r.t. Mean Sea Level (MSL) & Soundings w.r.t. Chart Datum / Sounding Datum. A separate file (xyz) (soft copy only) is also to be created for spot levels w.r.t. Chart Datum / Sounding Datum for dredging calculation purpose.

d) On completion of the cross-sections, dredge channel for the proposed class of waterway shall be identified/ established by linking deepest soundings on the cross-sections. Dredging quantity is to be estimated accordingly.

e) Dredging quantity is to be indicated in the report for each km length of the waterway.

f) Minimum & maximum reduced depth and length of shoal for each km length of the waterway to be indicated in the report.

g) Shallow patches /shoal and submerged sand-chur having less than 1.0 m depth, rocky outcrops, rapids and other navigational impediments are to be indicated on the charts.

h) The charts shall also show all prominent land features from the Topo-sheets/site.

1.4.3 Detailed Project Report (DPR)

Based on the results of above survey & studies, the scope of studies shall be (but not limited) to carry-out the following details:

Waterway Development

i. Suggest the proposed Class of waterway in reference to IWAI (Classification of Inland WEaterways in India) Regulation 2006, for horizontal and vertical clearances for the cross structures such as bridges, cables etc.

ii. Optimum dimension of the navigation channel, which can be developed by undertaking river conservancy work (dredging, bandalling), river training, bank protection etc.

iii. Report shall include the requirement of dredging and bandalling (with details of calculation) for providing and maintaining navigation channel of the selected Class.

Terminals

i. Location for the terminals or jetties shall be decided on the basis of the selected potential routes, type of services envisaged and other considerations necessary for locating an IWT terminal/jetty.
ii. For each selected terminal, two alternative sites shall be studied, assigning first and second priorities.
iii. Report shall also provide the details of land ownership etc. with source and supporting documents. Topographic survey for the terminal shall cover the complete land-side amenities and layout plan shall be prepared for all suggested locations clearly indicating all facilities e.g. jetty, approach to jetty, bank protection and travel related facilities, such as waiting areas, ticket sales counter, parking, luggage handling services, coffee shop, ATM, security of men & material, etc. Details of bunkering facility, water facility, turning circle for IWT vessels location of depth contours of 2 m and 2.5 m in the river near the terminal sites etc. shall also be provided
iv. Preliminary engineering design and drawings for setting up of terminals or jetties with related facilities including boarding/de-boarding of passengers. Further, the inter-modal transfer facilities, if required at any terminal, shall be indicated.
v. Geo-technical investigation is to be carried out as per standard guidelines if required at selected site.
vi. Prepare cost schedule for modification improvement of cross-structures cables etc. if required.
vii. River/Creek training/bank protection works particularly for those stretches where either the channel is narrow and needs to be widened by dredging.
viii. Alternatively, where it is anticipated that the bank may be erode due to continuous movement of vessels.

Navigational Aids

i. Sufficient details of the navigational aids, required for 24 hr., navigation facilities including day marks, buoys with lights, lights on masts at banks, DGPS stations, etc., along with their drawings and numbers with justification.
ii. Types of communication facilities required on the ferry/vessels etc.

Type of Ferries/Vessels

i. Suggestions for economical size of ferry/vessel for the proposed service as assessed as per traffic studies. Work out details of the type of vessels, their number and cost.
ii. Cost of vessels shall not be included in the cost of development of the waterway, in case, it is proposed that the vessels shall be owned and operated by separate agency.

Other Facilities

i. Suggest in adequate details, other required infrastructural facilities such as repair facilities, fuel and fresh water bunkering, channel patrol, security, enforcement of rules and regulations, pilotage, issue of navigation notices, navigation charts, warnings, rescue and salvage, pollution control measures etc.

ii. To prepare preliminary engineering designs, the data about soil characteristics shall be collected from the local sources based on the structures constructed nearby. In addition, wherever required, consultant may obtain soil data through trial pits/plate load test etc. and preliminary design shall be based thereon.

iii. To assess the environmental impacts due to these development works and suggest suitable environmental management plan (EMP) to mitigate the adverse impacts, if any, including its cost. All necessary information should be given in the report required for statutory environmental clearance from concerned authorities for undertaking the works proposed in the DPR, if so required.

iv. To prepare cost estimates for the entire proposed infrastructure for the proposed route. The cost components shall include dredging, jetties, approach roads, inter-modal transport facility (if any), vessels and other allied facilities with proper justification that the suggested solution is the optimum one. In case, phase-wise implementation is proposed, cost estimate shall be prepared accordingly.

v. To provide estimated cost of annual recurring/maintenance works with sufficient basis/justification.

vi. To prepare detailed time schedule for the whole project indicating the time requirement of the various components of the project from inception until commissioning. Suggestion shall also be given for executing the project in different phases with spilt up of the works and the costs thereto, traffic potential and EIRR/FIRR for each phase independently.

vii. To study and recommend necessary project organizational structure and work force required for execution of the project and its maintenance thereafter.

viii. To study the existing freight and tariff structure for rail, road and IWT mode and recommend a suitable freight structure for IWT together with its basis and subsidies, if any, that may be necessary in the initial years.

ix. Suggest user charges for using the waterway, terminals and other infrastructural facilities, which can be levied by the Authority on the operators/users without adversely affecting the commercial viability of IWT operations.

x. Workout Economic Internal Rate of Return (EIRR) considering the employment generation, fuel saving, saving in noise pollution and accidents, carbon credit which can be earned, savings in repair and maintenance of roads, saving in land acquisition etc. compared to road and railways for the projected traffic potential by IWT mode. Detailed working sheets should be given for this.

xi. Workout Financial Internal Rate of Return (FIRR) for the following options:

a) For the operators – Considering the rate they can charge for transportation of the goods by inland vessels and the user charge they shall pay to the Authority.

b) For the Authority - Based on user charges proposed to be levied by Authority from the operators for use of waterway, terminal etc.

xii. In order to develop Inland Waterway Transport as a part of integrated transportation system, mathematical models/traffic simulation studies covering the affected areas of proposed waterway, shall be developed to evaluate modal shift and the respective impacts on travel times and congestion in traffic as well as all modes. The model shall also cover zone-wise origin-destination interactions.

xiii. Detailed geotechnical investigations for various structures & components shall be carried out to establish the soil & rock strata along with their properties in sufficient detail for engineering and construction by using the organizations/Institutions/firms expert in the relevant field.

xiv. Geophysical survey (seismic) as dredging may be required, Geotechnical investigation (boreholes) to co-relate with seismic data and to design jetties and terminals.

xv. Engineering and other allied studies shall be carried out to ensure that the benefits envisaged are sustainable over a long period besides quality aspects and operational requirements based on the Geotechnical Investigation.

1.4.4 Environment Impact Assessment (EIA)

i. The Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) report as a part of Detailed Project Report (DPR). The EIA report shall be prepared considering all the relevant notifications issued by Ministry of Environment, Forest and Climate Change (MoEF&CC) or any other competent authorities (viz. EIA notification, 2006 and subsequent notifications/amendments issued time to time) accordance to all the relevant guidelines issued by MoEF&CC or any other competent authorities.

ii. The EIA report will be prepared for obtaining Environmental Clearances from the regulatory/statutory authorities besides the requirement of Impact Assessment Agency (IAA) spelled out during the review of the EIA report.

iii. The study shall be carried out in an integrated manner considering the impact of interlinking for both the connected basins.

iv. As outlined in the notification cited above, Public hearing shall be carried out as per the requirements of the fulfillment of EIA notification as a part of consultation with civil society.

Guidelines for EIA & EMP and Methodologies for data collection and monitoring as specified in the "Guidelines for Preparation of EIA and EMP by MoEF&CC shall be followed.

1.4.5 Reports, Documents & Soft Copies

The Consultant shall furnish the following reports. All reports, documents & soft copies shall be in English as applicable. Further, TMC reserves the right to demand Soft Copies of report & documents submitted as hard copies.

a. **Inception Report 3 (Three) Hard Copies:** Within 30 days of award of contract, the Consultant shall submit an inception report. The purpose of the Inception Report is to set out the objectives, approach, and methodology and conduct the reconnaissance on ground to identify the relevant locations for data collection, working program and study team of this Study. For each of the data collection tasks mentioned in Part I of the scope of services, the Consultant shall submit a detailed identification of data collection sites/ corridors/ areas, schedule of data collection activities and methodology.

b. **Data Collection – Supplemental Data Collection 3 (Three) Hard Copies: -** The Consultant shall submit hard copies of supplemental data collection, tabulated in a format acceptable to TMC as described in Scope of services.

c. **Draft Final Report 3 (Three) Hard Copies: -** The Consultant shall submit the Draft Final Report along with Terminal Designs (Good for construction Engineering Designs) as described in Part III of scope of services.

d. **Final Report 3 (Three) Hard Copies: -** The Consultant shall submit the Final Report and Terminal Design (Good for construction Engineering Designs) after obtaining approval from the TMC on Draft Final Report and incorporating any changes or feedback as advised by the TMC.

1.4.6 Compliance Statement For The Scope Of Work

In consonance with the scope of work the following shall be submitted in the prescribed format and in the designated deliverable schedule. The details of the various submissions based on the requirements of the SoW is as follows,

Field Survey Report

Hydrographic Survey & Bathymetric Survey Report

The Hydrographic, Bathymetric and Topographic survey shall be prepared to form a part of the DPR. The Report would contain the following;

1. **Topographic Survey report containing**

    a. Features of the bank along the proposed and identified waterway

b. Detailed features of the proposed land area to be used for the Terminal and the approach roads
c. The data will be in form of charts and descriptions for vividly describing the area and permit planning of engineering structures

2. Bathymetric Survey Report containing

a. The depths of the water in the waterway in the prescribed intervals reduced to chart datum (CD).
b. The features of the waterway containing the areas of erosion and accretion
c. Sand bars and shoals
d. Changing pattern of the river bed, including moving shoals by comparing with the older bathymetric charts

3. Geotechnical Survey Report Containing

a. Geotechnical characteristic of the soil in the bed including the dredge ability of the soil.
b. Soil characteristics and the foundation requirements at the terminal locations
c. Typical Foundation design

4. Environment Impact Assessment Report containing

a. Collection of ambient data on
    i. Air
    ii. Water
    iii. Noise
    iv. Surface and ground water
    v. Soil
b. Terrestrial and Marine Ecology
c. Implementation of the Development Plan
d. Prepare Impact on the development
e. Prepare the Detailed Management Plan
f. Risk assessment if any

5. Mathematical Model Studies

a. Wave Penetration and Wave propagation
b. Flow hydrodynamics and alignment of the terminal
c. Tranquility and flow regime
d. Siltation and Coastal Morphology

6. Detailed Project Report

The detailed project report would consider the above inputs and determine the following;

a. Site Condition
b. Passenger traffic
c. Alignment of the Channel with minimum dredging and maintenance
d. Location of the Terminals
e. Design of the Terminals
f. Design of the Vessels and determination of the fleet
g. Classification of the Channel
h. Navigation Aids
i. Cost Estimates
j. Financial and Economic Analysis

1.5 Brief Methodology & Approach

The principal objective of this assignment is to undertake a detailed project report for the development of the Vasai Creek for movement of water transport including the detailed design of the structures. The brief methodology of work would be as follows.

1.5.1 Site Reconnaissance & Data Collection

Thorough examination of the site is the first Job of a consultant to understand the dynamics at play. Often time site visits open up many avenues of engineering ideas, which is missed by the investigation at times. The site indicates the natural dynamics at work and the areas of concern, so that a better and more scientific investigation campaign can be planned.

During the site reconnaissance, old report and data shall be collected. The old data will be collated and the data gap identified so that the same could be augmented through site investigations.

1.5.2 Site Investigations (Data Collection)

Detailed site investigations are carried out regarding the following;

1. Hydrographic Survey to collect;
   a. Current
   b. Tides
   c. Waves
   d. Silt Charge
   e. Bed sediment characteristics
   f. Grain Size distributions

2. Bathymetric and Topographic Survey

For identifying the creek bed characteristics, locations of shoals and sand bars. Other identifiable features related to the navigation. The land features and contours.

3. Geotechnical Investigations

To determine the soil characteristics for dredging and details of the foundations to be adopted for the terminal structures.

4. Environmental Impact Assessment

Collection of ambient data and analyze them to determine the ambient environmental base line conditions. Juxtaposition of the development plan on to the base line characteristics and determine the Environmental Management plan and the Disaster Management Plan in the construction as well as the operation phase.

5. Mathematical Model Studies

Mathematical model studies with regard to the following shall be carried out for the ambient as well as for the post development condition. The mathematical model will help in determining the following;

   a. Location & Alignment of the terminals
   b. Wave disturbances and the tranquility at the terminals
   c. Tranquility for safe navigation
   d. Down time
   e. Siltation and maintenance dredging
   f. Morphological changes because of the Development

6. Detailed Project Report

The detailed project report would collate all the findings of the various studies and apply the same for a sustainable development. The main approach for the DPR would be as follows;

   a. Study of the available data and collected data for understanding the site dynamics, viz. eroding and accreting areas. Water flows, jumps if any, sand bars, hard beds etc.
   b. Detailed analysis and understanding of the site condition would help in identifying least interfering and expensive channel for navigation, which is stable and bereft of large scale siltation.
   c. After identification of the channel, measures to be implemented to keep it sustained shall be evaluated for short, medium and long-term time horizons.
   d. Concurrently, the probable traffic that are likely to use the facility would be identified. The traffic would be subdivided in to cargo traffic and passenger traffic, along with Ro-Ro facility. However, the present scope of the DPR is to cater for the Passenger services alone, the likely potential cargo traffic for the waterway shall also be identified.

e. Based on the demand of the traffic and the passenger generation the terminal location shall be chosen to be located at strategic locations. There can be several types of terminal, depending on the logistical connectivity, demand, land availability etc. These varieties of the terminal would be identified and detailed.
f. Amenities to be provided in the waterway including the terminals namely passenger facilities, amusement facilities etc.
g. Facilities on the waterway namely,
   i. River patrol and Ambulances
   ii. Ferry maintenance, retrofitting and capacity for New builds
   iii. Bunkering including LNG bunkering
   iv. Training centers for the crew
h. Waterway alignment and navigation aids
i. Vessel and Fleet size
j. Economies of ownership
k. VTMS
l. Philosophy of the waterways operations
m. Terminal and amenities design
n. Block Cost estimates
o. Financial Evaluation
p. Environmental Impacts
q. Preparation of the DPR

1.6 Structure of the Report

With the above methodology and approach the report will be subdivided in to various chapters and sections. The outlines of the chapters and presentation is modelled around the standard table of contents provided for the report, by IWAI, for the ease of scrutiny.

The standardization of the contents also shall help in examination and future reference.

2 Waterway / Detailed Hydrographic Survey

2.1 Hydrographic Survey

2.1.1 Waterway In General And Hydro-Morphological Characteristics

2.1.1.1 Waterways In General

The Ulhas River originates in a valley north of the Rajmachi hills formed by mountain streams draining the northern slope of those hills, which are part of the Sahyadri range of the western ghats in the Raigad district of Maharashtra. The district is the northernmost part of the Konkan lowlands of Maharashtra. It comprises the wide amphitheater like Ulhas basin on the south and hilly Vaitarna valley on the north together with plateaus and the slopes of Sahyadri. From the steep slopes of the Sahyadri in the east, the land falls through a succession of plateaus in the north and center of the district to the Ulhas valley in the south. These lowlands are separated from the coast by a fairly well-defined narrow ridge of hills that runs north-south to the east of the Thane creek, parallel to the sea, keeping a distance of about 6 to 10 km from the shores. Isolated hills and spurs dot the district area.

Rivers, Creeks, Islands, Lakes And Hot Springs

The two main rivers flowing through the district are the Ulhas and the Vaitarna. The Ulhas originates from the north of Tungarli near Lonavala, flows for a short distance before descending near Borghat, and meets the sea at Vasai Creek. The Ulhas River is 135 km long. The river has many tributaries; the two most important of them (within the boundaries of this district) are the Barvi and the Bhatsa. The Vaitarna, the largest of the Konkan rivers, rises in the Tryambak Hills in Nashik district, opposite to the source of the Godavari. The river flows across Shahapur, Vada and Palghar talukas and enter the Arabian Sea through a wide estuary off Arnala. The Vaitarna River is 154 km long and has a drainage area that practically covers the entire northern part of the district. It has a number of tributaries; the most important of them are the Pinjal, Surya, Daherja and Tansa.

Many small creeks are found all along the western coast, in which tidal waters flood upstream and fill up much low ground. In many cases human interference has helped in converting them into mud flats. The bigger creeks are Bhiwandi, Chinchani, and Dahanu Creeks. The Thane Creek is not a creek in the true sense, but a depression engulfed by the sea.

The northern part of the Salsette Island is part of Thane District, which is separated from the mainland by the Ulhas estuary and the Thane Creek but is connected through reclaimed land with the island city of Mumbai. Arnala Island is located in Vasai taluka, at the entrance to the Vaitarna estuary.

The district has no natural lakes. Artificial lakes have been constructed mainly to supply drinking water to Mumbai. The Tansa Lake formed across the Tansa River in the hills north of Bhiwandi behind the dam completed in the year 1892. The Modak Sagar (Lower Vaitarna) Lake on the river Vaitarna formed behind a dam completed in the year 1957. In the upper reaches of the same river, the Upper Vaitarna Lake formed behind another dam built in the year 1972. The Bhatsa Lake has been formed in the upper Bhatsa, north of Shahapur behind a dam built in the year 1981.

Several hot springs are in the Vasai Taluka in the bed of the Tansa River. They are near Akloli, Ganeshpuri and Vajreshwari villages. There are some more examples: Kokner (Maswan Tal:- Palghar) and Sativali (Saphale tal:- Palghar). The water temperatures are in the range of 42°-55° C. The average annual rainfall in the district is 2293.4 mm. The rainfall in the district increases from the coastal areas to the interior. The rainfall varies from 1730.5 mm at Mahim on the coast to 2588.7 mm at Shahapur in the interior. The rainfall during the south-west monsoon season, June to September, constitutes about 94% of the annual rainfall. July is the wettest month with a rainfall of about 40% of the annual total. The variation in the annual rainfall from year to year in the district is not large. The highest rainfall recorded in 24 hours at any station in the district was 481.1 mm at Dahanu on 1 September 1958.

In its course the Ulhas river flows passing industrial areas such as Kalyan, Ambernath, Bhiwandi, Thane, Kolshet, Ghodbunder and Vasai (Bassein). Along the river, the distance from Vasai (Bassein) to Kasheli near Thane is 29 Km and between Kasheli near Thane to Kalyan is about 17 Km.

The major tributaries meeting the Ulhas River are – The River Kalu (which is earlier joined by river Bhatsai) at 10 Km upstream of Kalyan, the River Mumbra at Mumbra, the Kamvadi River 12 Km downstream of Thane, the Kaman 7 Km upstream of Vasai (Bassein) and the Sopara Creek just upstream of Western Railway Bridge. All the above tributaries except Mumbra meet Ulhas River on its right (Northern bank). The seaward end of the river is also known as Vasai (Bassein) creek.

At Kasheli near Thane, a distributary of Ulhas River known as Thane Creek branches out and flows southward. It passes the industrial areas of Thane-Belapur and Mumbai and finally falls into the north end of Mumbai Harbour, just near and east of Trombay. The distance from the offtake to Trombay along Thane creek is about 24 Km and from Trombay to Ballard Pier is about 20 Km. The Nhava Sheva Port (JNPT) is about 8 Km from Trombay.

To the south of the creek lies the Bhayander shore, which is developed on both sides of the railway track. 2 railway bridges connect Naigaon and other stations to the western suburbs. Old bridge was built during the British Raj and has been closed since it was declared dangerous to commute. The new bridge is functional and has 4 tracks. Bhayander sea shore sees a huge number of people in the evenings which have been developed recently with protective measures for over enthusiasts. It houses a children park, playing ground, pooja area, Idol immersion (visarjan) area on the east side. On the west you have small garden benches where people can sit and chat. Small paths lowering into the sea also exist where people can stand and watch the waves hitting the shoreline.

The vertical clearance available under the old railway bridge is limited to 3.43 m above Mean High Water Springs(MHWS). The horizontal clearance between two spans under the old railway bridge is 18.7 m whereas under the new bridge the horizontal clearance between two spans is 52 m [9].

East of Panju Island, both the channels join in and the creek narrows. There are two power transmission lines crossing the Vasai Creek in line with Sansunavghar Village. The vertical clearance available near the transmission line is about 26.2 m above CD[10].

2.1.1.2 Hydro-Morphological Characteristics

The proposed waterways extending between its assigned extremities about 50 km long. The waterway is part of the Vasai (Bassein) creek and Ulhas River system as indicated above and passes through the Mira Bhayander Municipal Area on the south and Vasai-Virar Municipal area on the north. The fact that this waterway passes through such busy and thickly populated centers itself, is testimony to the potential it has for development. Though the ambit of the present study is limited to the study of the Vasai (Bassein) Creek and Ulhas river system, from the entrance on the Arabian Sea to Kalyan upstream as shown in Figure 2.1 for passenger movement, other aspects of potential development also shall be touched upon for completeness.

[9] Western Railways Engineering Departments

[10] MSEDCL

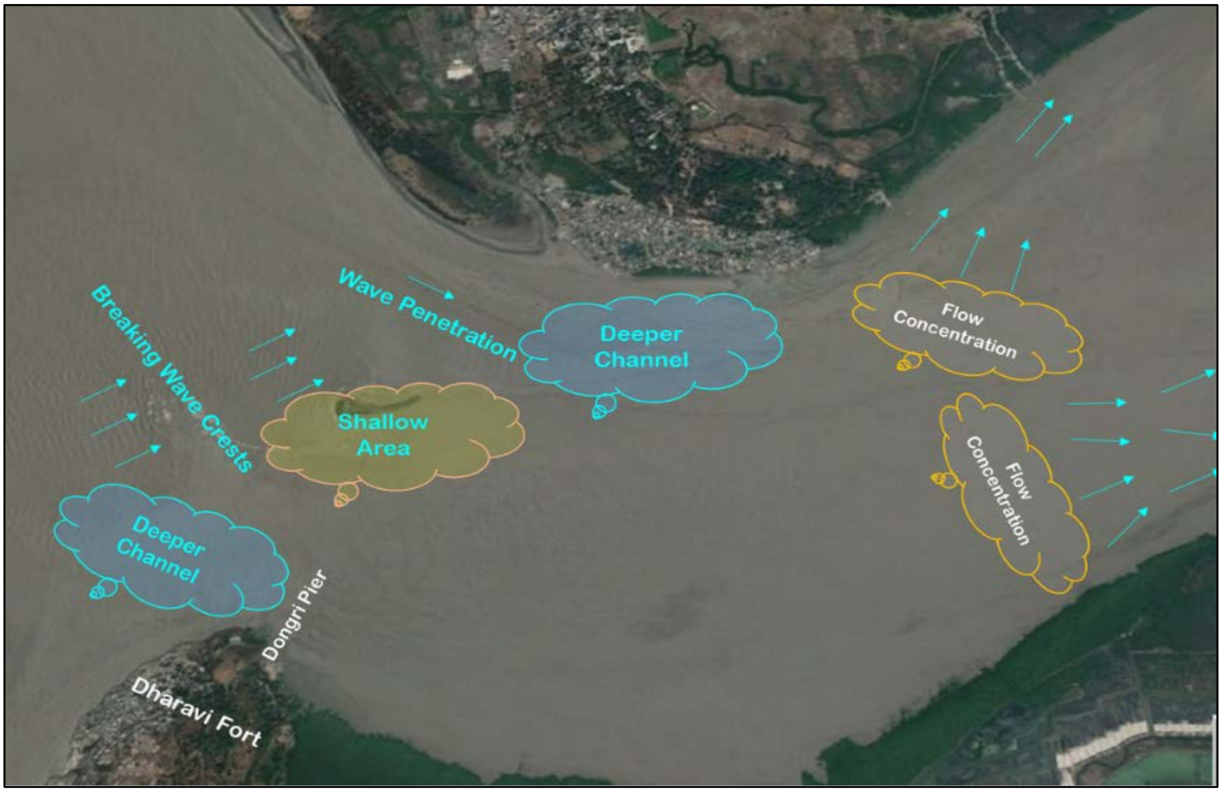
Figure 2. 1: Waterways Physiology - Vasai Creek – Ulhas River Systems - The Study Area

A general look at the waterway indicates a typical river outfall in a hilly terrain. The outfall mouth is wide and spread narrowing down as one moves upstream. The creek or estuary is tidal dominated manifested by the formation of the shoals and occasional island. The Panju Island is one such physiological feature at the entrance. The banks of the creeks are mostly hilly and with steep banks. At locations the areas are undulated and plain with vegetation and swampy low-lying areas. Geologically it is part of the Gondwanaland Plateau. Upstream of the Ghodbunder Fort, the waterways narrow to the minimum and the velocities are higher. Though there is no fall, the creek bed is steep. Moving upstream as the tidal effects reduces the meandering starts and the river narrows. The entire waterway is under the influence of the tidal prism.

A. Vasai (Bassein) Creek Entrance

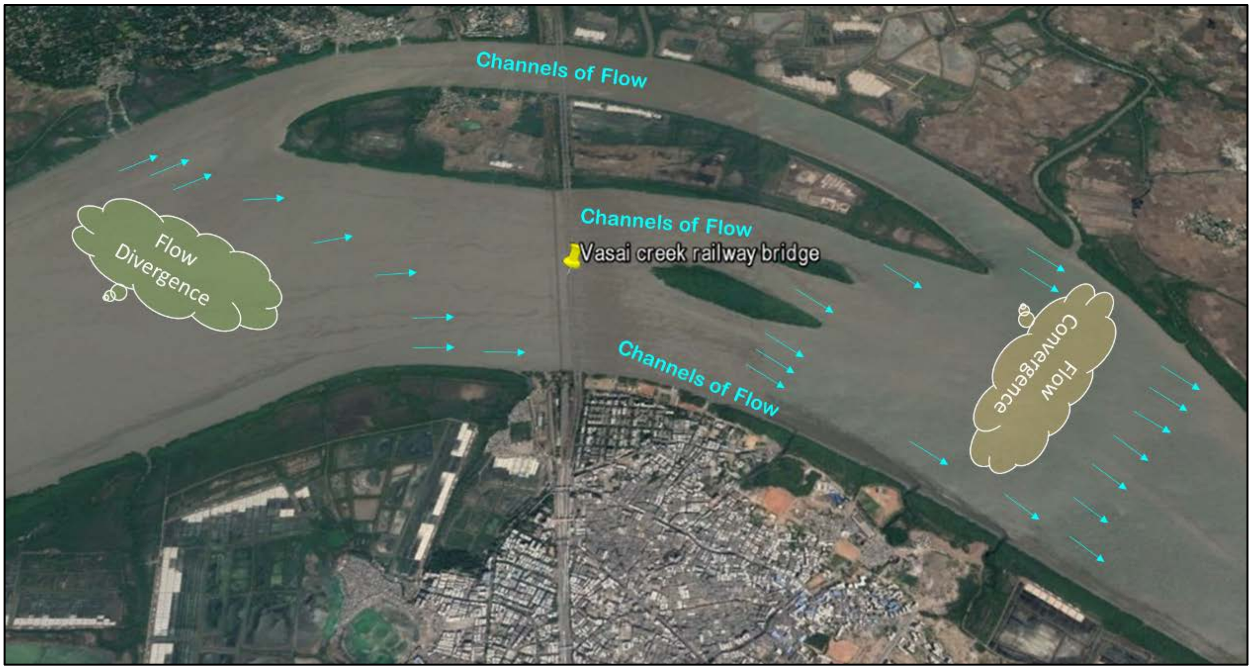
Vasai (Bassein) Creek is a landwards incursion from the Arabian sea. It extends inwards in to the landmass moves north-eastwards from the sea before taking a turn to the south-eastwards. Being a tide dominated estuary, the central portion is largely shallow, discernible from the breaking wave fronts in the Figure 2.2 below.

Figure 2. 2: Vasai (Bassein) Creek Entrance (Flood Tide)



The main flow is concentrated in the south and the north Channel hogging both the banks and identifiable from the above figure by the deeper channel label. After entry in to the creek and before the bend south-eastwards, there is a sparsely inhabited island called Panju island which splits the channel in to deep water channels. The Dharavi Fort is located on the south bank along with the Dongri Pier at its foothills. The Vasai fort is located on the right bank and the Vasai Jetty nearby about 2 km from the Naigaon Railway Station. A location which could be combined in the planning for amusement and passenger movement.

Figure 2. 3: Panju Island And Its Surrounding (Flood Tide)



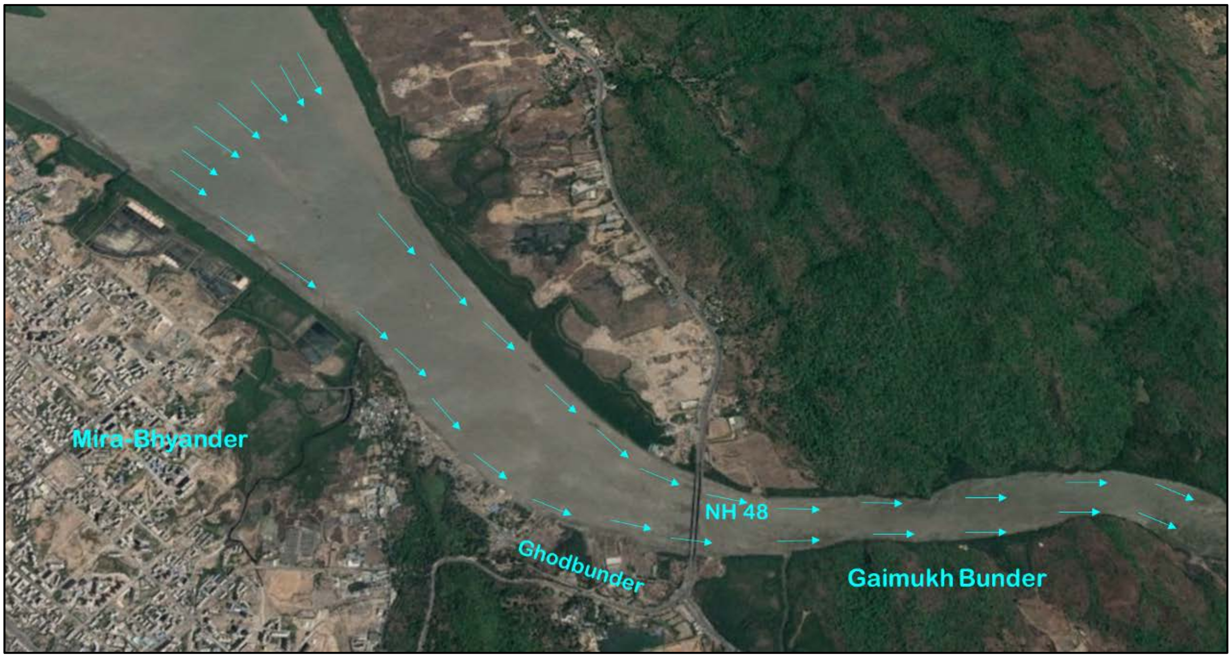
Panju Island is a village located in the middle of the creek nearly 500 m from the main land on the right bank. A large part of the area of the Island is swampy and mostly covered with mangroves. More than 1,300 people, majority of whom are fishermen live on the island. Their residences are mostly confined to the dry patches.

Densely populated Mira-Bhayander Municipal Corporation located on the left bank of the creek. The area has the required infrastructure with low level industrialization. Sopara creek, a small water flow from Pelhar lake area meets the creek near the railway track. The railway and the road bridges cross the creek by the Panju Island. The clear air draft of the Western railway old bridge is reported to be around 3.43 m.

B. Gaimukh Bunder and its environs

Upstream of the Panju Island, about 5.0 km away, the National Highway 48 (Mumbai to Delhi) cross the creek. On the left bank near the Ghodbunder, the Thane-Ghodbunder road (SH 42) joins the NH 48. Figure 2.4 shows the flow regime under the flood tide near the Bridge and indicates the reason for the increase in the flow velocities beyond Ghodbunder.

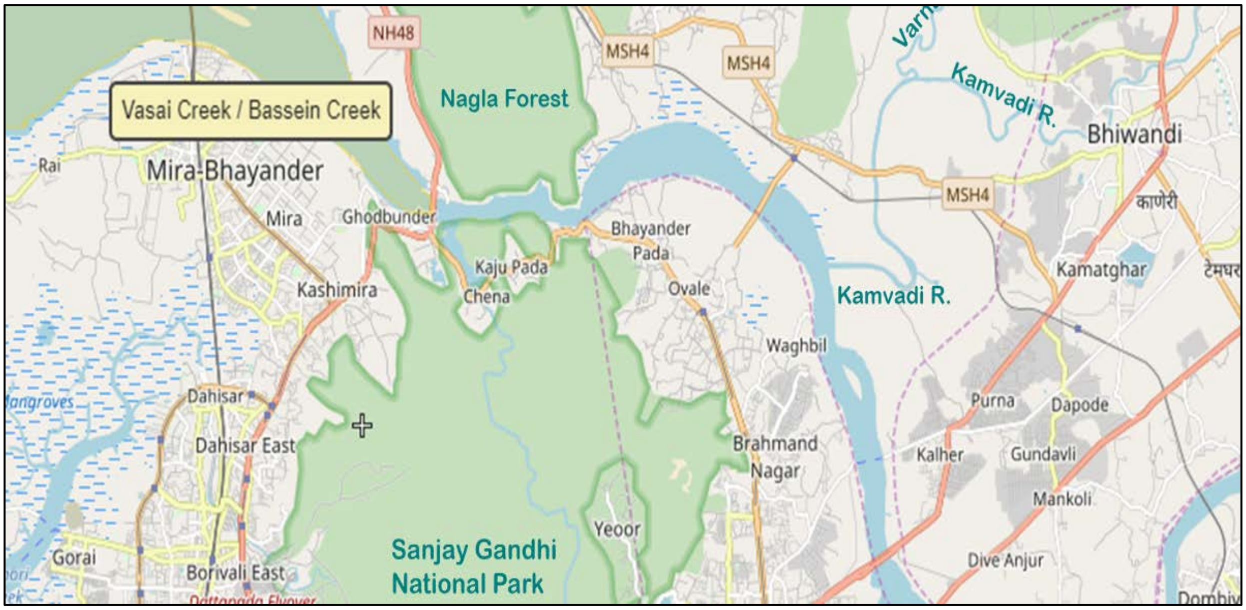
Figure 2. 4: Gaimukh Bunder (Flood Tide)



Gaimukh gaon is a village located near the state highway SH 42 on the right bank of the creek. There is existence of mangroves along the river/creek slopes up to Gaimukh gaon. The river gets narrower and hence the rise in current speed. There appears to be undulations in the creek bed and logically the bed must be rocky. The banks are steep and rocky. The Sanjay Gandhi National Park is on the left bank and the Nagla Forest is on the right bank as shown in the Figure 2.5.

Bharati Defense and Infrastructure Limited shipyard is located just downstream of the state highway bridge across the creek near Ghodbunder village. It is a privately-operated ship building facility spread over 12 acres of land. It is equipped with four slipways for building ships up to 125m length. It acts as a feeder yard to Ratnagiri yard. Reti bunder is just beside the shipyard towards Vasai end. It stretches to a length of 1 km along the creek. Ghodbunder village is located at 1 km from Retibunder. Two small creeks emerge from the creek near Ghodbunder village to move towards Kashimira village. The banks of the creek from Bharati shipyard to Bhayander pada near Gaimukh gaon is fully covered with mangroves. The creek turns at Kharbao to move to north-east for about a distance of 10 km from the main creek. However, the creek remains confined to its narrow stretches with very low depths.

Figure 2. 5: Gaimukh Bunder – Physical Details



Due to the presence of the national park and the forest areas the location is serene and would remain so even after the waterway is functional. The width of the creek is quite even and the beds are more level, hence the current speed appear to have reduced. On the right bank Kamvadi River Joins the creek. Banks are still higher especially in the left bank. Right bank has started merging with the valleys.

C. Diva - Dombivli Area

After the Old Agra road upstream, the Ulhas river has reached the plains and hence the flows are more even and mostly tidal in nature. Meandering is found under low flow conditions. The fresh water discharge is low. More frequent occurrences of vegetation and mangroves are seen along the banks, indicating influence of fresh water intermixing with the saline tidal water, a zone of transient salinity. Figure 2.6 shows the plan of the waterway, which indicates mostly of uniform flow, and meandering of the stream through the rocky landmass. Near Devi the swampy land is more prominent and low lying. As one moves further upstream towards the Dombivli area, the area is more crowded especially on the left bank.

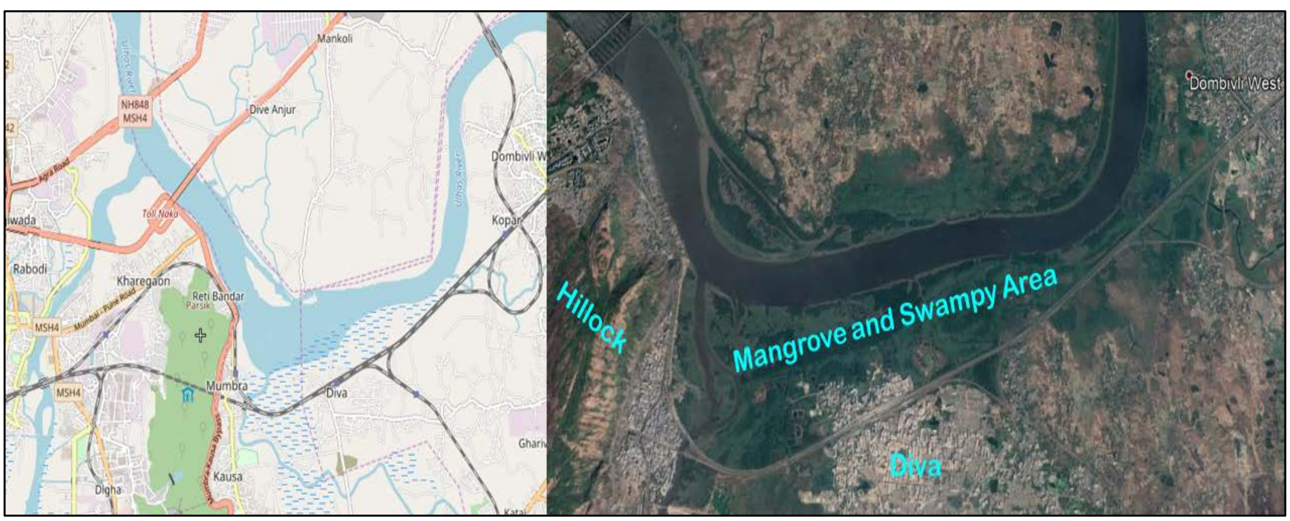
Kharbao is a municipal corporation on the Right bank, is being propped as an alternative to Mumbai and Thane region in the coming years.

Noticeable Construction of residential and industrial complexes are in full flow in the area.

Figure 2. 6: Diva And Dombivli Area

A closeup of the swampy area near Diva is show in Figure 2.7.

Figure 2. 7: Swampy Area Near Diva And The Forest Area To The West (Close Up)



D. Around Kalyan Area

The last part of the waterway between Vasai and Kalyan is described in this paragraph. The bank line is mostly uniform.

There are certain sand bars down stream of Kalyan, right in the middle of the river. NH 61 crosses the river near Kalyan which connects the City to the right bank.

Figure 2.8 shows the general features of the waterway and the area.

Figure 2. 8: Waterway Near Kalyan Area

The description above is associated with illustrations for flood tide scenario, similar analogies for the ebb tide also could be drawn albeit, the reverse being correct. Meaning thereby, the flow convergence would be flow divergence. But it must also be emphasized that exact simile may be a little farfetched, the spirit is only to be evaluated on case to case basis.

2.1.2 Existing Hydrological / Topographical Reference levels

2.1.2.1 Hydrographic Survey Details

Detailed Hydrographic survey was carried as per the prevailing International Standards and practices. finding the potential of inland navigation through M/s Horizon Geosciences of Mumbai. The survey included the following;

1. Bathymetry Survey
2. Hydrographic Survey consisting of;
    a. Tide
    b. Current
    c. Wave

d. Bed Samples Analysis

e. Water Sample

3. Existing Cross Structures

   a. Bridges

   b. Pipe-lines/Cables

   c. Electrical Lines/Transmission lines

4. Bend Location and Curvatures

Major considerations for the survey were:

a. The survey to be carried out in WGS'84 Datum.
b. The horizontal control through DGPS with minimum 24 hours' observations at the same platform/base/direct Real Time Kinematic (RTK) satellite navigation technique.
c. The vertical control shall be established with respect to the chart datum / sounding datum.
d. Chart datum/sounding datum shall be determined from the following methods: -
   i. For tidal reaches - Chart datum/ sounding datum already established by Nearest Port Authorities (Chart Datum),
   ii. Standard method shall be adopted for transfer of datum. For tidal reaches standard transfer of datum as per Admiralty Manual shall be adopted.
e. Bathymetric survey is carried out for minimum 100 m. wide corridor at the approximate center of the proposed waterways, i.e. 50 m width on both side from the center line of the channel.
f. Cross-section sounding lines / leveling is run from bank to bank at spacing of 50 m, to identify the navigable channel.
g. Continuous soundings are collected by running the boat at constant speed along the cross-section to get smooth contours. Intermediate line is to be run at bends, if the line spacing is more than the specified above.
h. For cross-sectional bathymetric survey more than 60 m in proposed Inland Waterways, spot levels at line spacing of 20 m. Spot levels should also cover 20 m. length grid on both banks. If any island or sandspur exist in the middle of the waterway, spot levels on the same at the same spacing should also be taken and indicated in the charts along the same cross-section line.
i. The soundings are reduced to the chart datum/ sounding datum established at every gauge stations.

The detailed report on the Hydrogaphic survey and the bathymetric charts, are enclosed as Annexure – B. Relevant details from the reports are extracted and reproduced in the following paragraphs to provide the necessary contextuality.

A. Reference Levels

The survey was carried out by our associates, namely M/s Horizon Geosciences of Mumbai. The survey was based on the Real Time Kinematic (RTK) satellite navigation technique, used to enhance the precision of position data derived from satellite-based positioning system such as, Global Navigation satellite systems (GNSS), such as DGPS. The survey control systems area vividly described in the Hydrographic survey. Bench Mark (BM) location at Vasai fort was provided by Maharashtra Maritime Board (MMB) whose Chart Datum value is 5.618 m. The details of the BM Pillars are given in Table 2.1 below. The value of Bench Mark was then transferred to the respective tide gauges where the tidal observations were carried out.

Table 2. 1: Reference Levels

BM no.	Location	Chainage (km)	Latitude (N)	Longitude(E)	Easting (m)	Northing (m)	BM above MSL (m) (A)	CD / SD (m) (B)
1	Bassien fort	5.827	19°19'44.8"	72°49'07.06''	270822.42	2168688.020	3.088	5.618
2	TBM, Reti Jetty	16.567	19°17'35.71	72°53'31.18"	278484.927	2134622.603	2.657	5.187
3	TBM, Vasai Jetty	5.875	19°19'45.37	72°49'10.77"	270931.124	2138 704.311	3.304	5.834

B. Chart Datum / Sounding Datum

Bench Mark location at Vasai fort was provided by Maharashtra Maritime Board (MMB), whose Chart Datum value is 5.618 m. The value of Bench Mark was then transferred to Tide Gauge 1 (ATG1) and ATG2 simultaneously by RTK observations. Tidal observations were carried out at ATG2 throughout the survey period. Chart Datum was obtained by sounding datum transfer from ATG2 to ATG3, ATG2-ATG4 and ATG2 to ATG5 at ATG3, ATG4 and ATG5 respectively.

Table 2. 2: The Reference Levels At The Tide Gauge Locations

Sl. No	Location of tide gauges	Chainage (km)	Stretch for corrected soundings and topo levels (km)	Sounding Datum of Tide Gauge with respect to CD (m)
			(50% stretch is selected on both side of tide gauge)	
1	ATG1	5.547		6.466
2	ATG2	14.916	0.00 KP(Vasai) to 16.50KP	6.153
3	ATG3	21.352	16.50KP to 34.0KP	7.373
4	ATG4	35.396	34.0KP to 37.00KP	5.896
5	ATG5	46.126	37.00KP to 52.00KP(Kalyan)	5.599

Yearly minimum and maximum Water Levels. Average of 06 years minimum Water Levels is used to arrive at Chart Datum (CD) / Sounding Datum (SD). FSL in case of Canals. 10 years minimum and maximum data at Dam, Barrages, Weirs, Anicut, Locks, Aqueducts is collected. Average of 10 years minimum Water level data is taken as SD. Maximum water level (MWL)/Full Reservoir Level (MWL/FRL) as HFL. Ponding limit of Pond Level / Minimum Draw Down Level (MDDL) is also to be collected / observed / measured. (Daily water level / discharge data is to be mentioned in the detailed survey report submitted separately.

2.1.2.2 Topographic Survey Details

All topographical features located in the survey area to be captured and presented in the survey charts & report attached separately. Details of various features are as follows:

a. Photographs of the prominent features along with its position.
b. Permanent structures located within this corridor are be indicated on the charts.
c. All prominent shore features (locks, bridges, aqueducts, survey pillars if available etc.) and other conspicuous objects to be fixed and location indicated on the chart
d. Cross structures, obstructing navigation to be identified.
e. Details (horizontal and vertical clearances above High Flood Level in non-tidal area and High Tide Level in tidal area) of bridges, aqueducts, electric lines, telephone lines, pipe lines, cables enroute to be included in the report along with their co-ordinates and location.
f. Details of water intake/ structures
g. Existing berthing place, jetty, ferry Ghats, approach roads etc.
h. Detailed condition of the banks is collected along with protection details (pitched/protected or eroded). Estimated length of bank protection required for eroded banks to be included in the

report.

i. Approachable roads / rails / places outside the corridor maybe incorporated from Topo-sheets/Google Map/Google Earth.

2.2 Existing Cross Structures

This section shall deal with the various cross structures that is crossing the waterway. The details enumerated in this section among other things will contain the rail and the road bridges, the pipe line bridges, transmission line and any other structures that might have effect on the navigation in the waterway.

2.2.1 Bridges

The details of the bridges on the waterway, some of which are not designed for navigation and do not have the required air draught are given in Table 2.3 below.

Table 2. 3: The Cross Over Bridges Along The Water Way (Starting From The Seaward End As Shown In Survey Charts)

Sl No	Structure Name and for road / rail	Chainage km)	Type of Structure (RCC,/ Iron,/ Wooden)	Position (Latitude & Longitude) (Deg;Min;Sec)		Position (UTM)		Length (m)	Width (m)	No of Piers	Horizontal clearance (clear distance Between piers) (m)	Vertical clearance w.r.t. HFL / MHWS (m)	Remarks
				Left Bank	Right Bank	Left Bank	Right Bank						
1	Vasai to Bhayander old Railway Bridge	9.344	Iron	19°;20';30.921" N, 72;50';57.685" E	19°;19';06.790" N, 72°;51';07.159" E	E274069.713, N2140065.973	E274314.153, N2137475.209	1709.707	7.877	92	18.7	3.43	Not in Use
2	New Bhayander to Vasai Rail Bridge	9.413	Iron	19°;20';30.811" N, 72°;50';59.933" E	19°;19';06.603" N, 72°;51';09.406" E	E274135.289, N2140061.775	E274379.679, N2137468.646	1721.42	10.803	38	52	4.43	In Use
3	New Bhayander to Vasai Rail Bridge	9.442	Iron	19°;20';30.766" N, 72°;51';00.849" E	19°;19';06.527" N, 72°;51';10.317" E	E274161.995, N2140060.066	E274406.239, N2137465.985	1721.42	10.803	38	52	4.43	In Use
4	Old Vasai Khadi Bridge (Ghodbunder)	17.93	RCC	19°;17';29.482" N, 72°;54';18.630" E	19°;17';14.758" N, 72°;54';17.286" E	E279868.088, N2134414.225	E279823.371, N2133961.898	445.855	10.516	6	100	8.83	In Use
5	New Vasai Khadi Bridge (Ghodbunder)	17.95	RCC	19°;17';29.202" N, 72°;54';19.456" E	19°;17';14.736" N, 72°;54';18.157" E	E279892.105, N2134405.310	E279848.788, N2133960.920	437.183	10.516	6	100	8.83	In Use
6	Kasheli Bridge I Old Agra Road/Bhiwandi Road/Highway No 35	33.78	RCC	19°;13';49.041" N, 73°;00';18.333" E	19°;13';42.170" N, 73°;00';06.183" E	E290293.321, N2127511.543	E289935.991, N2127304.318	408.317	13.319	9	40	14.27	In Use
7	Kasheli Bridge II/Old Kalyan – Bhiwandi Road/Highway no 35	33.83	RCC	19°;13';48.234" N, 73°;00';18.641" E	19°;13';41.417" N, 73°;00';06.617" E	E290302.049, N2127486.604	E289948.400, N2127281.026	410.836	13.217	9	40	14.27	In Use
8	Thane Road Bridge (Nashik Road)	35.42	RCC	19°;13';12.256" N, 73°;00';54.700" E	19°;12';58.025" N, 73°;00';40.358" E	E291342.689, N2126368.203	E290918.721, N2125935.380	605.874	20.591	9	52	11.32	In Use
9	Satpul Rail Bridge (Dombivli - Vasai)	46.15	Iron	19°;14';24.454 N, 73°;04';24.174 E	19°;14';14.382" N, 73°;04';31.625" E	E297486.204, N2128519.525	E297700.386, N2128207.375	378.565	19.172	5	70	15.38	In Use
10	Old Kalyan Bhiwandi Bridge (Bhiwandi – Murbad Road NH22)	51.76	RCC	19°;14';43.751" N, 73°;06';54.353"E	19°;14';42.785" N, 73°;07';02.704" E	E301878.875, N2129064.779	E302122.429, N2129032.456	245.750	9.519	9	30	9.47	In Use
11	New Kalyan Bhiwandi Bridge (Bhiwandi – Murbad Road NH22)	51.83	RCC	19°;14';44.676" N, 73°;06';54.380" E	19°;14';46.346" N, 73°;07';02.798" E	E301879.945, N2129093.224	E302126.341, N2129141.911	252.253	11.257	3	60	10.47	In Use

2.2.2 Pipe Lines / Cables

Two water pipeline bridges crossing the channel are presented in the table 2.4 below.

Table 2. 4: The Cross Over Bridges Along The Water Way

Sl No	Type of line	Chainage km)	Location	Position (Latitude & Longitude) (Deg;Min;Sec)		Position (UTM)		No of Piers	Horizontal clearance (clear distance Between piers) (m)	Vertical clearance w.r.t. HFL / MHWS (m)	Remarks (complete / under - construction)
				Left Bank	Right Bank	Left Bank	Right Bank				
1	Water Pipeline Bridge	33.814	Kasheli (In between Kasheli I & II Bridge)	19°;13';48.234"N, 73°;00';18.641" E	19°;13';41.417"N, 73°;00';06.617" E	E290302.049, N2127486.604	E289948.400, N2127281.026	9	40	11.27	Complete Length = 409.06 m Width = 17.990 m
2	Water Pipeline Bridge	35.660	Mumbra Reti Bunder	19°;13';06.703"N, 73°;01';00.743"E	19°;12';52.523" N, 73°;00';46.476" E	E291517.250, N2126195.448	E291095.522, N2125764.147	12	52	12.82	Complete Length = 599.789 m Width = 9.560 m

2.2.3 Electric Lines / Communication Lines

The details of the four transmission lines/Cables crossing the channel, are presented in the table below.

Table 2. 5: The Cross Over Transmission Lines / Cables Along The Water Way (Field Survey)

Sl No	Type of line	Chainage km)	Location	Position (Latitude & Longitude) (Deg;Min;Sec)		Position (UTM)		Horizontal clearance (clear distance Between piers) (m)	Vertical clearance w.r.t. HFL / MHWS (m)	Remarks (complete / under - construction)
				Left Bank	Right Bank	Left Bank	Right Bank			
1	Power Transmission Tower 1 Cable (Near Ghodbunder Village)	14.694	Near Bhayander (East)	19°18’36.177.”N, 72°53’14.123”E	19°18’17.729”N, 72°52’46.715”E	E278010.606, N2136580.400	E277202.297 N2135930.608	600	26.5	Complete Length = 1037.108 m
2	Power Transmission Tower 2 Cable (Near Ghodbunder Village)	14.842	Near Bhayander (East)	19°18’35.047”N, 72°53’16.247”E	19°18’14.818”N, 72°52’50.883”E	E78071.070, N2136452.640	E277322.901, N2135839.590	570	27	Complete Length = 967.258 m
3	Power Transmission Tower 3 Cable (Near Reti Bunder)	36.645	Near Parsik Bunder	19°12’38.778”N, 73°01’23.041”E	19°12’30.787”N, 73°01’07.183”E	E 292158.843, N 2125329.311	E291692.806, N125088.849	535	27	Complete Length = 524.416 m
4	Power Transmission Tower 4 Cable (Near Reti Bunder)	37.603	Near Reti Bunder	19°12’08.509”N, 73°01’32.017”E	19°12’03.451”N, 73°01’23.204”E	E 292410.523, N 2124395.553	E292151.275, N2124242.944	560	28	Complete Length = 300.831 m

2.2.4 Dams / Barrages / Locks / Weirs / Anicuts / Aqueducts

There are no dams, Barrages, Locks, weirs, anicuts or aqueducts in this stretch of the waterway.

2.3 Bends

2.3.1 Definition And Requirements

As per the recommendations of the PIANC, the channel alignment should be assessed with regard to:

i. Shortest channel length
ii. Conditions/basins, etc. at either end of the channel
iii. Need to avoid obstacles or areas of accretion which are difficult or expensive to remove or require excessive (and hence costly) maintenance dredging
iv. Prevailing winds, currents and waves
v. Avoiding bends, especially close to port entrances
vi. Environment on either side of the channel, such that ships passing along it do not cause disturbance or damage

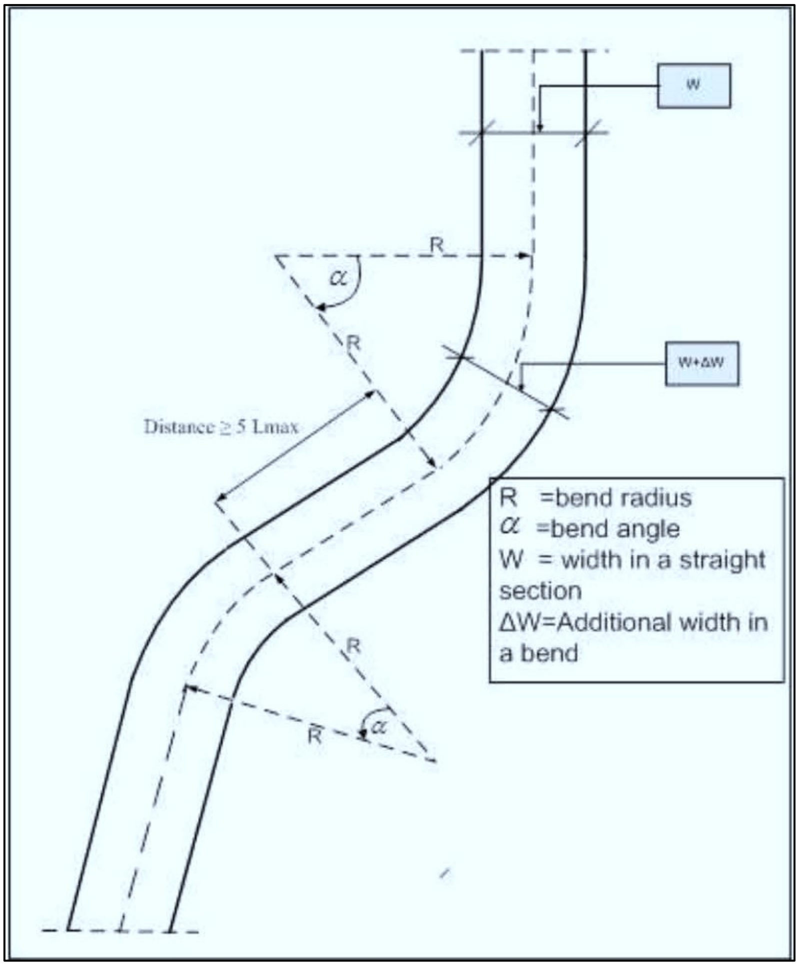
Straight channel sections are preferable to curved ones and the designer should strive for an alignment consisting of a series of straight sections connected by smooth bends, where necessary, without abrupt angles (see Figure 2.9 below). Individual sections may have different widths and depths and be navigated at different speeds.

It is preferable to have the prevailing currents aligned with the channel to minimise crosscurrents. The same applies to wind and waves, although these may come from any direction. Usually, the prevailing wind and wave directions are used in design to judge whether the likely access downtime due to strong winds or high waves from other directions is acceptable.

It is also advisable that the channel be aligned such that the ship is not heading directly at the quay or jetty during its approach.

Any channel whose direction is perpendicular to the berthing face should be aligned to one side of the quay or jetty, so the ship must turn (or be swung) to arrive at its berth. This minimizes the risk of ships contacting the jetty or quay in the event of losing control during the approach.

Figure 2. 9: Bend Configurartion



A bend will normally join two straight channel sections. However, two bends could also occur sequentially, although such features should be avoided, where possible.

In some cases, concatenated bends will be unavoidable and maneuvering simulation provides the only technique to determine the adequacy of their design. Of particular importance will be the positioning of the vessel in the first bend. This must be correct (usually with little margin for error) if the succeeding bend(s) are to be navigated successfully. If possible, the distance between successive bends should be greater than five ship lengths of the largest design ship (see Figure 3.3). Transitions shorter than this length should be investigated in a maneuvering simulation study. If two bends turn in the same direction the distance between the two bends should be greater than 3 ship lengths of the largest design ship.

A bend may or may not have banks. Where banks are present the channel may be almost like a canal at low water, and where they are not present, it may simply indicate a turning maneuver from one channel section to another. Ship behavior and, as a result, bend marking, will differ for each type.

The bend with banks could cause the ship to change its behavior due to bank effects so their presence will need to be indicated.

Bend radius and bend angle should initially have been chosen in the concept design stage following the suggestions made in Section 3.1.6 of the 'PIANC Harbour Approach Channel Guidelines'. Simulator based studies can be used to determine if the particular configuration is suitable or can be optimised. It will soon become apparent if the ship handler is comfortable when navigating a bend as the problems of too long a bend at too great a radius will be manifest in disorientation and excessive use of the rudder. The problems of too small a bend radius may result in the ship crossing the channel boundary and, in such a situation, it may be necessary to explore the use of tugs to aid the ship if the radius cannot be increased and the ship speed is low enough. The design of the maneuvering lane and the special considerations at the bends are discussed in the next chapter on fairway development.

2.3.2 Bend Location

There are totally 18 bends in the present layout of the channel. Additionally, in the secondary channel that connects the Mira-Bhayander terminal. The location of the bends is given in table 2.6.

Table 2. 6: Location Of The Bends In The Channel

Sr. No	KP	Bends (KP)	Easting (m)	Northing (m)	Lat (deg Min Sec)	Long (deg min sec)
1	0.0 to 2.0	1.631	267300.28	2136721.13	19;18;39.40154 N	72;47;07.29943 E
2	4.0 to 6.0	5.324	270680.88	2138179.94	19;19;28.22396 N	72;49;02.43199 E
3	8.0 to 10.0	8.211	272975.71	2139859.80	19;20;23.77464 N	72;50;20.30338 E
4	10.0 to 12.0	11.055	275715.16	2139315.05	19;20;07.17006 N	72;51;54.36071 E
5	16.0 to 18.0	17.990	279908.41	2134177.93	19;17;21.81519 N	72;54;20.10829 E
6	20.0 to 22.0	21.281	283159.92	2134022.43	19;17;18.02710 N	72;56;11.50759 E
7	24.0 to 26.0	24.249	285765.62	2135079.00	19;17;53.38264 N	72;57;40.30580 E
8	26.0 to 28.0	27.072	288211.02	2133733.87	19;17;10.57673 N	72;59;04.58215 E
9	30.0 to 32.0	30.390	289337.57	2130660.64	19;15;31.07635 N	72;59;44.37339 E
10	32.0 to 34.0	33.834	290156.75	2127369.12	19;13;44.35932 N	73;00;13.71381 E
11	36.0 to 38.0	36.111	291612.52	2125646.11	19;12;48.87670 N	73;01;04.21790 E
12	38.0 to 40.0	38.101	292618.68	2123979.64	19;11;55.06220 N	73;01;39.30270 E
13	38.0 to 40.0	42.089	296444.89	2124703.33	19;12;19.98990 N	73;03;49.98000 E
14	44.0 to 46.0	44.975	296828.34	2127499.28	19;13;51.04229 N	73;04;02.04123 E
15	46.0 to 48.0	47.197	298510.17	2128858.95	19;14;35.85934 N	73;04;59.10119 E

Sr. No	KP	Bends (KP)	Easting (m)	Northing (m)	Lat (deg Min Sec)	Long (deg min sec)
16	48.0 to 50.0	49.390	300348.38	2127718.45	19;13;59.43023 N	73;06;02.45941 E
17	50.0 to 52.0	50.224	301168.30	2127820.01	19;14;03.02344 N	73;06;30.49026 E
18	50.0 to 52.0	51.465	301966.44	2128753.46	19;14;33.65820 N	73;06;57.46746 E

The bends in the channel are in general points of 'weakness' as far as the speed of the ferry service is concerned. The bends makes the vessel introduce the change in the rudder angle and so there is a turn in the direction of the travel of the vessel. This would entail, turning of the vessel, either at the speed with which it was travelling before or reduce the speed to confine itself in the channel, if the channel is not wide enough. Therefore, often times depending on the length and the speed of the vessel the width requirements at the bends are increased. Speed of the vessel in an operating channel in general is maintained at a constant figure. Therefore, mostly additional dredging depth (if required) is added to the existing channel at the bends.

It is imperative to determine the radius of bends which is one of the main considerations in the decision of

1. Length of the Vessel
2. Speed at which it can travel to negotiate the bend with least channel modification and the financial impact
3. Modification in the channel width etc.

The radius of the curvatures of the bends indicated above is given in the next section.

2.3.3 Radius Of Curvatures

Table 2.7 indicates the radius of the bends in the channel along with their locations. The radius varies between 5045 m to 257 m.

Table 2. 7: Location Of The Bends Along With Radius Of Curvatures

Sr.No	KP	Bends (KP)	Lat (deg Min Sec)	Long (deg min sec)	Radius (m)
1	0.0 to 2.0	1.631	19;18;39.40154 N	72;47;07.29943 E	1046
2	4.0 to 6.0	5.324	19;19;28.22396 N	72;49;02.43199 E	1415
3	8.0 to 10.0	8.211	19;20;23.77464 N	72;50;20.30338 E	2110
4	10.0 to 12.0	11.055	19;20;07.17006 N	72;51;54.36071 E	2343
5	16.0 to 18.0	17.990	19;17;21.81519 N	72;54;20.10829 E	1527
6	20.0 to 22.0	21.281	19;17;18.02710 N	72;56;11.50759 E	653
7	24.0 to 26.0	24.249	19;17;53.38264 N	72;57;40.30580 E	2311
8	26.0 to 28.0	27.072	19;17;10.57673 N	72;59;04.58215 E	2043

Sr.No	KP	Bends (KP)	Lat (deg Min Sec)	Long (deg min sec)	Radius (m)
9	30.0 to 32.0	30.390	19;15;31.07635 N	72;59;44.37339 E	1447
10	32.0 to 34.0	33.834	19;13;44.35932 N	73;00;13.71381 E	747
11	36.0 to 38.0	36.111	19;12;48.87670 N	73;01;04.21790 E	5045
12	38.0 to 40.0	38.101	19;11;55.06220 N	73;01;39.30270 E	1069
13	38.0 to 40.0	42.089	19;12;19.98990 N	73;03;49.98000 E	909
14	44.0 to 46.0	44.975	19;13;51.04229 N	73;04;02.04123 E	1093
15	46.0 to 48.0	47.197	19;14;35.85934 N	73;04;59.10119 E	330
16	48.0 to 50.0	49.390	19;13;59.43023 N	73;06;02.45941 E	257
17	50.0 to 52.0	50.224	19;14;03.02344 N	73;06;30.49026 E	328
18	50.0 to 52.0	51.465	19;14;33.65820 N	73;06;57.46746 E	351

2.4 Velocity And Discharge Details

2.4.1 Data Collection

Data with regard to, three important hydraulic parameters that defines the flow in a channel was collected, namely, Tide, Current speed and direction and Discharge at selected sections. The tide gauge was installed at regular intervals to aid accurate determination of bed soundings.

2.4.1.1 Tide Data Collection

Water level measurements are carried out for non-tidal reaches of finalized streams. Scope included fixing of water level gauges at every 10-km interval along the river and at upstream and downstream of any river structures, such as Dams, barrages, etc. Water level observations is taken at 60 minutes interval for 12 hours in a day (6 AM to 6 PM) for the entire duration of survey. The gauges are connected to the nearest Bench Mark by leveling and its “zero level value” is established with respect to Mean Sea Level (MSL). At least 2 gauges (one U/s and one D/s at 10 Km apart) is read simultaneously and soundings is carried out.

Bench Mark location at Vasai fort was provided by Maharashtra Maritime Board (MMB), whose Chart Datum value is 5.618 m. The value of Bench Mark was then transferred to tide gauge locations viz. ATG1 and ATG2 simultaneously by RTK observations. Tidal observations were carried out at ATG2 throughout the survey period. Chart Datum was obtained by sounding datum transfer from ATG2 to ATG3, ATG2-ATG4 and ATG2 to ATG5 at ATG3, ATG4 and ATG5 respectively.

It was ascertained that the tidal effect reaches the extreme end of the waterway, meaning thereby the water way between Vasai and Kalyan (National Waterway 53) is completely tidal. Table 2.8 indicates the location, the geographical bearings, the chainage, period of data collection and the tidal variation at each of the stations. They are located approximately at 10 km intervals.

Table 2. 8: Details Of The Tide Gauge

Tide Gauge no	Location	Chainage (km)	Easting (m)	Northing (m)	Tidal variation (m)	Period of observation
1	Vasai	5.547	270975.00 E	2138228.00 N	5.1	21.04.2017 to 27.04.2017
2	Panju Island	14.916	277668.537 E	2136124.908 N	3.809	09.05.2017 to 18.5.2017
3	Gaimukh	21.352	283300.28 E	2133871.1 N	4.112	6.05.2017 to 25.05.2017
4	Thane Kalwa	35.396	290993.07 E	2126007.730 N	4.315	08.05.2017 to 9.05.2017
5	Satpul	46.126	297620.390 E	2128299.940 N	2.401	12.05.2017 to 29.05.2017

The tidal data of the control station at Panju Island which served as the control station for the survey and all other tidal stations were connected to it. The tidal level of the other locations is also reproduced for deciding on the depths in the channel, enabling calculation of the dredging quantity.

Figure 2. 10: Tidal data at Panju Island on Vasai Creek (ATG 2 – Control Station)

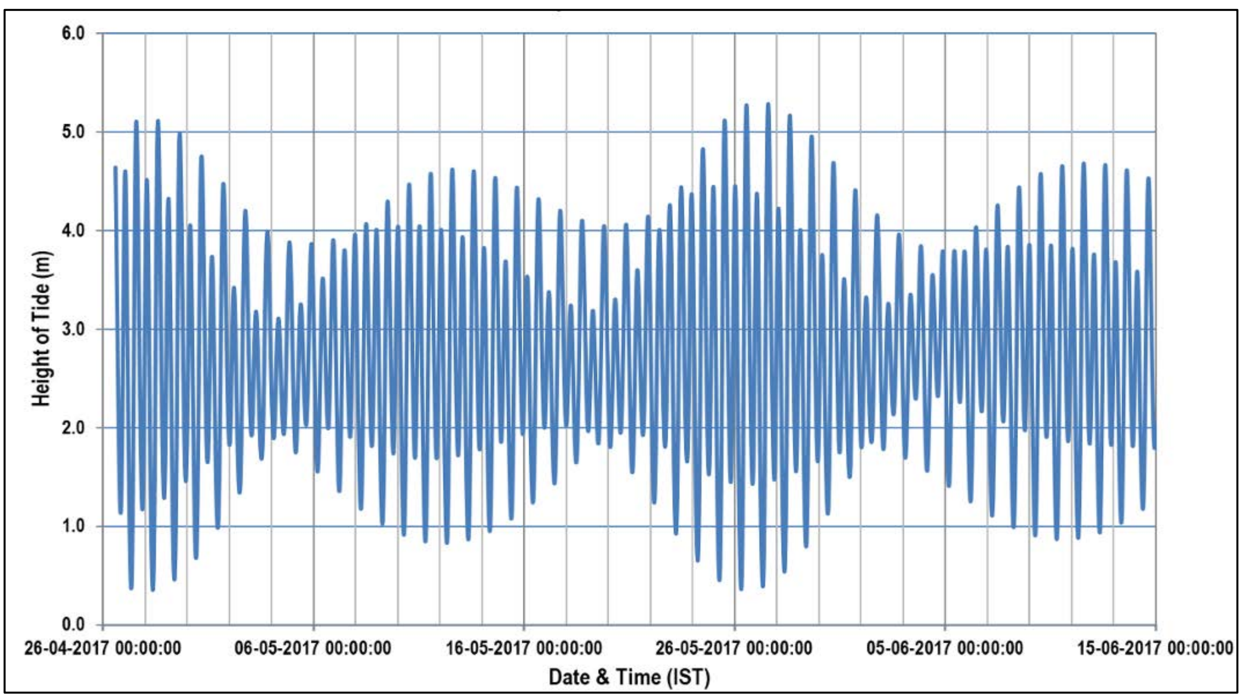


Figure 2. 11: Tidal data at Gaimukh Island on Vasai Creek (ATG 3)

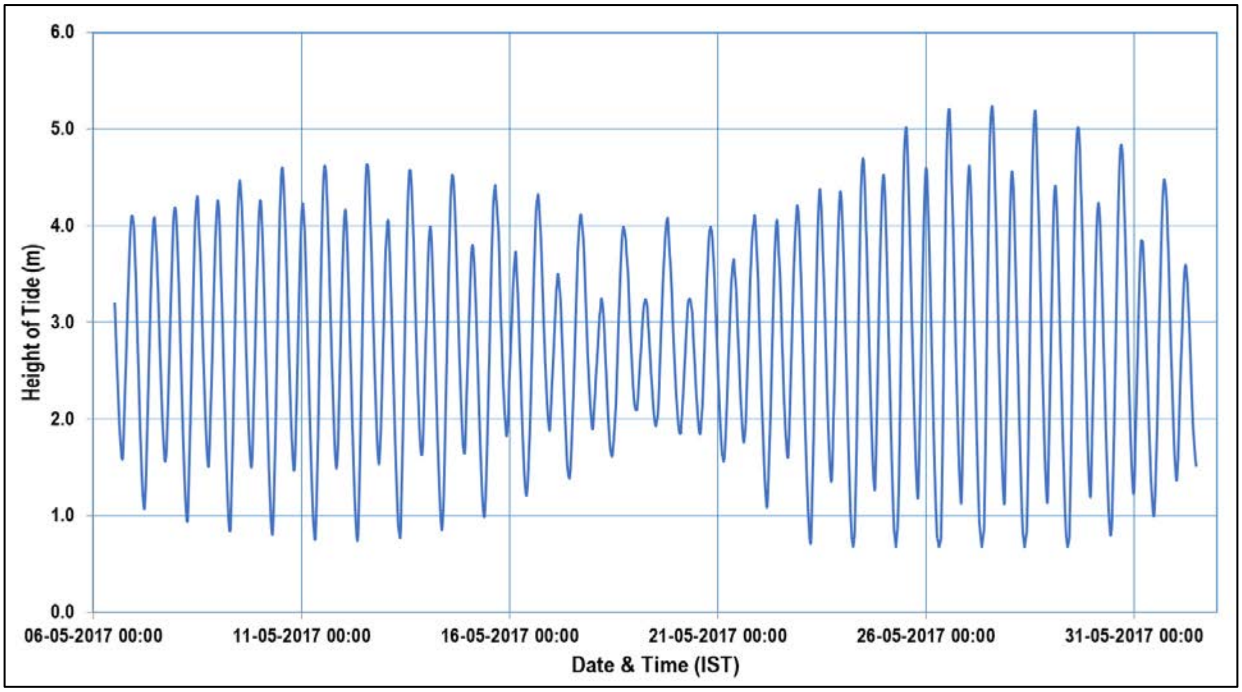


Figure 2. 12: Tidal data at Mumbra station on Vasai Creek (ATG 4)

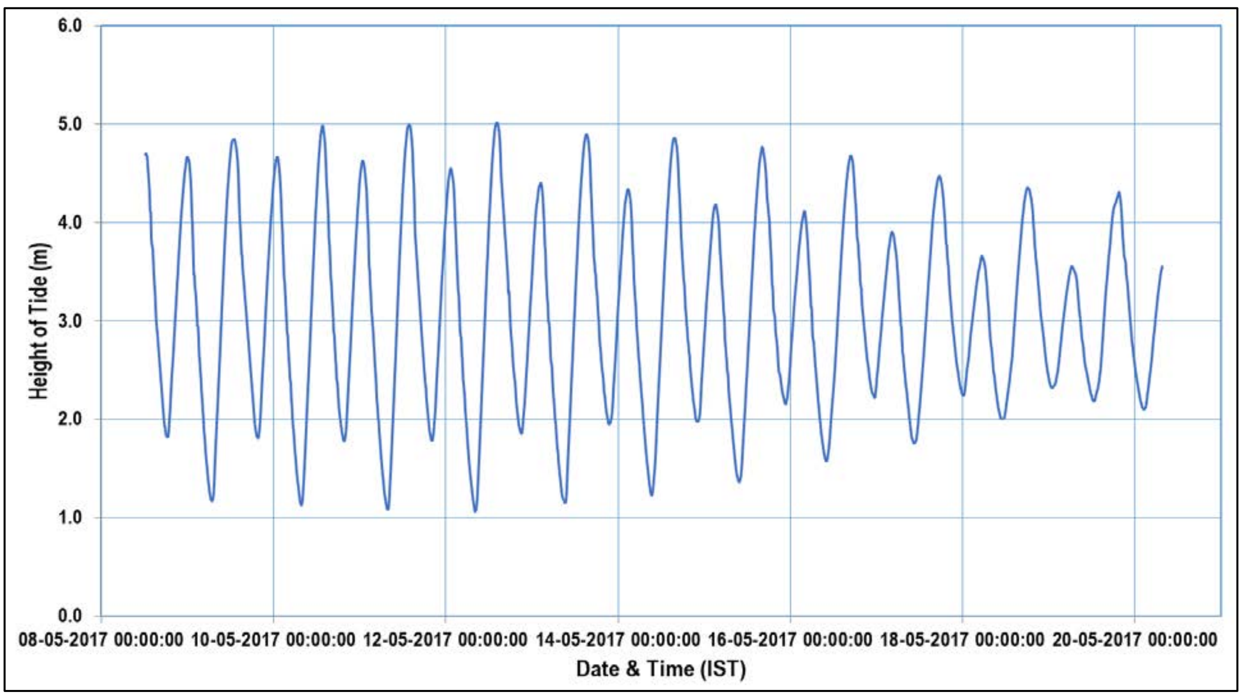
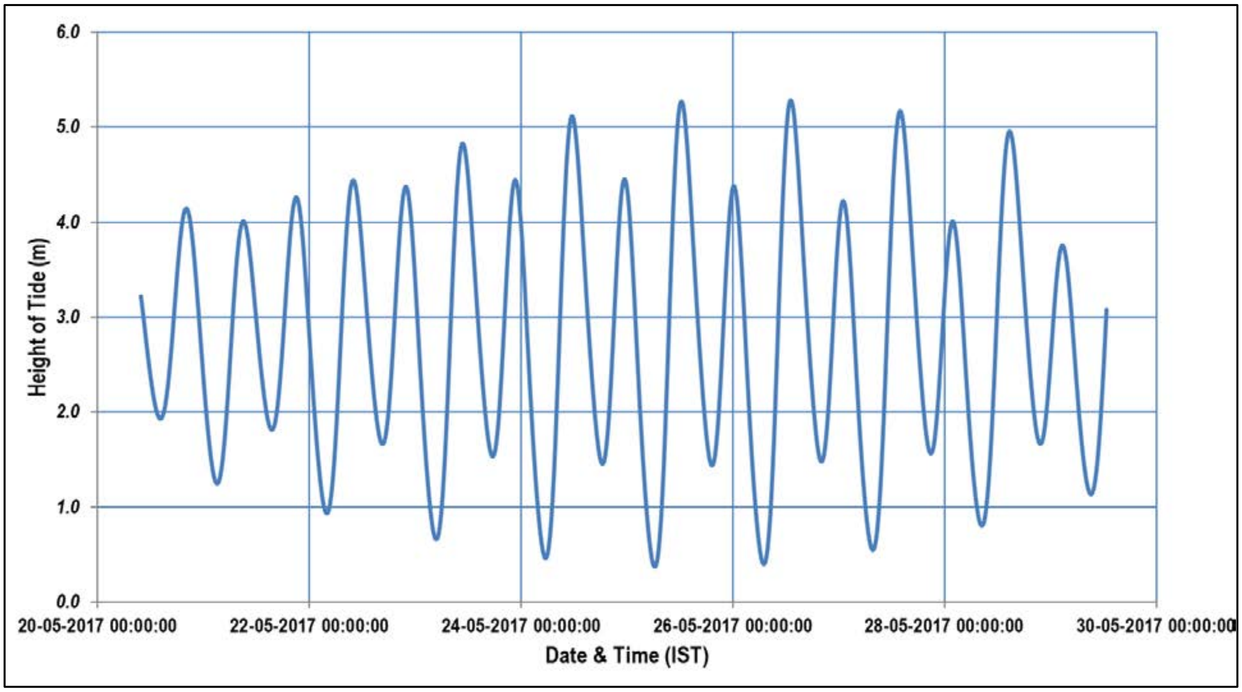


Figure 2. 13: Tidal data at Sat Pul on Vasai Creek (ATG 5)



The above data was reduced to the respective sounding datums and to correctly represent the water level variation.

2.4.1.2 Velocity Data Collection

Velocity data was collected at 5/6 locations with the station 5 and 6 being too close to each other. Table 2.9 gives the details of the Current Meters stations, including the location, water depth, depth of data collected and the consequential discharge at the section.

Table 2. 9: Current Data Collection Stations on Vasai Creek

Station No.	Chainage (km)	Geographic Location		Current Meter obs. date	Observed Depth (m) (D)	Velocity (m/sec.) 0.5 D	Average Velocity (m/sec.)	Discharge (m^3/s)
		Latitude	Longitude					
1	1.423	19°18'35.61 N	72°47'01.89 E	20170425	3.6	0.98	0.847	43807.72
2	11.325	19° 19' 34.97 N	72°52' 31.01 E	20170426	3.9	0.801	0.756	9729.48
3	20.253	19°17'25.72 N	72°56'25.38 E	20170511	13.9	0.264	0.359	3008.52
4	29.087	19°13'00.41 N	73°00'42.87 E	20170511	4.4	0.333	0.314	1660.20
5	40.225	19°14'27.47 N	73°04'24.26 E	20170512	10.6	0.454	0.363	1742.88
6	50.105	19°14'27.47 N	73°04'24.26 E	20170512	11.7	0.391	0.312	1179.80

Figure 2. 14: Current data collection Stations on Vasai Creek

The Figure 2.14 shows the location of the stations on a Google imagery map.

The collected data was analyzed and presented in Table 2.10 below.

Table 2. 10: Current Data Details Including The Discharge On Vasai Creek

Location	Period of Observation		Depth of Observation (m)	Observation Depths	Current Speed (m/s)			Direction of Maximum Current Speed (deg)	Date & Time of Occurrence (IST)	Average discharge (m3/s)
	From	To			Max	Min	Avg			
1. Vasai	26 April 2017 13:30	29 April 2017 11:30	3.6	Surface	2.026	0.003	1.092	239.1	28 April 2017; 05:30	43807.72
				Mid-Depth	1.781	0.025	0.98	232.2	28 April 2017; 05:20	
				Bottom	1.575	0.015	0.847	223.6	28 April 2017; 05:20	
2. Panju Island	27 April 2017 17:40	29 April 2017 16:40	3.9	Surface	1.51	0.039	0.755	143.2	28 April 2017; 11:50	9729.48
				Mid-Depth	1.47	0.013	0.801	141.8	28 April 2017; 11:50	
				Bottom	1.368	0.017	0.756	143.6	29 April 2017; 12:30	
3. Gaimukh	11 May 2017 14:20	15 May 2017 10:40	13.4	Surface	1.216	0.008	0.358	40.8	12 May 2017; 10:50	3008.52
				Mid-Depth	1.414	0.011	0.359	48.7	12 May 2017; 11:00	
				Bottom	1.246	0.013	0.264	43.1	12 May 2017; 11:00	
4. Kasheli	11 May 2017 16:50	15 May 2017 12:10	2.2	Surface	0.811	0.012	0.35	315.3	12 May 2017; 03:50	1660.2
				Mid-Depth	0.8	0.025	0.333	315.4	12 May 2017; 03:50	
				Bottom	0.713	0.012	0.314	307.8	13 May 2017; 04:10	
5. Satpul	12 May 2017 15:50	15 May 2017 13:40	8.5	Surface	0.781	0.012	0.465	59.4	14 May 2017; 13:30	1742.88
				Mid-Depth	0.816	0.025	0.454	59.3	13 May 2017; 13:20	
				Bottom	0.723	0.016	0.363	61.8	13 May 2017; 14:00	
6. Kalyan	12 May 2017 13:50	15 May 2017 15:30	11.2	Surface	0.715	0.022	0.456	210.8	12 May 2017; 17:00	1179.80
				Mid-Depth	0.683	0.02	0.391	201.3	13 May 2017; 04:10	
				Bottom	0.726	0.006	0.312	212.2	13 May 2017; 13:50	

It could be seen from above that the maximum speed in noted at the entrance, possibly due to the selection of the current station. Similarly, high speeds are noted on the side channel near the Panju Island. The current velocity at the Gaimukh station is coming third, which was further studied in detail in the Model study. Again, possibly due to the great depths that one encounters at these locations. For the rest of water way, the velocity and the discharge are in the predictable lines. Table 2.11

indicates the maximum current speed at the various stations at the bottom, mid depth and surface (three depths), under the flood and the ebb tides.

The flood and the ebb effects in the channel, vary with the location and the configuration of the channel.

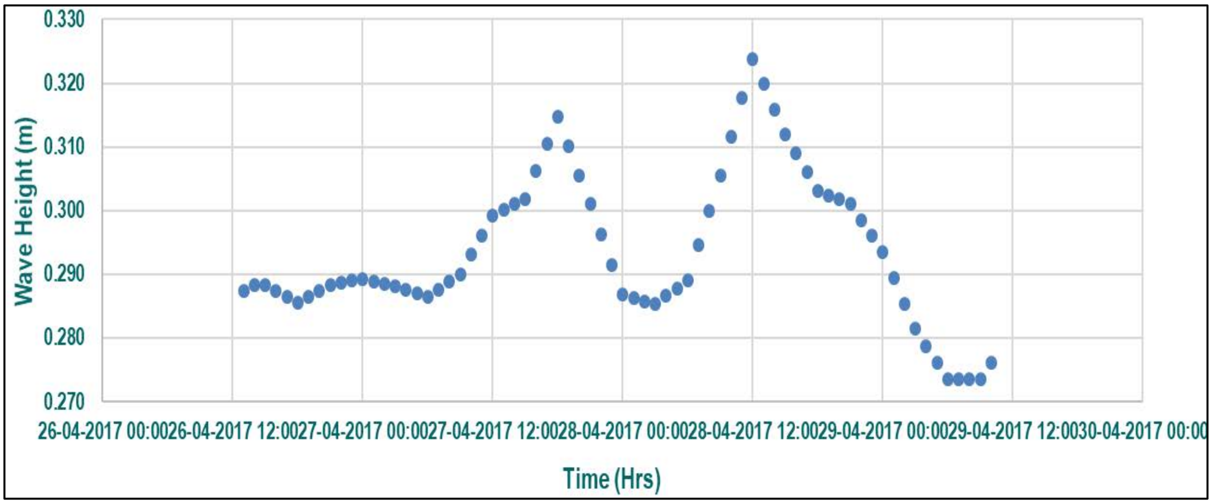
Table 2. 11: Current Data Details Under The Flood And The Ebb Tides In Vasai Creek

Location	Observation Depth	FLOOD				EBB			
		Minimum		Maximum		Minimum		Maximum	
		Speed (m/s)	Direction (degree)	Speed (m/s)	Direction (degree)	Speed (m/s)	Direction (degree)	Speed (m/s)	Direction (degree)
Vasai		NE-E (45°- 90°)				SSW-WSW (220°- 245°)			
	Bottom	0.091	74.1	1.272	59.7	0.089	223.2	1.575	223.6
	Mid-Depth	0.025	49.9	1.378	61.9	0.103	223.0	1.781	232.2
	Surface	0.003	45.0	1.451	63.6	0.029	240.8	2.026	239.1
Panju Island		SE-SSE (135°- 165°)				WNW-NNW (300°- 330°)			
	Bottom	0.067	138.7	1.368	143.6	0.017	310.2	1.010	324.3
	Mid-Depth	0.029	159.7	1.470	141.8	0.024	323.6	1.088	328.3
	Surface	0.058	146.3	1.510	143.2	0.119	305.4	1.131	329.4
Gaimukh		N-NE (0°- 45°)				S-SW (180°- 225°)			
	Bottom	0.023	28.8	1.246	43.1	0.014	219.3	0.706	214.4
	Mid-Depth	0.042	34.4	1.402	44.9	0.074	196.5	0.828	224.9
	Surface	0.017	23.6	1.216	40.8	0.008	225.0	0.802	223.0
Kasheli		E-SE (90°- 135°)				WNW-NNW (300°- 345°)			
	Bottom	0.020	90.0	0.503	127.7	0.013	308.7	0.713	307.8
	Mid-Depth	0.031	99.2	0.497	125.1	0.030	342.8	0.800	315.4
	Surface	0.012	90.0	0.472	125.9	0.013	302.5	0.811	315.3
Satpul		NE-E (45°- 90°)				SW-W (225°- 275°)			
	Bottom	0.016	76.0	0.723	61.8	0.027	267.6	0.603	233.4
	Mid-Depth	0.058	87.0	0.816	59.3	0.057	266.0	0.664	236.7
	Surface	0.015	70.3	0.781	59.4	0.075	252.1	0.740	233.9
Kalyan		N-NE (0°- 45°)				S-SW (180°- 225°)			
	Bottom	0.006	45.0	0.726	22.2	0.045	192.8	0.441	204.8
	Mid-Depth	0.035	4.9	0.683	24.3	0.021	202.8	0.683	201.3
	Surface	0.067	36.5	0.693	21.0	0.025	206.6	0.715	210.8

2.4.1.3 Wave Data Collection

Wave data measurements were carried out at the same locations where the other data, viz. Vasai, Panju Island, Gaimukh, Kasheli, Satpul, and Kalyan were also collected (refer Figure 2.13). The wave data was required to determine the navigability of the waterways and would aid in the design of the vessels for the waterway navigation. The collected data at the six stations are presented in summary form. The detailed data is plotted and presented in Figure 2.15 through 2.20

Figure 2. 15: Wave Data Collected At Vasai Station



Similar data was collected at the other stations and are presented below in the same format.

Figure 2. 16: Wave Data Collected At Panju Island Station

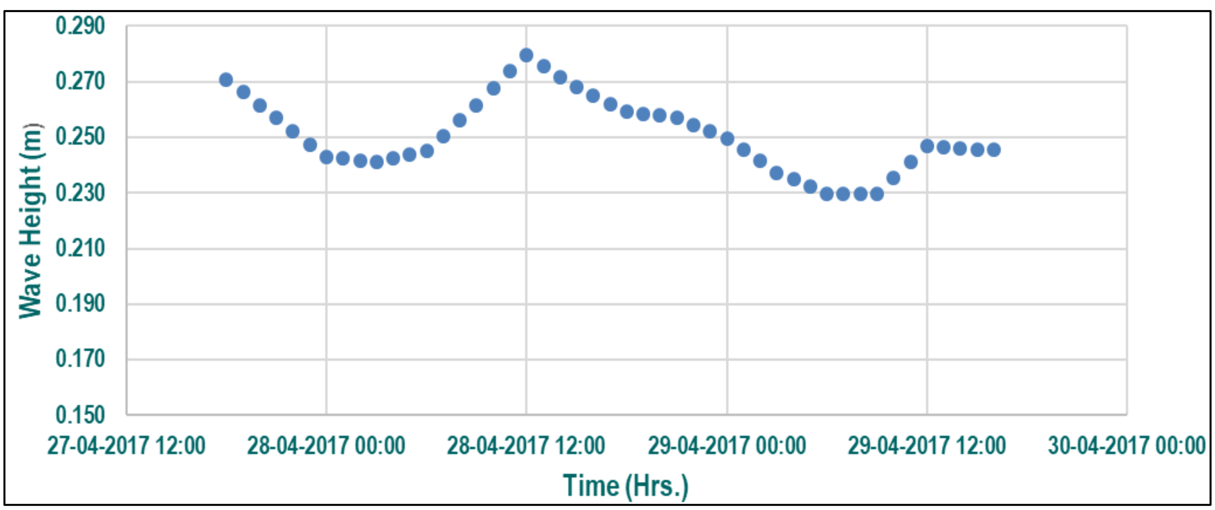


Figure 2. 17: Wave Data Collected At Gaimukh Station

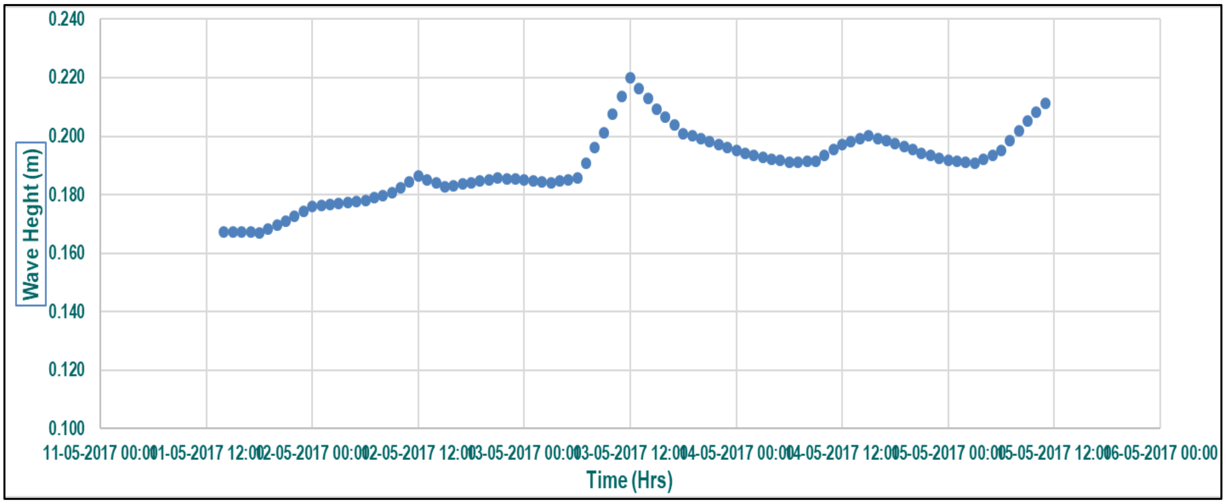


Figure 2. 18: Wave Data Collected At Kasheli Station

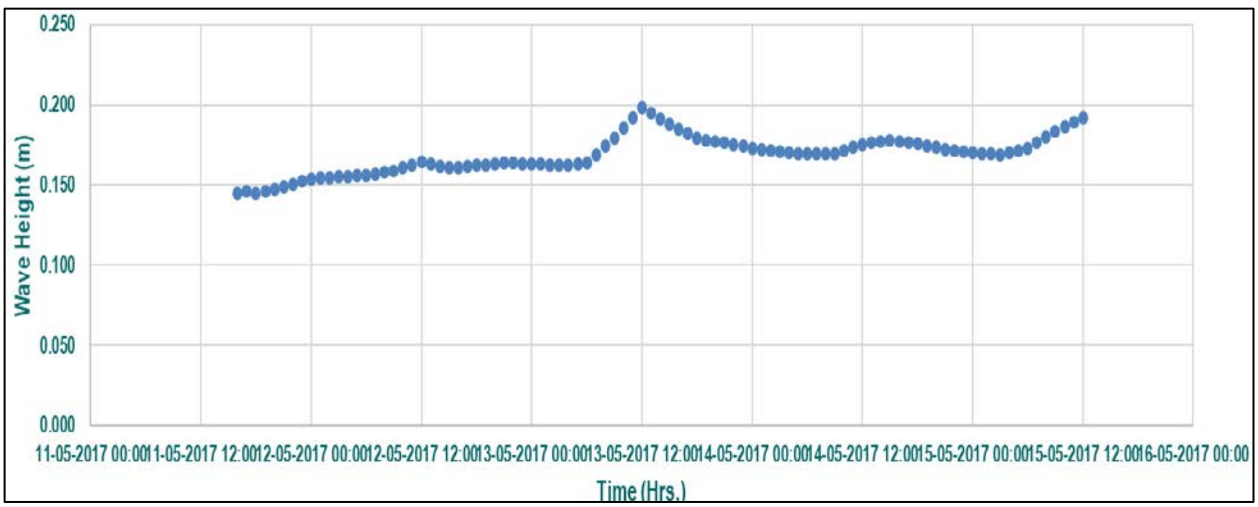


Figure 2. 19: Wave Data Collected At Satpul Station

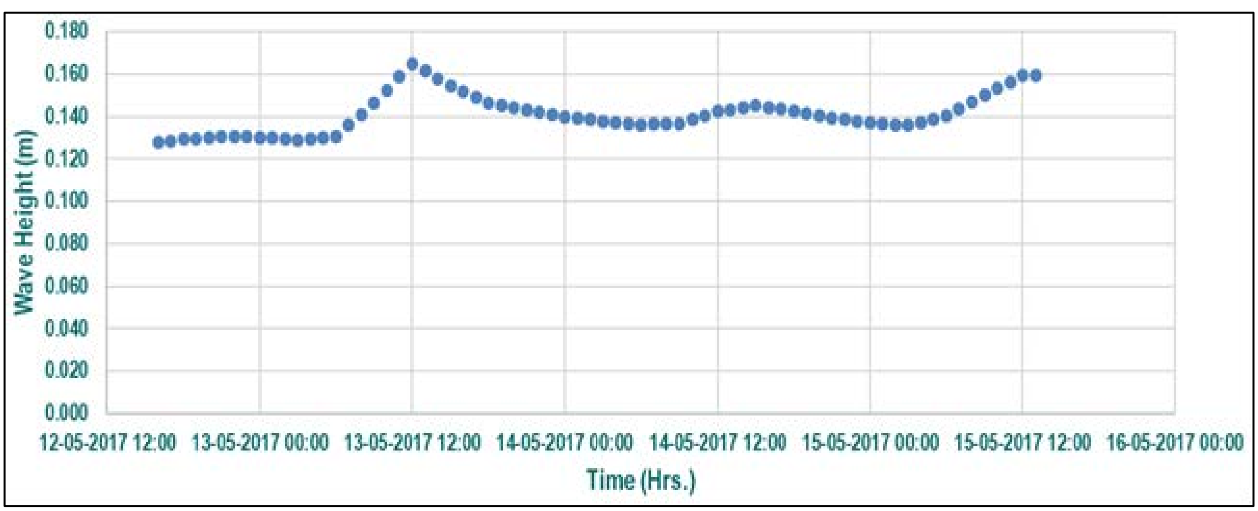
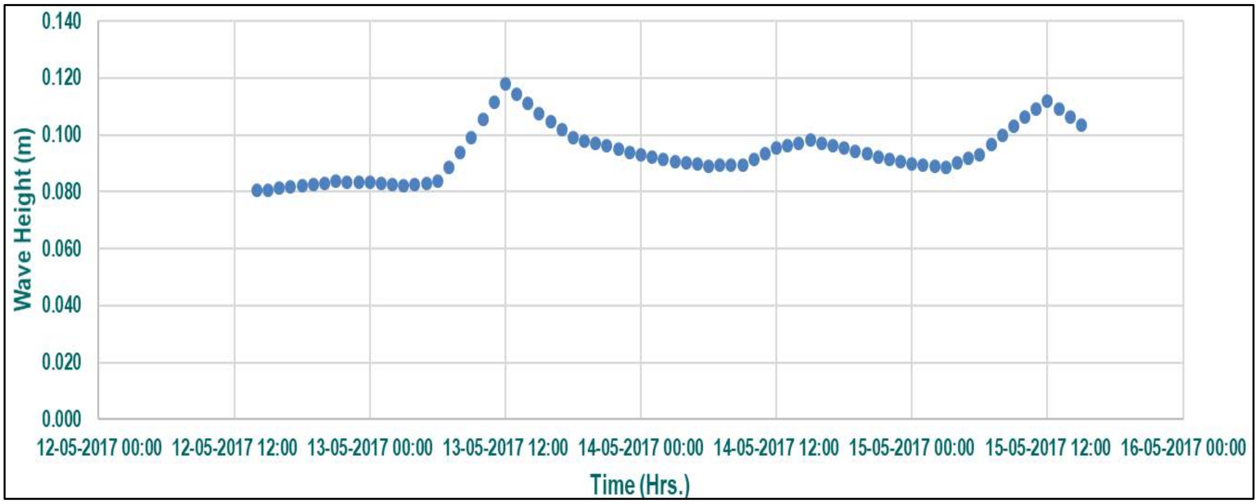


Figure 2. 20: Wave Data Collected At Kalyan Station



The maximum and minimum wave heights, Directions of the highest waves, and the average wave period for all the stations are given in Table 2.12. The data is on the predictable lines with the wave height reducing as one moves inland from Vasai to Kalyan.

Table 2. 12: Wave Details In Vasai Creek

Location	Significant Wave Height, Hs (m)			Direction corresponding to maximum Hs (deg)	Average Wave Period (s)
	Minimum	Maximum	Average		
Vasai	0.274	0.324	0.294	29.19	9.39
Panju Island	0.230	0.280	0.251	131.19	13.16
Gaimukh	0.167	0.220	0.190	28.21	16.74
Kasheli	0.145	0.198	0.169	141.71	18.97
Satpul	0.128	0.165	0.141	78.71	19.86
Kalyan	0.081	0.118	0.094	27.71	22.70

The minimum significant wave heights at the various stations starting from Vasai (Figure 2.15) to Kalyan (Figure 2.20) as one moves upstream reduces from 0.274 m to 0.081 m. Not surprisingly, the predominant wave directions also vary based on the wind directions and the available fetch.

2.5 Waterway Description (Stretch-Wise of 20 Km)

2.5.1 General

The waterway from Vasai to Kalyan, is about 52 km. The Waterway commences from the sea (Arabian Sea) and moves inland to Kalyan Bridge where the waterway ends. A preliminary discussion on the state of the waterway with the aid of Google imagery and other tools were discussed in the paragraph 2.1.1.1. In the following section, detailed discussions of the water vis-à-vis the defining parameters such as depths, water flow, shoals etc. shall be included. In addition, the state of the bank line and the study stations would also be dealt in detail.

2.5.2 Stretch – 1 (From Vasai To 20 Km Upstream)

The description of this stretch is based on the survey chart **GW-CBS-075-BA-01** and **GW-CBS-075-BA-02** submitted as a part of the Survey Report.

Entrance to the Bassein or Vasai Creek, is bifurcated by a sand bar right at the entrance, which can be seen in the image shown as Figure 2.21. Though the water depths in form of soundings were collected in both the north and the south channels, better depths were noticed in the southern channel.

Figure 2. 21: Image Showing The High Sand Bar At The Entrance Between KP 2.50 And KP 3.0 Km

Hence the channel commences approximately at about 19^0 18' 00" N and 072^0 46'40" E. In the beginning of the channel the water depth varies between 1.3 to 3.5 m with mixture of shallows and deep areas. The shallow depths of 1 to 1.5 m are intermixed with higher depths up to 3.5 to 4 m up to chainage 0.5 Kilometer Post (KP). In this section the term KP and the km would be used with the same effect and at times interchangeably. After the 0.5 km chainage the depths are higher than 3.3 m. The depths are consistent thereafter and encounters depths up to 12 m around the chainage 2.0 km. There is a ADCP station CM1, located around the 1.4 km chainage. The station CM1, was also equipped to collect data with regard to water (TSS) and bed soil samples.

Between the KP 5.00 to 5.50 lies the Koliwada Jetty on the right bank at Vasai, as could be seen from image shown in Figure 2.22. The waterway from chainage 3.00 km moves in the north-east direction and moves almost shore parallel to the right bank. This is because of the higher depths that are naturally available due to higher flow velocities in the channel leading to the north of the Panju Island. Panju Island is a 'aerofoil' shaped Island with the wider portion towards the creek entrance to the west. The Island divides the creek in to two unequal halves with the deeper and narrower portion falling to the north and wider and shallower part to the south.

Figure 2. 22: Image Showing The Koliwada Jetty (Vasai) Between KP 5.00 And KP 5.50

The Naigaon Panju Ferry terminal, an existing service as shown in Figure 2.23 lies between chainage 8.00 km to 8.50 km.

Figure 2. 23: Image Showing The Naigaon Ferry Terminal Between KP 8.00 And KP 8.50

Towards to the tailing edge of the 'aerofoil' shaped Panju Island the depths in the northern channel reduces but stays around 3.5 m or more, this continues till KP 10.50. There are no shoals or sand bards along this stretch of the Channel.

Three bridges, one old and abandoned and other two relatively new cross the creek almost dividing the Panju Island in to half as shown in Figure 2.24.

Figure 2. 24: Location Of The Old And The New Railway Bridge

The old bridge has a low 'head room' of 3.43 m and the new bridges are with an air draught of 4.43 m. For the success of the waterway, the old bridge must be dismantled, and then the limitation of 4.43 m must be factored in the vessel design at least in the initial stage.

These bridges occurring between KP 8.5 to 9.00, with the old railway bridge occurring to the western extreme. These likely impediments (bridges) for the channel navigation, needs to be catered to in the design for the success of the waterway, especially since the waterway would function as a passenger services facility to start with.

On the left bank between chainage 9.00 KP and 9.50 KP lies the Bhayander East Jetty flanked by a garden with amenities of enjoyment. The Mira-Bhayander Municipal area lies on the left bank of the creek.

Figure 2. 25: Glimpses Of The Old And The New Railway Bridge

Upstream of the Railway Bridges between KP 9.00 to 9.50 on the left bank lies the Bhayander Flower garden and the Bhayander Jetty in that order as Shown in Figure 2.26.

Figure 2. 26: Location Of The Flower Garden And Jetty On The Left Bank At Bhayander

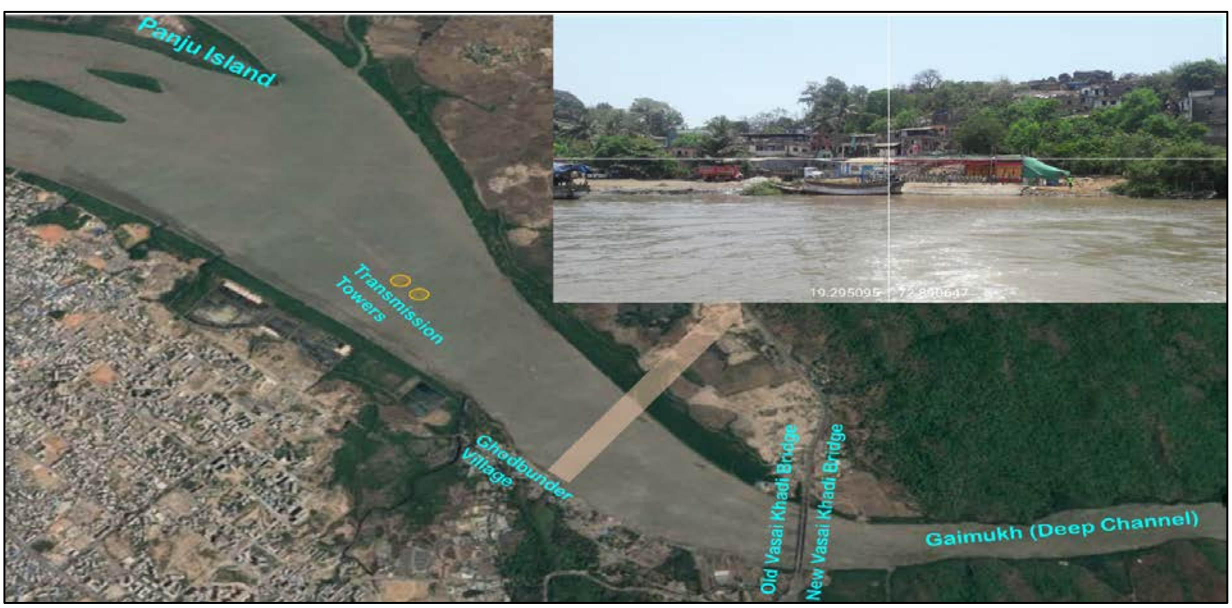
Beyond KP 10.00 or just around it, the channel gets shallower and depths of 3.2 m or less are found. On the southern bank of the Panju Island to the eastern tip (275858.742 N, 2137995.935 E), there is a small area found to be eroded. There is no plausible explanation to this local erosion since the overall shoreline is found to be stable.

The depths in the channel hovers around 3 to 4 m up to chainage 12.50 km. Beyond this chainage the depths further reduced to around 2.3 or so. The depths in the channel remain around 2 to 3 m up to chainage 14.5 km, beyond which the depths increase rapidly. Between KP 14.50 and 15.00 there are two transmission towers as shown in Figure 2.27.

The Ghodbunder village on the left bank of the creek, lies at Chainage 16.50 km. There are no developed Jetties but landing points for small crafts. The depths in the channel is more than 5.00 m probably due to the flow contraction between the ravines. At about 16.50 km chainage the depths in the channel increases beyond 10.0 m and around the old and new Vasai Khadi bridge, occurring at 17.90 Km chainage, the depths of 13.00 m and beyond can be seen. These bridges one old and one new are both provided with 6 trestles with a horizontal clearance of 100 m. The bridge offers vertical clearance of 8.83 m above the MHWS/MFL.

Figure 2.27, shows the portion of the channel, between the transmission tower, and the Gaimukh area beyond the Vasai Khadi Bridge at chainage 17.90 km.

Figure 2. 27: Location Of The Transmission Towers And Ghodbunder Village



The Creek front near the Ghodbunder village is busy with beaching of the small craft vessels. Looking upstream one can see the Vasai Khadi Bridge, both the old and the new. The bridge has adequate air draft and horizontal clearance for navigation. At about Chainage 19.00 km the hill area starts and the flow gets confined to a narrow channel. The current speed as well as the depth in the channel grows. Beyond the Vasai Khadi bridge, at about KP 18.00, the depths in the channels increases beyond 20 m. This area has steep banks and is serene with Nagla Forest on its right bank and the Sanjay Gandhi National Park on the left bank.

Figure 2. 28: Location Of The Transmission Towers And Ghodbunder Village

2.5.3 Stretch – 2 (From Chainage 20 Km (Gaimukh) To 40 Km Upstream)

This stretch begins from the Gaimukh area on the straights before the creek takes a turn to the south-east direction before finally turning towards north-east. The deep channel is mostly confined to the middle portion, with shallows along the bank. Between Chainage 21.000 km and 21.500 km the channel turns to the north-east as shown in Figure 2.28.

Figure 2. 29: Gaimukh Area On The Waterway

On the left bank along the bank, reclamations could be seen, for maritime and protection of the bank. Sheet pile protections are given for protecting the Ghodbunder road along the left bank (figure 2.29). Beyond the KP 21.500 the flow turns north-east and also expands, as the hilly area is now finished and flow plane increase, the velocity drops, the channel becomes shallower. The depth in the channel up to the chainage 23.000 km varies between 6.00 m to 9.00 m.

Figure 2. 30: Jetty At Gaimukh For Waterway Transport

There is construction on the banks in the Gaimukh area for starting a new waterway transport system in the area by Maharashtra Maritime Board (Figure 2.30).

Figure 2. 31: Areas Around The Proposed Nagla Bunder

Between KP 22.000 and KP 23.000, on the left bank residential properties are mushrooming. There is a complex by M/s Lodha Builders which can be seen in the Figure 2.31 above. The deeper channel is moving towards the left bank.

Between KP 23.000 and 24.000 on the left bank along the mangrove habitat is an area of erosion. This area is about 500m long and the erosion is mild. This may be result of deposited silt getting carried away under high current conditions. Also, can be seen from the Figure 2.32, between KP 25.500 and 26.000, there lies a ramp to the creek and beside it stands the Bangala Pada Temple. The depths in the channel is much above the desirous depths up to chainage 28.500 km. and beyond. As the channel move towards Kalyan, the mangrove habitat is on the right bank. At about KP 28.000 the Kamori River joins the Ulhas river system.

Figure 2. 32: Areas Of Erosion And Baglapada Mandir

The channel at about KP 29.500 near Dive on the right bank gets divided in to two parts. The deeper and wider southern channel is used for the design of the present waterway. The channel up to chainage 32.500 km has a depth in excess of 7.00 m.

Figure 2. 33: Areas Around Dive And Kolshet

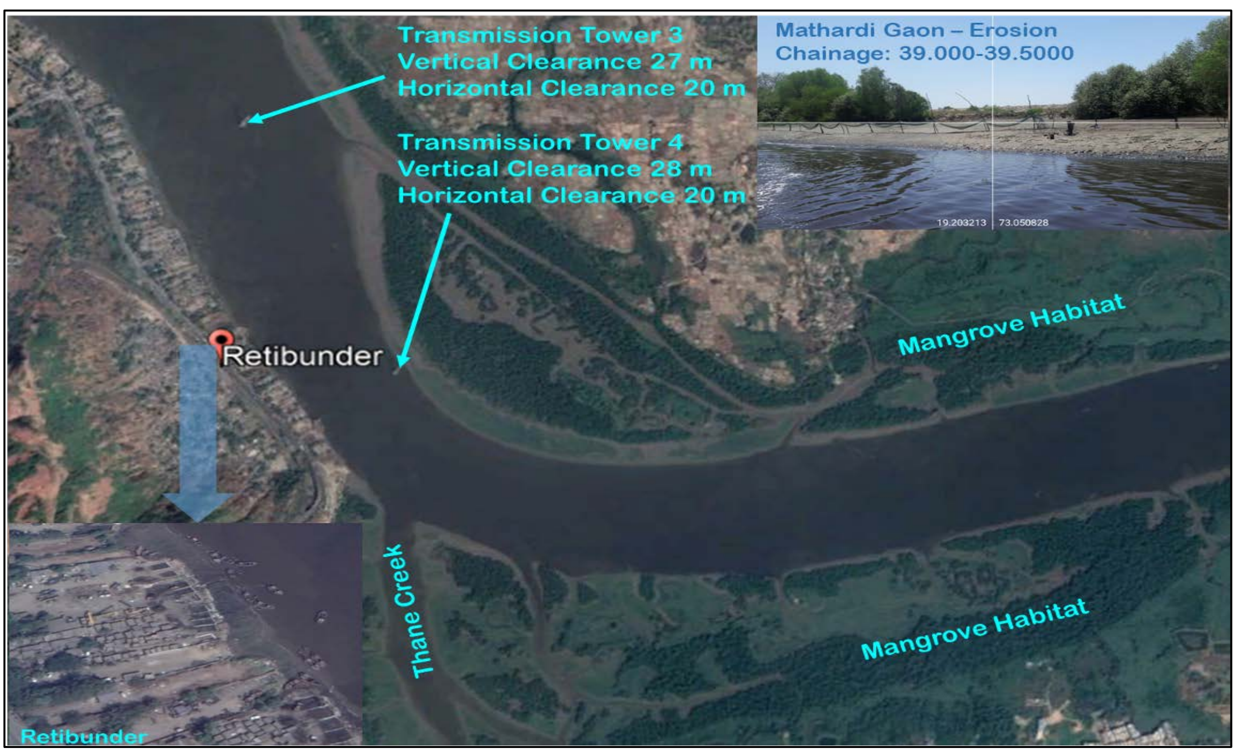
There are no shoals or sand bars in the channel up to KP 35.000. Between KP 33.500 and 34.000, two bridges known as Kasheli Bridge I and Kasheli Bridge II, carrying the old Agra Road/Bhiwandi Road/National Highway no. 35 cross the creek as can be seen from the Figure below. The bridges have 9 trestles with a 40 m horizontal distance between them offering a vertical clearance of 14.27 m. Sandwiched between them is a water pipe line bridge with 9 trestles, 40 m horizontal clearance and a vertical clearance of 11.27 m. Immediate upstream of the bridge on the right bank there is an area of coast erosion as indicated in the Figure 2.34.

There are mangrove habitats along the both banks. Beyond the 35.000 KP the channel shallows up and depth reduces to 2.5 to 3.00 m. Between the KP 35.000 and 35.000 Thane Road Bridge to Nasik crosses the river. The bridge has 9 trestles of 52 m span with a vertical clearance of 11.32 m. About 300 m upstream the Mumbra-Retibunder water pipeline bridge with 12 trestles, 52 m span and 12.82 m vertical clearance crosses the river. Depths in the channel improves a bit and hovers around 4 to 5 m. There is a transmission tower no. 3 located at around chainage 36.65 KP, near Retibunder. Thane Creek Joins the Vasai Creek between KP 34.500 and 35.000.

Figure 2. 34: Areas Around Dive And Kolshet

Transmission tower 4 is located at about chainage 37.600 km. Between the KP 37.000 and 40.000 the channel has adequate depths. Retibunder is on the left bank of the Creek/River (Figure 2.35).

Figure 2. 35: Areas Around Retibunder



2.5.4 Stretch – 3 (From Chainage 40 Km To 52.20 Km Upstream)

The channel in this last stretch is deep and no dredging would be required for the continued navigation. The channel passes through the Mangrove habitat area on either bank. Diva Junction on the left bank. Locating a terminal may be difficult for lack of land. The bank is swampy and crisscrossed with small creek lets as could be seen from the Figure 2.36 below.

The River takes turn towards the north at about KP 42.000, before it become almost south-north up to 44.5000 km chainage. There is an area of erosion near the Mhatardi Gaon, between chainage 40.500 and 41.000 km. The area is highly polluted area with Dombivli on the left. Diva junction lies west. Dombivli is also a busy area.

Figure 2. 36: Diva Junction

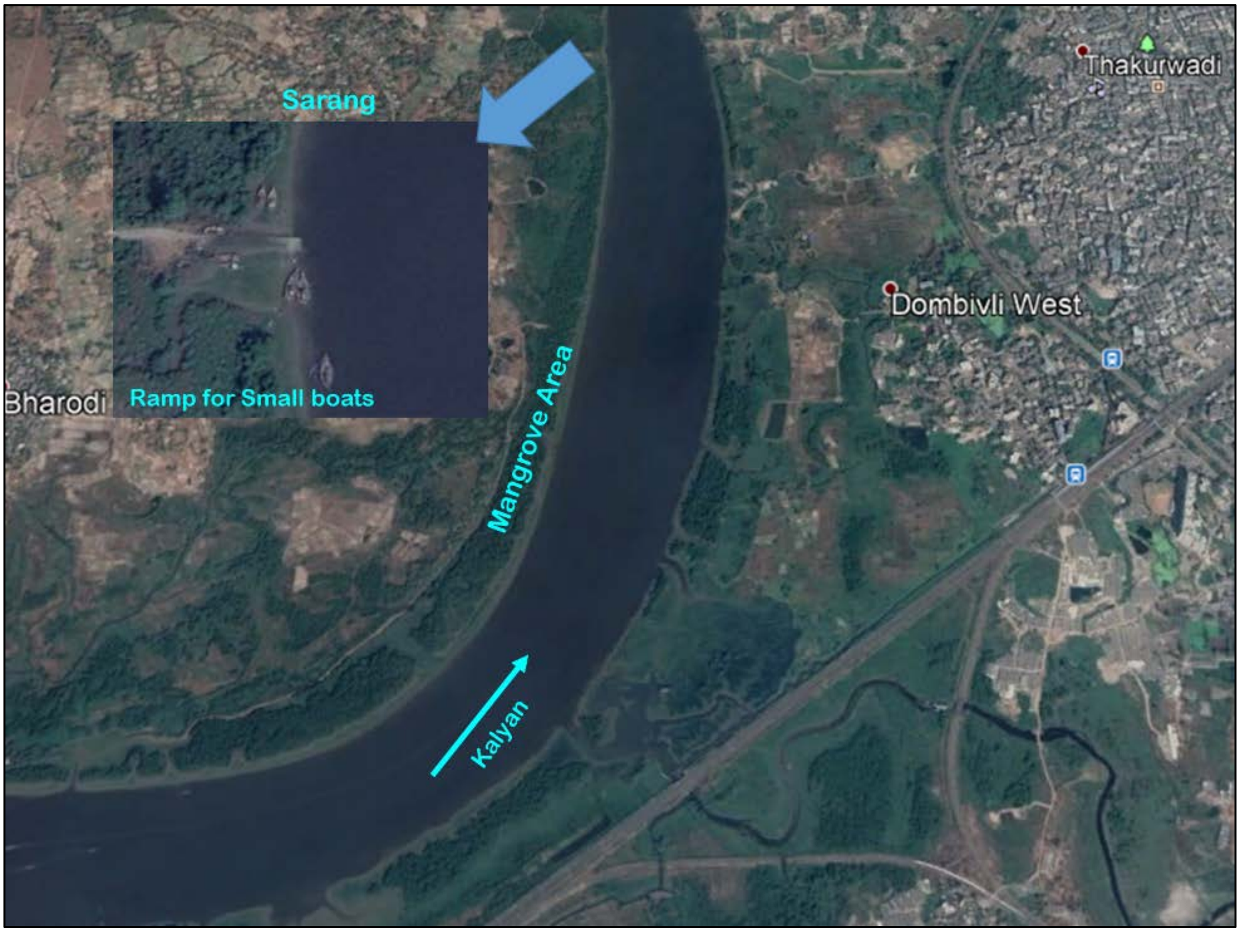
As the channel takes a turn to the left and travels almost true north to chainage 44.500 km, depths in the channel remain good and varies between 8 m and 13 m.

Sarang a small habitat lies on the right bank. Mangrove could be seen on either bank of the river. Bharodi lies to the south of Sarang and between these two places lies Sri Ram Nagar.

Number of creek-lets adorns the banks. There is a ramp on the right bank between 44.000 km and 44.500 km as could be seen from the Figure 2.37.

The radius of the bend in the creek could be the design parameter for the length of the vessel to be adopted. There are vacant flat lands which could be used for industrialization and other purposes.

Figure 2. 37: Dombivli Area



The creek/River takes a turn after chainage 44.500 km to the north-east and the turns to south-east. From Chainage 44.500 km to 46.000 km the channel depths are good and no dredging would be required. There is a Jetty at Sarang and a zone of erosion around 44.600 km as shown in Figure 2.37.

Figure 2. 38: Mathagaon And Sat Pul Bridge

On the left bank the water front is busy and boat landings are present along the bank line. A sloping ramp can also be found upstream of Sarang. Depths up to the Satpul Bridge and beyond is very good up to chainage 47.000 km.

From the beginning of the south-eastern turn, the depths decrease to almost 0 m depth, intermixed with the other depths up to 3.0 m.

Beyond chainage 48.000 km, the channel shallows down further with exposed shoals as seen in Figure 2.39 below. This may create impediments to navigation and needs to be dredged out.

The channel creation would be required for these last 5 km if Kalyan is to be taken in to the ambit of the waterway, which is a must. Lot of water front activity is in progress near Kalyan and there is a ramp, one jetty and several landing points down stream of the Kalyan-Bhiwandi bridge. There are two bridges one old and one new. The old bridge has 9 trestles with 30 m horizontal and 9.47 m vertical clearance. The new bridge has only 3 spans each 60 m with a vertical clearance of 10.47 m. Both the bridges are adept for navigation. The waterway ends at the Kalyan Bridge.

Figure 2. 39: Kalyan Bridge And Environs

2.6 Water Soil Samples Analysis And Results

2.6.1 Sample Collection And Anaysis Methodology

Water and Soil samples were collected at the data collection stations indicated in Figure 2.40. The collected data is analyzed and presented in the following section.

The data with respective to water and soil was collected, using water collection Jars. The water sample was collected at 3 levels namely, Surface, Mid Depth and the Bottom. The analysis of the samples was carried out using laser diffraction techniques as described in AWWA Standard No. 2560D and ISO-13320-1. Instrumentation calibrated using NIST traceable standard particles.

The soil samples were collected using Grab samplers and the collected samples were subjected to Grain Size Analysis. The constitution of the sample with regard to the soil particle size is plotted on logarithm paper and presented for computing the various soil parameters to be used in the siltation studies.

Figure 2. 40: Data Collection Stations For Soil And Water

2.6.2 Water Sample Analysis

The results of the water sample analysis in the 6 stations are presented in this section.

2.6.2.1 Water Sample 1 – Vasai Station

A. Surface Water

The water analysis statistics is presented in table below.

Table 2. 13: Surface Water Analysis Statistics – Vasai Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	11:13:41	(HH:MM:SS)
Total Concentration	255.60	μ l/l
Mean Size	224.78	microns
Standard Deviation	145.41	microns
Optical Transmission	0.95	
D10	15.80	microns
D16	324.02	microns
D50	345.90	microns
D60	352.61	microns
D84	369.25	microns
D90	373.53	microns
D60/D10	22.32	
Surface Area	59.14	cm^2/l
Silt Density	0.14	
Silt Volume	34.41	μ l/l
Particle Model	Random	

It could be seen from the total concentration of the total suspended solids is 255.60 µl/liter which is rather low and the water is generally non turbid. The Figure 2.41 shows the diameter of the sediment that makes up the volume of the Total Suspended Solid (TSS). Clearly about 86% of the sediments has a median diameter of 0.302 mm.

Figure 2. 41: Volumetric Concentration Of TSS In The Surface Water – Vasai Station

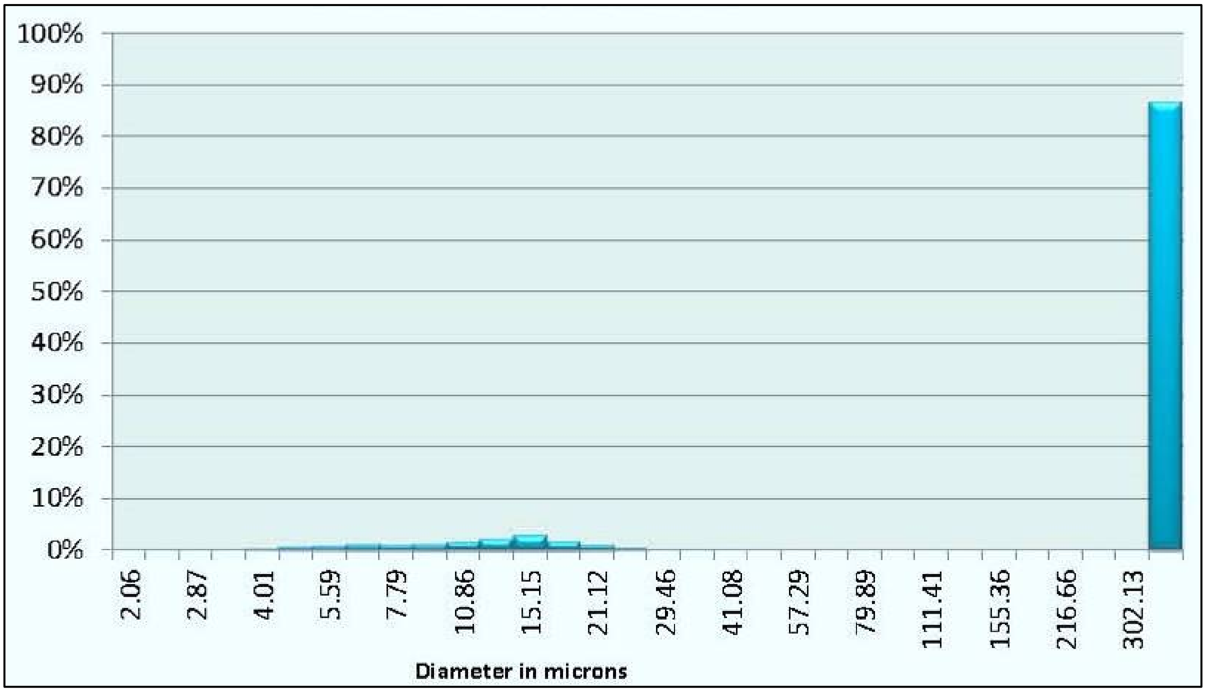
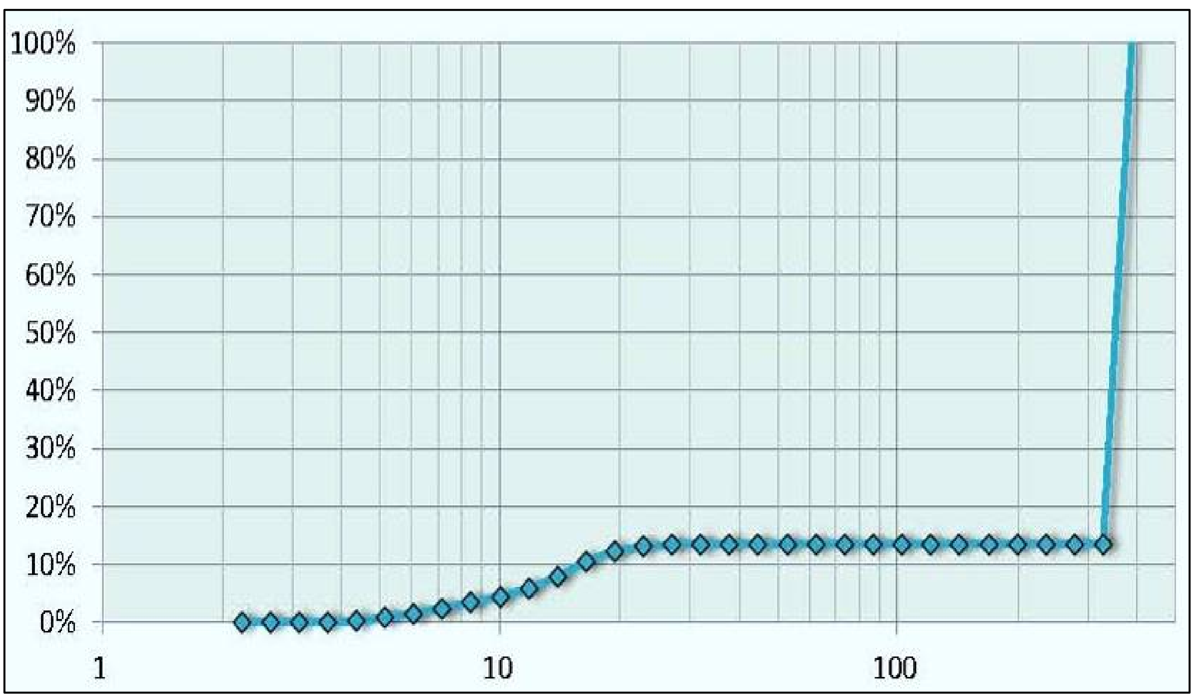


Figure 2. 42: Cumulative Volume Concentration Of TSS In The Surface Water – Vasai Station



B. Mid Depth

Corresponding parameters for the water at the mid depths are;

Table 2. 14: MId Depth Water Anaylsis Statistics – Vasai Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	11:16:27	(HH:MM:SS)
Total Concentration	333.67	μ l/l
Mean Size	222.92	microns
Standard Deviation	142.71	microns
Optical Transmission	0.88	
D10	20.18	microns
D16	281.30	microns
D50	341.85	microns
D60	349.31	microns
D84	367.86	microns
D90	372.66	microns
D60/D10	17.31	
Surface Area	70.92	cm^2/l
Silt Density	0.14	
Silt Volume	47.00	μ l/l
Particle Model	Random	

Figure 2. 43: Volumetric Concentration Of TSS In The Water In The Mid Depth – Vasai Station

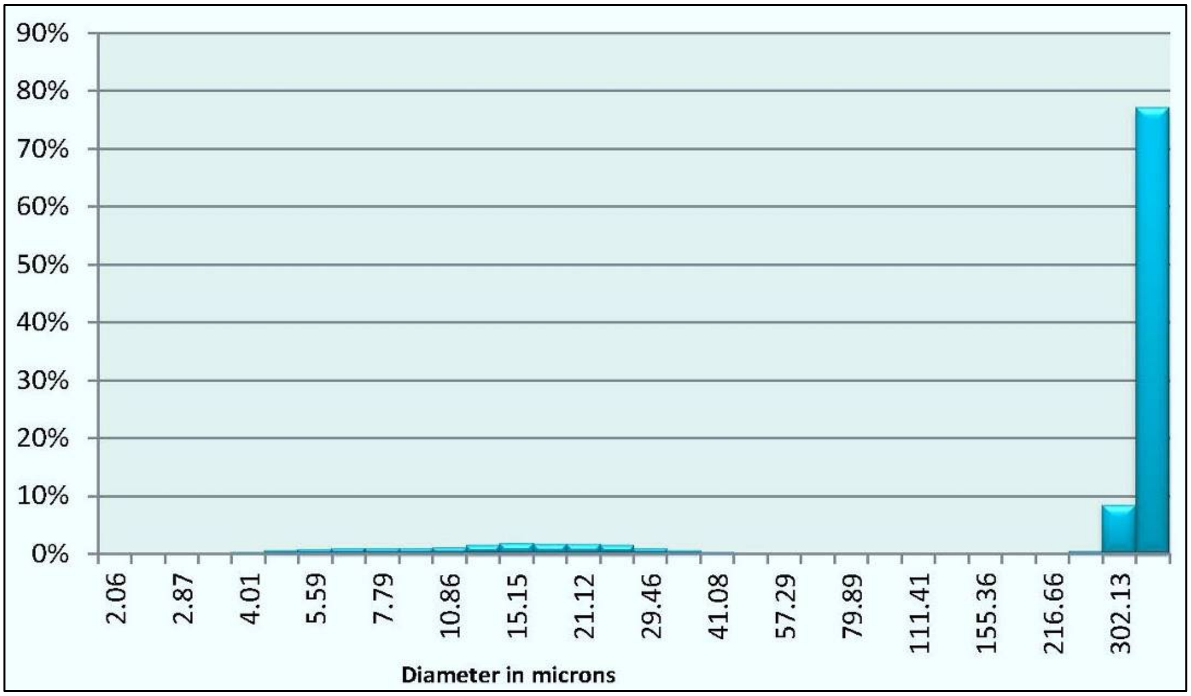
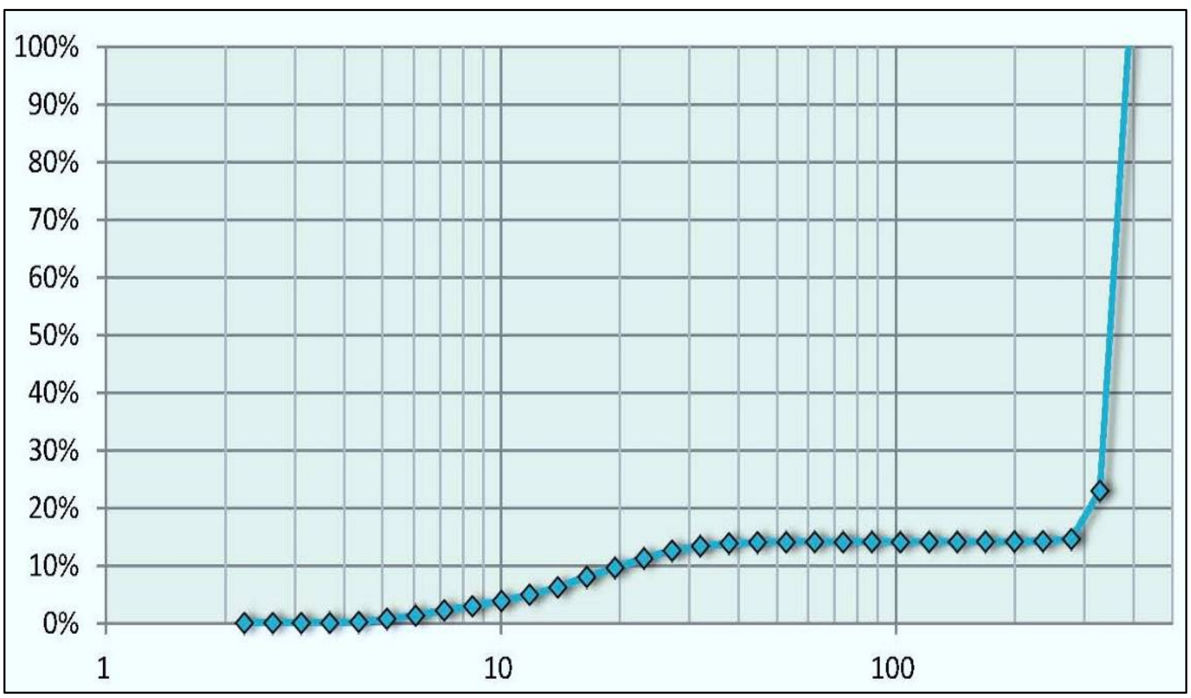


Figure 2. 44: Cumulative Volume Concentration Of TSS In The Mide Depth Water – Vasai Station



The above description indicates that the water in the mid depth is also equally clear and the TSS is rather low with a similar median diameter.

C. Bottom

The TSS concentration at the bottom of the water column at the Vasai data collection station is;

Table 2. 15: Water Bottom Analysis Statistics – Vasai Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	11:42:57	(HH:MM:SS)
Total Concentration	779.43	μ l/l
Mean Size	21.36	microns
Standard Deviation	120.29	microns
Optical Transmission	0.36	
D10	5.15	microns
D16	6.28	microns
D50	16.62	microns
D60	21.08	microns
D84	61.47	microns
D90	329.14	microns
D60/D10	4.09	
Surface Area	991.42	cm^2/l
Silt Density	0.85	
Silt Volume	662.13	μ l/l
Particle Model	Random	

Figure 2. 45: Volumetric Concentration Of TSS In The Water In The Bottom – Vasai Station

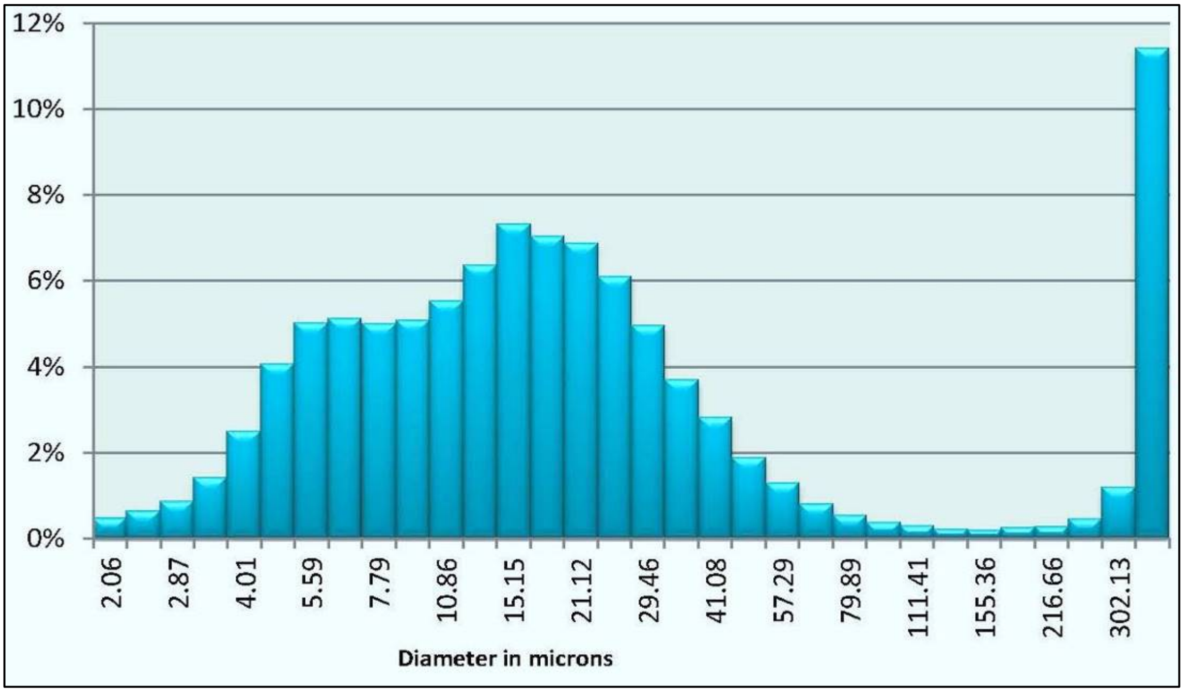
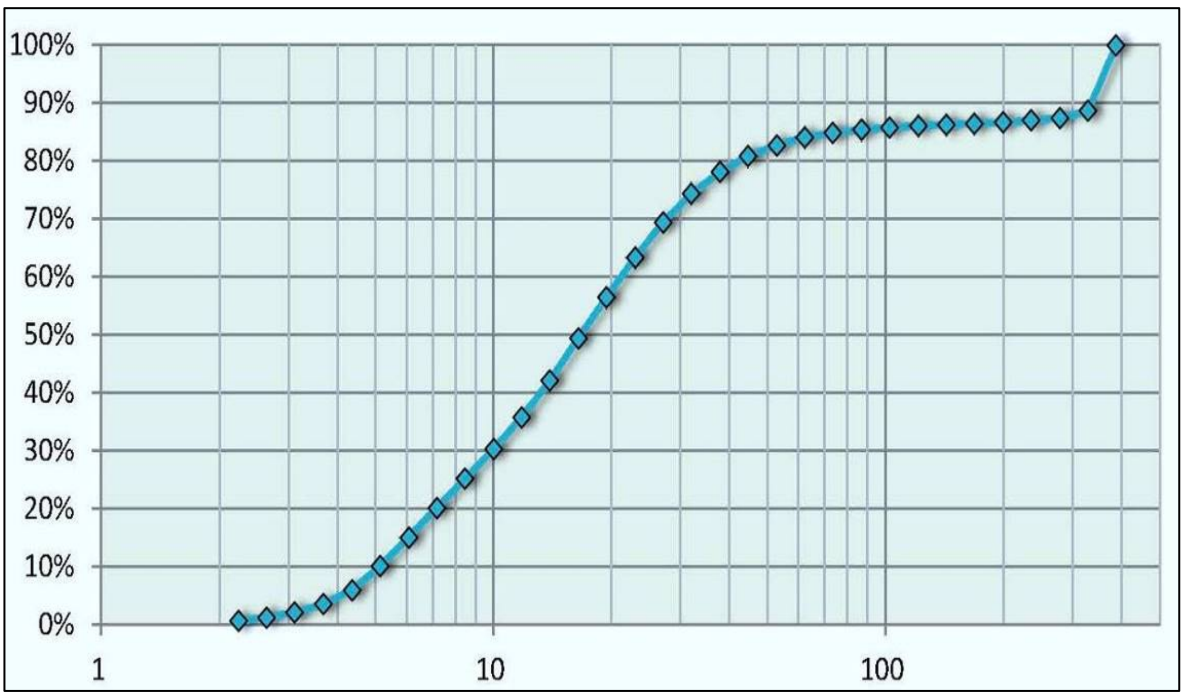


Figure 2. 46: Cumulative Volume Concentration Of TSS In The Bottom – Vasai Station



2.6.2.2 Water Sample 2 – Panju Island Station

Data collected at the Panju Island station was also analyzed and the findings are given below;

A. Surface Water

The main finding of the TSS samples obtained from the surface water sample are,

Table 2. 16: Surface Water Analysis Statistics – Panju Island Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	11:39:26	(HH:MM:SS)
Total Concentration	837.22	μ l/l
Mean Size	18.90	microns
Standard Deviation	99.10	microns
Optical Transmission	0.33	
D10	5.10	microns
D16	6.23	microns
D50	15.88	microns
D60	19.79	microns
D84	43.61	microns
D90	136.77	microns
D60/D10	3.88	
Surface Area	1109.80	cm^2/l
Silt Density	0.89	
Silt Volume	741.71	μ l/l
Particle Model	Random	

The corresponding Volumetric and the cumulative volumetric Plots are given as 2.47 and 2.48. It can be seen in the volumetric as well as in the cumulative volumetric concentration plots, that the TSS composition is more homogenous with all soil fractions present with greater uniformity. This indicates higher turbidity due to higher speed or turbulence driven by other external forces.

In the mid depth samples for the station, higher diameter soils are in suspension emphasizing the turbulence driven by higher current, which was also obtained from the site data.
At the bottom, predictably the finer soils are in suspension as indicated in the plot.

Figure 2. 47: Volumetric Concentration Of TSS In The Water In The Surface Water – Panju Island Station

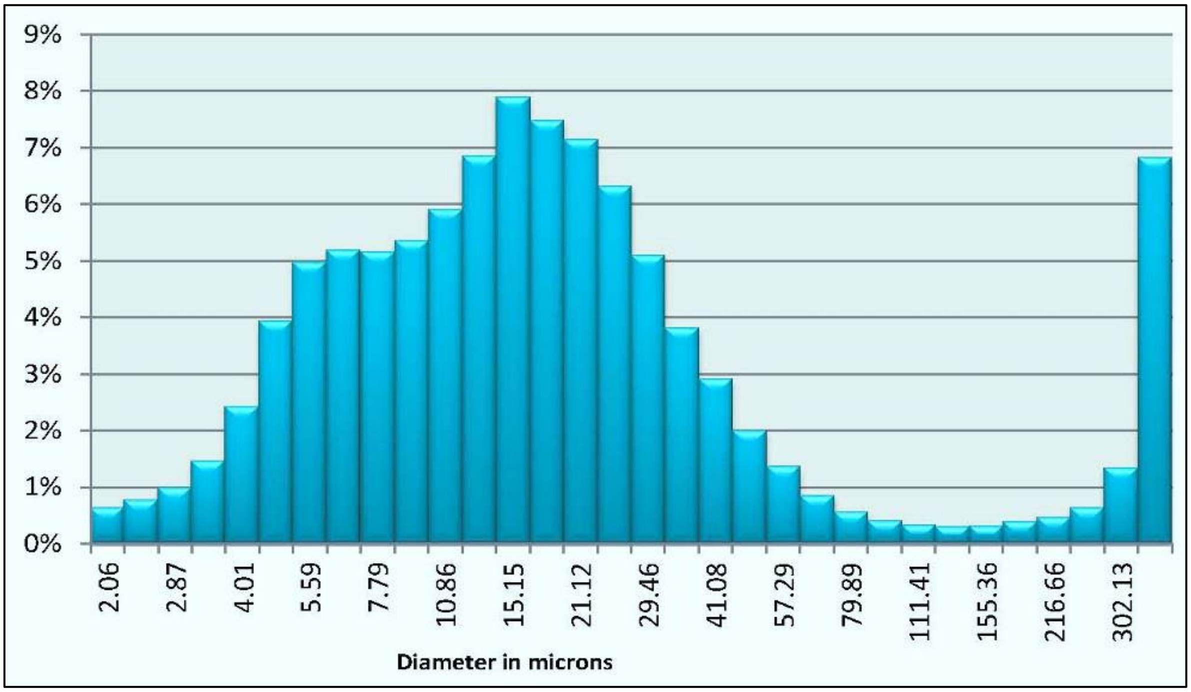
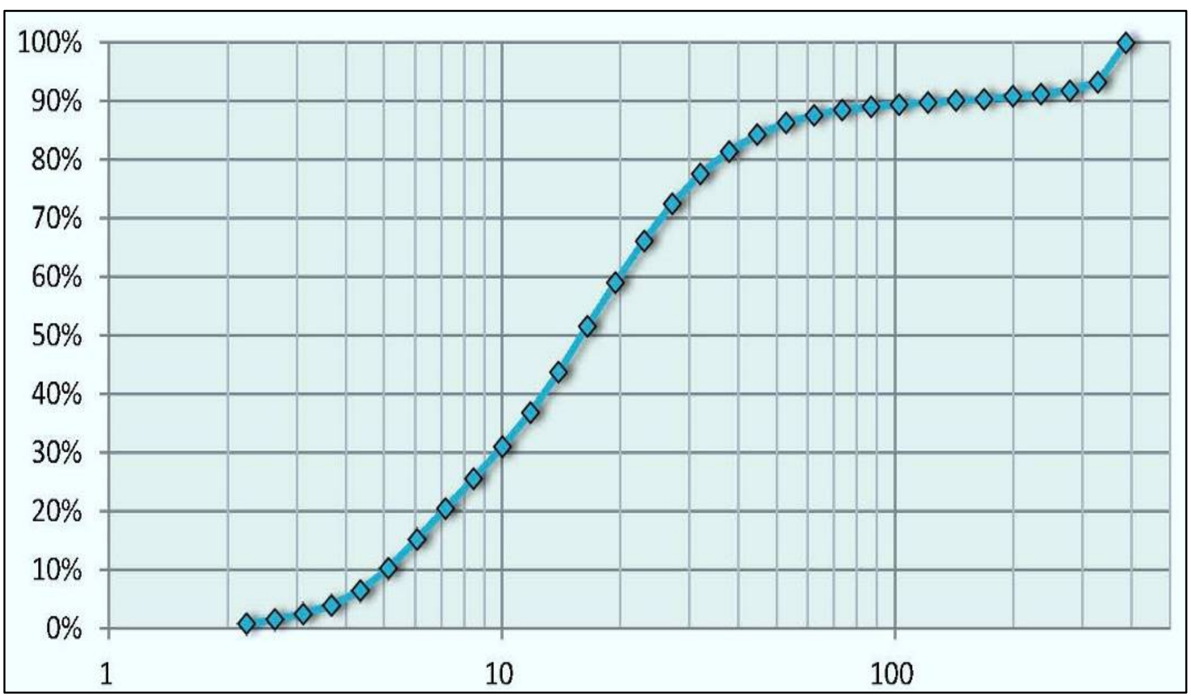


Figure 2. 48: Cumulative Volume Concentration Of TSS In The Surface Water – Panju Island Station



B. Mid Depth

In the mid depth samples were analyzed and given in the following section;

Table 2. 17: Mid Depth Water Analysis Statistics – Panju Island Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	11:52:06	(HH:MM:SS)
Total Concentration	1395.99	μ l/l
Mean Size	78.45	microns
Standard Deviation	120.61	microns
Optical Transmission	0.23	
D10	21.99	microns
D16	31.93	microns
D50	84.16	microns
D60	95.63	microns
D84	300.11	microns
D90	339.99	microns
D60/D10	4.35	
Surface Area	710.42	cm^2/l
Silt Density	0.42	
Silt Volume	582.65	μ l/l
Particle Model	Random	

Figure 2. 49: Volumetric Concentration Of TSS In The Water In The Mid depth – Panju Island Station

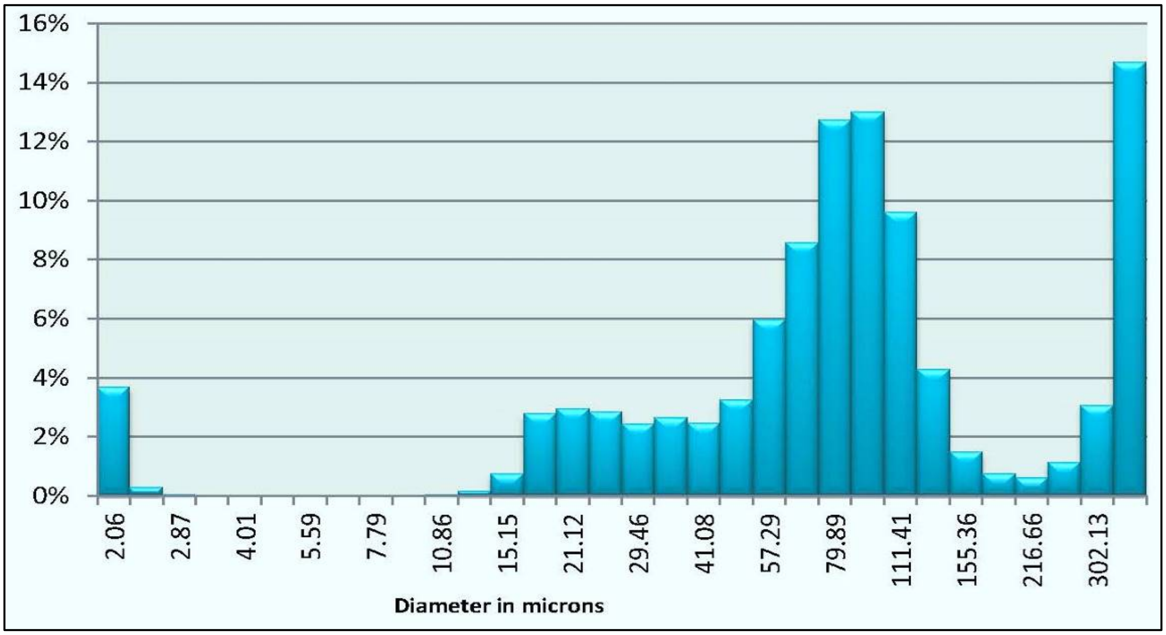
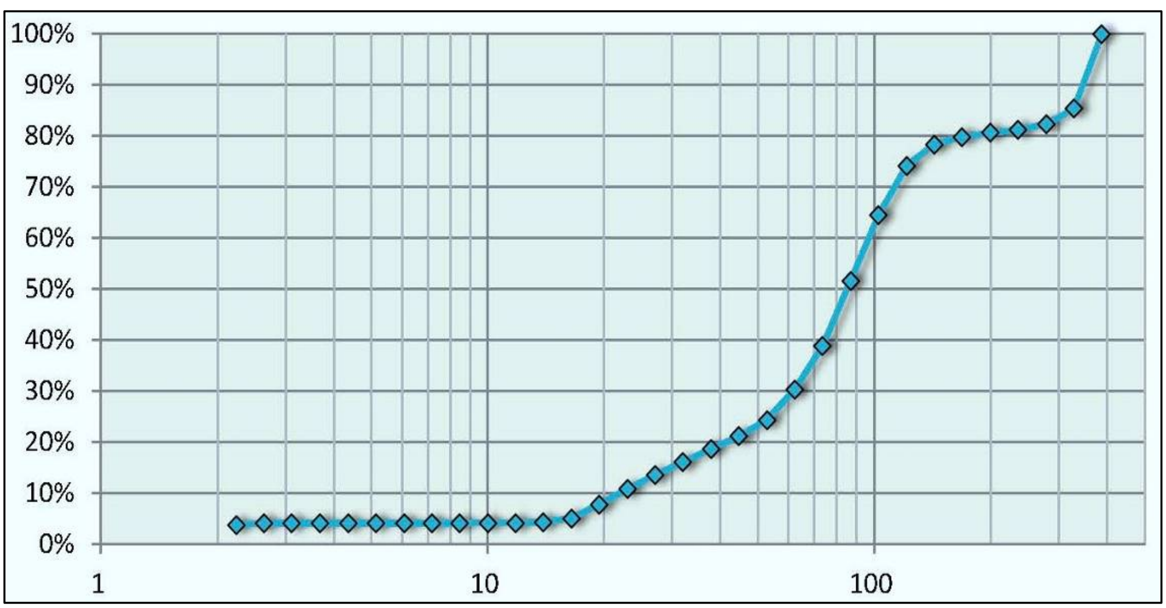


Figure 2. 50: Cumulative Volume Concentration Of TSS In The Mide Depth Water – Panju Island Station



C. Bottom

At the bottom, the corresponding analysis is;

Table 2. 18: Water Bottom Analysis Statistics – Panju Island Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	12:04:53	(HH:MM:SS)
Total Concentration	1459.97	μ l/l
Mean Size	43.91	microns
Standard Deviation	169.78	microns
Optical Transmission	0.26	
D10	5.49	microns
D16	7.50	microns
D50	36.43	microns
D60	55.33	microns
D84	345.72	microns
D90	358.47	microns
D60/D10	10.08	
Surface Area	1406.66	cm^2/l
Silt Density	0.66	
Silt Volume	960.63	μ l/l
Particle Model	Random	

And the volumetric concentration plots are,

Figure 2. 51: Volumetric Concentration Of TSS In The Water In The Bottom – Panju Island Station

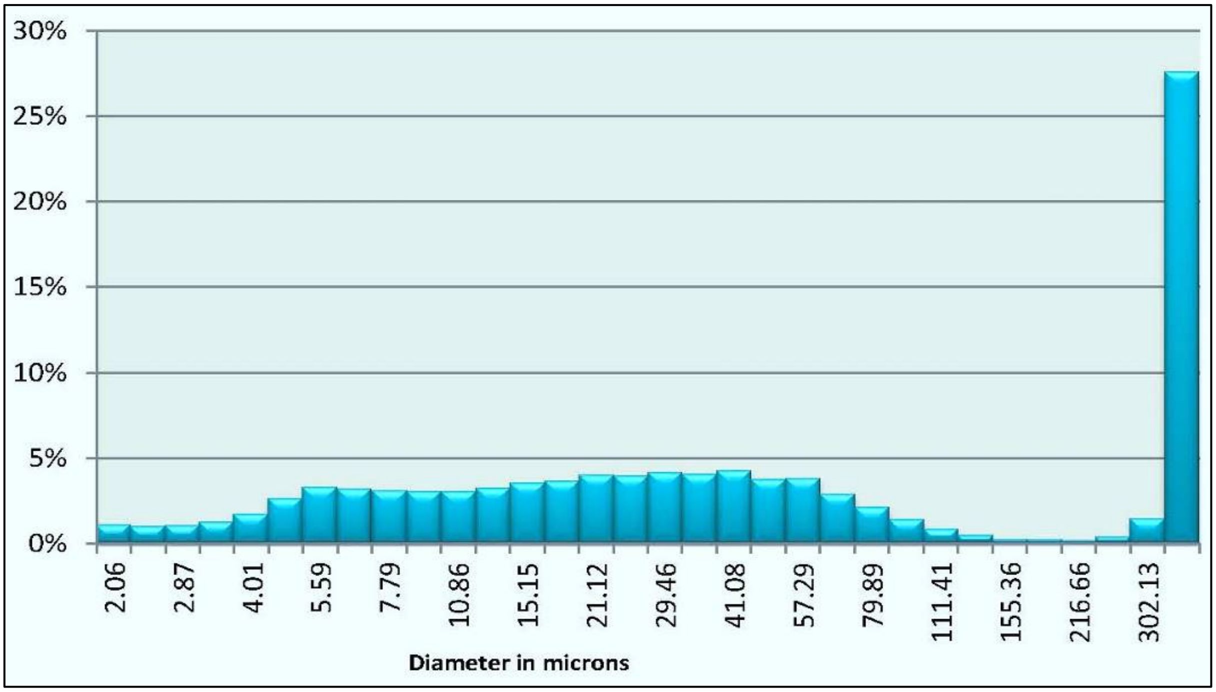
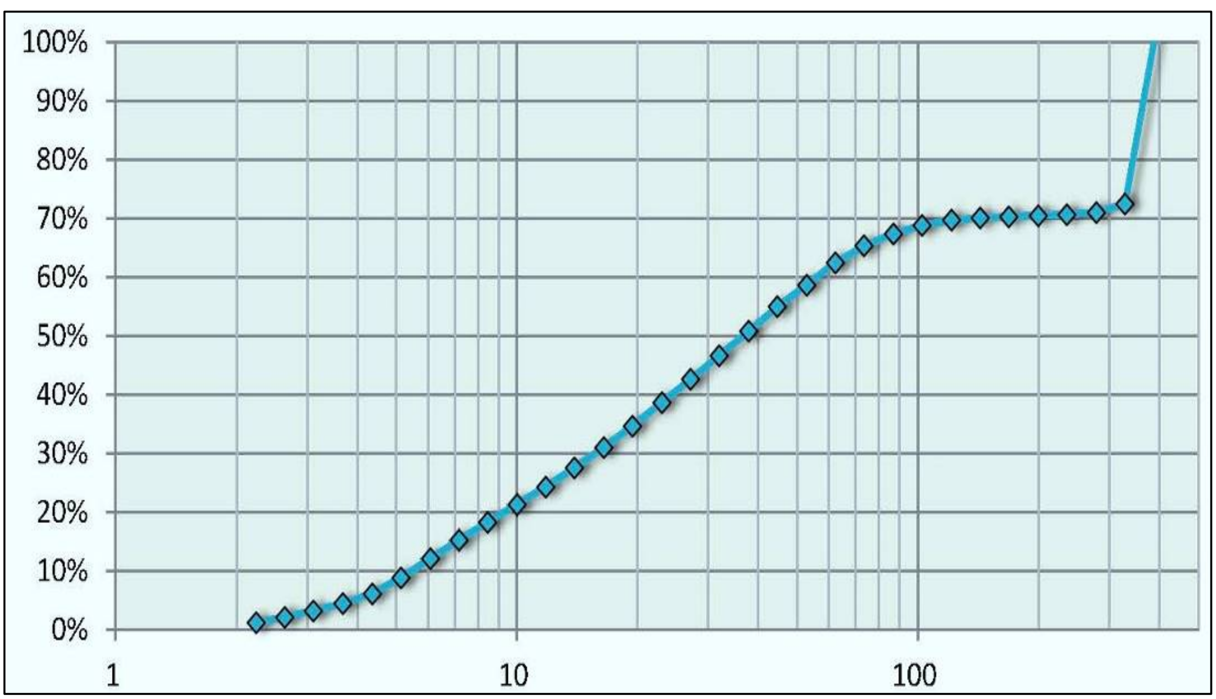


Figure 2. 52: Cumulative Volume Concentration Of TSS In The Bottom – Panju Island Station



2.6.2.3 Water Sample 3 – Gaimukh - Station

At the Gaimukh station as well samples at 3 levels were collected and analyzed. The analyzed data is presented as follows;

A. Surface Water

Computational Statistics for the Surface water sample shows the D50, values are 0.022 mm falling in the silt range. Meaning thereby reduction in the soil diameters as one moves land ward.

Table 2. 19: Surface Water Analysis Statistics – Gaimukh Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	12:27:55	(HH:MM:SS)
Total Concentration	498.99	μ l/l
Mean Size	22.26	microns
Standard Deviation	36.94	microns
Optical Transmission	0.60	
D10	7.47	microns
D16	9.96	microns
D50	21.29	microns
D60	25.53	microns
D84	49.09	microns
D90	64.59	microns
D60/D10	3.42	
Surface Area	458.35	cm^2/l
Silt Density	0.93	
Silt Volume	461.65	μ l/l
Particle Model	Random	

Figure 2. 53: Volumetric Concentration Of TSS In The Water In The Surface Water – Gaimukh Station

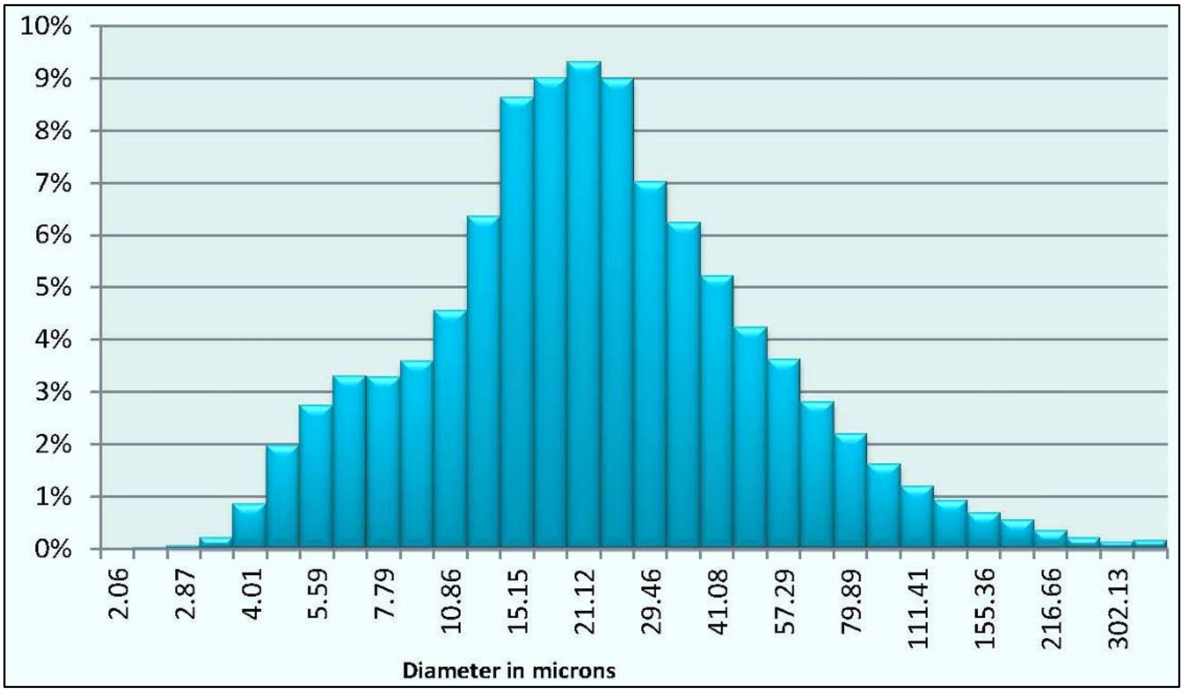
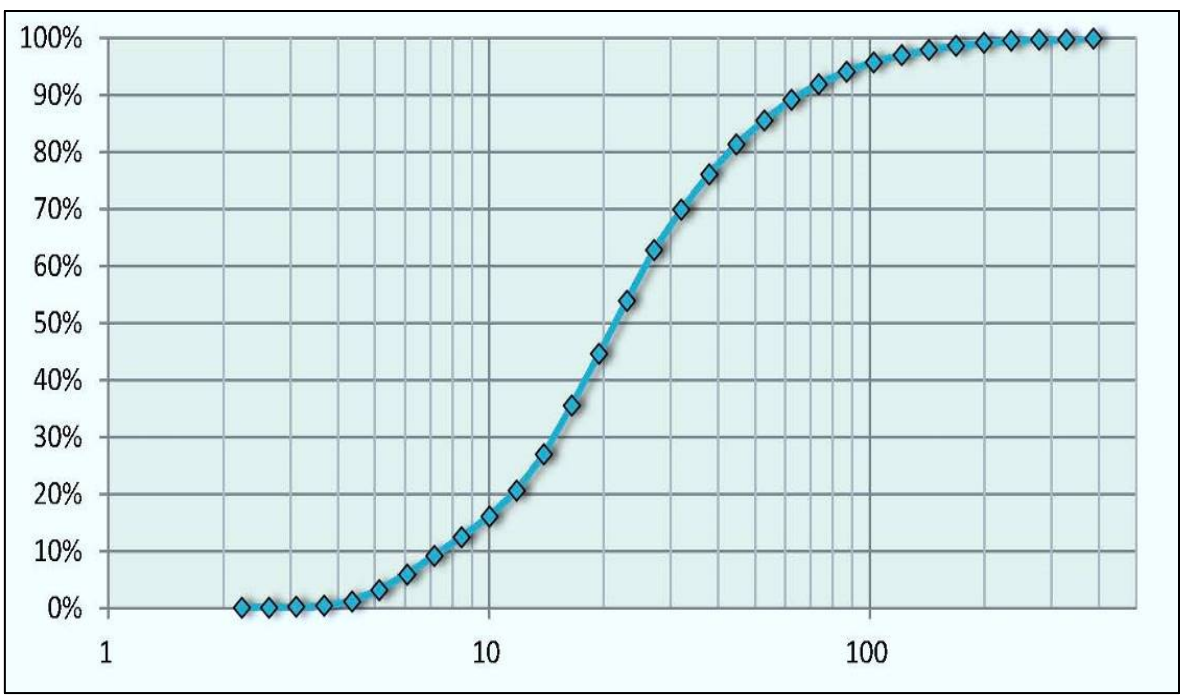


Figure 2. 54: Cumulative Volume Concentration Of TSS In The Surface Water – Gaimukh Station



B. Mid Depth Water

The samples at the mid depth gives the following finding;

Table 2. 20: Mid Depth Water Analysis Statistics – Gaimukh Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	12:25:11	(HH:MM:SS)
Total Concentration	573.34	μ l/l
Mean Size	24.58	microns
Standard Deviation	72.24	microns
Optical Transmission	0.57	
D10	7.59	microns
D16	10.11	microns
D50	21.90	microns
D60	26.43	microns
D84	53.82	microns
D90	83.42	microns
D60/D10	3.48	
Surface Area	510.88	cm^2/l
Silt Density	0.89	
Silt Volume	510.70	μ l/l
Particle Model	Random	

Figure 2. 55: Volumetric Concentration Of TSS In The Water In The Mid Depth – Gaimukh Station

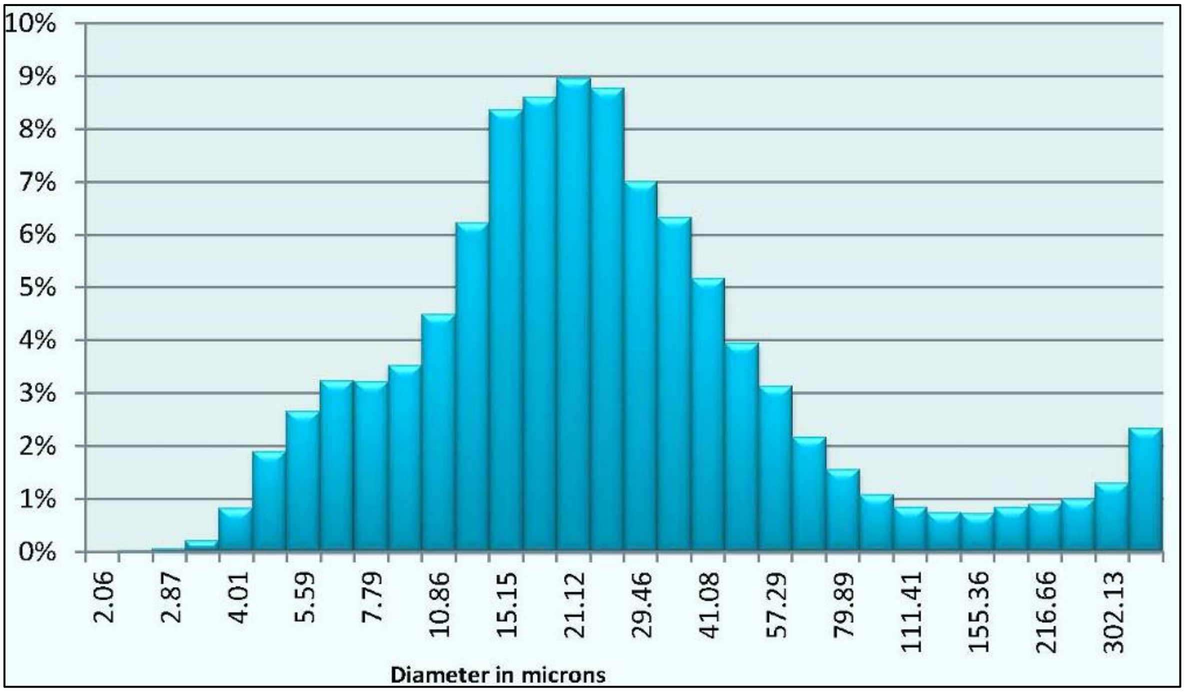
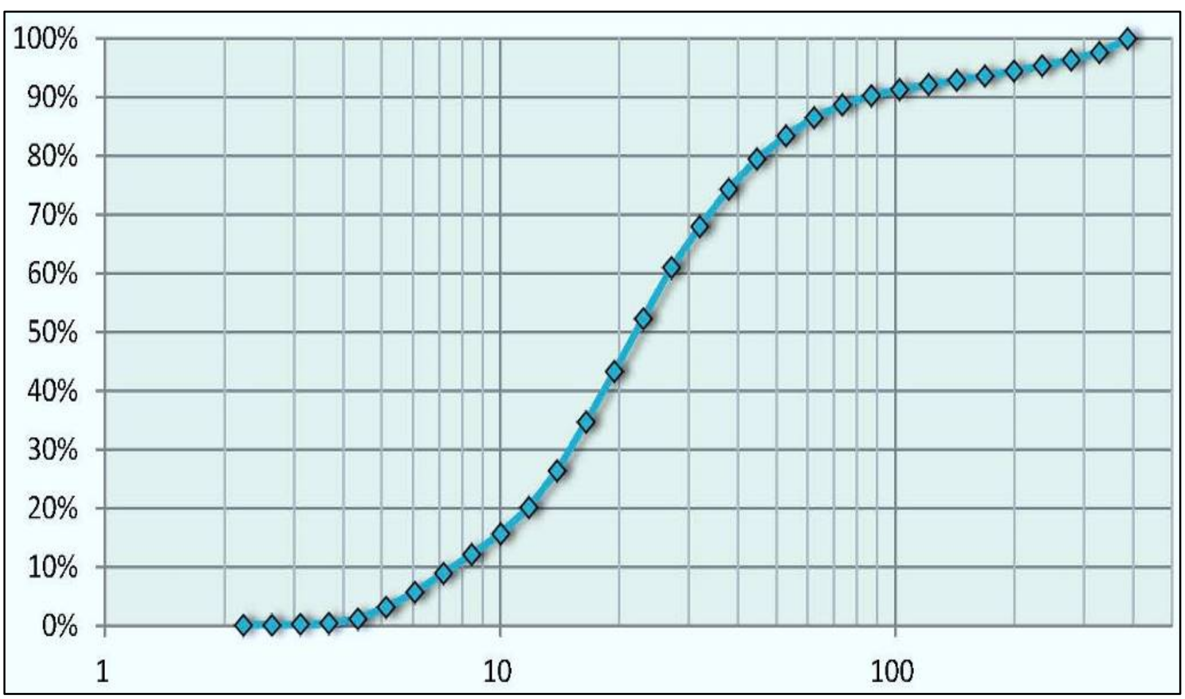


Figure 2. 56: Cumulative Volume Concentration Of TSS In The Mid Depth Water – Gaimulh Station



C. Bottom Water

The samples from the bottom water gives the following findings;

Table 2. 21: Water Bottom Analysis Statistics – Gaimukh Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	12:18:00	(HH:MM:SS)
Total Concentration	888.49	μ l/l
Mean Size	30.80	microns
Standard Deviation	111.51	microns
Optical Transmission	0.46	
D10	7.86	microns
D16	10.53	microns
D50	23.33	microns
D60	29.25	microns
D84	157.04	microns
D90	276.67	microns
D60/D10	3.72	
Surface Area	735.46	cm^2/l
Silt Density	0.80	
Silt Volume	711.72	μ l/l
Particle Model	Random	

The D50 for the soil sample is o.023 mm and so in the silt range similar to the earlier sample. However, the bandwidth of the particle is wider, indicating the calmer water in the bottom.

The D10, D30 and D60 values help calculating the coefficient of gradation;

The volumetric concentrations plots are as follows;

Figure 2. 57: Volumetric Concentration Of TSS In The Water In The Bottom – Gaimukh Station

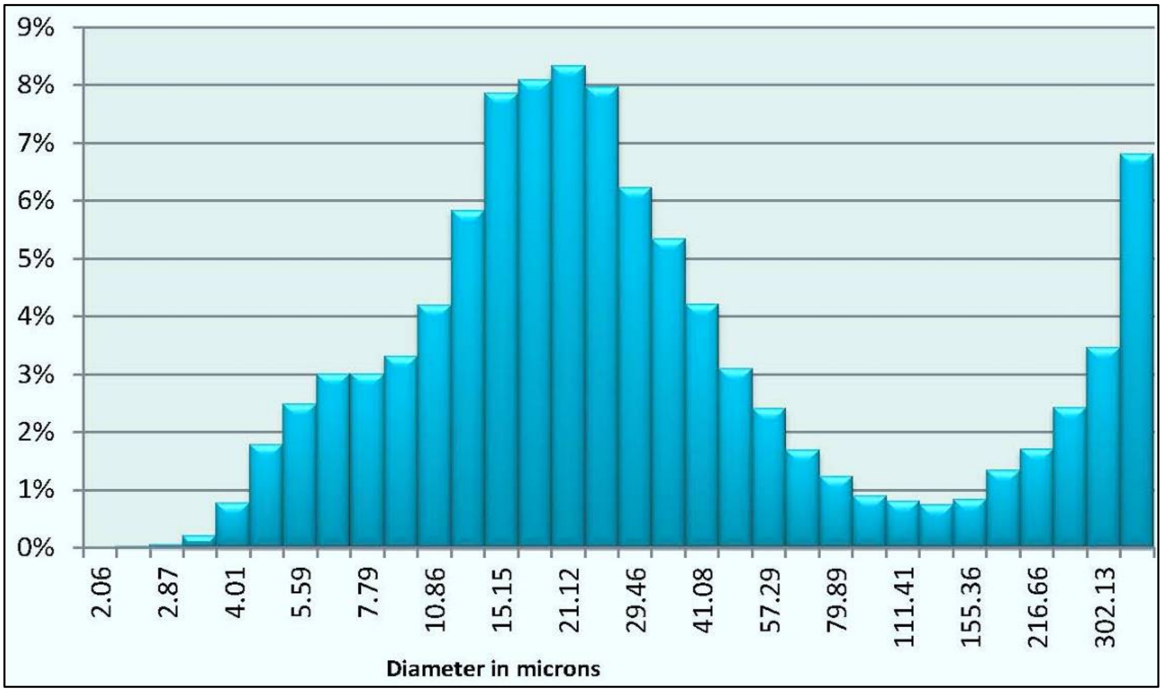
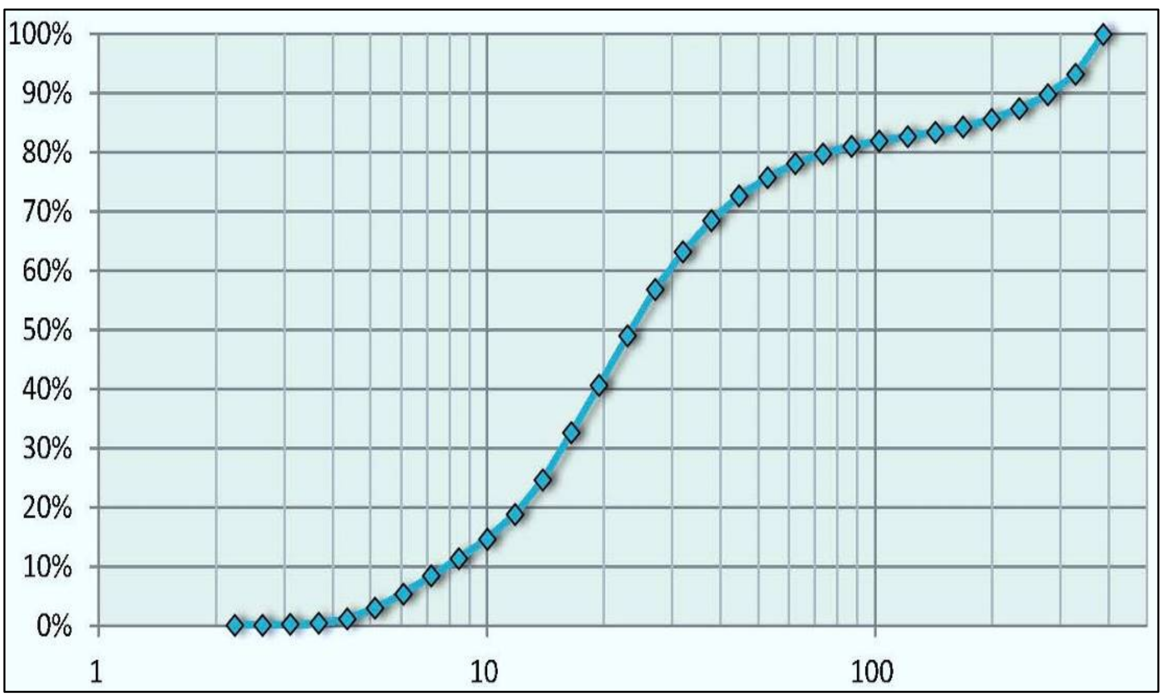


Figure 2. 58: Cumulative Volume Concentration Of TSS In The Bottom Water – Gaimukh Station



2.6.2.4 Water Sample 4 – Kasheli - Station

The Kasheli station is located in the portion of the river that has high banks on either side due to hillocks.

A. Surface Water

The computational statistics are;

Table 2. 22: Surface Water Analysis Statistics – Kasheli Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	12:42:13	(HH:MM:SS)
Total Concentration	56.27	μ l/l
Mean Size	42.01	microns
Standard Deviation	43.47	microns
Optical Transmission	0.99	
D10	12.06	microns
D16	16.30	microns
D50	51.37	microns
D60	63.34	microns
D84	95.38	microns
D90	109.48	microns
D60/D10	5.25	
Surface Area	30.72	cm^2/l
Silt Density	0.70	
Silt Volume	39.49	μ l/l
Particle Model	Random	

The Concentration plots are;

Figure 2. 59: Volumetric Concentration Of TSS In The Water In The Surface Water – Kasheli Station

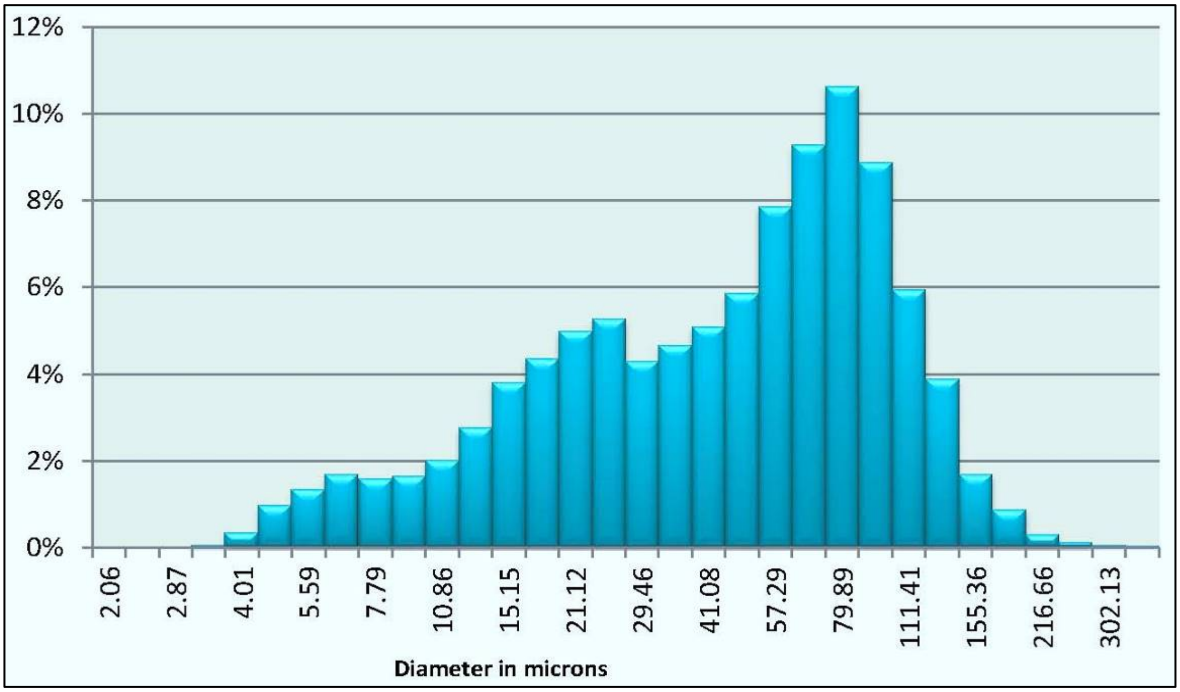
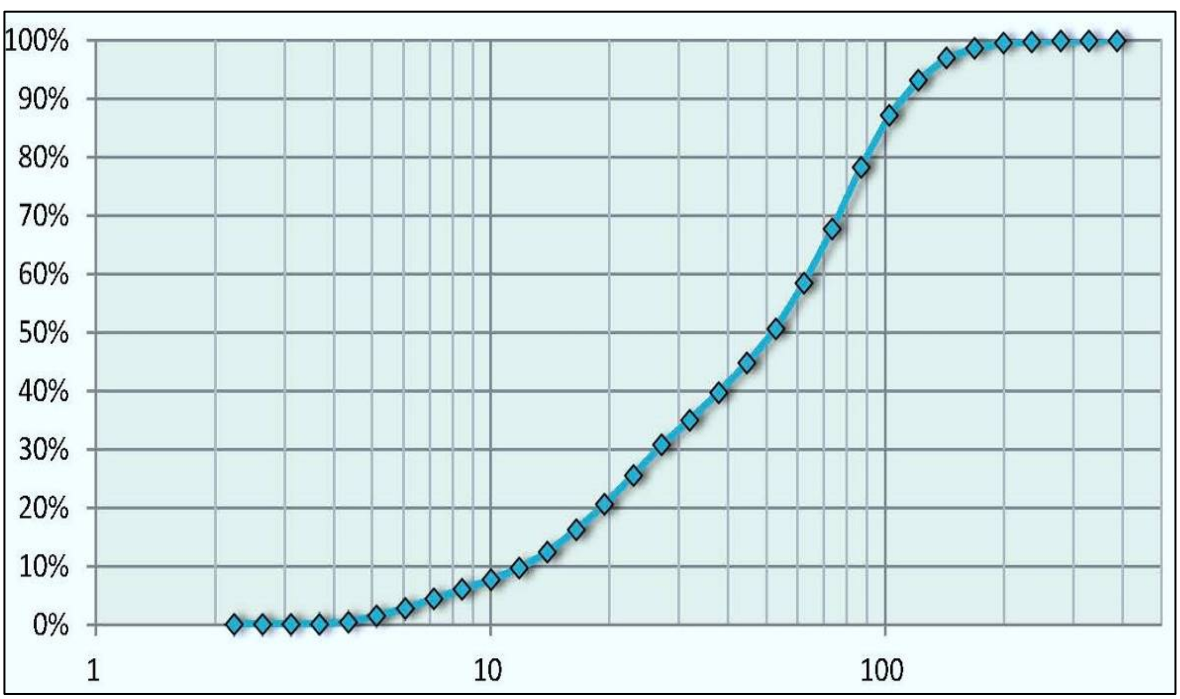


Figure 2. 60: Cumulative Volume Concentration Of TSS In The Surface Water – Kasheli Station



In the above analysis the D50 value of the soil = 0.05 mm which is in the Fine sand category.

B. Mid Depth Water

Table 2. 23: Mid Depth Water Analysis Statistics – Kasheli Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	12:51:03	(HH:MM:SS)
Total Concentration	179.41	μ l/l
Mean Size	46.46	microns
Standard Deviation	45.82	microns
Optical Transmission	0.91	
D10	14.07	microns
D16	18.66	microns
D50	55.98	microns
D60	65.92	microns
D84	96.47	microns
D90	111.63	microns
D60/D10	4.68	
Surface Area	85.84	cm^2/l
Silt Density	0.69	
Silt Volume	123.82	μ l/l
Particle Model	Random	

Figure 2. 61: Volumetric Concentration Of TSS In The Water In The Mid Depth – Kasheli Station

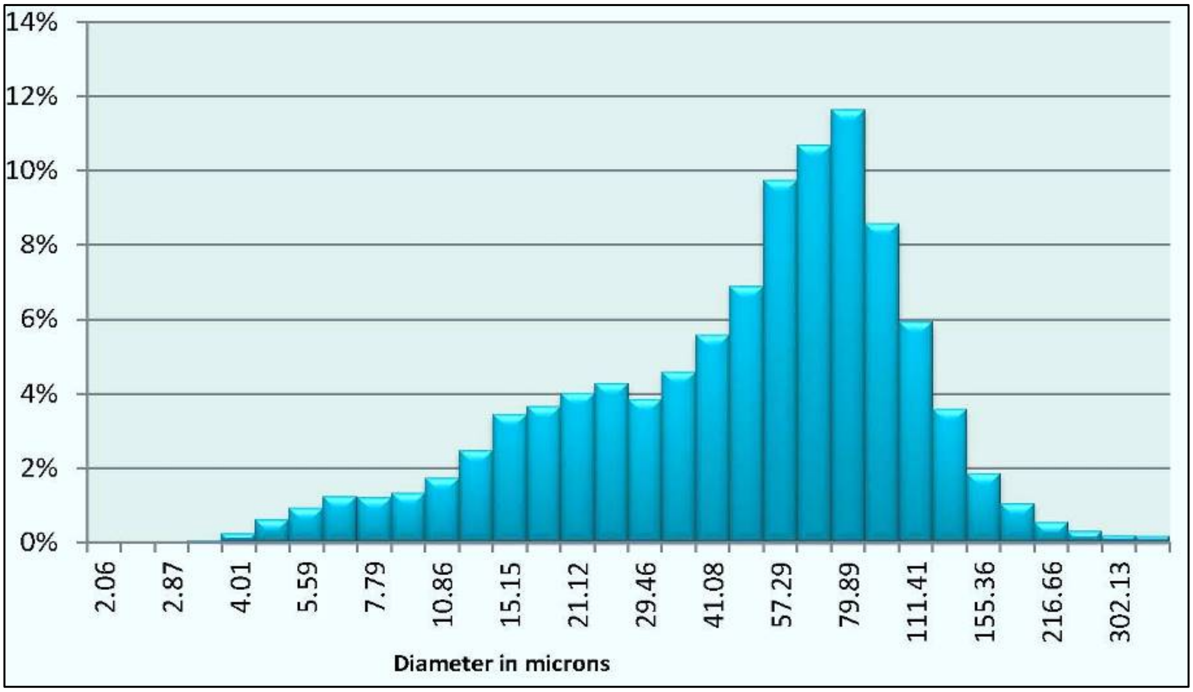
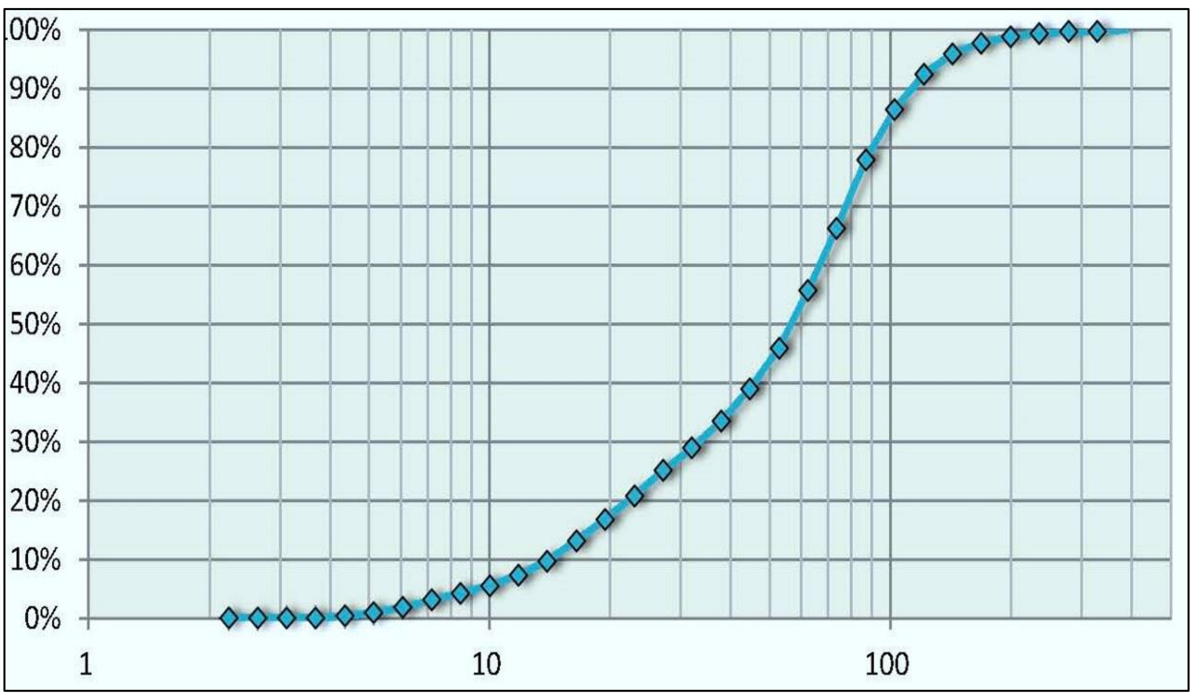


Figure 2. 62: Cumulative Volume Concentration Of TSS In The Mid Depth Water – Kasheli Station



The above table indicates a D50 value of 0.056 mm falling in the fine sand range. The suspended sediments are mostly that range.

C. Bottom Water

The statistics for the bottom water sample is as follows;

Table 2. 24: Water Bottom Analysis Statistics – Kasheli Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	12:48:30	(HH:MM:SS)
Total Concentration	297.98	μ l/l
Mean Size	82.91	microns
Standard Deviation	133.89	microns
Optical Transmission	0.88	
D10	18.03	microns
D16	25.74	microns
D50	79.01	microns
D60	103.57	microns
D84	313.30	microns
D90	340.03	microns
D60/D10	5.75	
Surface Area	101.14	cm^2/l
Silt Density	0.48	
Silt Volume	142.81	μ l/l
Particle Model	Random	

D_{50} value is 0.079 mm.

Figure 2. 63: Volumetric Concentration Of TSS In The Water In The Bottom – Kasheli Station

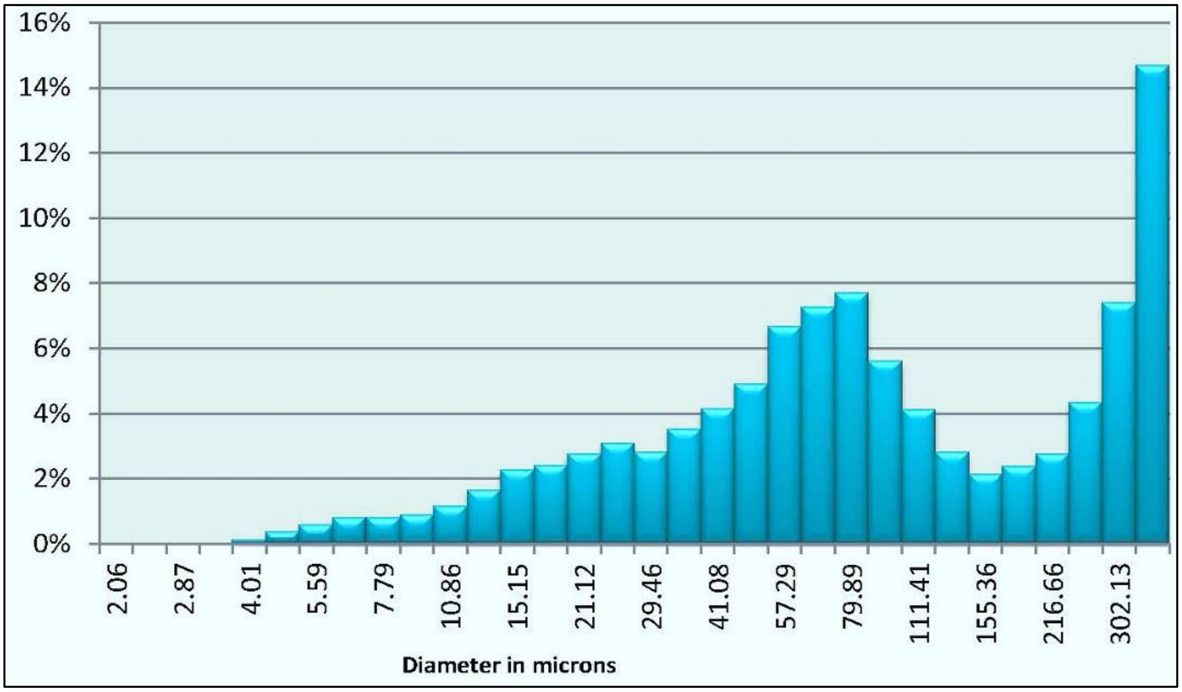
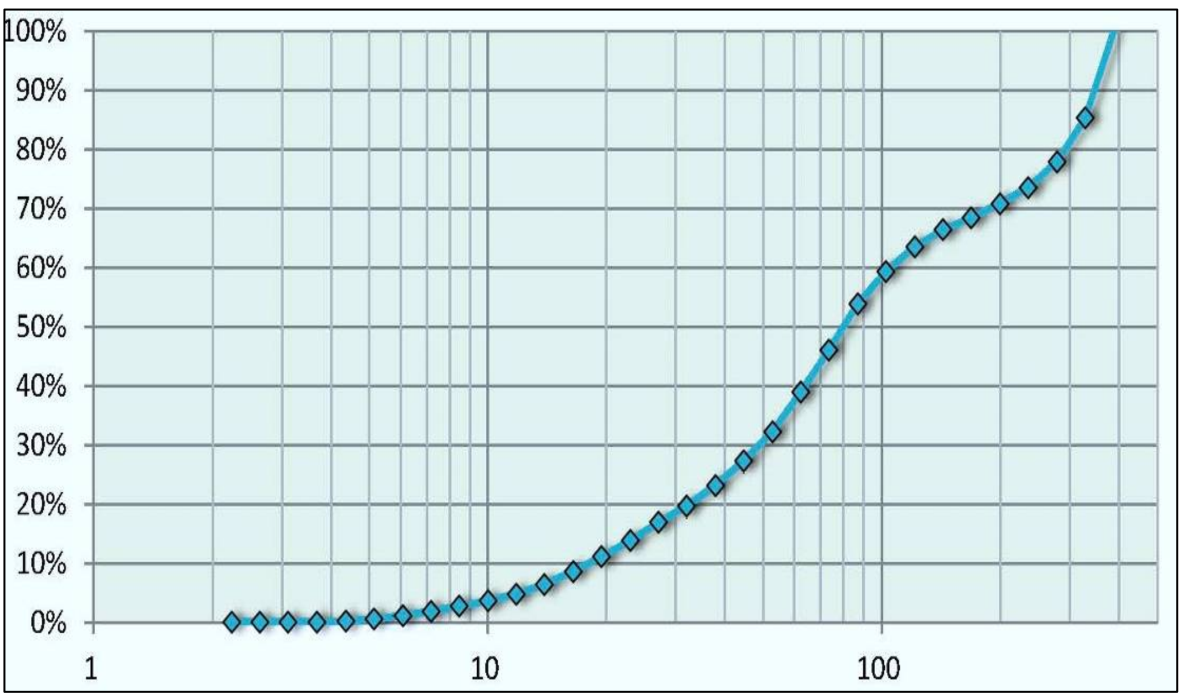


Figure 2. 64: Cumulative Volume Concentration Of TSS In The Bottom – Kasheli Station



2.6.2.5 Water Sample 5 – Sat Pul - Station

The samples from the Satpul Station is presented in this paragraph;

A. Surface Water

The computational statistics for the surface water at Satpul station is,

Table 2. 25: Surface Water Analysis Statistics – Sat Pul Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	12:59:35	(HH:MM:SS)
Total Concentration	88.28	μ l/l
Mean Size	81.40	microns
Standard Deviation	66.64	microns
Optical Transmission	1.00	
D10	30.95	microns
D16	44.59	microns
D50	87.06	microns
D60	99.14	microns
D84	145.33	microns
D90	173.98	microns
D60/D10	3.20	
Surface Area	22.33	cm^2/l
Silt Density	0.38	
Silt Volume	33.56	μ l/l
Particle Model	Random	

The D50 value for this sample is 0.087 mm. The concentration volume is;

Figure 2. 65: Volumetric Concentration Of TSS In The Water In The Surface – SatPul Station

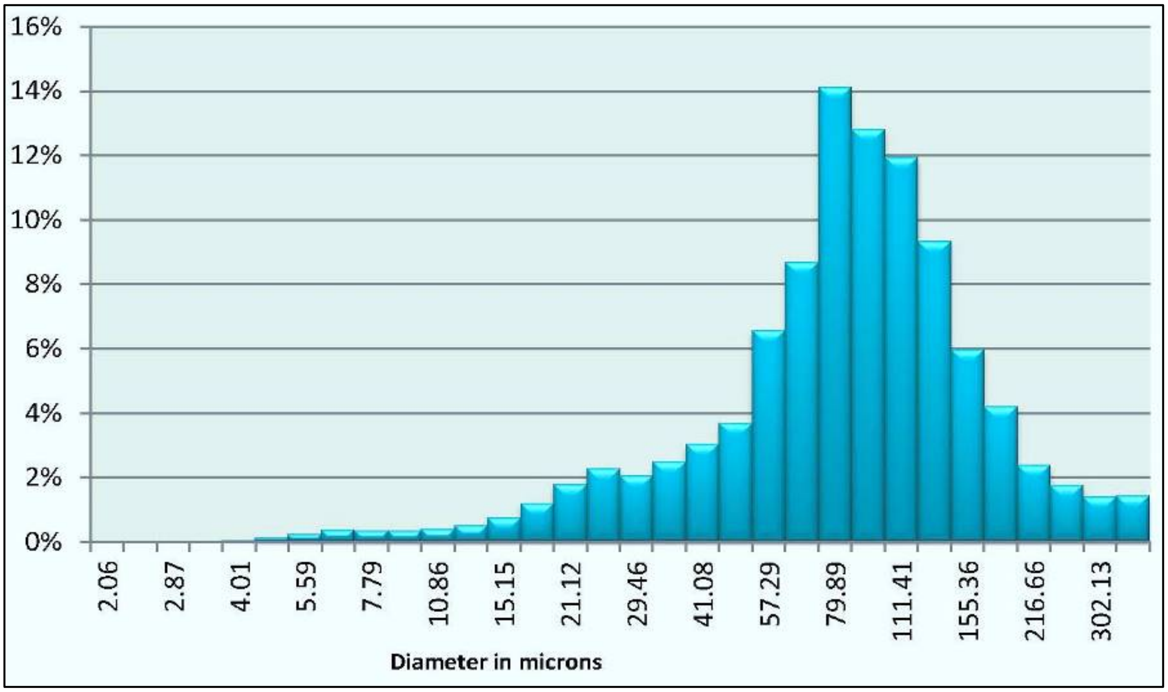
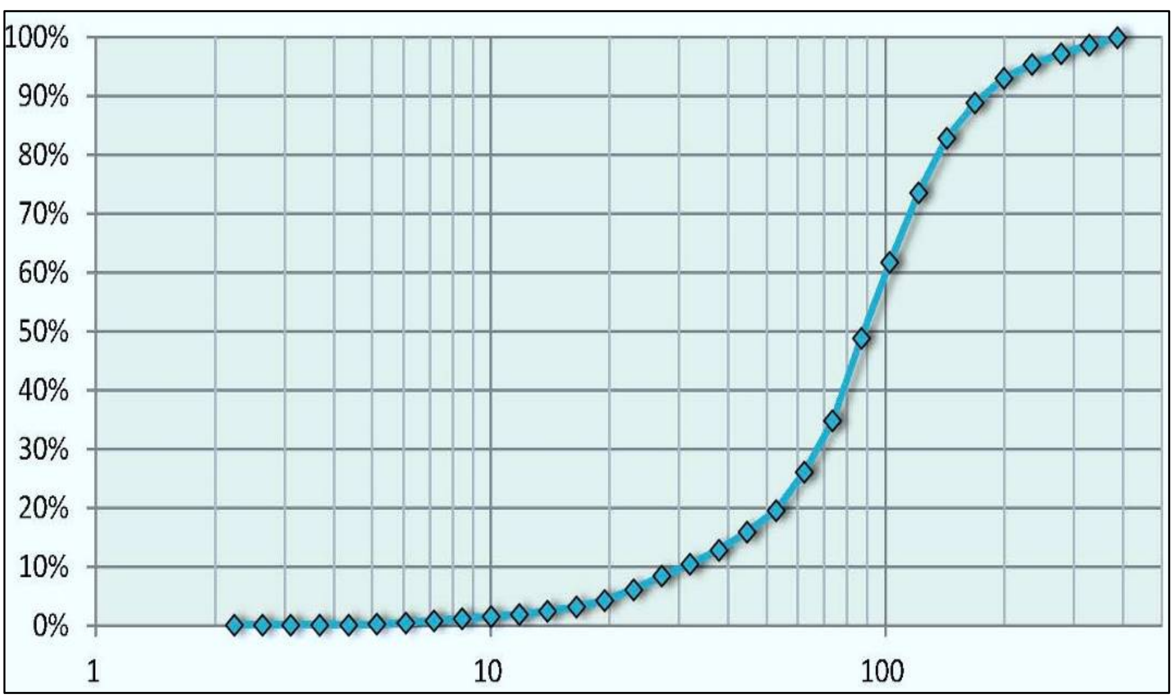


Figure 2. 66: Cumulative Volume Concentration Of TSS In The Surface Water – SatPul Station



B. Mid Depth

At the mid depth the sample collected and analyzed to give the following results;

Table 2. 26: Mid Depth Water Analysis Statistics – Sat Pul Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	13:11:43	(HH:MM:SS)
Total Concentration	122.66	μ l/l
Mean Size	165.53	microns
Standard Deviation	134.86	microns
Optical Transmission	0.99	
D10	50.50	microns
D16	65.23	microns
D50	244.63	microns
D60	288.64	microns
D84	348.67	microns
D90	360.38	microns
D60/D10	5.72	
Surface Area	19.15	cm^2/l
Silt Density	0.21	
Silt Volume	25.11	μ l/l
Particle Model	Random	

D50 = 0.244 mm – Medium to Coarse Sand.

Figure 2. 67: Volumetric Concentration Of TSS In The Water In The Mid Depth – Sat Pul Station

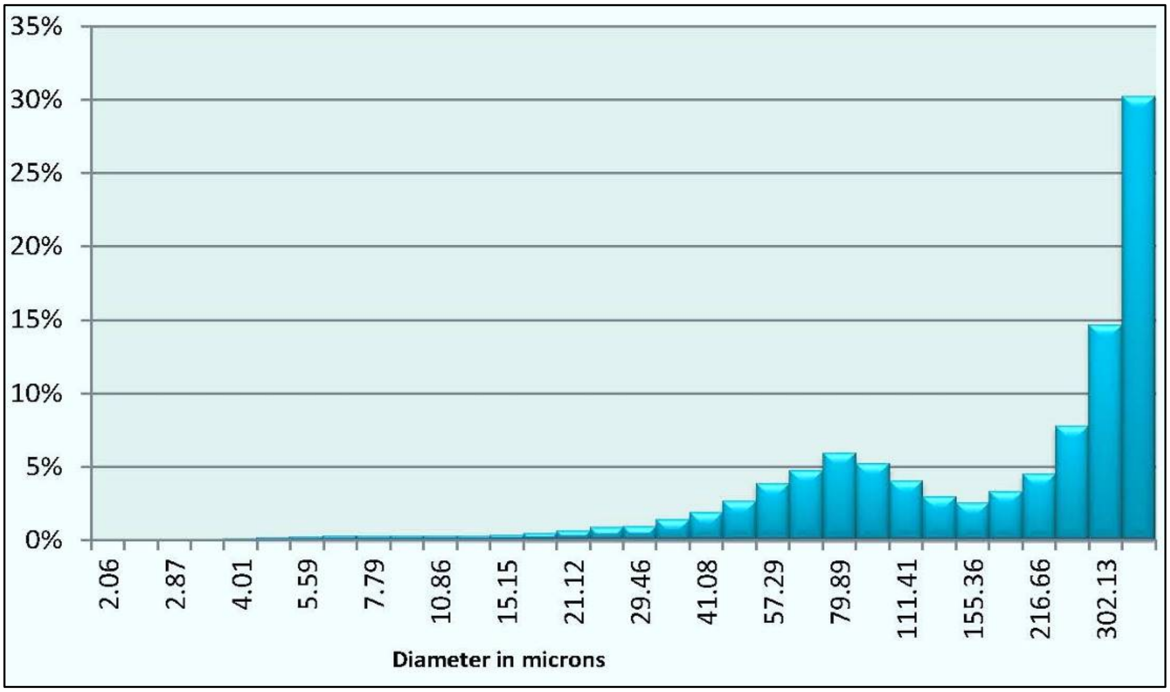
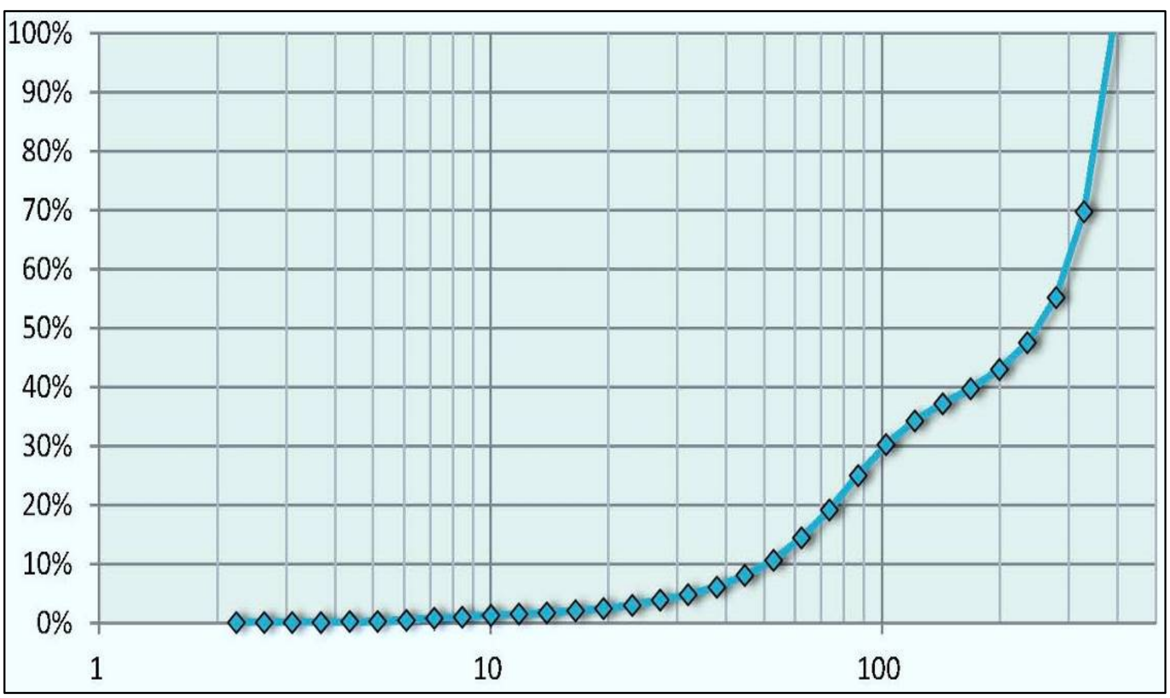


Figure 2. 68: Cumulative Volume Concentration Of TSS In The Mid Depth Water – Satpul Station



C. Bottom

Similarly, in the bottom sample the various parameters are;

Table 2. 27: Water Bottom Analysis Statistics – Sat Pul Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	13:19:32	(HH:MM:SS)
Total Concentration	59.78	μ l/l
Mean Size	103.80	microns
Standard Deviation	66.54	microns
Optical Transmission	1.01	
D10	33.41	microns
D16	56.18	microns
D50	129.39	microns
D60	143.23	microns
D84	183.53	microns
D90	198.65	microns
D60/D10	4.29	
Surface Area	14.32	cm^2/l
Silt Density	0.21	
Silt Volume	12.47	μ l/l
Particle Model	Random	

D50 = 0.129 mm

The Volumetric concentration plots are,

Figure 2. 69: Volumetric Concentration Of TSS In The Water In The Bottom – Sat Pul Station

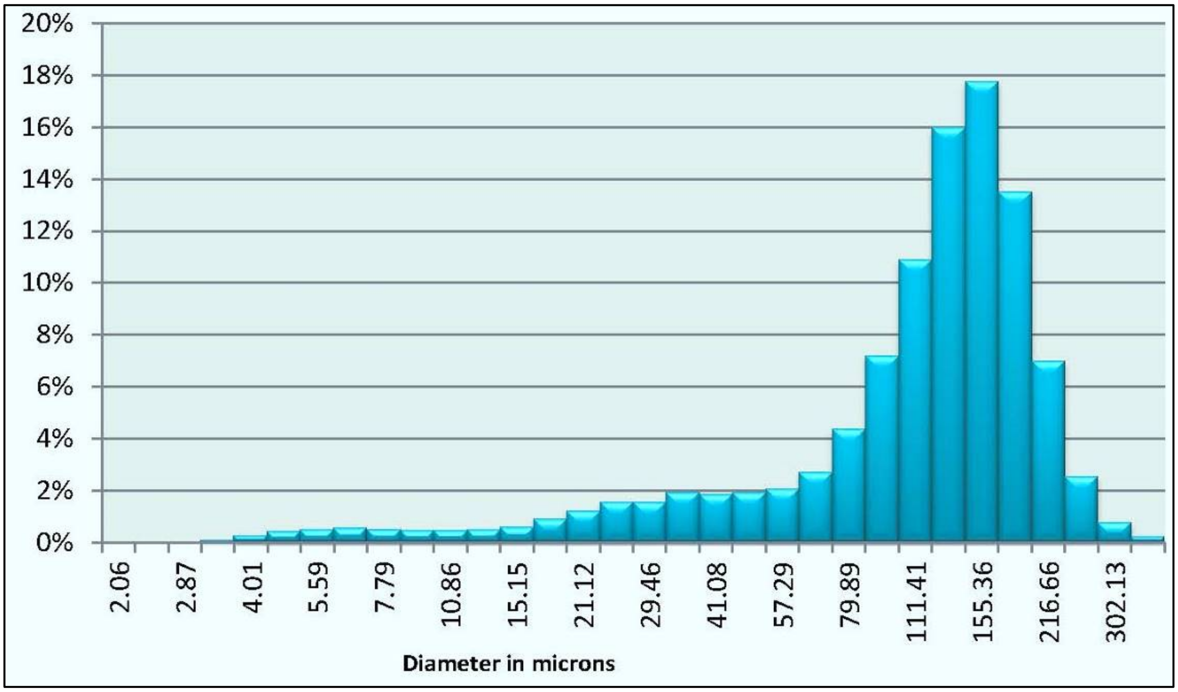
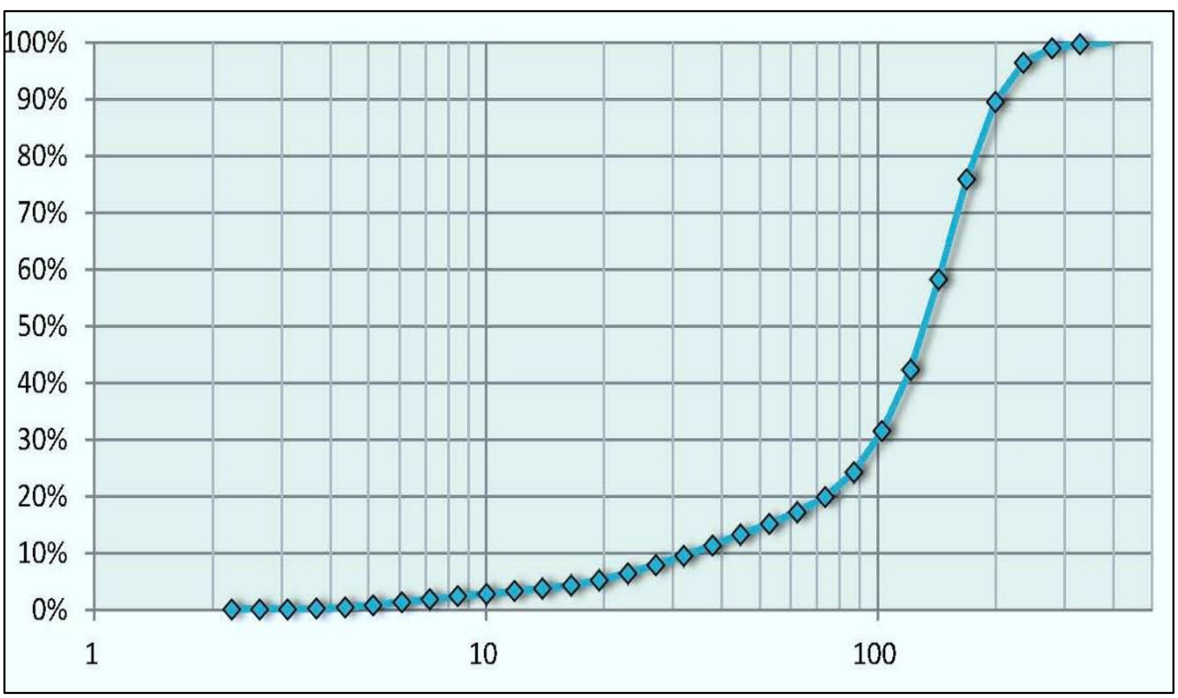


Figure 2. 70: Cumulative Volume Concentration Of TSS In The Bottom Water – Sat Pul Station



2.6.2.6 Water Sample 6 – Kalyan - Station

The data collected at the Kalyan station at 3 levels were collected and analyzed.

A. Surface Water

The computational statistics are;

Table 2. 28: Surface Water Analysis Statistics – Kalyan Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	14:42:09	(HH:MM:SS)
Total Concentration	75.30	μ l/l
Mean Size	58.89	microns
Standard Deviation	46.80	microns
Optical Transmission	0.98	
D10	18.75	microns
D16	26.91	microns
D50	73.19	microns
D60	83.28	microns
D84	116.30	microns
D90	130.89	microns
D60/D10	4.44	
Surface Area	30.56	cm^2/l
Silt Density	0.52	
Silt Volume	39.49	μ l/l
Particle Model	Random	

With the D50 value equaling to 0.07 mm in the silt range.

Figure 2. 71: Volumetric Concentration Of TSS In The Water In The Surface Water – Kalyan Station

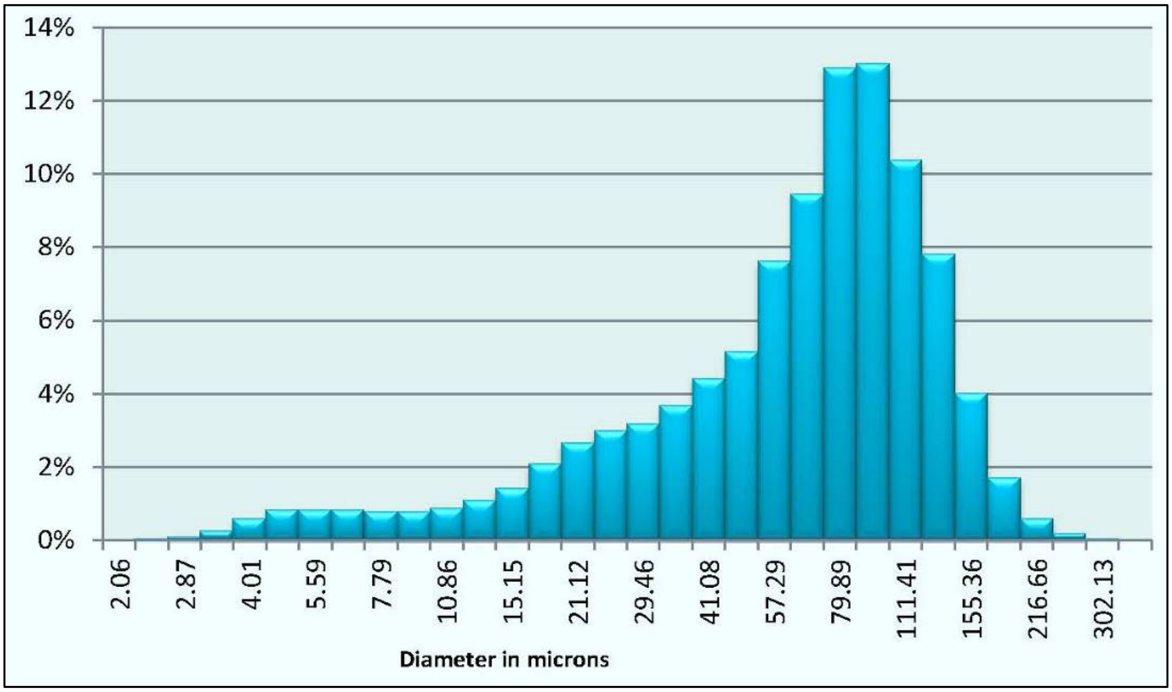
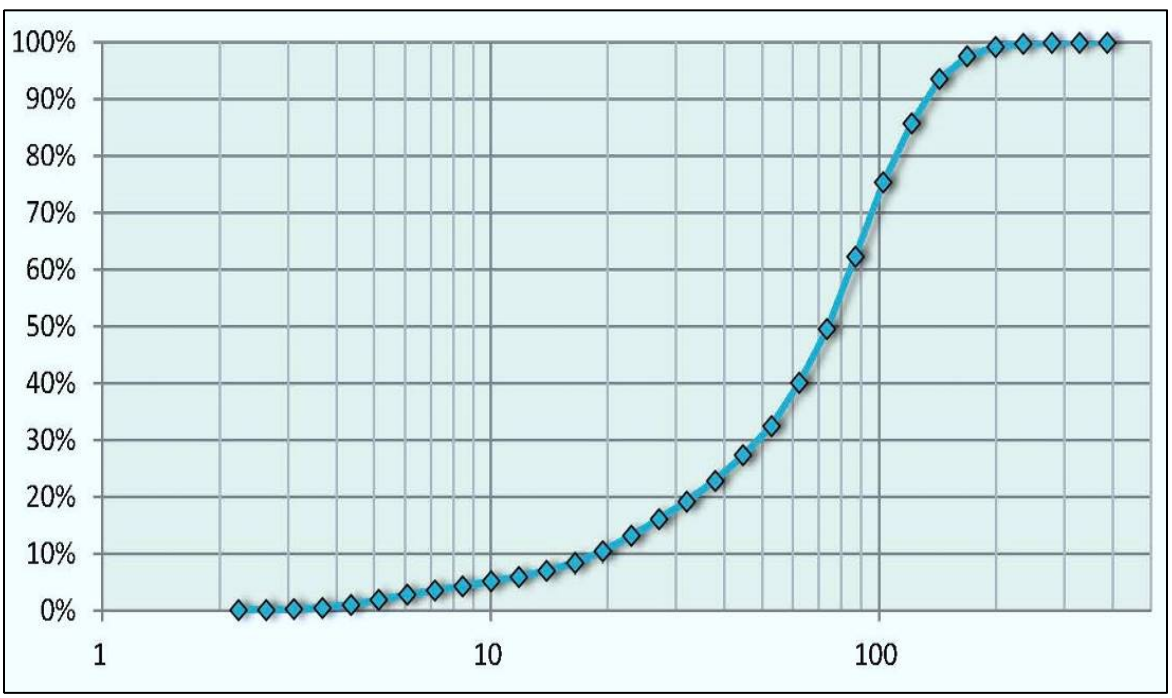


Figure 2. 72: Cummulative Volume Concentration Of TSS In The Surface Water – Kalyan Station



B. Mid Depth Water

The mid depth sample analysis report is as under;

Table 2. 29: Mid Depth Water Analysis Statistics – Kalyan Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	14:28:28	(HH:MM:SS)
Total Concentration	110.33	μ l/l
Mean Size	58.59	microns
Standard Deviation	57.05	microns
Optical Transmission	0.97	
D10	22.75	microns
D16	29.86	microns
D50	60.11	microns
D60	70.97	microns
D84	121.41	microns
D90	151.32	microns
D60/D10	3.12	
Surface Area	39.53	cm^2/l
Silt Density	0.64	
Silt Volume	70.19	μ l/l
Particle Model	Random	

The D50 value is around 0.06 mm. The sediment median size lies in the fine sand.

Figure 2. 73: Volumetric Concentration Of TSS In The Water In The Mid depth – Kalyan Station

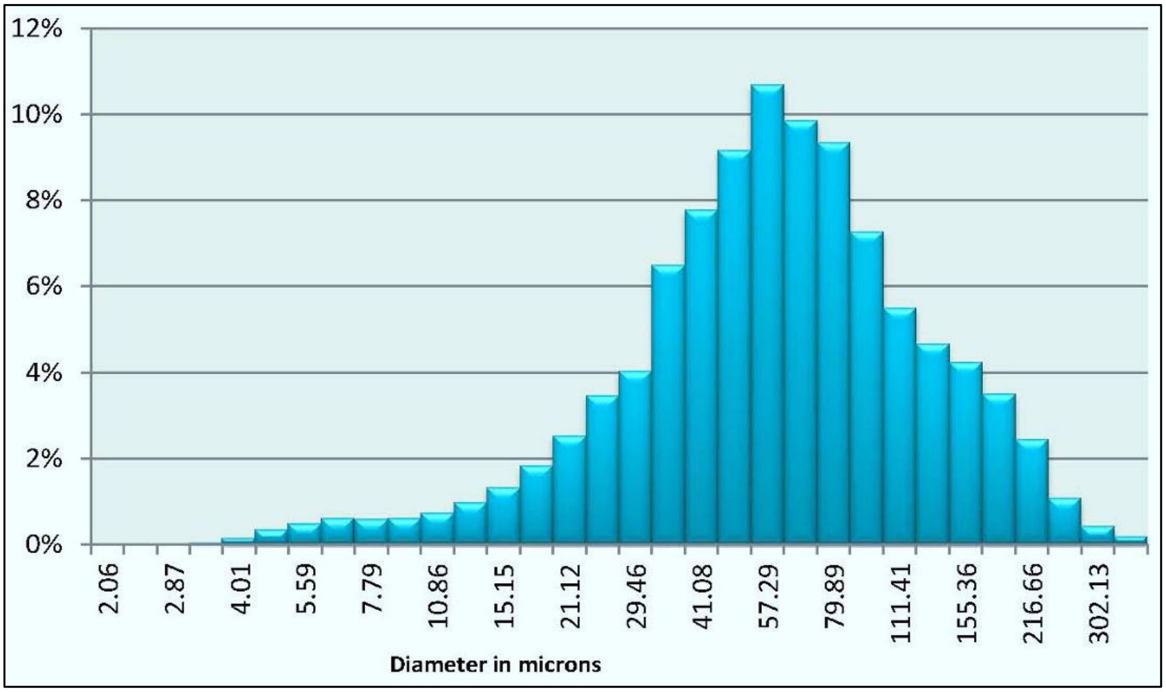
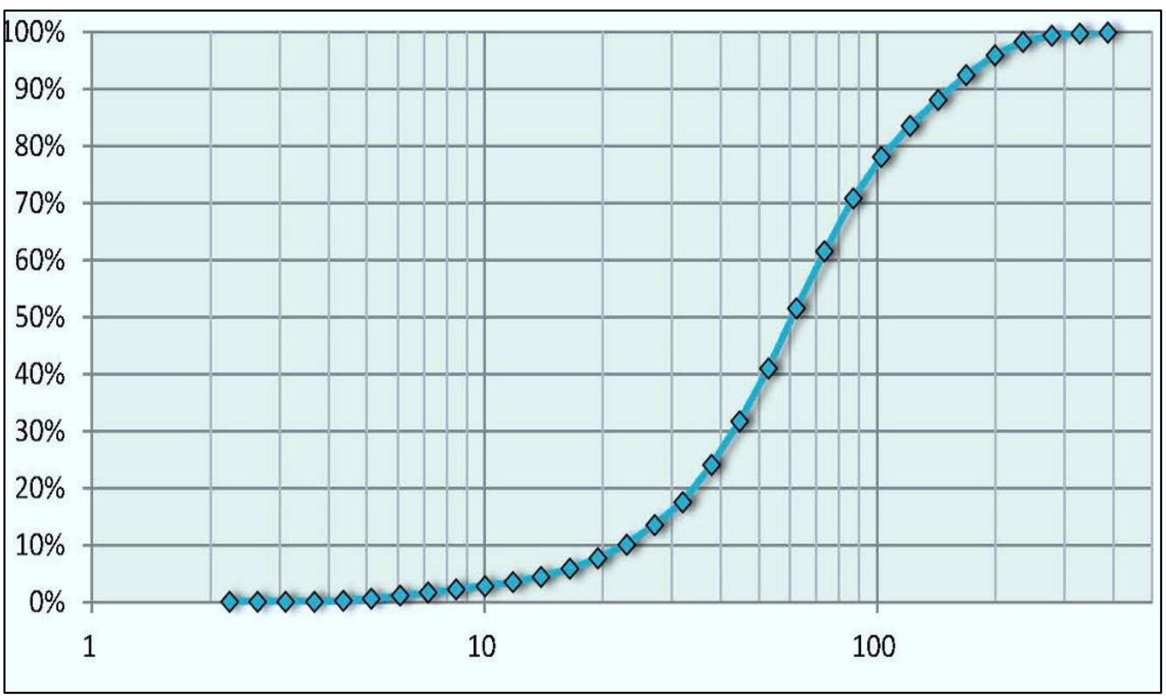


Figure 2. 74: Cummulative Volume Concentration Of TSS In The Mid Depth Water – Kalyan Station



C. Bottom

Bottom TSS sample analysis report is given as;

Table 2. 30: Water Bottom Analysis Statistics – Kalyan Station

Computed Statistics		
Process Date	06/20/2017	(MM/DD/YYYY)
Process Time	14:40:11	(HH:MM:SS)
Total Concentration	134.90	μ l/l
Mean Size	132.22	microns
Standard Deviation	140.96	microns
Optical Transmission	0.97	
D10	33.62	microns
D16	49.47	microns
D50	156.24	microns
D60	237.93	microns
D84	345.03	microns
D90	358.03	microns
D60/D10	7.08	
Surface Area	29.38	cm^2/l
Silt Density	0.27	
Silt Volume	36.75	μ l/l
Particle Model	Random	

Figure 2. 75: Volumetric Concentration Of TSS In The Water In The Bottom – Kalyan Station

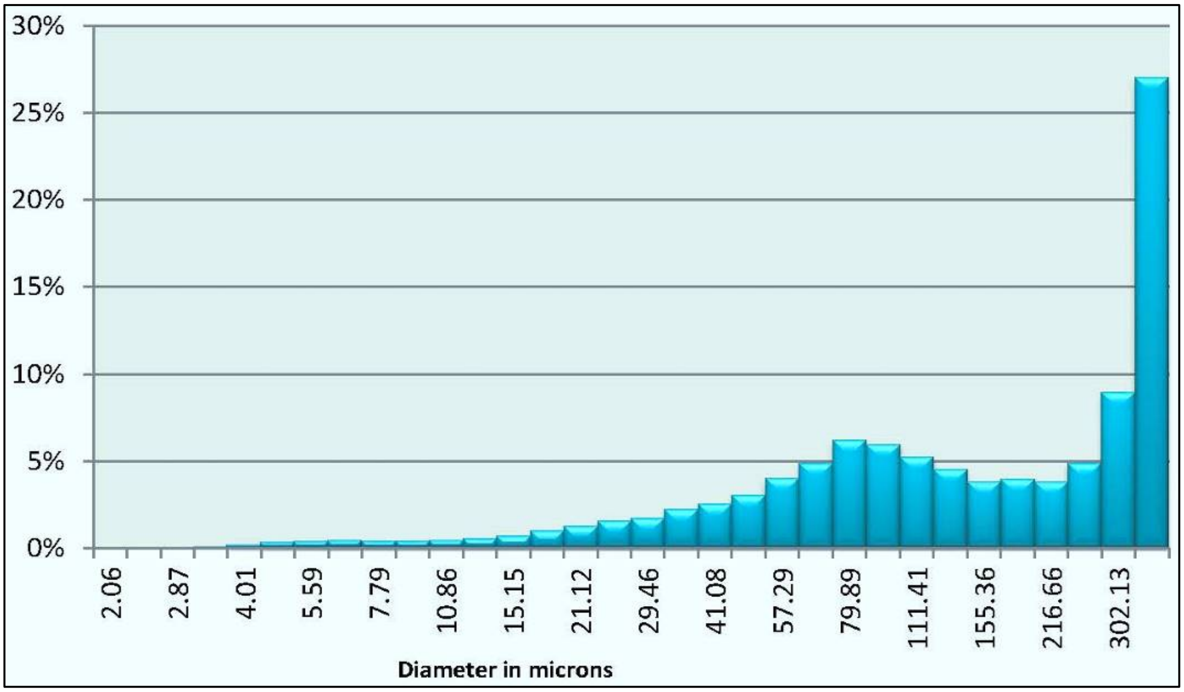
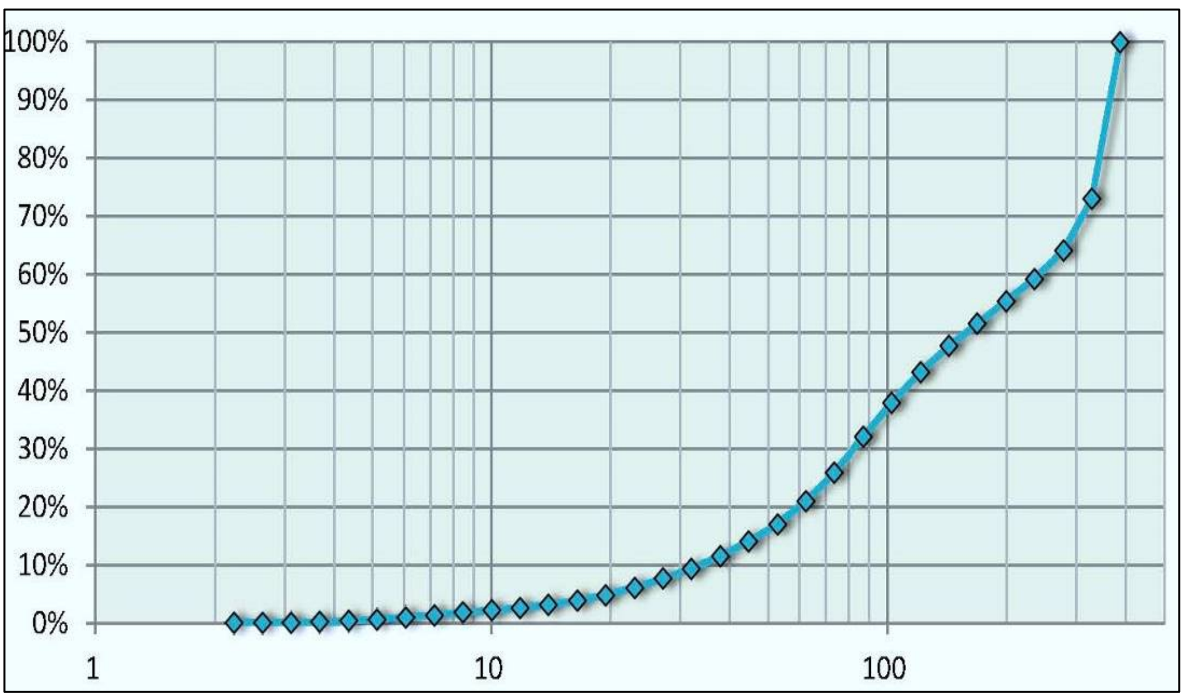


Figure 2. 76: Cumulative Volume Concentration Of TSS In The Bottom Water – Kalyan Station



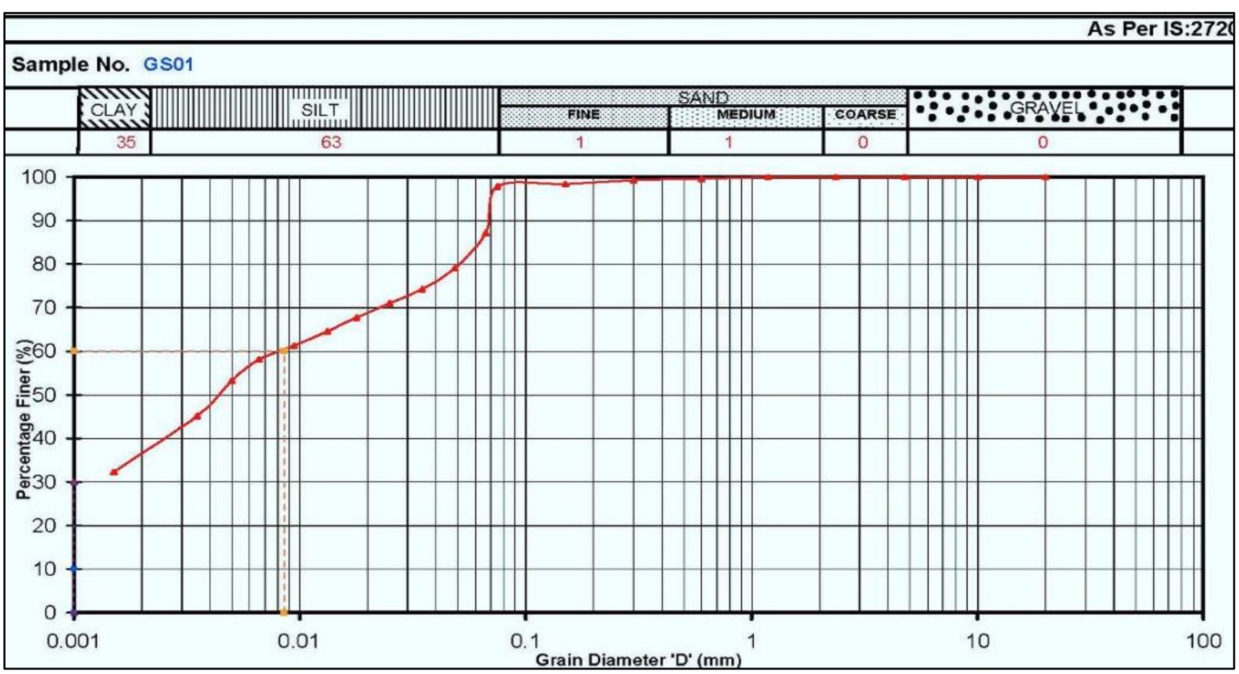
2.6.3 Soil Sample Analysis

Soil samples were collected with grab samplers and the same was analyzed for the grain size composition. The locational details of the stations as could be seen from Figure 2.40. Table 2.12 details the salient features of the soil samples collected at the 6 locations followed by the gain size distribution curves at the 6 data collection stations.

Table 2. 31: Soil Data Analysis At The 6 Data Collection Stations In Vasai Creek

Sample ID	Location	Grain Size Analysis (%)				Specific Gravity	C*u*	C*c*
		Mechanical analysis		Hydrometer Analysis				
		Gravel	Sand	Silt	Clay			
GS01	Vasai	0	2	63	35	2.63	-	-
GS02	Panju	0	1	9	40	2.61	-	-
GS03	Gaimukh	0	1	68	31	2.65	-	-
GS04	Kasheli	0	2	79	19	2.67	3.75	0.53
GS05	Sat Pul	11	57	25	7	2.75	263.42	1.01
GS06	Kalyan	0	9	64	27	2.62	-	-

Figure 2. 77: Grain Size Analysis – Vasai Station



Clearly the median diameter of the soil is in the silt range. This is in general agreement with the TSS analysis carried out before. The presence of large quantities of silt and clay is also due to the proximity to the Arabian Sea, which carries fine sediments in the monsoon season.

Except for the Sat Pul station, other stations have similar kind of soil, with Sat Pul station foundation soil has greater percentage of Sand.

Figure 2. 78: Grain Size Analysis – Panju Island Station

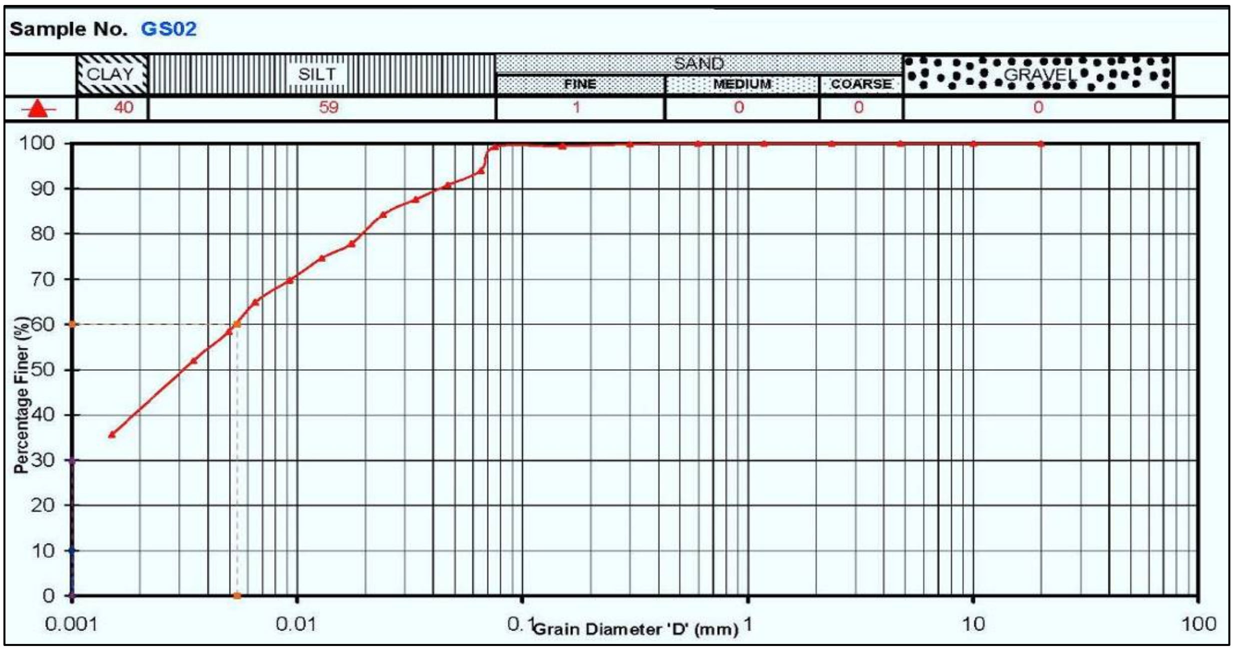


Figure 2. 79: Grain Size Analysis – Gaimukh Station

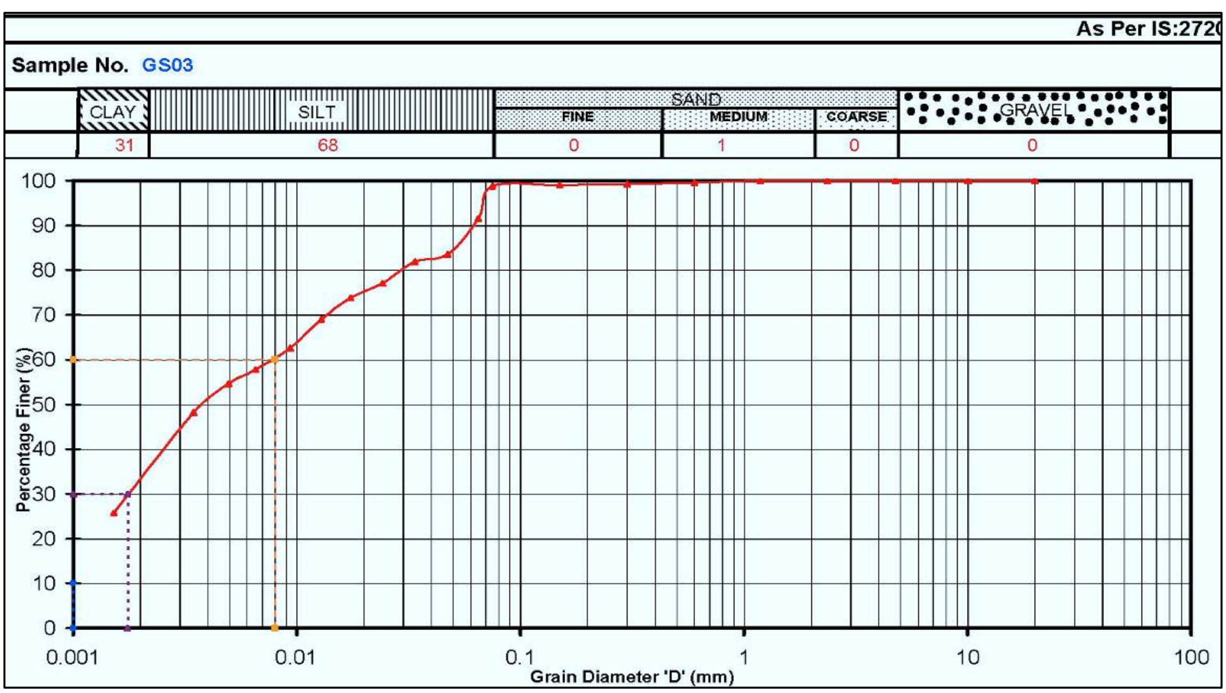


Figure 2. 80: Grain Size Analysis – Kasheli - Station

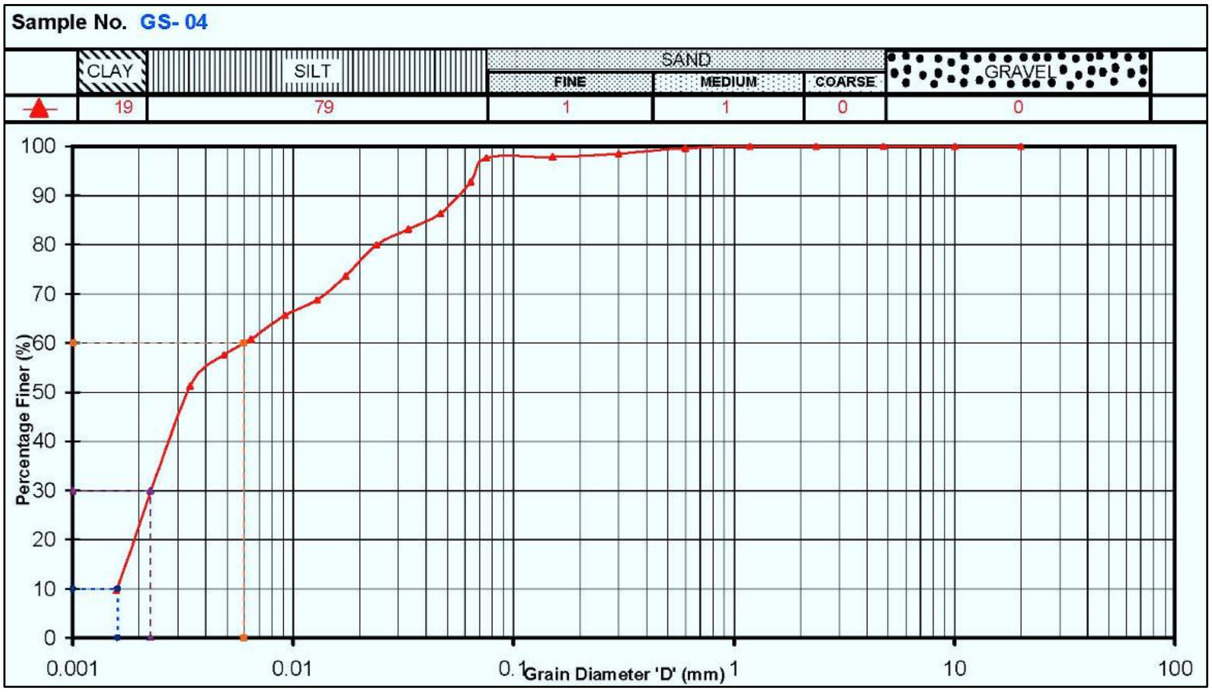


Figure 2. 81: Grain Size Analysis – Sat Pul Station

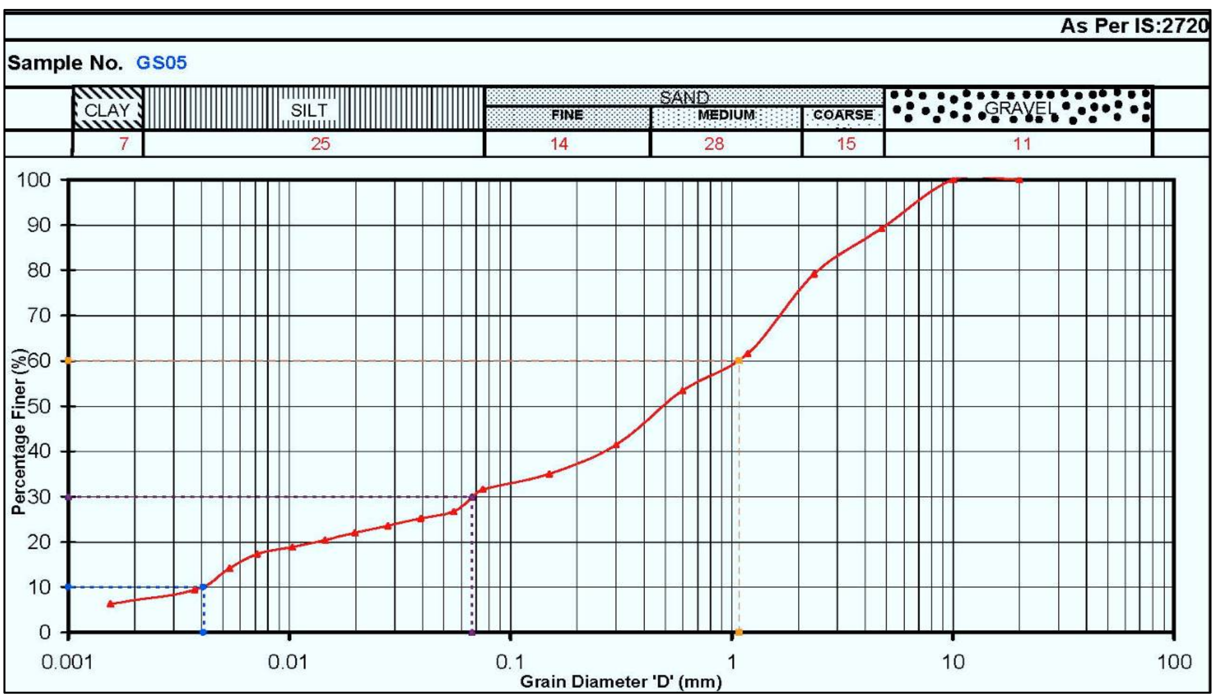
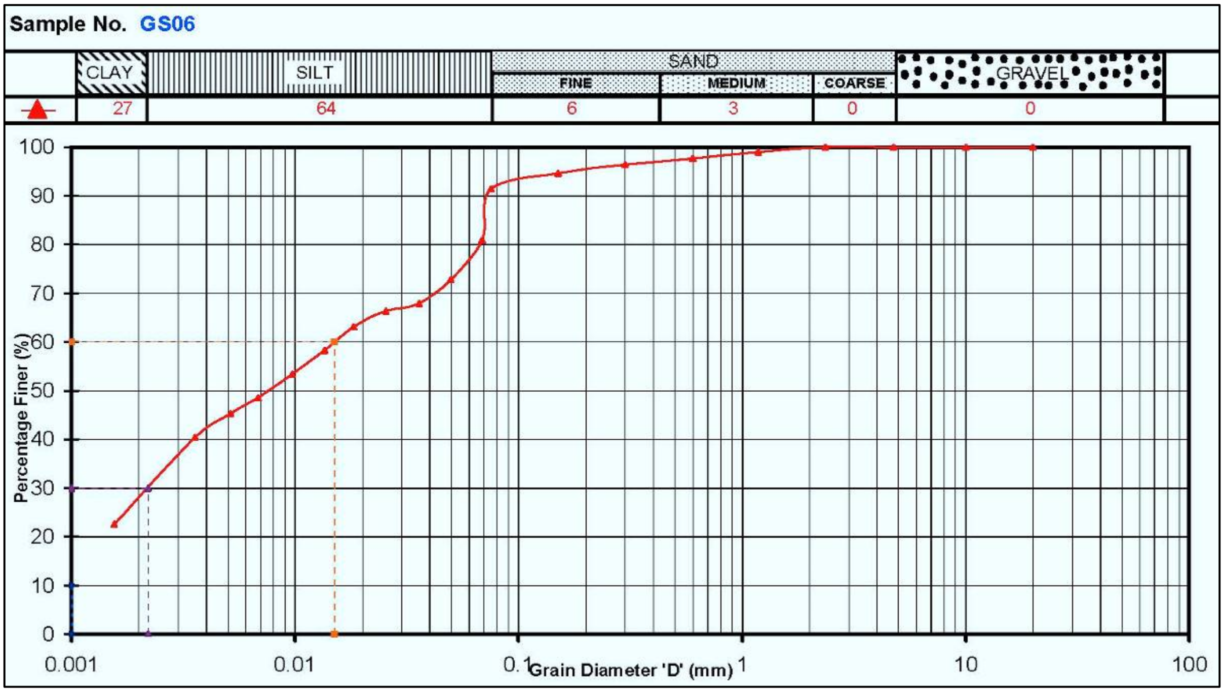


Figure 2. 82: Grain Size Analysis – Kalyan Station



2.7 Tidal Heights

The tidal heights obtained from 4 tidal station along the river namely, Panju Island, Gaimukh, Satpul and Kalyan stations for design of the structures and determination of the top level of the Jetty/Platforms, tidal heights are presented in Chapter 6 on Designs. The extreme station tidal heights and one in between is presented below, as assessed by the consultants based on collected data and Model study

Station Name:		**Vasai (Panju Island)**
Mean High Water Spring (MHWS)	:	+ 5.45 m
Mean High Water Neap (MHWN)	:	+ 4.30 m
Mean Low Water Neap (MLWN)	:	+ 1.85 m
Mean Low Water Spring (MLWS)	:	+ 0.32 m
Mean Sea Level (MSL)	:	+ 2.63 m

Station Name:		**Gaimukh**
Mean High Water Spring (MHWS)	:	+5.25 m
Mean High Water Neap (MHWN)	:	+4.20 m
Mean Low Water Neap (MLWN)	:	+ 2.05 m
Mean Low Water Spring (MLWS)	:	+ 0.52 m
Mean Sea Level (MSL)	:	+ 2.03 m

Station Name:		**Satpul**
Mean High Water Spring (MHWS)	:	+5.21 m
Mean High Water Neap (MHWN)	:	+4.17 m
Mean Low Water Neap (MLWN)	:	+ 2.03 m
Mean Low Water Spring (MLWS)	:	+ 0.42 m
Mean Sea Level (MSL)	:	+ 2.01 m

Station Name:		**Kalyan**
Mean High Water Spring (MHWS)	:	+ 5.20 m
Mean High Water Neap (MHWN)	:	+ 4.15 m
Mean Low Water Neap (MLWN)	:	+ 2.01 m
Mean Low Water Spring (MLWS)	:	+ 0.31 m
Mean Sea Level (MSL)	:	+ 2.01 m

3 Fairway Development

3.1 Proposed Class / Type of Waterway

3.1.1 Classification By Inland Water Authority Of India (IWAI)

The Inland Water Authority of India (IWAI) defines the waterway into various classes based on the requirements and the waterway condition, enabling navigation for majority of the time. The waterway is classified in the following categories for safe plying of self-propelled vessels up to 2000-ton Dead Weight Tonnage (DWT) and tug-barge formation in push-tow units of carrying capacity to 8000 tons. The classification applicable to rivers is given as

Table 3. 1: Waterway Classification By IWAI Regulations, 2006 Notified In Part – III, Section 4 Of The Gazette Dated 20-26, January, 2007

Waterway Classification	Water Depth (m)	Bottom Width (m)	Bend Radius (m)	Vertical Clearance (m)	Horizontal Clearance (m)
Class - I	1.20	30.00	300.00	4.00	30.00
Class - II	1.40	40.00	500.00	5.00	40.00
Class - III	1.70	50.00	700.00	7.00	30.00
Class - IV	2.00	50.00	800.00	10.00	50.00
Class - V	2.00	80.00	800.00	10.00	80.00
Class - VI	2.75	80.00	900.00	10.00	80.00
Class - VII	2.75	≥ 100.00	900.00	10.00	100.00

In addition, the IWAI specifies, the vertical clearance for power cables or telephone lines or cables for any transmission purpose for all the classes of waterways mentioned above,

i. Low voltage transmission lines including telephone lines – 16.50 meter
ii. High voltage transmission lines, not exceeding 110 KV – 19.00 meter
iii. High voltage transmission line, exceeding 110 KV – 19.00 meters + 1 cm extra for additional KV.

Finally, IWAI recommends that in case of underwater pipeline, power cables and other cables, norms to be followed would be dictated by site conditions.

IWAI indicates that the classification shall be effective only if,

a. The minimum depth is available for minimum of 330 days
b. The vertical clearance of the cross structures over the waterway should be available at least in central 75% of each of the spans.

3.1.2 Comments On The Classification By Inland Water Authority Of India (IWAI)

This 2006 Gazette appears to be based on basic assumptions that are both rudimentary and conservative. The width in a channel on the bend in the channel is determined not only by the size of the vessel but the speed at which it is moving. Often times in natural channels the bends are fixed and altering them is not practical. However, the same bends could be used for larger vessels with certain restrictions, which could be imposed on a natural waterway. Therefore, in order to follow the mandates of Table 3.1 the size of vessels for each of the category needs to be defined as well. Presumably, IWAI in the table 3.1, is trying to fix the length of the vessel based on the bend radius criteria. However, the method is appearing to be too crude. In addition, there is no mention of the Passenger vessels and Ro-Ro vessels in the Gazette. The entire focus is on the cargo movement. Therefore, the applicability of such gazette to a predominantly passenger waterway may be questionable.

In the more advanced countries with more prevalent Inland water transportation, continuous research is carried out for upgradation of the waterway norms so that more scientific correlation between the various operating parameters are established.

In the next sections some of these theories and practices would be enumerated.

3.1.3 Bridge Administration Manual US Coast Guard

3.1.3.1 Navigational Concepts And Clearances

The U. S. Army Corps of Engineers (USACE) is responsible for designing, establishing, and maintaining federal project channels that have been authorized by Congress. Their manuals provide excellent guidance for the planning, layout, and design of deep-draft and shallow-draft waterways, and they may be useful when considering proposed bridge locations and clearances. (See USACE Engineer Manuals EM-1110-2-1611 and EM-1110-2-1603).

Open-river navigation is normally preferred by commercial towboat operators since it often eliminates delays encountered in passing through locks. However, restrictive bridge clearances and movable-span bridge opening schedules often discourage commercial navigation even on an open river system.

a. Maintenance of a river system can also be a major challenge due to constant changes in channel width and depth and in some cases channel alignment. These potential changes are particularly important when considering bridge locations and clearances.

Canalized streams involve construction of locks if dams and anicuts are also located to maintain adequate depths for navigation during periods of medium or low water flows. These waterways normally have greater channel width and depth.

Intra-coastal waterways have been developed principally to assist commercial navigation by providing protected navigation along the East and Gulf Coasts of the United States. In recent years, these waterways have also become favorite routes for recreational vessel traffic.

No distinction shall be made between commercial and recreational vessels, nor shall the use or purpose of a vessel on the waterway be considered as a basis for making any such distinction. Increase in the number and size of recreational vessels is particularly significant regarding bridge clearances along the Intracoastal Waterways and the coastal river systems.

Most federally-authorized inland and coastal waterways have been designed to accommodate commercial barge tows consisting of a towboat pushing one or more barges. This is known as a “composite unit” when the barges are rigidly connected by wires or chains causing them to react to sea conditions as one unit.

The tow speed and direction are controlled by the towboat, which is normally positioned behind the barge(s) being pushed. The length of these tows may be one barge plus the towboat (150’-350’) or may be more than 1200’ with multiple barges.

The amount of control maintained by the towboats depends on their size, power, and maneuverability. Long tows often use some type of bow thruster or control units. These are independent power units located in the bow or stern of the towboat or attached to the lead barge. These units help control the direction of the bow or front ends of the tows. Most towboats are also equipped with twin propellers and large flanking rudders to assist in maneuvering through sharp bends and narrow bridge openings. This ability to maneuver, however, varies greatly and must be carefully considered when evaluating proposed bridges along meandering river streams. The movement of a vessel is affected by the power of its propulsion unit, the size and location of its rudders, the underwater design of the vessel, and the direction and velocity of currents, wind, ice drift, and channel dimensions.

The pivot point of a vessel is normally about one-third of the distance from the bow to the stern. In other words, a vessel’s stern maneuvers right and left while the bow remains fairly constant.

This characteristic makes vessel handling similar to that of pushing or maneuvering a wheelbarrow. However, a towboat does not normally follow the barge track when going around bends or negotiating turns.

This particular navigational characteristic, known as the swept path of a vessel, is recognized by the USACE when it designs bends in waterways. Such waterways are normally widened to compensate for the movement of large vessels, especially tugs with tows.

The effect of currents on vessels is a particularly important factor when considering bridge clearances. Tows and all other vessels are affected by the velocity and alignment of currents relative to the path of the vessel.

Currents moving at an angle to the path of the vessel are referred to as crosscurrents. These currents can be encountered in river crossings, in bends, near side or divided channels, in the entrance to canals and in approaches to locks and bridges.

Open-river navigation, in particular, recognizes and takes advantage of the current flows, which normally move from the concave bank of one bend across the descending stream to the concave bank of the next bend.

The straight reaches between alternate bends in a meandering stream are called crossings. Tows leaving one bend, usually from along the concave bank, must cross the stream toward the opposite bank to approach the concave bank of the next alternate bend. This series of bends in a meandering stream is nature's way of controlling the flow of water (much like the slalom movements of skiers coming down a steep mountain). Vessel operators normally follow this natural current flow as they descend a river.

If a bridge alignment is located close to or within a bend in a waterway, the crosscurrents may create significant difficulty in transiting through a bridge. This will necessitate increased horizontal clearances and bridge alignments that are perpendicular to the actual current flow to ensure the safety of navigation.

As a general rule, bridges should not be located in a bend or where crosscurrents can be expected. When more than one bridge is required in a given locality, the bridges should be close together with piers and fender systems in line or far enough apart to permit tows passing one bridge to become properly aligned for passage through the next bridge

The required bridge horizontal and vertical clearances to accommodate a given design vessel (the largest vessel expected to use the waterway) should be determined based on the following factors in descending order of importance:

i. Traffic pattern (one-way or two-way traffic)

ii. Design vessel beam, length and vertical height

iii. Channel cross-section shape; current speed and direction

iv. Quality and accuracy of aids to navigation

v. Variability of channel direction and current flow

3.1.3.2 Waterway Designs

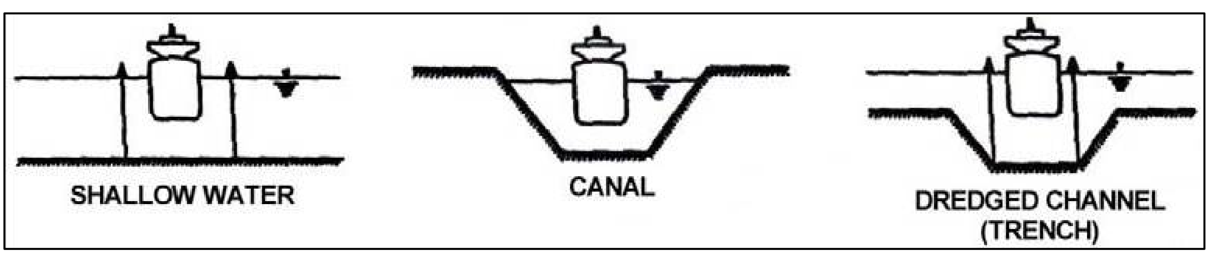
Navigation channels can be classified into several types of cross sections.
Understanding these types may help in understanding vessel navigational impacts. Figure 3-1 illustrates the three primary types of channels: shallow water, canal and trench, which are defined as follows:

Shallow Water - Wide, unrestricted waterways without channel banks, found near the ocean end of port entrance channels and in large bays, usually provided with range markers and channel edge buoys. Vessel movements are influenced by substantial bottom effects but negligible bank forces (cushion and suction). Strong ship yawing forces (sideways movement) are often encountered from crosscurrent effects and wave action.

Canal - Narrow, fully restricted channels with clear and visible banks, often with minimal or no aids to navigation. Vessels experience negligible yawing forces, since currents are aligned with the channel, except at turns. Strong bank effects (cushion and suction) result in vessels often being forced onto one side or another of the channel centerline.

Trench - Dredged or open-type restricted channels, intermediate between canals and shallow water, with submerged banks on each side, usually provided with range markers and channel edge buoys or beacons. Vessel yawing forces from crosscurrents and wave effects are often present. Waves and winds are often a factor in navigation.

Figure 3. 1: Three Primary Types Of Channels



3.1.3.3 Determining Horizontal Clearance Requirements

If a channel has been established, the authorized clearances for a new or modified bridge should completely span the authorized channel within practical engineering limits. The horizontal clearances for bridge piers over other waterways should be based on the following data and calculations:

- Determine whether one-way or two-way vessel traffic is anticipated through the bridge site.
- Ascertain the length and width (maximum beam) of the largest vessels or composite barge tows plying the waterway. This is known as a design vessel or design ship.
- Determine the maximum currents for the waterway at the bridge site. Tidal currents are normally available from the National Oceanographic and Atmospheric Agency (NOAA). Tidal Current Tables and river discharge current data are published by the U. S. Geological Survey (USGS).
- Determine the type of channel cross section at the bridge site (canal, trench or shallow water).
- Determine whether there are extensive or little or no aids to navigation near the bridge site. Note that with a waterway designed for two-way traffic, there are always extensive aids to navigation.
- Using the above information, and the Table 3.2 (Straight Reaches of a Waterway, Without Crosscurrents, Having One-Way Vessel Traffic) or Table 3.3 (Straight Reaches of a Waterway, Without Crosscurrents, Having Two-Way Vessel Traffic). Determine the beam multiplier. Multiply the beam multiplier times the maximum beam of the design vessel. This will provide the minimum horizontal clearance needed for a proposed bridge across one-way and two-way, straight waterways.

Table 3. 2: Straight Reaches Of A Waterway Without Crosscurrents, Having One Way Vessel Traffic

Maximum Current (Knots)	Beam Multipliers (Extensive aids to navigation seen near the bridges site)			Beam Multipliers (Little or no aids to navigation seen near the bridges site)		
	Canal	Trench	Shallow water	Canal	Trench	Shallow water
0.0 - 0.59	2.5	2.75	3.0	3.0	3.5	3.5
0.6 - 1.59	3.0	3.25	4.0	3.5	4.0	4.5
1.60 - 3.0	3.5	4.0	5.0	4.0	5.0	5.5

(Source: Bridge administration manual of U.S. coast guard)

Table 3. 3: Straight Reaches Of A Waterway Without Crosscurrents, Having Two Way Vessel Traffic

Maximum Current (Knots)	Beam Multipliers (Normally two-way traffic requires extensive aids to navigation)		
	Canal	Trench	Shallow water
0.0 - 0.59	4.0	4.5	5.0
0.6 - 1.59	4.5	5.5	6.0
1.60 - 3.0	8.0	6.5	8.0

(Source: Bridge administration manual of U.S. coast guard)

- For example, for one-way vessel traffic with a standard barge width of 14 m in a one-way, straight canal channel with tidal currents of 1.5 knots and little or no aids to navigation, multiply

14 m (beam) x 3.5 (beam multiplier) = 49 m (horizontal clearance). This would be similar to the Intracoastal Waterway along the East Coast of Florida, which has a channel width and a Guide Clearance of 125 feet (38.10 m).

- For example, for two-way vessel traffic with a standard 14 m wide barge tow meeting a similar tow in a trench channel with tidal currents of 3.0 knots, multiply 14 m (beam) x 6.5 (beam multiplier) = 91 m (horizontal clearance).

The above calculations can be used to determine the minimum horizontal clearance requirements for waterways used by commercial and/or recreational vessels.

The horizontal clearance requirements for bridge projects involving large deep-draft waterways with maximum currents greater than 3.0 knots can be developed using computer models and Ship Simulator Design studies. Computer modeling and ship simulator studies are available through various institutions if the horizontal clearance proposed is questionable.
Bridge crossings should be designed to be a minimum distance from bends in a waterway equal to five times the design vessel length for the waterway. Experiments conducted by the USACE have determined that this distance is needed to allow a tow or large vessel to align itself with the designated channel for safe passage through a bridge opening.

Proposed bridges should be designed to fully span waterways, if they are in a bend.
If a full span is not feasible and a federal channel is involved, greater consultation is to determine the exact channel width, including wideners, at the proposed crossing location and any anticipated increases in channel width.

Since the swept path of a vessel making a turn in a bend of the waterway is wider than the path in a straight channel reach, a greater horizontal clearance is required in turns and bends.

A modeling or ship simulator design study to determine the necessary horizontal clearance requirements may be required if the proposed bridge is in a bend and cannot fully span the waterway. In some instances, proposed horizontal clearances can be tested by placing temporary markers in the waterway to delineate the pier or fender locations at the bridge site and by arranging for a commercial tow or a Coast Guard vessel to transit the waterway. Comments from other waterway users sometimes can be invaluable as experience is the substitute of none.

3.1.3.4 Determining Vertical Clearance Requirements

High-level fixed bridges, whenever practicable, to minimize potential conflict between land and waterborne modes of transportation is necessary. As discussed earlier a balance between transportation modes is essential to further the strategic goals of tying India together through improvement and renovation of our national transportation infrastructure.

The vertical clearance requirement for fixed bridges is often a critical issue, which must be fully investigated and determined during project development and the bridge permitting process. The concept of a design vessel helps to establish vertical as well as horizontal clearance requirements. Waterway surveys before any cross structures are built in all cases would go a long way to help determine vertical clearance requirements. These surveys will help identify existing and prospective vessels using the waterways that exceed established vertical guide clearances, and possibly require an increased clearance for a planned bridge.

The navigational evaluation should include a review of all cross structures between the proposed site and other fixed bridges, both upstream and downstream, to determine the minimum vertical clearances available on the waterway. If a proposed fixed bridge will replace an existing cross structure, which has unlimited vertical clearance, it is necessary to determine whether the proposed bridge will accommodate existing and prospective navigation.

Discussions with vessel operators on the waterway, local marinas, and shipping companies will help in defining the mast heights of vessels using the waterway.

State and local environmental permitting agencies can provide information about planned marine facilities on the waterway that may attract larger vessels in the future.
Safety factors for variable wave heights created by wakes from passing vessels and wind directed currents for exposed bridges, as well as potential sea level rise, should be considered during these evaluations.

In other cases, especially for shallow-draft waterways, the established Guide Clearances may influence the type and size of vessels using a particular waterway. This is especially true with large recreational craft such as sailboats for which mast heights are often designed to allow passage under fixed bridges in a certain market area.

The implementing authorities does not attempt to establish the exact number of vessels that must be able to pass beneath a proposed fixed bridge. Under the bridge statutes we must ensure that bridge proposals meet the reasonable needs of navigation, not all of the needs. However, every effort should be made to reasonably accommodate existing and prospective navigation that may use the waterway in the future.

In some cases, alternate waterway routes may be available which will have minimum impact on navigational transit times.

These vessel restrictions and the proposed mitigation should be fully described in the Navigational Evaluation report of the waterway.

3.1.3.5 Special Considerations For Determining Bridge Clearances For Inland River Systems

The swept path of a tow, or the width of the corridor a tow must occupy when transiting a particular reach of the river, is especially important when considering the placement of bridge piers. Unlike smaller canalized streams, open river navigation can extend from bank to bank well beyond the authorized channel limits. This is especially important when evaluating bridge clearances and pier locations for two- way traffic conditions.

Pooled rivers with locks and dams tend to have channels that are more stable in both depth and location. However, not all locks and dams are alike. Some structures are designed to allow tows to pass over the dam and bypass the lock when the river reaches high water stages. This seasonal variation may result in two navigable channels, one for high water and one for low water stages, normally on opposite sides of the river. Understanding these conditions, including where tows wait for lockage, is important when considering the proposed location of navigational spans and bridge piers.

In establishing the proper horizontal clearances for bridges over fast flowing rivers, the most important item is often proper pier placement based on the actual channel location and dimensions used by tows transiting the waterway.

As previously discussed, vessels use the natural current flow of a descending river to navigate. This requires the location of the navigational openings to be over the actual usable channel.

These effective horizontal clearances must be wide enough to accommodate the full width of the corridor that vessels require when transiting a particular reach of a waterway and should be measured normal to the axis of the channel. This will help compensate for channel skew.

Whenever there are multiple bridges along a waterway, the concept of “running the bridges” must be considered. Tows do not run through bridges one at a time. Instead, they navigate a reach of the river and often are unable to stop quickly if the channel is obstructed.

Therefore, if several bridges are in close proximity, it is important to understand how the river pilots approach the bridge openings, what navigational “marks” are used to transit several bridges, and whether a proposed new bridge will be compatible with these navigational concepts or may compromise safe bridge transits.

River pilots and the commercial towboat industry are the primary source of navigational information for river systems and should be consulted whenever new bridge construction and major modifications to existing bridge structures are being considered.

A. Dimension and Draught of the Navigational Channel

The draught in the channel determines the vessel draught; hence deeper depth in the channel, draught of the vessel would increase proportionally. However, if the depth were created artificially, there would be consequential cost on account of maintenance dredging. Therefore, an optimum depth for accommodating the biggest vessel and having the lowest maintenance must be chosen.

The horizontal clearance under the bridge required for the design vessel depends on the waterway alignment, (i.e. whether it is on a straight reach or bend), channel cross section at the bridge, maximum tidal current at the bridge site and on the type of vessel traffic (one-way or two-way). Considering all above parameters, horizontal clearance requirements for one way and two-way traffic are tabulated in Table 3.2, and 3.3.

Considering a current of 1.59 knots or 0.8 m/s, and no cross currents due to the confined dimensions of the canal, the width of the Canal would be 4.5 times the width of the vessel.

In addition to the above guidelines, oftentimes model studies and maneuvering studies are carried out, to see the impact and behavior of the vessels under the extant conditions.

Lastly the length of the vessel is generally constrained by the radius of the sharpest bend it negotiates, during its Journey. In the present case the radius of the smallest bend is 257 m and the largest one is about 5045. These parameters would be utilised to determine the vessel length in the next section. Hence, the width and the depths in the channel are dependent on various factors some of which have been discussed above. They are,

- Size of the vessel or the convoys of the vessel
- Waterway layout including its geometry
- The speed of the vessels
- Obstructions in the waterway etc.

These aspects are discussed in the following sections.

3.1.3.6 Vessel Size

The vessel size is the first and the foremost aspect that needs to be addressed for determining the waterway dimensions. Vessel size of the present as well as the future requirements would be clearly identified in the beginning for designing and planning of the waterway peripherals. In other words, though waterway could be designed in phases, the structural design of the berthing structures and other permanent structures would have to be fixed at the beginning only with a futuristic approach. Ideally, a modular approach is most sustainable. In this the components are built in a modular fashion based on the demand. Therefore, the structural components are designed for the biggest design vessel that could possibly use the water way. However, the length of the berths and the other structures, such as the dolphins, their number and pitch, shall be based on the present requirements. And as the length of the vessel increases additional infrastructure could be added.

Accordingly, the cross structures and bridges (the horizontal and vertical clearances) is being used for design for the future vessels. The waterway design is akin to any large infrastructure projects, and are done in a phased manner, to achieve the master plan scenario. Hence, the master plan must be agreed from the beginning and so also the phases, that are needed to achieve the same in a fixed or variable time frame. Hence, the waterway developmental stages are to be clearly defined and the approximate time horizon for such implementations may be earmarked.

In the first phase of the development in the Vasai creek, only passenger traffic is considered. However, enough flexibility would be built in the system so that at a later stage the waterway may be utilized for Ro-Ro / cargo movement as well. In essence, the design vessel would be selected with a firm view on the future development.

Vessel type is another factor that influences the waterway dimensions, viz. whether the vessel is self-propelled, pusher or towed type, or may be moves in convoys akin to waterways in United States of America.

3.1.3.7 Waterway Layout & Geometry

The waterway layout and the geometry of the waterway determines the width of the waterway, at various location. In the straight reaches the width would be the least increasing with the radius of the bend and the length of the vessel.

3.1.3.8 Speed Of The Vessel

The maximum speed of the vessel in the waterway is an important parameter. With increase in the speed of the vessels, the maneuvering becomes difficult. Hence, the waterway geometry would be decided by the speed of the vessel using the waterway.

3.1.3.9 Obstructions on the waterway

Last but not the least is the cross structures and the horizontal and the vertical clearances they offer for the vessel movement.

These clearances limit the movement of the vessels as far as the width and the mast height of the vessel is concerned.

3.1.3.10 Computation of the Vessel width

In the present waterway, the minimum horizontal and the vertical clearances is offered by Vasai to Bhayander Old Railway bridge at chainage 9.344 km. The horizontal and the vertical clearances are 18.70 m and 3.43 m respectively. Clearly for the waterway to function, this bridge which is not in use needs to be dismantled, at least for 4 to 5 spans in the middle. The next is the New Vasai-Bhayander Railway bridge which offers 4.43 m vertical clearance, and a horizontal distance between piers is 52 m. The vertical clearance is reasonable in all other cross structures along the waterway. However, the Old Kalyan Bhiwandi Bridge offers a horizontal clearance of 30 m. However, since this bridge is at the end of the proposed waterway, this bridge could be neglected for calculation of the vessel width.

Following the method prescribed by the Bridge Administration Manual by the US Coast Guard, the beam multiplier of 3.0, with adequate navigation aids and a current speed of 0.8 m/s. Hence, the width of the vessel is = 40/3 ≈13.333 m. It must be remembered that these are only guidelines and are approximate in nature. Hence, a width of vessel may be fixed at 14.00 m.

3.1.4 Provisions of PIANC

3.1.4.1 Channel Width

The channel is part of the fairway (usually dredged) to allow passage of deep draught vessels as indicated in Figure 3.2 and Figure 3.3.

In many dedicated channels the A to N will be close to the edge of the channel to indicate the limits of safe navigation, but on those with a range of traffic, the fairway markers may be positioned to allow the passage of smaller vessels on either side of the dredged channel. In other cases, both the deep-water channel and the outer lanes for smaller vessels may be marked.

Figure 3. 2: Channel & Fairway Definition (Channel Bed Width + Width At Nominal Bed Level)

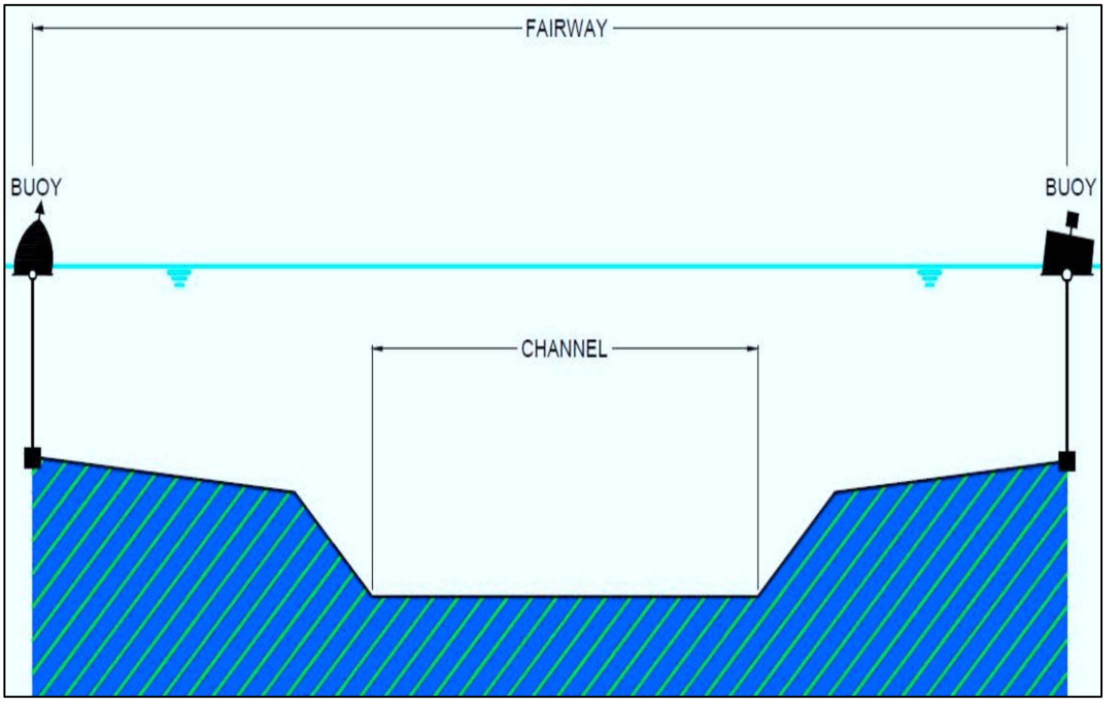
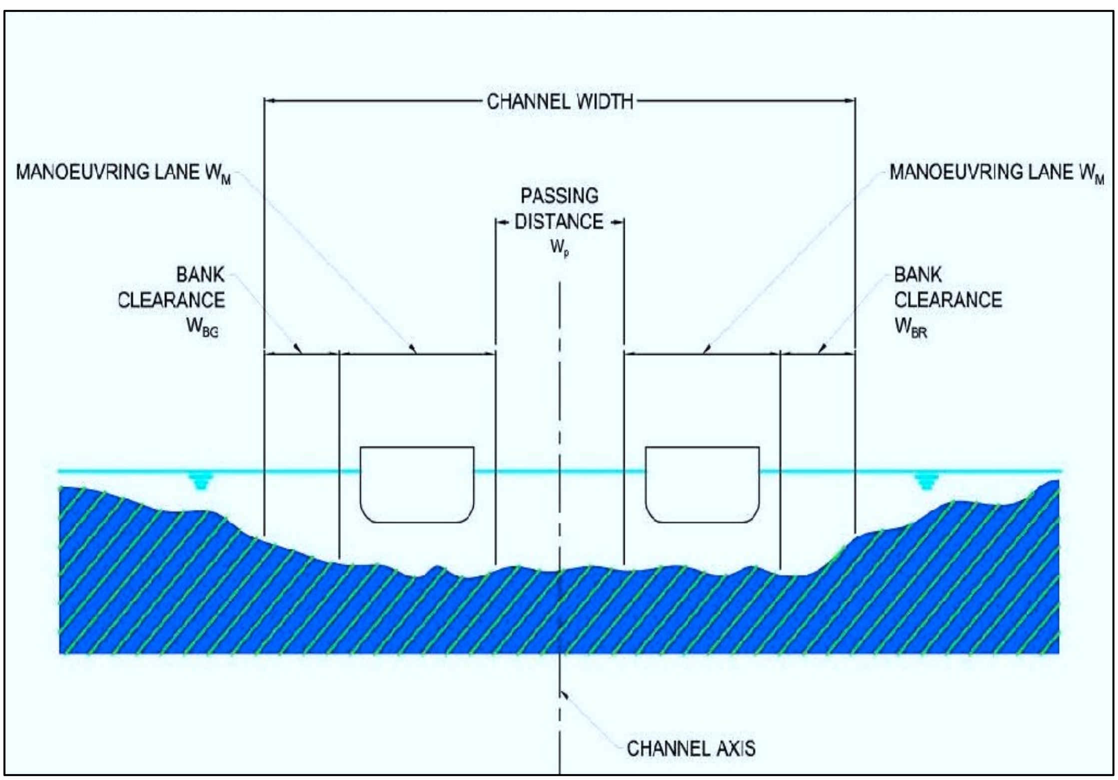


Figure 3. 3: Element Of Channel Width

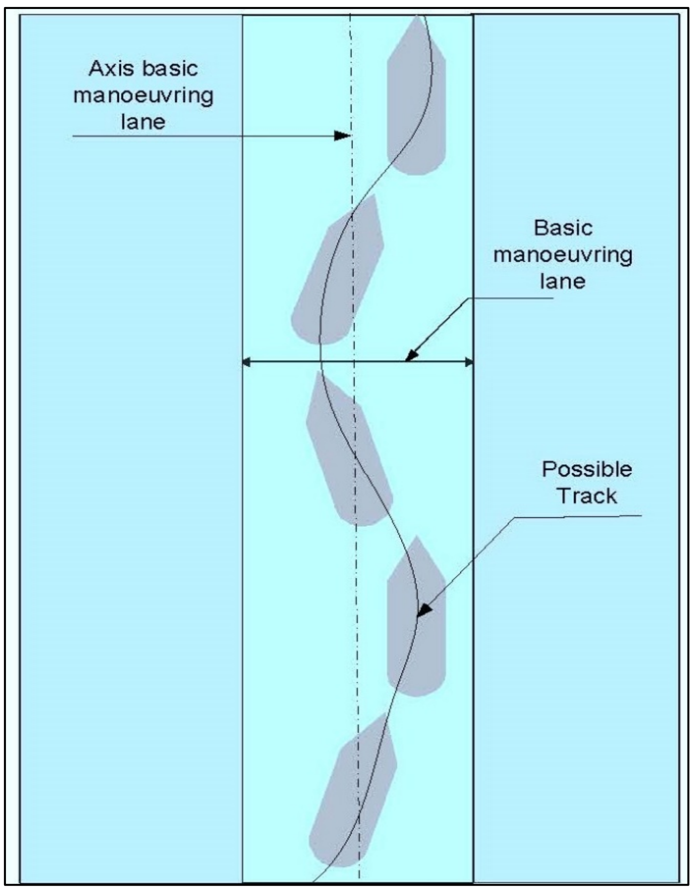


3.1.4.2 Basic Maneuverability

The dynamics of ships are such that, when under manual control (as is usually the case in approach channels) they will follow a swept path, which, in the absence of any external forces from wind, waves, current, etc., will exceed their breadth by some amount (Figure 3.4).

This is due to the speed of response of both the ship-handler in interpreting the visual cues indicating the ship's position in the channel, and that of the ship in reacting to the rudder and main engine. The width of the swept path, which is the basic maneuvering lane, will depend on a number of factors, but the key elements are:

Figure 3. 4: Basic Maneuvering Lane



- The inherent maneuverability of the ship (which will vary from ship to ship and with water depth/draught ratio)
- Ability of the ship-handler
- Visual cues available to the ship-handler
- Overall visibility
- Of these, the first two is the most important since the other two can be dealt with by suitable A to N both outside (e.g. buoys) and onboard the ship (e.g. radar).

The ship maneuverability basically consists of the following three characteristics:

a. Course keeping ability with low rudder angles $\delta_R < 5$ deg.

b. Course changing ability with medium rudder angles $\delta_R = 10$ to 20 deg.

c. Turning ability with a hard-over rudder

In the course keeping operation (under manual control or active auto pilot) in the channel, the ship will have some amount of drift (lateral deviation) from its course caused by unsteady turbulence effects, even if in calm water. Due to this drift, the ship has a 'snaking' trajectory in the channel. The magnitude of drift depends on both the inherent maneuverability and the ship handling. The ship drift may be hard to detect for a small amount of deviation, although an auto-pilot may detect it. However, the ship-handler can recognize the drift when the lateral deviation from the channel center line becomes considerable. This detectable drift ("snaking" amplitude) should be the primary design consideration for the determination of channel width as the basic maneuvering lane. With skilled monitoring of a ship's passage, it is possible to monitor lateral drift from a planned course to within a beam width of the ship, depending on the beam of the ship.

3.1.4.3 Environment Forces

A. Cross Winds

Cross wind effects depend on:

- Ship speed
- Windage of the vessel (relative to lateral submerged area)
- Depth/draught ratio (because a ship's resistance to lateral motion increases as the depth/draught ratio approaches unity since wind causes less drift at small under keel clearances)
- Wind speed and direction relative to the ship

B. Cross Currents

Cross-currents affect a ship's ability to maintain a course, while longitudinal currents affect its ability to maneuver and stop. The maneuverability of a ship changes as its depth/draught ratio approaches unity. As a result, its ability to cope with currents will also change as the water depth becomes shallower. Cross-currents affect the course keeping motion similar to cross winds. However, in order to keep a straight course under cross-currents, the ship should be operated to run obliquely to the current, with the rudder amidships, to compensate for the current velocity perpendicular to the ship's desired course (i.e. the line of the channel).

C. Waves

Waves will naturally influence the channel depth design as a result of the ship's vertical motions (pitching, heaving and rolling). However, they may also have effects on the width design. The ship generally makes a yawing motion in waves due to unsteady wave forces. Therefore, the channel width should include the drift due to such yawing. In addition to unsteady wave forces, there are steady 2nd-order wave drift forces, which are similar to wind forces. In following waves, course instability may occur (which may result in broaching) in the case of long waves and relatively small vessels. These wave drift forces may be considered depending on the local wave conditions.

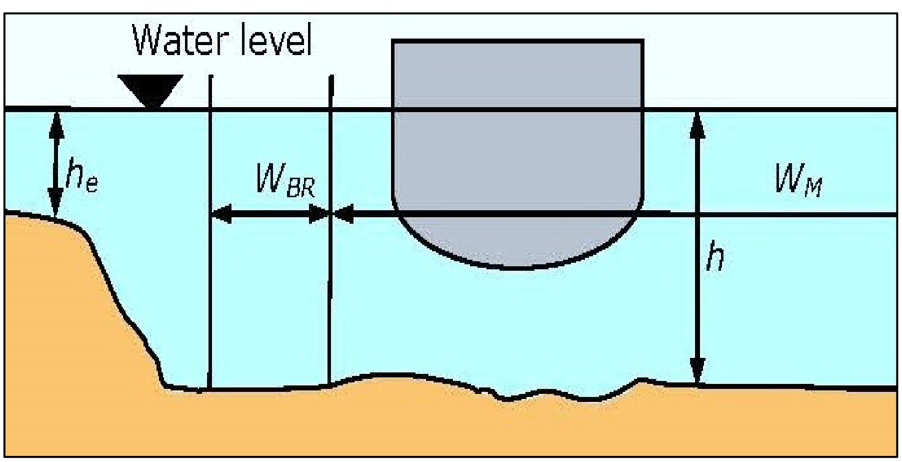
D. Bank Clearances

When a ship navigates in the vicinity of a channel edge, flow around the ship's hull varies and becomes laterally asymmetrical with respect to its longitudinal center line. This generates hydrodynamic forces due to the asymmetrical flow. To avoid uncontrollable situations in a channel with underwater banks, additional width outside the maneuvering lane is required (see Figure 3.5).

Important factors are:

- Ship speed
- Bank slope or bank structures
- Cross-section/symmetry of the channel
- Under keel clearance (ratio *h*/ *T*)
- Distance between the ship and bank

Figure 3. 5: Sloping Channel Edges And Shaols (Bank Clearances)



Ship and Ship Interaction

Similar dynamic interaction forces due to asymmetrical flow also act on two ships when they are transiting close to each other. The ship-ship interaction should be considered both for meeting (ships travelling in opposite directions) and overtaking maneuvers.

3.1.4.4 Channel Width

With the above factors and the assigning various values as per the table 3.5 of the PIANC guidelines the singe way channel would be equal to 4.9 B and the two-way traffic would require a 6.7 B. Hence, the channel width considering two-way traffic = 6.7 m x 14m = 93.8 m say 100 m. Hence a width of 100 m shall be provided for the entire stretch of the river for allowing two-way traffic. This is valid for a vessel with a Beam of 14.00 m. The other dimensions of the ship will be dealt in the ship design section.

3.2 Details Of The Shoals

3.2.1 Location And Length Of The Shoals

As per details in Annexure – B, there exists a shoal in the beginning, starting at chainage 0.000 Km extending up to approximately 0.500 Km, with depths vaying between 0.0 m to 2.2 m.

Figure 3. 6: Shoal In The Beginning Of The Channel

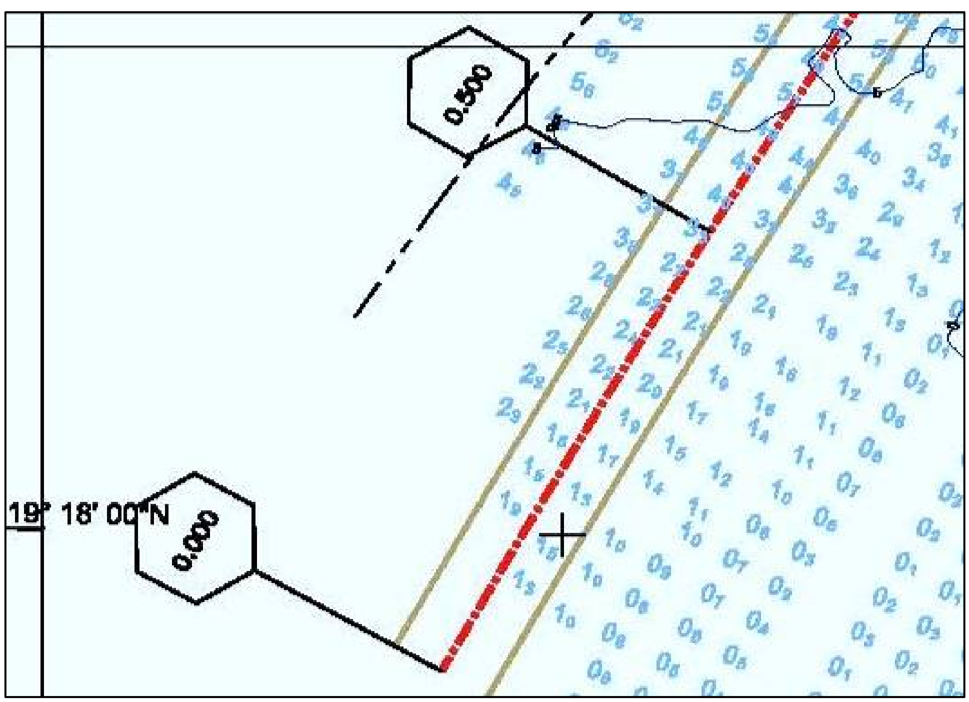
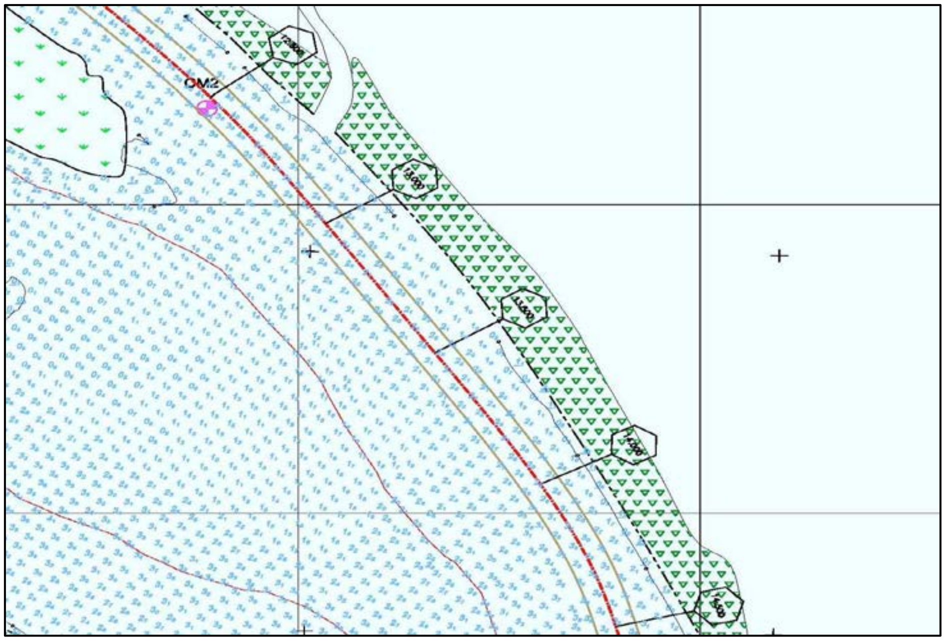


Figure 3. 7: Shoal Between Chainage 12.800 Km & 14.200 Km



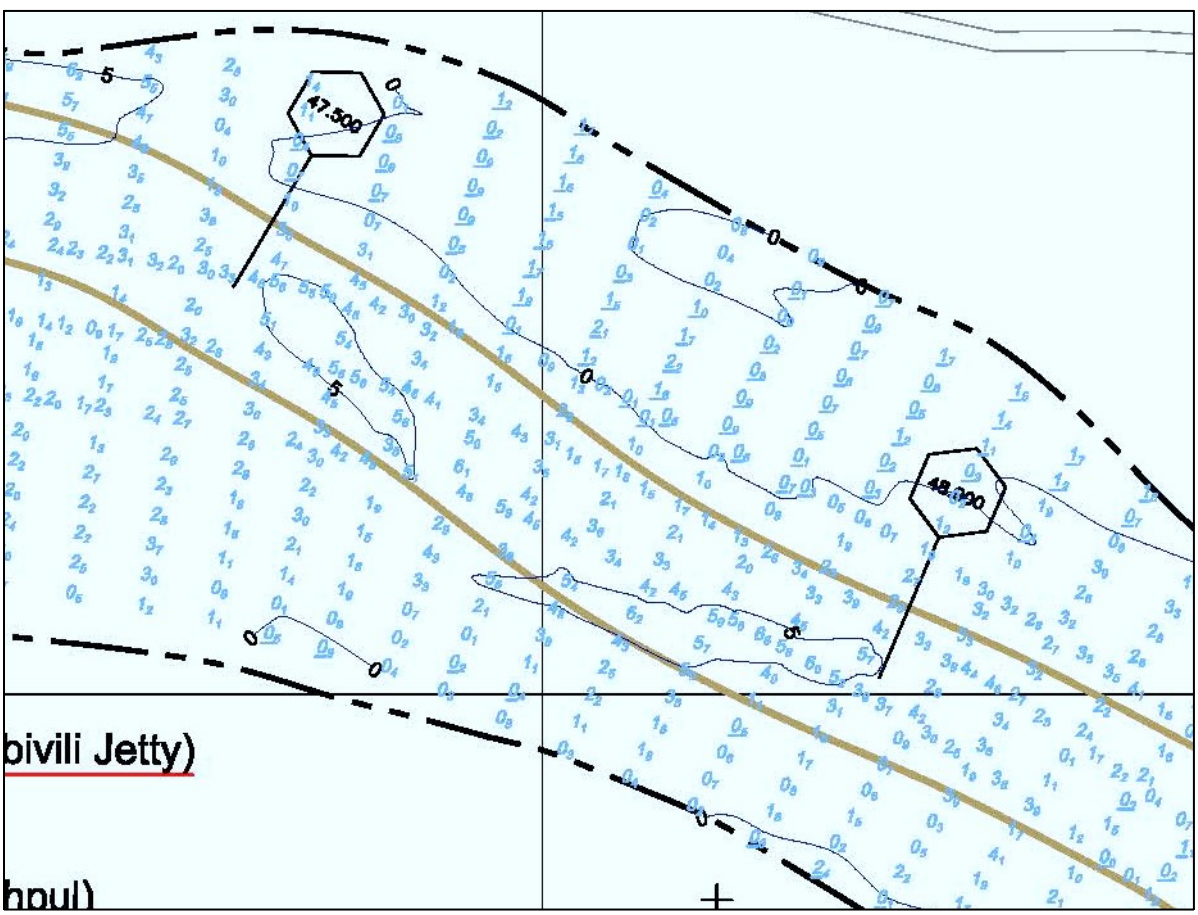
The second shoal in encountered as one moves upstream. It starts at chainage 12.750 km and continues up to chainage 14.200 km.

The depth along the Shoal varies between 2.0 and 2.90 m and extends to cover the entire channel as shown in the Figure 3.7 above. The third shoal appears at about chainage 48.000 km and consists of areas which gets exposed in certain stage of the tide.

The following google imageries shows the exposed shoals near the Kalyan area, lying right in the middle of the channel. These shoals are confined in a small stretch of about 500 m and indicates the lack of depths for any kind of navigation in the channel. This could be further examined in the Figure 3.9 and 3.10 which starts at chainage 47.500 km or there about.

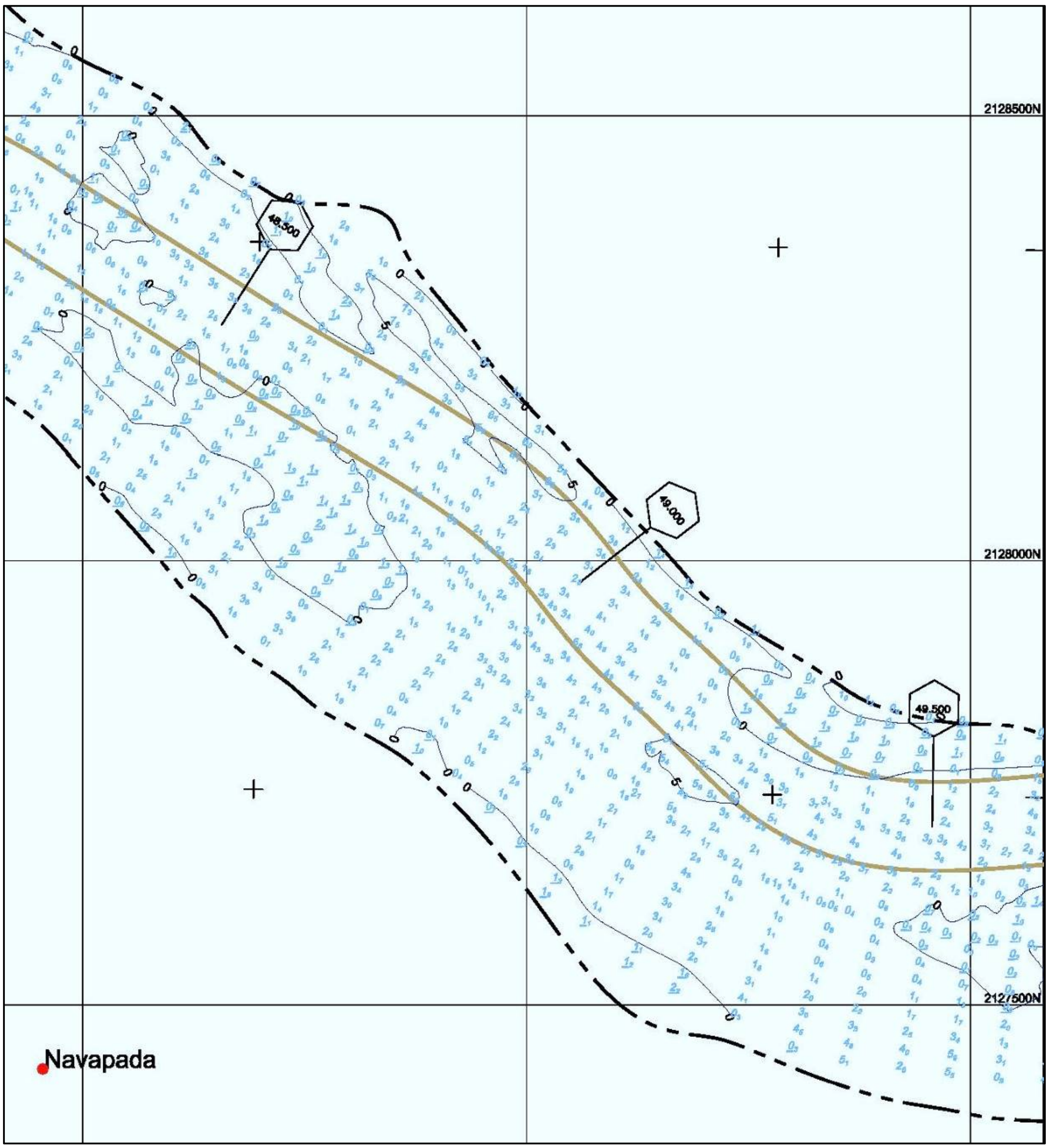
Figure 3. 8: Shoals Exposed In The Channel Near End Of The Proposed Waterway Near Kalyan

Figure 3. 9: Shoals Staring Around Chainage 47.500 Km To 48.200 Km Showing Shallow Depths



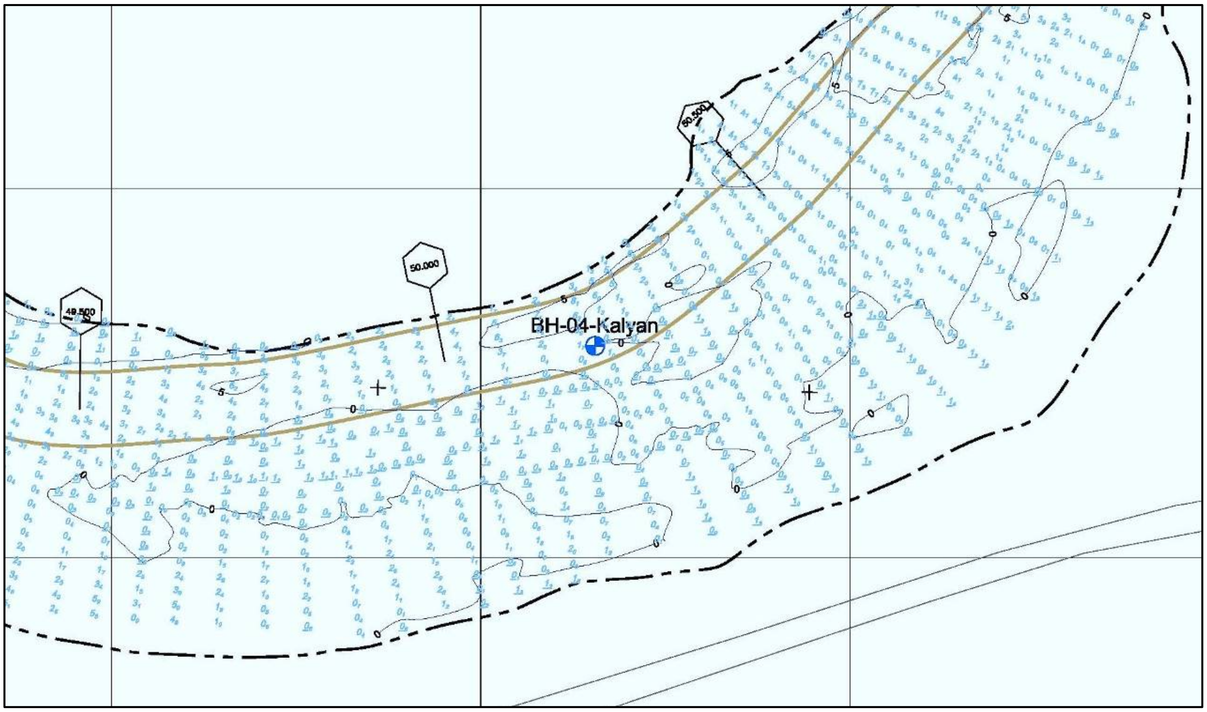
The width of the shoals is rather thin and depths are between 2 to 2.60 m CD. But as one crosses the chainage 48.000 km, the shoal covers the entire channel of 100 m as can be seen in Figure 3.9. The Figure 3.10 shows the channel from the upstream area beyond the area shown in Figure 3.9.

Figure 3. 10: Shoals Staring Around Chainage 48.200 Km To 49.700 Km Showing Shallow Depths



Depths in this area is rather low and the exposed shoals could be seen along and inside the channel. Part of the exposed shoals also fall inside the proposed channel area. This shoal area continues up to chainage 50.500 km as shown in Figure 3.11.

Figure 3. 11: Shoals Staring Around Chainage 49.500 Km To 50.500 Km Showing Shallow Depths



This is the longest shoal which extends for about 3 km with depths lesser than 0 m CD.

3.3 Waterway Hydrodynamics (Model Study)

3.3.1 Need for Model Study

The waterways unlike the roadways, are marked channels which offers the adequate depths for the movements of vessels. This entails maintenance of a dug-up channel in the water body, sufficient for the seamless movement of vessels, if the water depths are not adequate. In addition, the depth, the current, wave and other marine environment such as tide, may affect the movement of the vessels, or affect their efficiency. Further, when a deeper channel is artificially created in a shallow water zone, there is every likelihood of movement of sediments from the shallower region to the deep channel, making the channel shallower and finally making the channel unfit for movement. Hence, regular cleaning of the waterway is necessary.

Therefore, in order to ascertain the existing hydrodynamics and the altered conditions after creation of the channel by dredging, the effect of current, wave, tide on the waterway movement, siltation in the channel it is necessary to simulate the flow conditions in a mathematical model. Apart from the effects of movement of vessels the model studies would comment on the following;

1. The erosion and accretion potential in the creek
2. Shoreline changes

3. Flow vectors indicating the appropriateness of the alignment of the berthing structures

In this chapter the model study aspects in detail would be described, except for the alignment of the berthing structures, which would be discussed along with the terminal designs. The mathematical model studies were carried out by M/s DHI, New Delhi/Copenhagen, and is attached along with this report as Annexure C.

3.3.2 Scope Of Model Study

In this background, numerical modelling studies to investigate the hydrodynamic regime and sediment transport in the creek is conducted to support the potential expansion of the existing as well as the new facility inside the creek.

Accordingly, the following broad scope of numerical modelling was proposed:

1. Task 1 – Met-Ocean Data Collection and Review
   Collection and review of existing met-ocean data delivered by the client, the head supplier or the client and other relevant sources, preparation of data as input data for the numerical study and assessment of data quality for all modelling relevant input data.
2. Task 2 – Spectral Wave Model Studies, SW
   Spectral wave model will be set up and simulated for identifying wave propagation in to the estuary, for a typical season. The calibration will be based on the existing site measurements.
3. Task 3 – Siltation Studies, MT
   Suitable model will be developed for calculation of annual sediment budget in the creek. The computation shall include most vulnerable areas and the areas of erosion.
4. Task 4 – Flow Hydrodynamic - HD
   Hydrodynamic model studies for evaluating the flow regime, especially at the proposed terminal locations, for one typical season. The calibration will be based on existing site measurements of hydrodynamic processes. The HD model will be the basis for sediment transport model.
5. Task 5- Assessment of Shoreline Changes
   Appropriate model will be used to evaluate the coastal morphology and the shoreline change to demarcate the erosion as well as the deposition areas.

This discussion is based on the primary data collected at site as well as secondary data from the sources and would be considered for environmental and other statutory clearances for the proposed development. Concurrently, a detailed field campaign shall be organized for data collection and based on those data a Detailed Project Report shall be prepared for submission and help preparing strategies for detailed engineering and project implementation.

3.3.3 General Site Condition And Shoreline

3.3.3.1 Site Condition

The Ulhas River is one of the west flowing river in Maharashtra joining into the Arabian Sea. The boundary of the basin comprises of the main Sahyadri hills on the East, Westerly off shoots on the North and South and on the West a narrow opening at the end emptying into the sea. The Ulhas basin lies between North latitudes of 18º 44'N to 19º 42'N and East longitudes of 72º 45'E to 73º 48E. The Ulhas drains an area of 4,637 sq. km, which lies completely in Maharashtra. The Thane, Raigad and Pune districts fall in the basin. The important tributaries of the Ulhas River are Pej, Barvi, Bhivapuri, Murbari, Kalu, Shari, Bhasta, Salpe, Poshir and Shilar. The Kalu and Bhasta are the major right bank tributaries which together accounts for 55.7% of the total catchment area of Ulhas.

The average rainfall in the Ulhas basin is 2,943 mm. The basin receives most of the rainfall from the South-West monsoon during June to October. Almost 99% of the total rainfall in the basin is received during this period. The average maximum and minimum temperatures are 38.9° C and 12.4° C respectively. May is the hottest month of the year and January is the coldest month of the year.

3.3.3.2 Shoreline Environment

The bathymetry map extracted from DHI's in-house tool C-map for the study area is shown in Figure 3.12. The bathymetry map indicates 10 m contour within approx. 13 km from the mouth of the creek in the Arabian Sea. There are sandy shoals and pockets of shallower depths inside the creek.

Figure 3. 12: C-Map Bathymetry In The Vicinity Of The Study Area

3.3.3.3 Tides

The Naval Hydrographic Chart No 211 provides information on the tides and tidal levels with respect to Chart Datum (CD) and is reproduced in Table 3.4. All the levels are with respect to chart datum specified by the Naval Hydrographic Office, India. Analysis of the tidal data reveal that the spring and neap tidal ranges are 3.6 m and 1.4 m respectively.

Table 3. 4: Tidal Levels And Datum For Vasai Creek

Description	Abbreviation	Water Level (m CD)
Mean High Water Spring	MHWS	4.4
Mean High Water Neap	MHWN	3.3
Mean Sea Level	MSL	2.5
Mean Low Water Neap	MLWN	1.9
Mean Low Water Spring	MLWS	0.8

By and large in the narrow estuarine areas, spatial variation of tide is likely to be prominent and the areas like Ulhas River is not an exception and there is significant variation in high water levels as one travels upstream compared to the open area water levels. This results in increased tidal current upstream of river.

3.3.3.4 Wind

During the months of June, July and August, the wind direction in the project area is SW- WSW. For rest of the months, predominant wind direction is NNE-N-NNW. The wind speed is less than 10 m/s for 98.05% of the time. The wind roses and statistical analysis are specified in the next Section.

3.3.3.5 Wave Climate - Offshore Conditions

Wave heights off the coast vary in accordance with oceanic winds. In general, it is observed that the predominant direction of waves in the deep sea are from SW direction. It is also observed that waves are less than 2 m, 3 m, and 4 m in height for 78.7%, 94.3% and 99.3% of the time respectively. Further, the wave roses and statistical analysis are given in the next Section.

3.3.4 Analysis Of Primary and Secondary Data

This section describes the analysis of the primary and secondary information on bathymetry, water levels, currents, winds, waves and sediment characteristics. Spatial as well as temporal variation of various parameters and the features identified were discussed and presented.

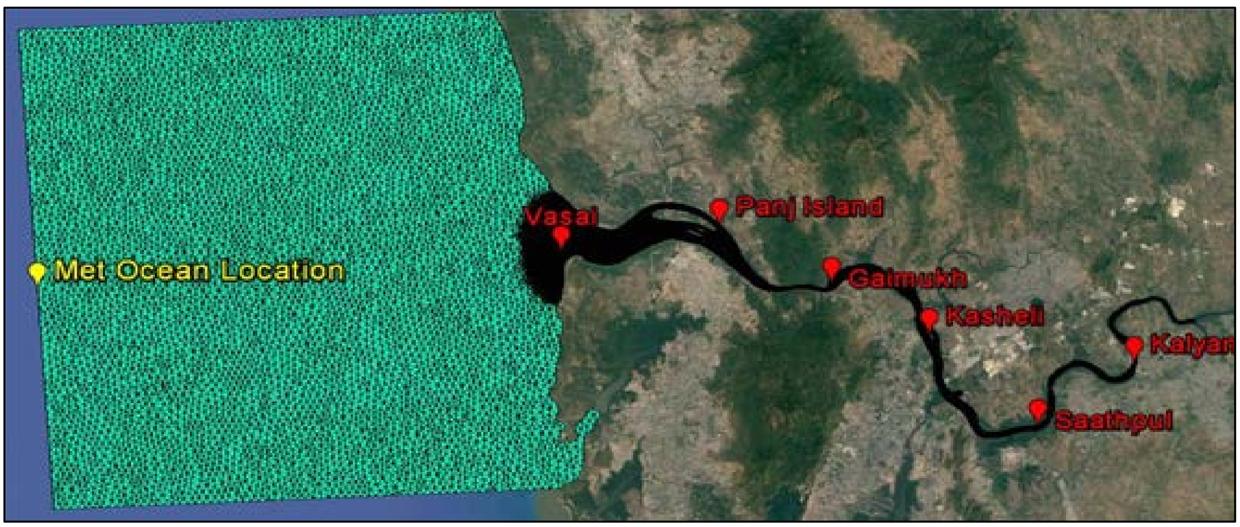
3.3.4.1 Primary Data

The primary data pertinent for the model calibration and validation has been collected, analysed and given in chapter 2. The same data would be utilised for the model input and calibration.

3.3.4.2 Secondary Wind And Wave Data

Secondary data on wind and waves is procured from DHI Global Metocean database which covers the period of 38 years from 1 January 1979 to 31 December 2016. The database has been derived from a well-established regional wave hindcast model. Such data obtained at a point 19°17'12.63"N and 72°28'46.72"E (Figure 3.13) forms a very useful data set, particularly for transforming waves from deep water to shallow water areas. Since, the data represents only offshore conditions, land and sea breeze effects are not accounted for.

Figure 3. 13: Offshore Wind And Wave Data Location



3.3.4.3 Wind Data Analysis

Offshore hourly wind data from DHI Metocean data portal from January 1979 to December 2016 is acquired. This is a global high accuracy wind dataset derived from Climate Forecast System Reanalysis (CFSR) for the period from 1979 upto 2016 with hourly values at a spatial resolution of 0.3 ˚ during 1979 to 2010, and 0.2˚ from 2011 and onwards.

It should be noted that since the Metocean data are from offshore region, land and sea breeze effects are not represented in the data. Furthermore, due to the limited spatial and time resolution of the Metocean wave hindcast model, cyclones cannot be expected to be fully resolved in the data.
The annual wind rose generated from the Metocean wind fields for 1 January 1979 to 31 December 2016 is presented in Figure 3.14. The rose analysis reveals that most prominent wind direction is southwest and west and varying in direction from south southwest to northeast. The wind speeds

during this period ranges from 2 to 10 m/s. Figure 3.9 of the detailed report in Annexure C shows the scatter plot of wind fields for 1 January 1979 to 31 December 2016.

The exceedance probability of the wind speed is shown in Figure 3.15 based on Ocean data between 1976 and 2016.

Figure 3. 14: Annual Wind Rose (Speed And Direction) During 1 January 1979 To 31 December 2016

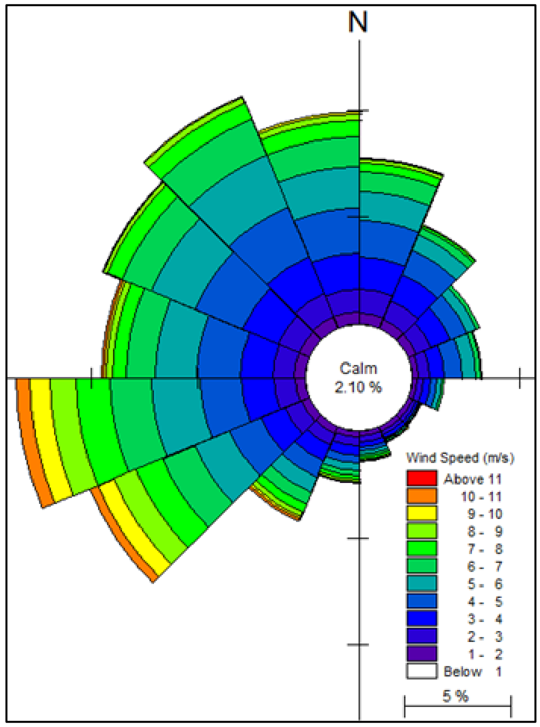
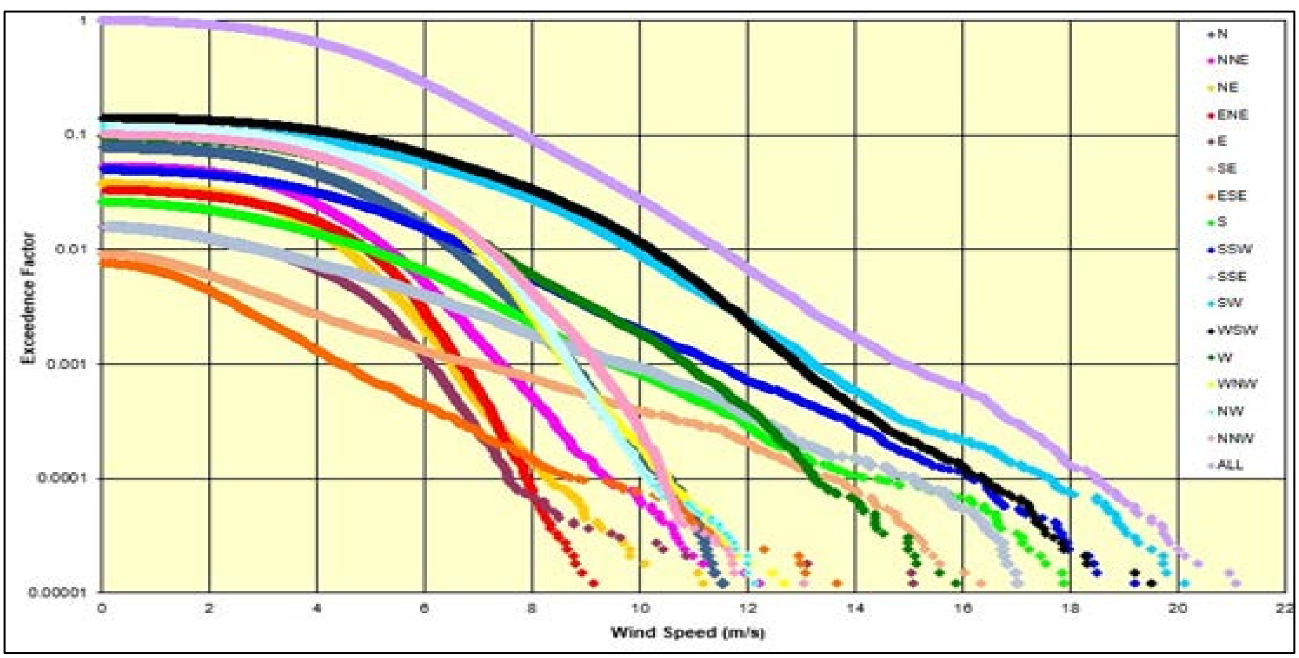
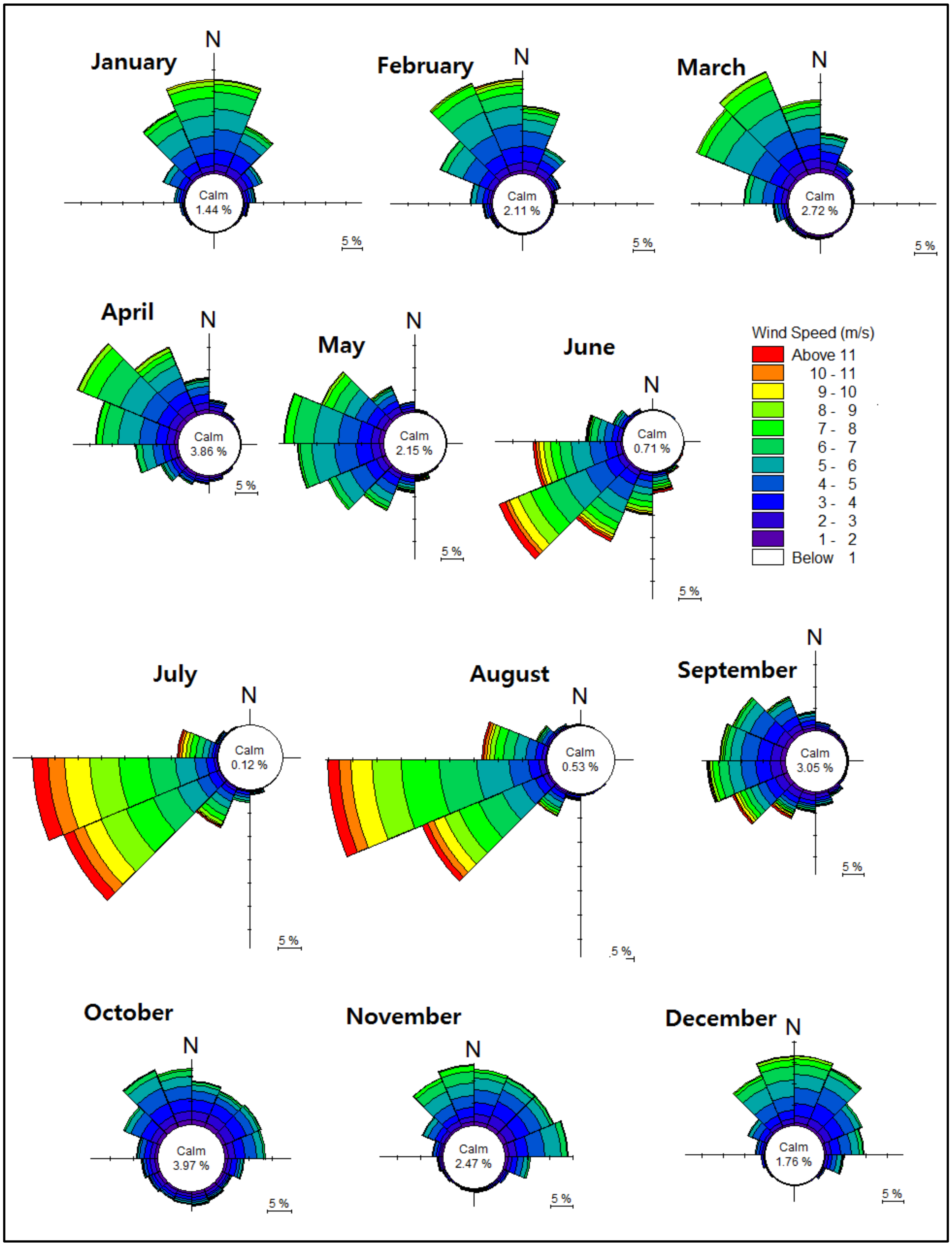


Figure 3. 15: Exceedance Probability Of Wind Speed Based On Met Ocean Database (1979 -2016)



Similarly, the monthly wind roses (January-December) for the data set from January 1979 to December 2016 are presented in Figure 3.16 and the corresponding monthly statistical analysis are given in Annexure I to the detailed model study report.

Figure 3. 16: Monthly Wind Roses From 1 January 1979 To 31 December 2016



3.3.4.4 Offshore Wave Data Analysis

The DHI global wave model (GWM) dataset is generated by DHI's 3rd generation MIKE 21 Spectral Wave Model based on the high accuracy global CFSR wind dataset from NCEP/NOAA. The CFSR wind dataset is an exceptionally good basis for global (and regional) wave modelling.

The results have been calibrated and validated against a number of offshore buoys and satellite data. The geographical resolution for GWM flexible mesh varies from 20 km-100 km. It is to be noted that waves during cyclones may not be well represented (resolved) and data extracted in minor enclosed areas and nearshore may be affected by the spatial resolution.

Figure 3.17 shows the rose plots for significant wave height and peak wave period respectively. The figures clearly indicate that the predominant wave direction is south-west.
The Exceedance probability plot for significant wave height and peak wave period is given in Figure 3.18 and 3.19 respectively.

The statistical analysis corresponding to significant wave height vs wave direction and significant wave height vs peak wave period from 1 January 1979 to 31 December 2016 is given in Table 3-4 and Table 3-5 respectively in the main report included in Annexure C. Approximately 90 percentage of significant wave height are occurring in the range of 0.5 m to 2 m. From the whole data 90 percent of wave periods are occurring in the rage of 9 to 18 seconds.

Figure 3. 17: Annual Wave Height And Period Rose During 1 January 1979 To 31 December 2016

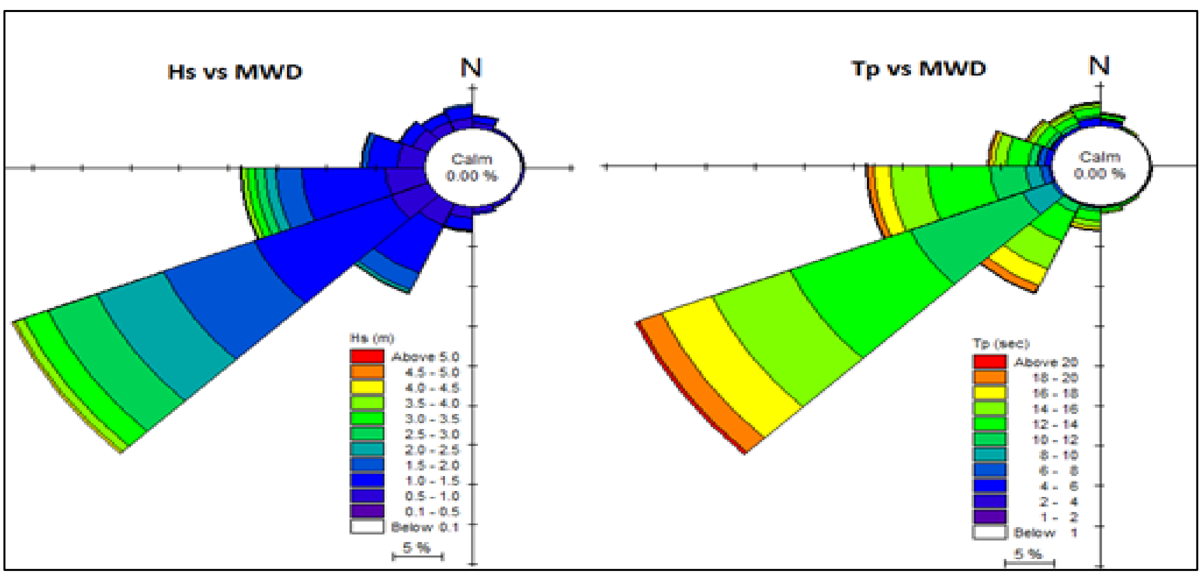


Figure 3. 18: Percentage Of Exceedance Probability Of Wave Height Based On Metocean Data (1979 -2016).

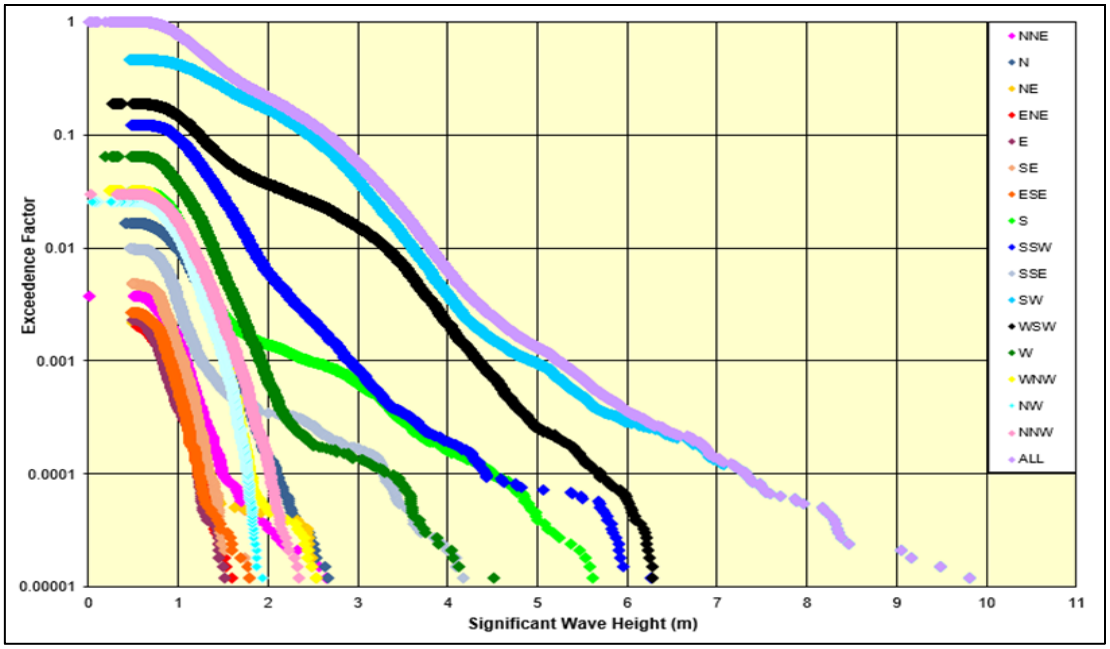
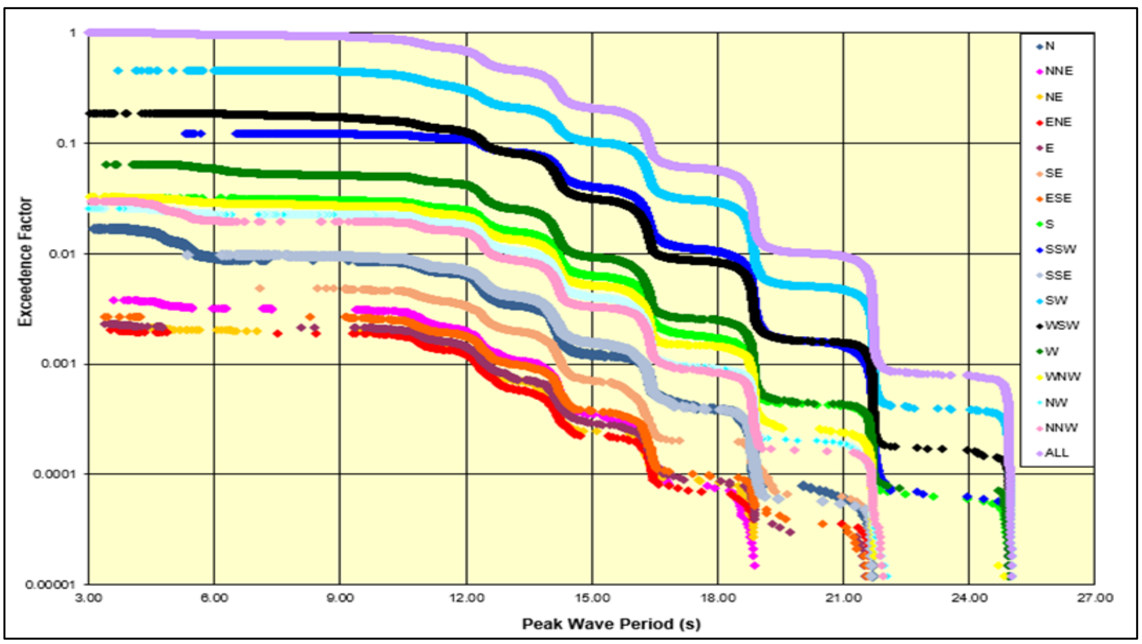


Figure 3. 19: Percentage Of Exceedance Probability Of Wave Period Based On Metocean Data (1979 -2016)



3.3.5 Wave Transformation Modelling

3.3.5.1 The Model

A local wave transformation model was setup for the Vasai site to simulate the wave transformation between the offshore wave climate described in the above section to the nearshore area of Vasai coast.

Wind-wave modelling of the region has been undertaken using MIKE21 Spectral Wave (SW), a state-of-the-art third generation spectral wave model developed by the MIKE by DHI. The model enables real time domain simulations and allows for the growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas. The fully spectral formulation is based on the wave action conservation equation, with the directional-frequency wave action spectrum as the dependent variable. The following sections detail the mesh and bathymetry generation, boundary condition specification and model calibration.

3.3.5.2 Bathymetry

The overall approach is to set-up a two-dimensional numerical model in order to capture the hydrodynamic regime and sediment transport in the creek. The bathymetry of the creek is obtained from echo sounder survey (see Figure 3.20). For the offshore area bathymetry data was obtained from C-map source. C-Map is a global digitised chart, which includes the water depth contours and water surface elevation data (tidal stations) for the entire globe. Figure 3.21 depicts the interpolated bathymetry from the two sources.

Figure 3. 20: Surveyed Bathymetry Data

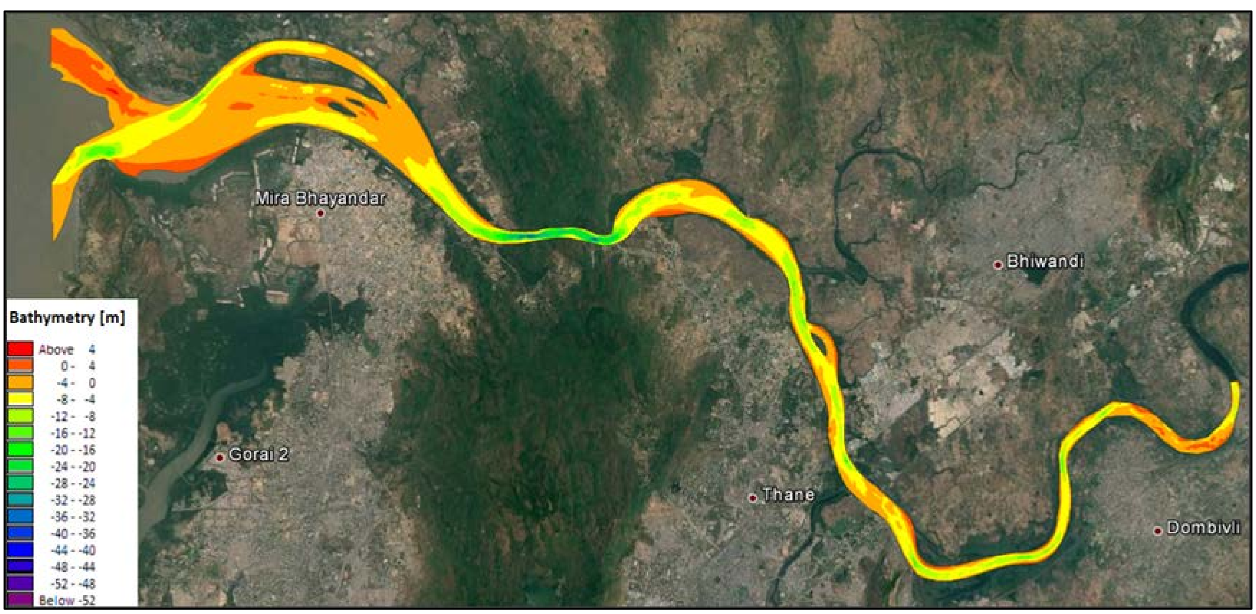
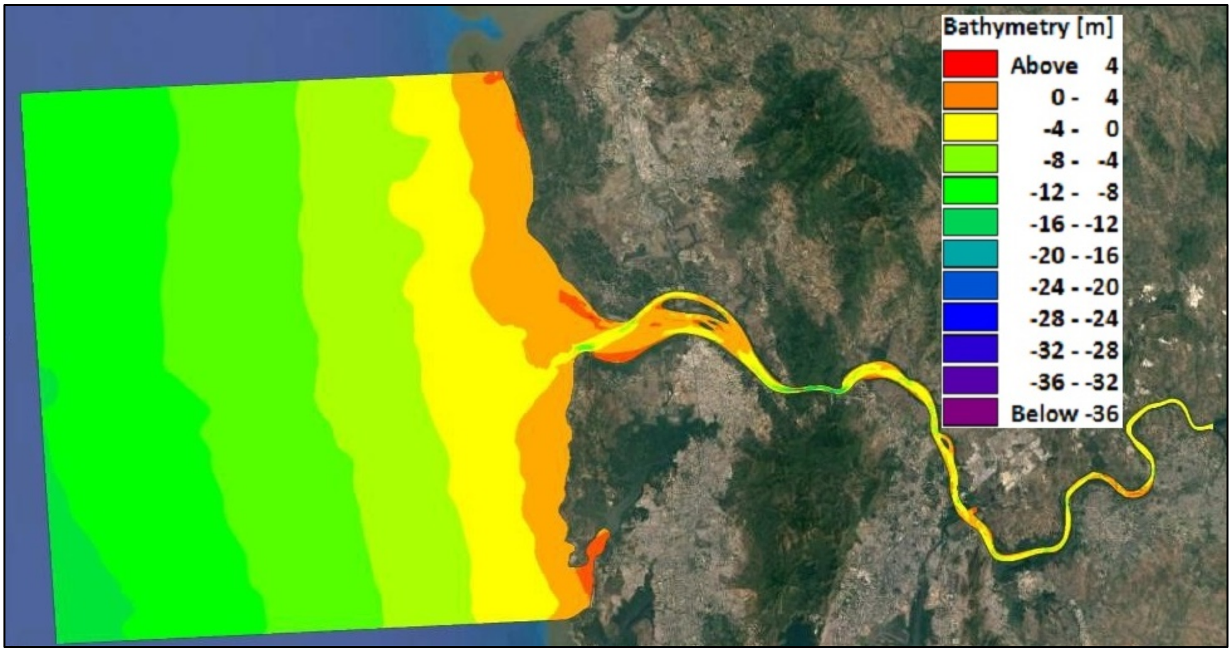


Figure 3. 21: Bathymetry Of A Full Model Domain (Hd & Sw Model)



3.3.5.3 Boundary Conditions

The model was run with wind and wave boundary conditions. Reliable time series of wind and wave conditions as boundary information are crucial for establishing wave climate. Offshore boundary conditions were extracted from DHI Metocean database at 20 m water depth as shown in (3.13). The spatial resolution of the DHI Metocean data is 0.25 deg and the temporal resolution is 1 hr.

The significant wave height, peak wave period and mean wave direction obtained from the met ocean database were applied along the model west boundary (Figure 3.22, Figure 3.23, and 3.24 respectively).

The wave boundary conditions were specified by time varying wave climate and wind speed and direction was specified as time varying and spatially constant. The north and south boundaries were defined as lateral boundary. No current, ice coverage and diffraction were used.

Figure 3. 22: Time Series Plot Of Significant Wave Height Used At Offshore Boundary

Figure 3. 23:Time Series Plot Of Peak Wave Period Used At Offshore Boundary

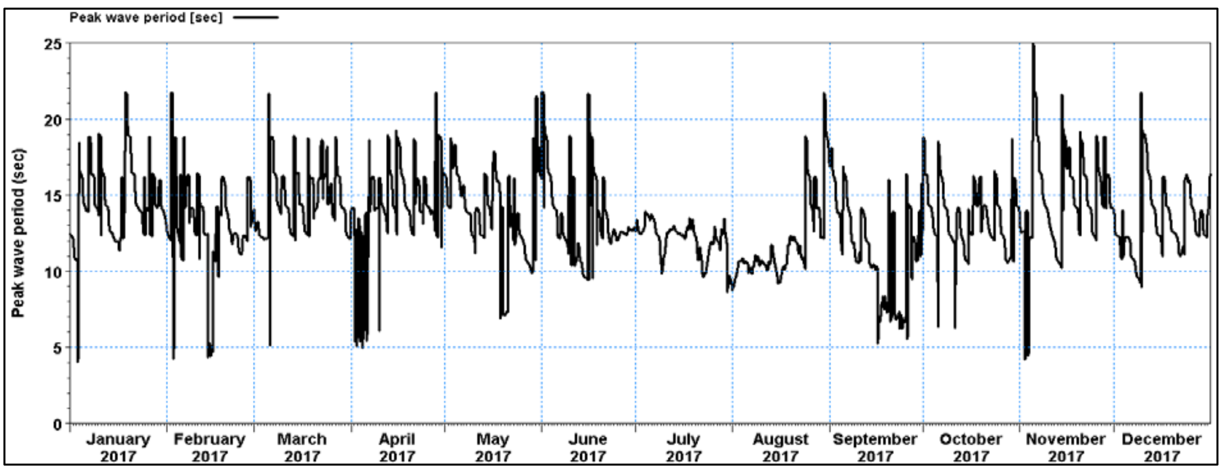
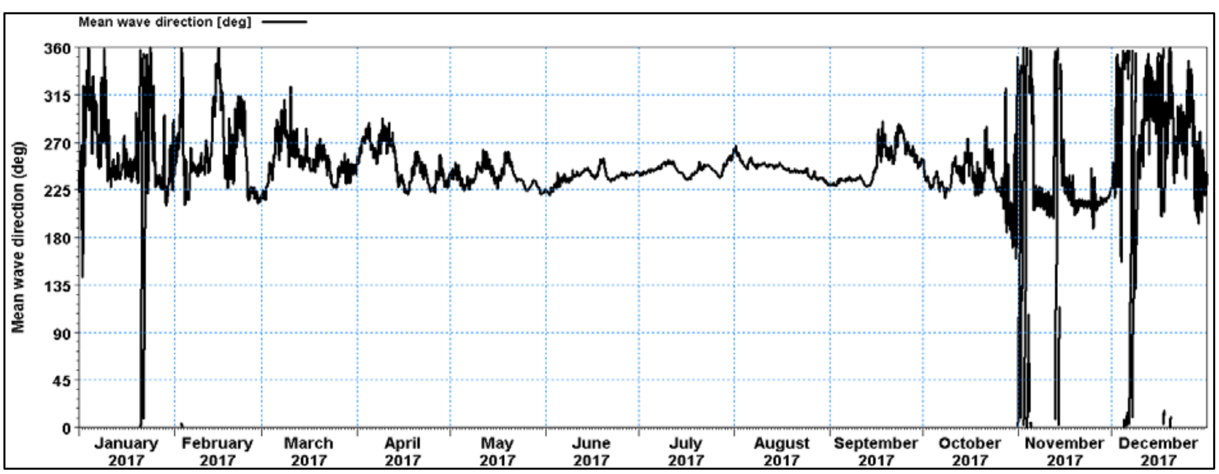


Figure 3. 24: Time Series Plot Of Mean Wave Direction Used At Offshore Boundary

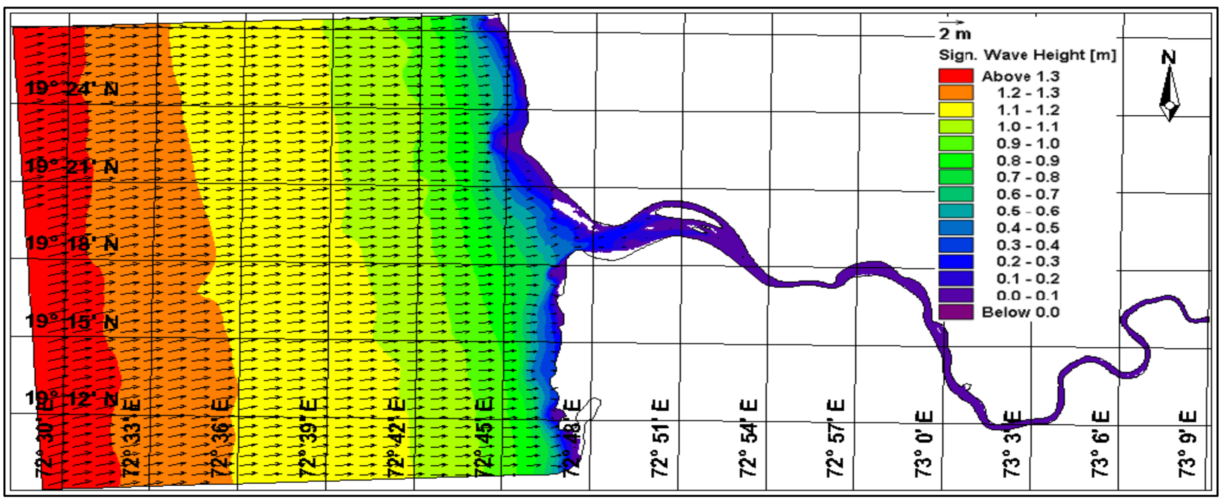


3.3.5.4 Model Result

In this section, the simulated wave heights inside the creek using SW model were compared with field data collected in the creek.

Figure 3.25 shows the typical transformative wave conditions from offshore to the nearshore and in the creek region. The figure indicates that the significant wave height gradually decreases between offshore boundary and the entrance of the Vasai creek. As the wave enters into the creek wave height further dissipates. The maximum significant wave height noticed at Vasai location is 0.45 m and peak wave period is 3 sec. The significant wave height thus computed agrees fairly well with the measurements at Vasai location.

Figure 3. 25: Snapshot Of Significant Wave Height During The Simulation



3.3.6 Hydrodynamic Modelling

Hydrodynamic modelling is carried out using DHI's MIKE21 FM (Flexible Mesh) HD model. The model simulates 2D free-surface flows, solving the depth averaged Navier-Stokes equations and is applicable to the simulation of hydrodynamic processes in lakes, estuaries, bays, coastal areas and seas. The FM module of MIKE 21 is based on Flexible Mesh approach using triangular and quadrangular elements for addressing geometrical flexibility to complex coastlines, like archipelago, lagoons, estuaries etc.

3.3.6.1 Bathymetry

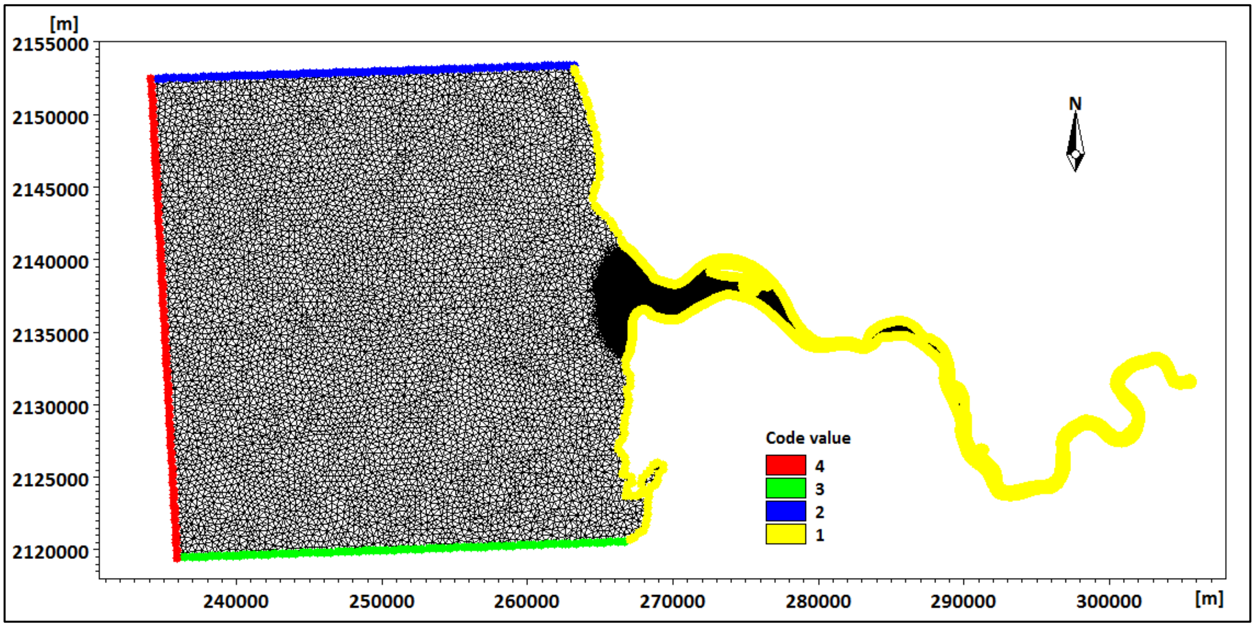
The bathymetry and extent of domain used for the hydrodynamic studies is same as that of the Spectral wave model.

3.3.6.2 Boundary Conditions

The offshore model boundaries are shown in Figure 3.26. The boundaries are marked with code values of 2, 3 and 4.

Wind is introduced over computational domain as atmospheric boundary condition through a speed dependent wind friction coefficient. The source of winds is derived from the met ocean dataset.

Figure 3. 26: Model Boundaries (Yellow: Land Boundary; Blue, Green And Red: Offshore Boundaries



3.3.6.3 Bed Resistance

The MIKE21 hydrodynamic model is governed by the Reynolds-Averaged Navier-Stokes (RANS) equations, which are depth-integrated over the water column to finally yield the St. Venant equations. In the governing equations, the friction parameter is expressed as Manning number. A varying manning number is applied throughout the model domain to get a reasonable calibration to the tidal water level, both amplitude and phase.

3.3.6.4 Production Period

The hydrodynamic modelling is carried out for a period of 37 days which cover the full spring and neap phase of tidal cycle. The production period of the hydrodynamic model is given below.

Tide with north east monsoon winds: 23 April 2017 to 30 May 2017.

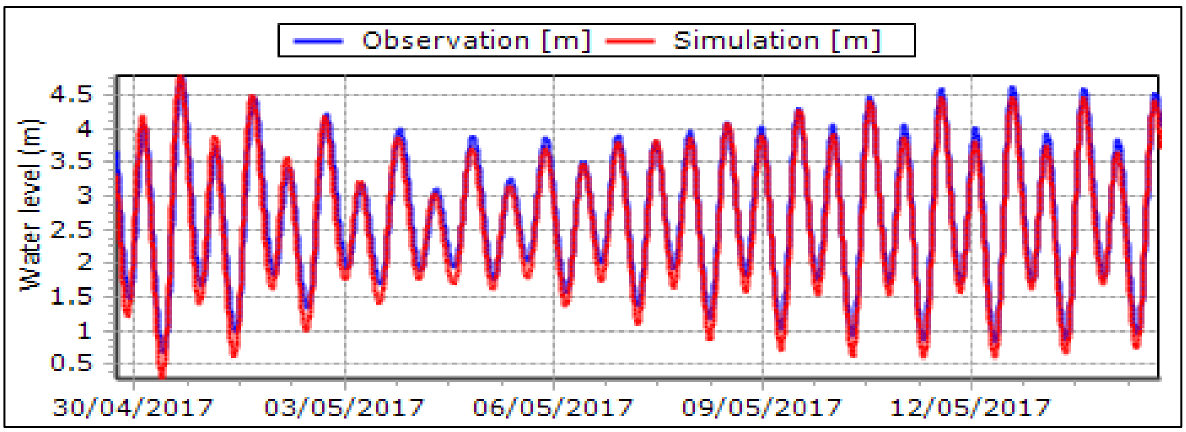
3.3.6.5 Model Calibration And Validation

The model has been calibrated against measured water level and current data gathered during the survey carried out during the months of April and May 2017

Water level

The comparison of measured and modelled water level data at Panju Island (3.27), Gaimukh (3.28) and Saathpul (3.29) respectively are given in the detailed report. Figure 3.27 shows the comparison at the Panju Island location. At three locations the simulated tidal levels are having a good agreement with the measured data in terms of amplitude and phase. At Saathpul, the modelled amplitude exceeds the measured records. This might be due to the prediction data calculated based on 8 tidal constituents. The comparison of the simulated and measured water levels are in the acceptable range with Index of agreement of 0.99 0.98 and 0.92 respectively.

Figure 3. 27:Comparison Of Measured And Simulated Water Level At Panju Island



Current speed

The comparison of current speeds at 6 locations has been presented in Figure 3.28. A slight phase and amplitude lag between measurements and model is noted, which originates from the tide driven boundary condition. Figure 3.27 shows the comparisons at the Panju Island station. For other station comparisons the detailed report at Annexure C can be referred.

The current trend, however has been captured excellently by the model, which confirms that the model can reproduce the tidal currents correctly.

Figure 3. 28: Modelled And Measured Current Speed At Vasai

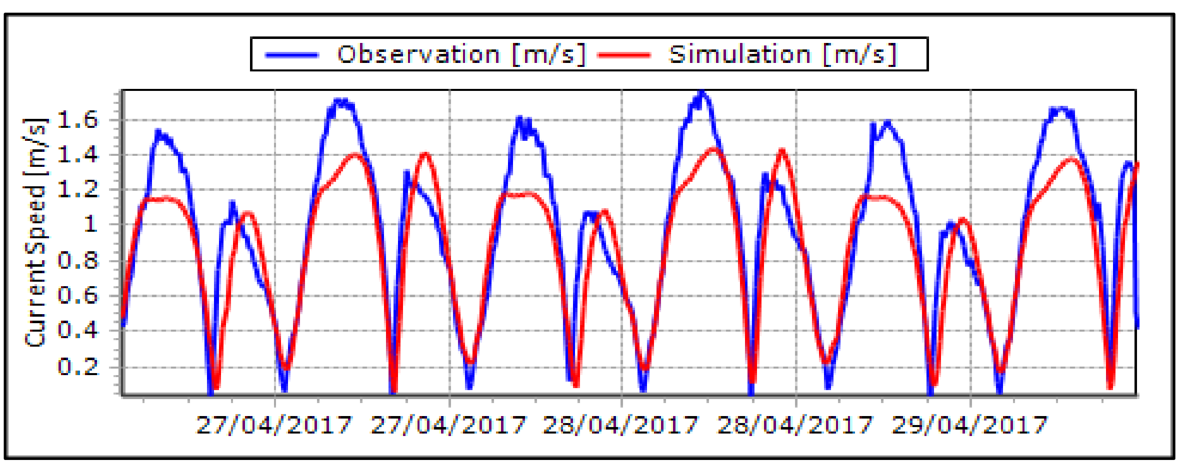
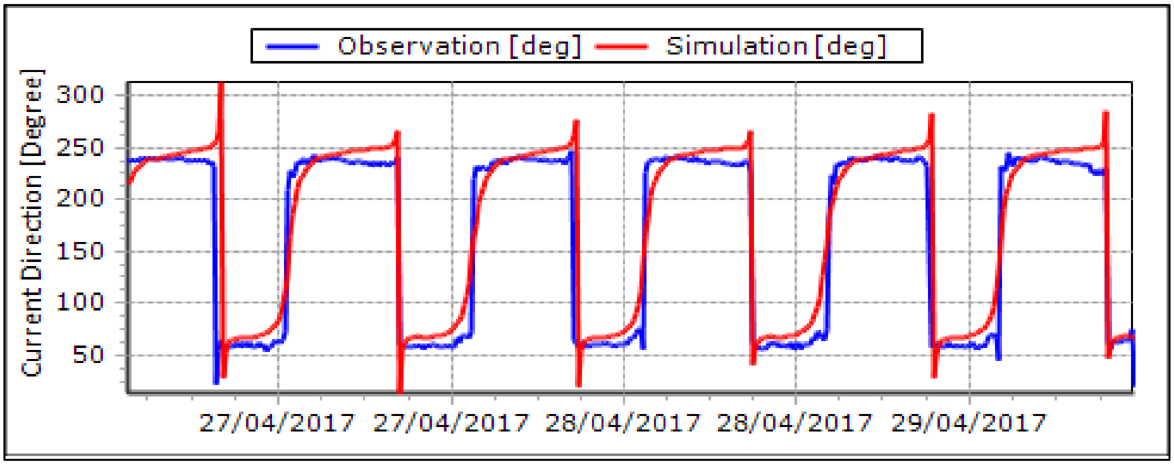


Figure 3. 29: Modelled And Measured Current Direction At Vasai



3.3.6.6 Hydrodynamic Model Results

Baseline Conditions

The calibrated hydrodynamic model applied to reproduce the baseline conditions during pre-monsoon. The model results were analysed in the region with particular focus in the Vasai Creek. The focus has been given to two-time stamps during spring tide. Figure 3.30 give snapshot of flow pattern during flood and ebb tides for typical spring period. The snapshot of flow pattern during neap period is shown in Figure 3.31.

Detailed reporting is at Annexure C.

Figure 3. 30: Depth Averaged Flow Vectors In The Modelling Domain In The Spring Tide (Typ)

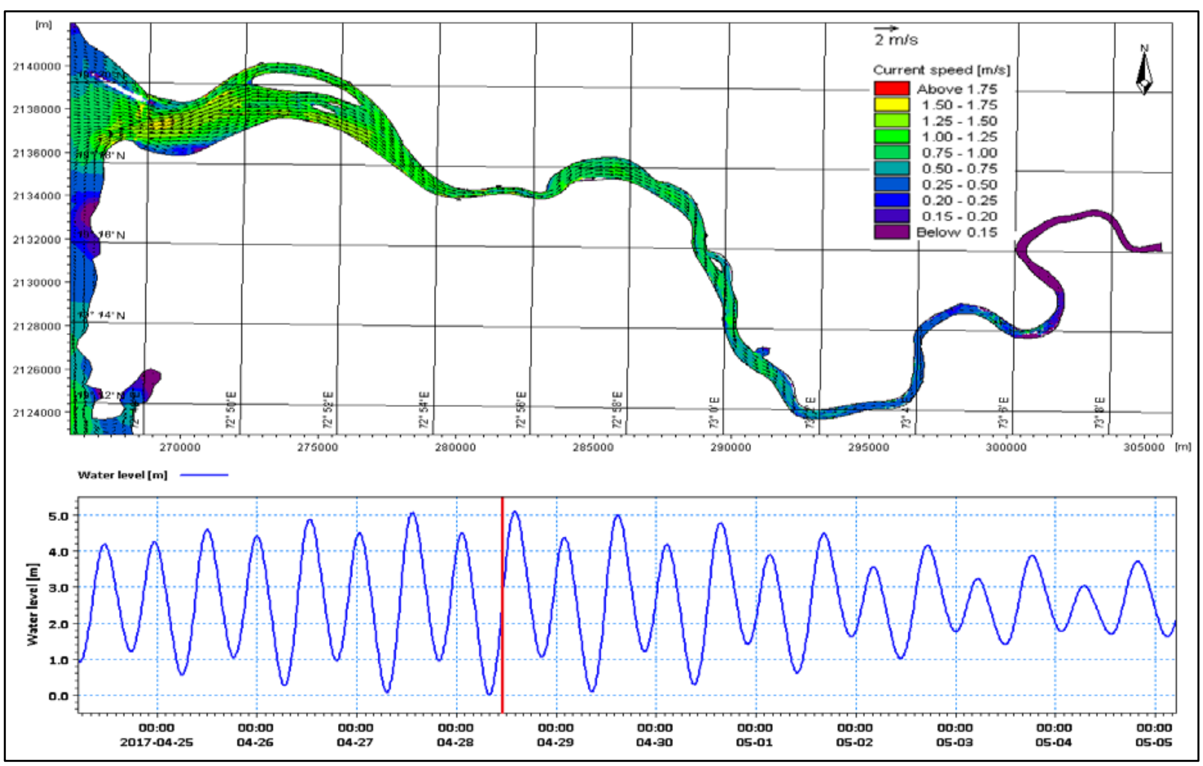
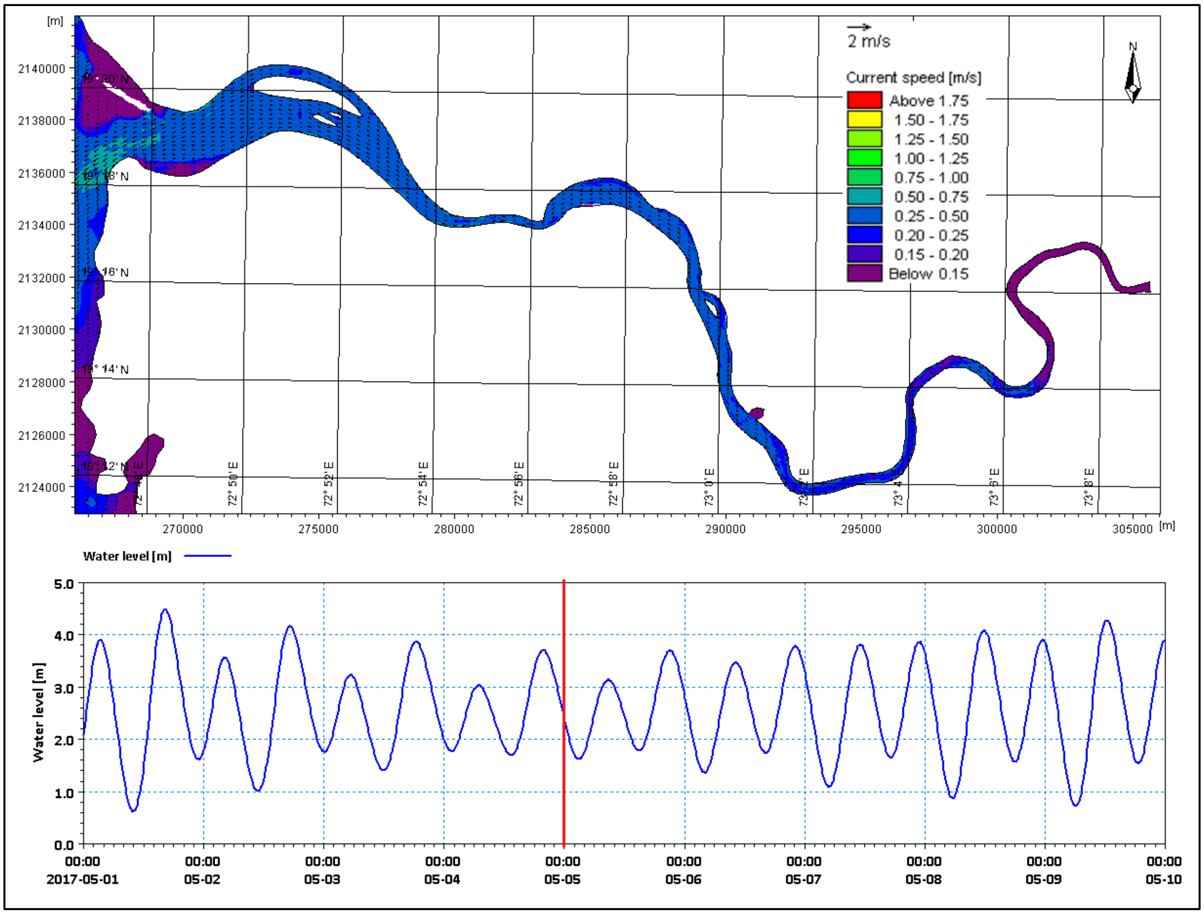


Figure 3. 31: Depth Averaged Flow Vectors In The Modelling Domain In The Neap Tide (Typ)



Proposed Navigational Channel

M/s C Borne Services has provided the general arrangement plan of navigational channel and jetty structures wide the drawing numbers mentioned in the Table 3.5.

The north and south layout of navigational channel over laid on to the bathymetry information as shown in Figure 3.32 and Figure 3.33. The bathymetry in the navigational channel is maintained to a minimum value of -3 m CD.

Jetty layouts for 10 stations as shown in Table 3.5 are over laid on to the model results to visualise the hydrodynamic regime in the vicinity of the jetty structures.

Table 3. 5: Details Of Jetty Drawings Having The General Layout Arrangement

S. No	Drawing Number	Jetty Plan
1	KE_1138_AD_GA_751.dwg	Anjur Dive Jetty
2	KE_1138_DB_GA_951.dwg	Dombivli Jetty
3	KE_1138_GB_GA_351.dwg	Ghodbunder Jetty
4	KE_1138_KH_GA_651.dwg	Kalher Jetty

S. No	Drawing Number	Jetty Plan
5	KE_1138_KL_GA_551.dwg	Kolshet Jetty
6	KE_1138_MB_GA_251.dwg	Mira Bhayander Jetty
7	KE_1138_NB_GA_451.dwg	Naglabunder Jetty
8	KE_1138_PS_GA_851.dwg	Parsik Jetty
9	KE_1138_VF_GA_151.dwg	Vasai Fort Jetty
10	KE-1138-KLN_GA_1051.dwg	Kalyan Jetty

Figure 3. 32: Zoom-In Model Domain Showing Bathymetry With Proposed Channel (Vasai To Gaimukh)

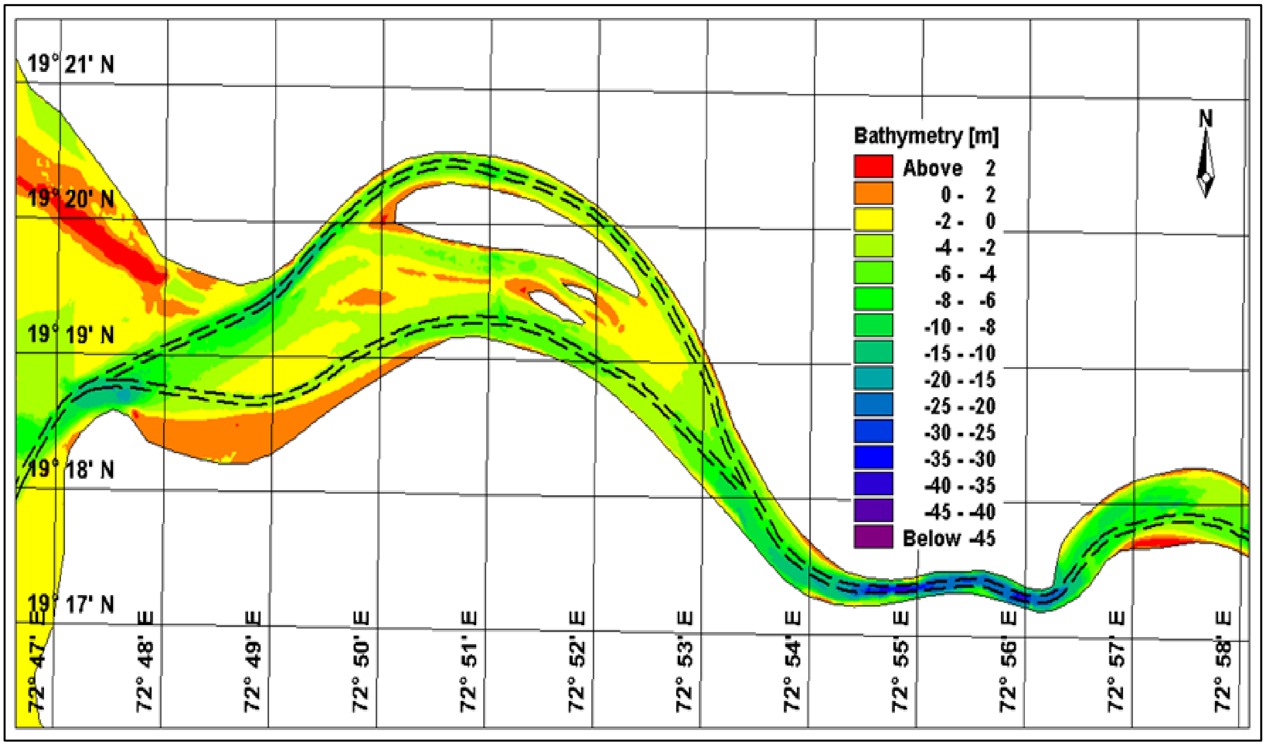
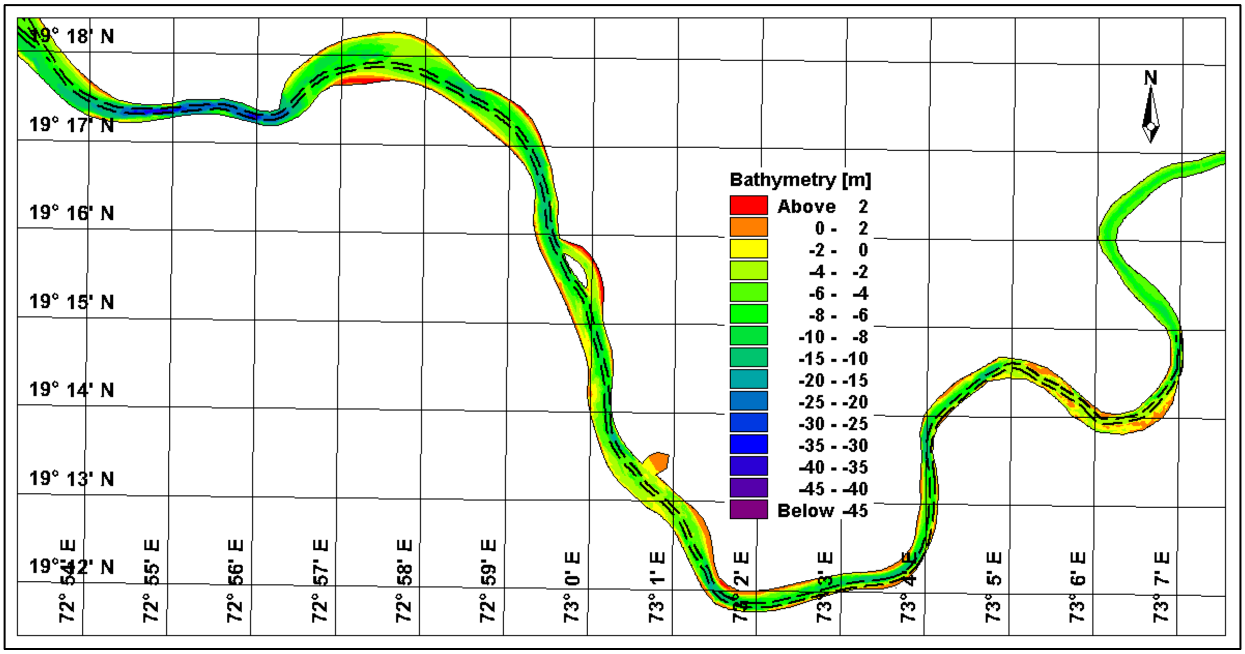
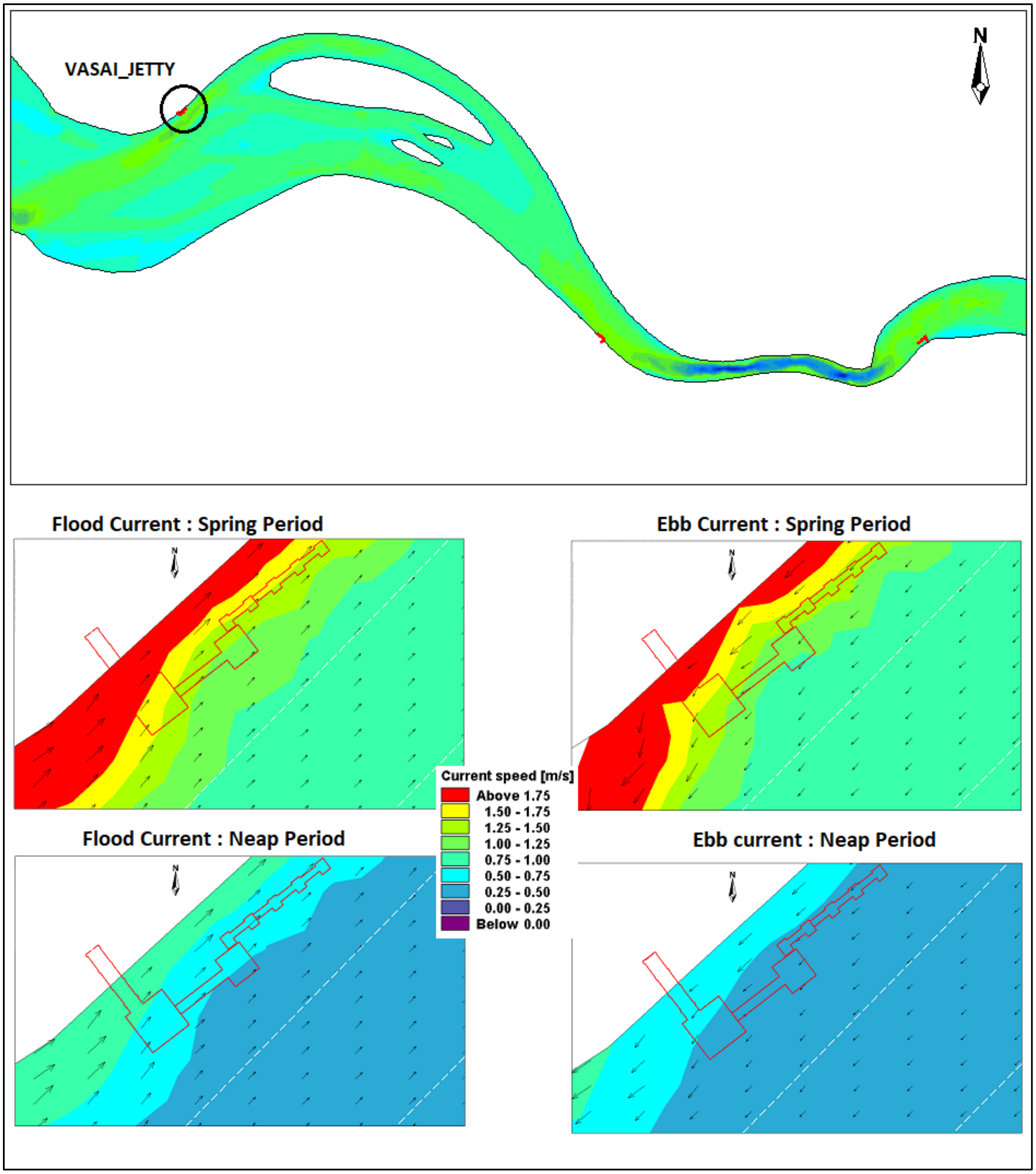


Figure 3. 33: Zoom-In Model Domain Showing Bathymetry With Proposed Channel (Gaimukh To Kalyan)



Flood and ebb current speed extracted at eight proposed jetty locations during spring and neap tide periods are given in the Terminal design section for indicating the correctness in the alignment of the berthing structures. It can be seen from the figures that proposed jetty locations are well aligned with respect to the flow conditions. The currents are parallel to the proposed jetties during both flood and ebb phase of the tide and current directions angles are off by only (2 deg – 4 deg) at some locations.

Figure 3. 34 : Depth Averaged Flood And Ebb Velocities At The Vasai Jetty During Spring And Neap Period (Typ)



The current speeds at all the stations remains unchanged except at Saathpul.

At this location, the current speeds are increasing with the introduction of navigational channel. Further, the flow pattern shows that highest currents with a magnitude of 1.5 m/s are witnessed at the mouth of the Vasai creek during spring tide.

3.3.7 Sedimentation Study

Sediment transport is dependent on hydrodynamic conditions. In this section, the calibrated hydrodynamic model (see section 5.5 of Annerure B) is extended by sediment transport process calculations. The sediment transport model is calibrated and applied for the morphological study. The DHI's MIKE 21 FM Mud Transport (MT) model is used to assess the sedimentation in the proposed study area.

3.3.7.1 Mud Transport (MT) Model

DHI's MIKE 21 Mud Transport (MT) module is a state-of-the-art cohesive sediment transport model that simulates the erosion, transport, and deposition of mud or sand/mud mixtures (< 63 μm) under the action of currents and waves in marine, brackish or freshwater environments. The model is capable of handling flocculation as well as hindered settling in the water column in addition to sliding and consolidation in the bed.

3.3.7.2 Model Bathymetry

The bathymetry and extent of domain used for the mud transport studies is same as that of the hydrodynamic model.

3.3.7.3 Boundary

At each open boundary in the model, concentration of suspended sediment matter is specified.

3.3.7.4 Sedimentation Model Results

The calibrated model of hydrodynamic and mud transport was used to simulate flow and sediment pattern from April – May 2017. The base line conditions Total Suspended Sediment (TSS) was implemented in the model and the bed level changes indicated. The same may be seen from the report in Annexure C.

In this section the sedimentation in the navigational channel after the dredging of the channel has been completed would be discussed for its relevance. The TSS at the six stations is given in table 3.6. The bed level change proposed channel is shown in a series of the pictures extracted from the model is given in the Report annexed Annexure C, one of the typical figures is reproduced here for ready reference.

The detailed discussion, on the bed level change at all the terminal locations is also given in the report.

Abstracts from the report is reproduced for ready reference;

Table 3. 6: Total Suspended Solid Concentrations At The Six Locations In The Proposed Scenario

Location	Total SSC (kg/m3)	
	Maximum	Average
Vasai	2.126	0.509
Panju Island	2.049	0.740
Gaimukh	2.110	0.826
Kasheli	1.965	0.788
Saathpul	1.814	0.545
Kalyan	1.073	0.184

Bed level changes

From the simulation, it is seen that erosion occurs in the most of the proposed jetty location with average bed level changes of -0.07 m. Typical erosion accretion pattern of the simulation is shown in Figure 3.35 and Table 3.7.

Figure 3. 35: Bed Thickness Change At The Proposed Jetty Locations:Vasai Fort, Ghodbunder And Naglabunder

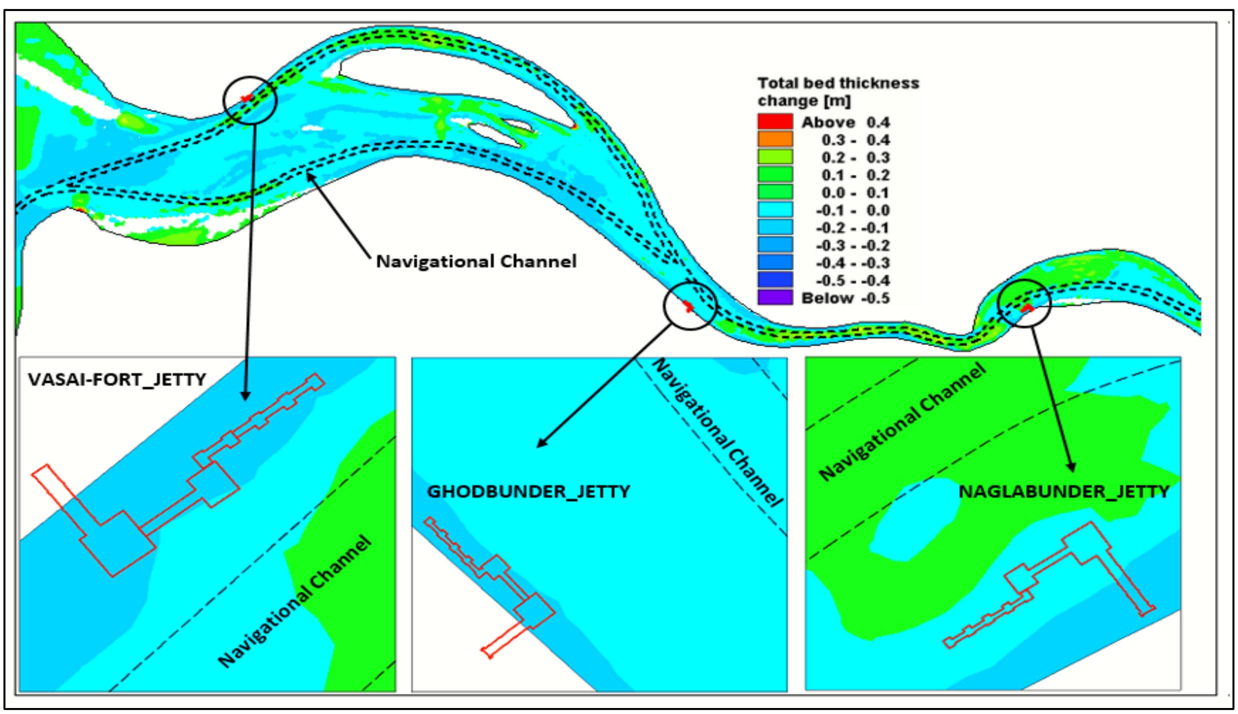


Table 3. 7: Total Bed Thickness Change At The Six Measured Locations For Proposed Scenario

Location	Total bed thickness change (meter)
Vasai	0.001
Panju Island	0.017
Gaimukh	0.099
Kasheli	0.001
Saathpul	0.001
Kalyan	0.053

3.3.8 Maintenance Dredging And Dredge disposal

3.3.8.1 Maintenance Dredging

Based on the siltation rates calculated using mud transport modelling the annual maintenance dredging quantities are estimated for the selected siltation area along the Navigational channel are shown in Figure 3.36 and Figure 3.37.

Figure 3. 36: Siltation Area: Area 1, Area 2 And Area 3

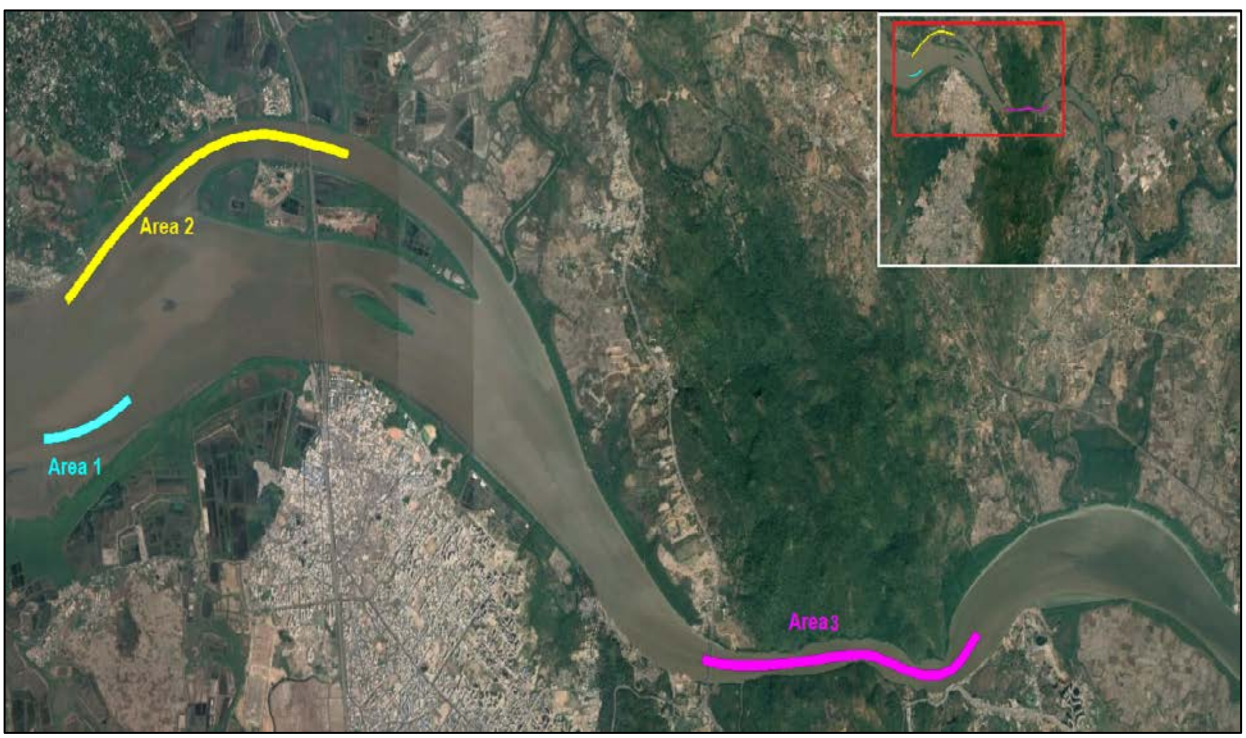


Figure 3. 37: Siltation Area: Area 4, Area 5 And Area 6

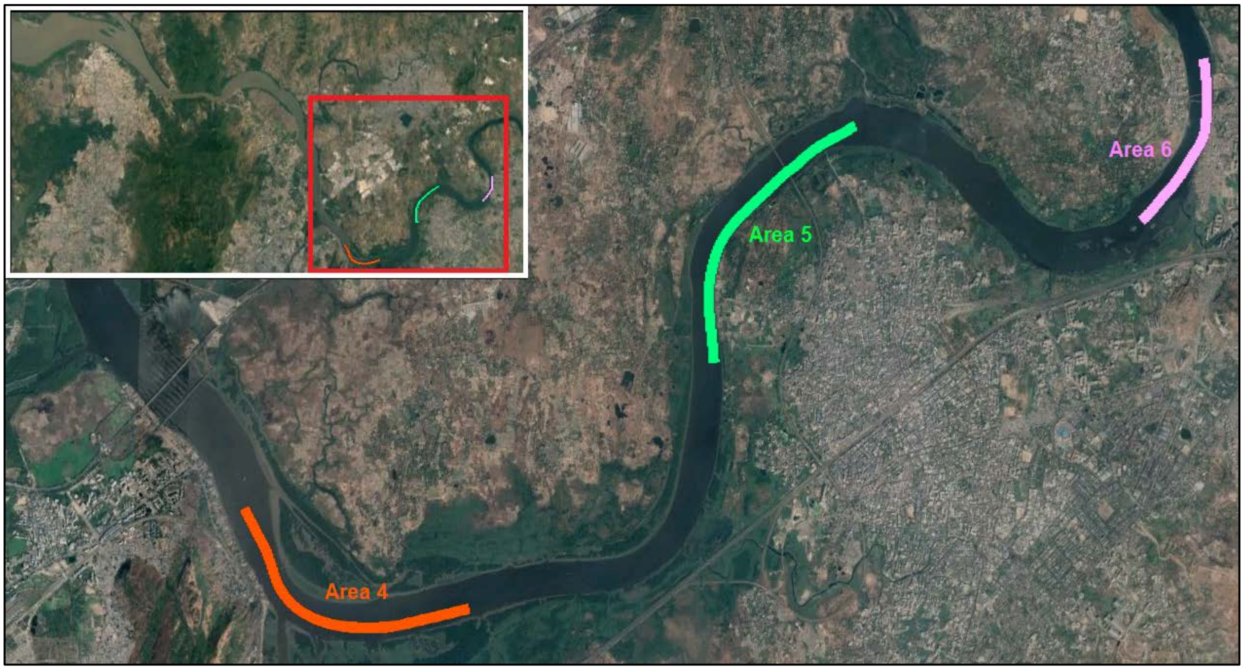


Table 3.8, lists the Maintenance dredging quantities estimated at various sections of the proposed development

Table 3. 8: Bed Thickness Change And Annual Siltation Quantities For Various Sections

Section	Area m²	Total bed level change (15 days)	Total bed level change Thickness/Year	Sediment deposit	Average Water depth
		M	M	M³	M
Area 1	133225	0.02	0.37	49447.8	3.0
Area 2	470102	0.05	1.17	552007.5	7.0
Area 3	418145	0.12	2.77	1159428.7	23.5
Area 4	302142	0.04	1.02	307885.1	8.9
Area 5	303147	0.02	0.57	173202.2	6.6
Area 6	181620	0.04	0.93	169218.8	5.3

From the above table 3.8 the following inferences were made with regard to annual maintenance dredging quantities:

- To maintain a depth of 3 m with respect to CD in the Area 1 at the Navigational channel maintenance dredging quantity of 49447 m³ per annum is required for an average of 0.37 m siltation

- To maintain a depth of 7 m with respect to CD in the Area 2 at the Navigational channel maintenance dredging quantity of 552007 m³ per annum is required for an average of 1.17 m siltation
- To maintain a depth of 23.5 m with respect to CD in the Area 3 at the Navigational channel maintenance dredging quantity of 1159428 m³ per annum is required for an average of 2.77 m siltation
- To maintain a depth of 8.9 m with respect to CD in the Area 4 at the Navigational channel maintenance dredging quantity of 307885 m³ per annum is required for an average of 1.02 m siltation
- To maintain a depth of 6.6 m with respect to CD in the Area 5 at the Navigational channel maintenance dredging quantity of 173202 m³ per annum is required for an average of 0.57 m siltation
- To maintain a depth of 5.3 m with respect to CD in the Area 6 at the Navigational channel maintenance dredging quantity of 169218 m³ per annum is required for an average of 0.93 m siltation

3.3.8.2 Dredge Spoil Disposal

Since the bathymetry in the navigational channel is proposed to be maintained to a minimum value of -3 m CD. The maintenance dredging quantity is estimated to be approx. 50,000 m3 per annum The dredged material is proposed to be disposed on northern side or the southern side of the creek entrance to protect the shoreline. Erosion spots are observed at the shoreline near the Creek entrance as shown in Figure 3.39. The extent of erosion/accretion in section 10 below where the shoreline changes along the Vasai creek were mapped for the years 1999, 2003, 2011 and 2017 using aerial imagery.

In addition, dredged material is proposed to be disposed at the places of low lying areas, identified along the river course and shown in section 3.4.2.5.

3.3.9 Shoreline Changes

3.3.9.1 Introduction

Shoreline change is considered to be one of the most dynamic processes in the coastal area. It has become essential to map shoreline changes as an input data for coastal process assessment. In recent years, remote sensing data has been used for shoreline extraction and mapping. The accuracy of image orthorectification, as well as image classification, are the most significant factors affecting the accuracy of the extracted shoreline. In this section, the shoreline changes along the Vasai creek were mapped for the years 1999, 2003, 2011 and 2017 using aerial imagery.

3.3.9.2 Data And Methodology

Data

The Landsat archive data for different years was downloaded from the website http:// earthexplorer.usgs.gov/. The important factors considered for finalizing the satellite images were cloud cover, similar tide conditions, similar season data, uniform projection factors, etc. The satellite data further underwent radiometric correction and data scaling to enable maximum visual interpretation.

Primarily, Landsat maps on 1: 25,000 prepared using Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images consist of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9 of 2011-17 period and Landsat 4-5 Thematic Mapper (TM) data of 1999 - 2003 period available at Earth explorer (USGS) have been utilized. The resolution is 30 meters for bands 1 to 7.

Digitization of Shoreline

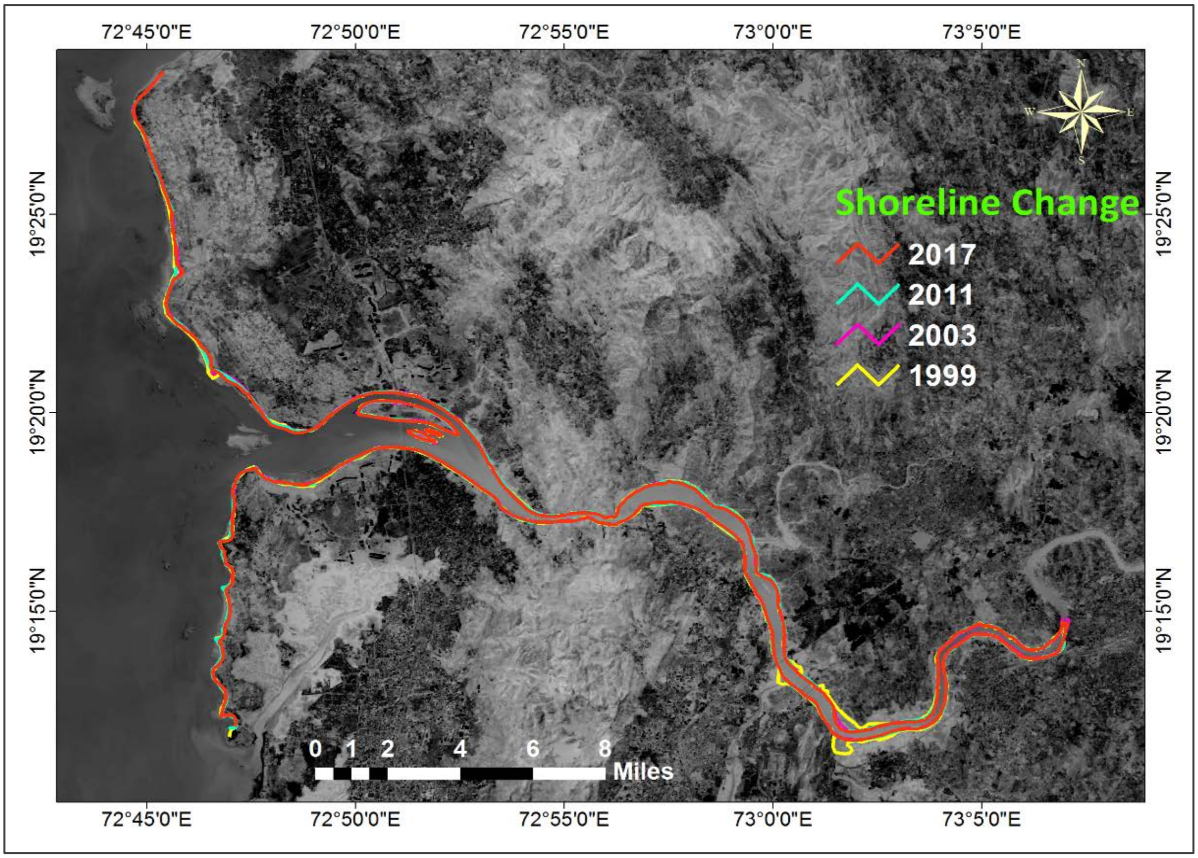
Environmental Systems Research Institute (ESRI) Geographic Information System (ArcGIS 10.5) software was used for shoreline analysis. The shoreline features were identified using the tonal differences between the land and the sea. From the Landsat 4-5 Thematic Mapper (TM) data, base map was prepared and the onscreen digitization of coastline was carried out.

A band ratio technique was applied to differentiate the land and water pixels. Further vectorization technique was applied to get the shoreline features in Arc-GIS environment. To further refine the results, visual interpretation was carried out for editing the shoreline features to confirm to the High Tide Line (HTL). The digitized shoreline for the years 1999, 2003, 2011 and 2017 in the vector format (shape file) are used to calculate the rate of shoreline change (Figure 3.38).

The major task involved is preparation of a digital shoreline change in GIS environment using existing databases of coastal Landsat maps prepared on 1:25,000 scale, depict and quantify shoreline changes as eroding/accreting/stable, show status of shoreline.
The tasks considered are:

- Identify and classify the shoreline as shoreline under erosion, stable and accretion.
- Analyse satellite data of following period for selected hotspot areas (areas showing severe shoreline changes)
- Measure the extent of erosion/ deposition.

Figure 3. 38: Digitized Shorelines (HTL) For Vasai Creek During 1999-2017 Period



3.3.9.3 Results

The objective of this study is to understand the dynamics of shoreline changes occurring near study area and evaluating the cause of the same. The distance of migration either seaward (accretion) or landward (erosion) length were measured with the help of ArcMap GIS software.

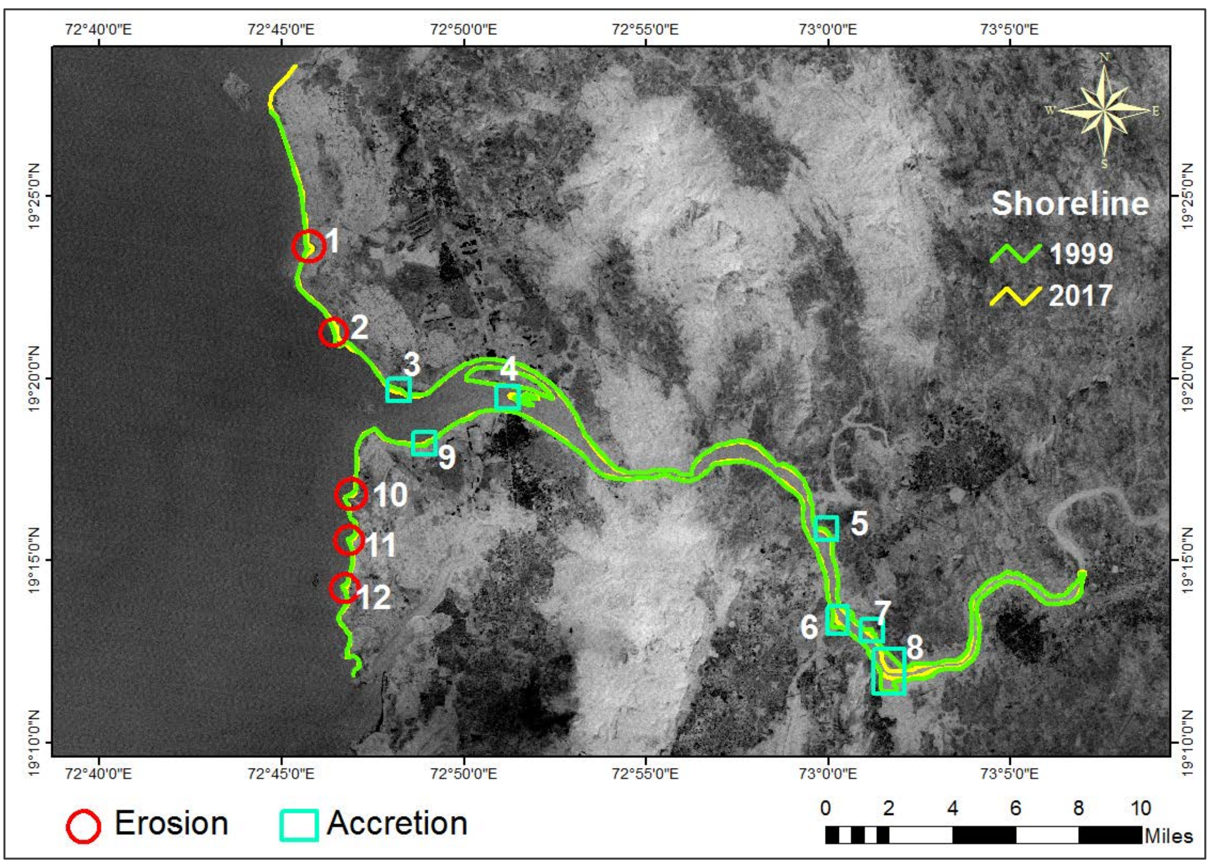
From the analysis, it is observed that the river banks are stable in the study area and accretion has been observed at some locations. Erosion spots are observed at the shoreline near the Creek entrance as shown in Figure 3.39. The extent of erosion/accretion is shown in table below

Hence it is concluded that there will be no significant shoreline impact for the proposed development.

Table 3. 9: Erosion / Deposition Locations In The Study Region During 1999-2017 Period

Location	Geographical Coordinate		Erosion	Accreation
	Logitude	Latitude		
1	72.76	19.39	200	-
2	72.77	19.35	241	-
3	72.80	19.32	-	135
4	72.85	19.32	-	260
5	72.99	19.26	-	145
6	73.00	19.22	-	318
7	73.02	19.21	-	189
8	73.02	19.19	-	680
9	72.81	19.30	-	171
10	72.78	19.27	143	-
11	72.78	19.25	143	-
12	72.77	19.23	150	-

Figure 3. 39: Erosion / Accretion Locations In Study Area



3.3.10 Conclusions

Met-ocean measurements on tides, waves and currents were available for the period April and May 2017. Tidal data reveal that the spring and neap tidal ranges are 3.6 m and 1.4 m respectively with a spatial variation of tide is likely to be prominent. This results in an increased tidal current upstream of river with a range of 1.5 m/s during the observation period. The wave heights in the creek ranges from 0.03 m to 0.35 m, wave period from 8 to 25 sec and wave directions are highly variable at all locations. Long period swells in the Bay undergo significant reduction in wave height. The larger wave heights in the Vasai Creek may occur during local wind events based on the shorter wave period.
Secondary data at offshore depth (25 m contour) on wind and waves is procured from DHI Global Metocean database, which covers the period of 38 years from 1 January 1979 to 31 December 2016. The statistical analysis of wave climate reveals that approximately 90 percentage of significant wave heights are occurring in the rage of 0.5 to 2 m and 90 percent of wave periods are occurring in the rage of 9 to 18 sec.

The simulated maximum significant wave height noticed at Vasai location is 0.45m and peak wave period is 3 sec.

The current trend captured by the model confirms that the model can reproduce the tidal currents accurately. Further, the flow pattern has been analysed during spring and neap tide period. The proposed jetty locations are well aligned with respect to the flow conditions.

The total suspended solids (TSS) in the creek vary between 980 to 1600 mg/L. The wide variations of the TSS temporally and spatially are associated with changes in current speed as the tide progresses. Bed level changes shows a deposition of 0.15 m occurs in most of the river mouth area and erosion occurs at some parts of the river mouth.

Maintenance dredging quantities estimated at various sections of the proposed development. To maintain a depth of 3 m with respect to CD in the Area A at the Navigational channel maintenance dredging quantity of 49447 m^3 per annum is required.

The shoreline changes along the Vasai creek were mapped for the years 1999, 2003, 2011 and 2017 using Landsat aerial imagery. Environmental Systems Research Institute (ESRI) Geographic Information System software was used for shoreline analysis. From the analysis, it is observed that the river banks are stable in the study area and accretion has been observed at some locations. Erosion spots are observed at the shoreline near the Creek entrance.

3.4 Proposed Conservancy Activities

3.4.1 Low Cost Structures (Bandalling, Sub-merged Vanes etc.)

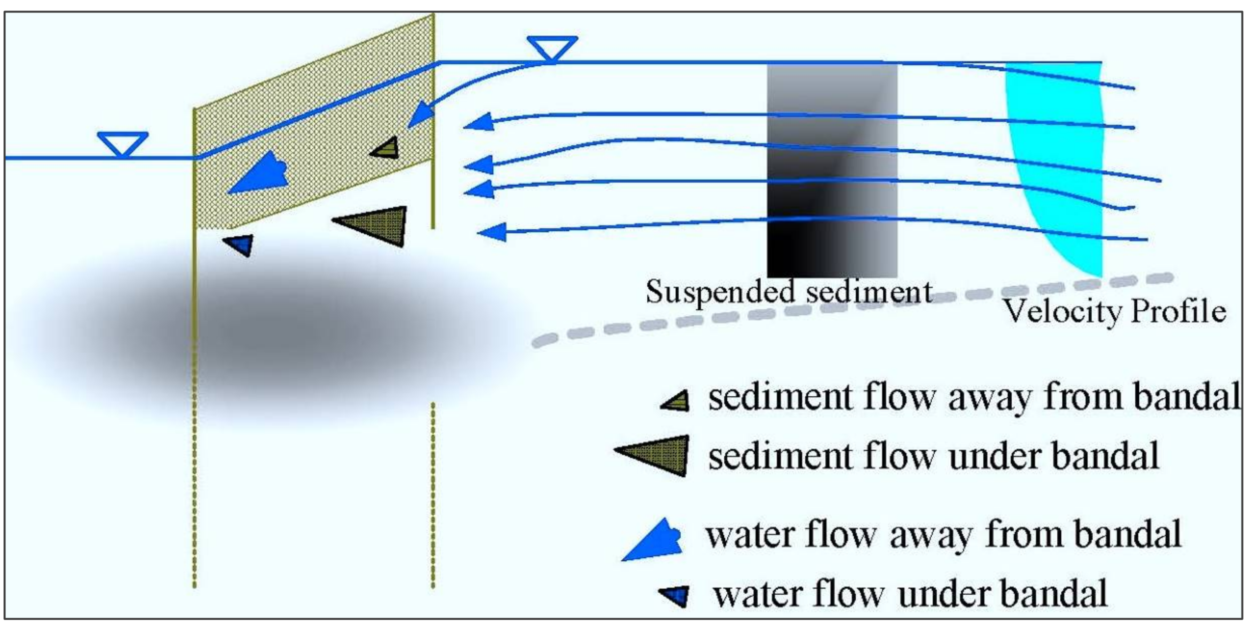
3.4.1.1 Bandalling

Bandalling is a locally bamboo made structure used for the river course stabilization by river bank erosion protection. Due to the locally available low-cost materials and labours, the construction of the bamboo bandalling is cost effective for the protection of erosive floodplain land. Due to the effect of the constructed bamboo bandalling structures in the river bends reach, the secondary current is not able to attack the bending river reach, accelerating the river bank sedimentation. It is also observed that water flow velocity is diverted towards the main channel and that of less magnitude near the river bank. Due to this low flow velocity near the river bank and the disturbed secondary current, there is huge sedimentation occurs near the erosive bending river reach between the constructed bamboo bandalling structures indicating that the bamboo bandalling structures can be used successfully as the river bank stabilization.

Working Principles

The working principles of bandals for the control of water and sediment flow are shown schematically in Figure 3.40, where sediments are transported as bed load and suspended load.

Figure 3. 40: Principles Of Bandalling



Source: Md. Lutfor Rahman et al, Department of Civil Engineering, DUET, Gazipur,

Within the lower half of the flow depth, major portion of the sediment flow is concentrated, whereas, within the upper half water discharges are more. Bandals are commonly applied to improve or maintain the flow depths for navigation during low water periods in alluvial rivers of Indian sub-continent. The essential characteristics of bandals are that they are positioned at an angle with main current and there is an opening below it while the upper portion is blocked. As an empirical rule the blockage of the flow section should be about 50% in order to maintain the flow acceleration.

The surface current is being forced to the upstream face creating significant pressure difference between the upstream and downstream side of bandals.

The flow near the bed is directed perpendicular to the bandals resulting near bed sediment transport along the same direction.

Applicable Areas

Clearly, the Bandalling can be used for protection of the erodible coastline and training of the flow regime in the navigation canal. There are 6 eroding areas in the entire stretch of the waterway, namely,

1. Eastern tip of the Panju Island as shown in Figure 2.25.
2. Two Locations between Chainage 23.000 km and 24.000 km as shown in the Figure 2.31 on left bank
3. Upstream of the Kasheli Bridge – II (Old Agra Road/NH 35) refer Figure 2.34 between Chainage 34.000 km and 34.500 km on right bank
4. Between Chainage 36.000 km and 36.500 km near Parsik Bunder left bank
5. Between chainage 40.500 km and 41.000 km on right bank.
6. On the right bank between chainage 44.500 km and 45.000 km

Hence, bandalling works could be utilized in these areas for stoppage of erosion if desired. However, the extent of erosion can be seen from the attached imageries. Bandalling through usage of Bamboo, is a low-cost arrangement and therefore, are in general renewed on a yearly basis. This is a local arrangement and could be taken up by the local authorities independent of the waterway authorities. However, many a times in western and advanced countries with regard to Inland waterways, the total waterway including the bank protection works are taken up by the waterway authorities.

The second use of the bandalling is to have the flow channelization. Intelligent placing of the bandalling structures can direct the primary current to the main channel there by increasing the flow intensity. There are other types of bandalling works such as pitched slopes and geo-fabric protections. There are mostly used for shore erosion control.

For the present erosion at the 6 locations temporary bandalling may be carried out for enabling the shore to recoup from the loss of material along the shoreline.

The use of bandalling for flow channelization may not be effective in the present context,since the entire stretch is tidal and bandalling is effective in closing flows to subsidiary channels.

3.4.1.2 Submerged Vanes

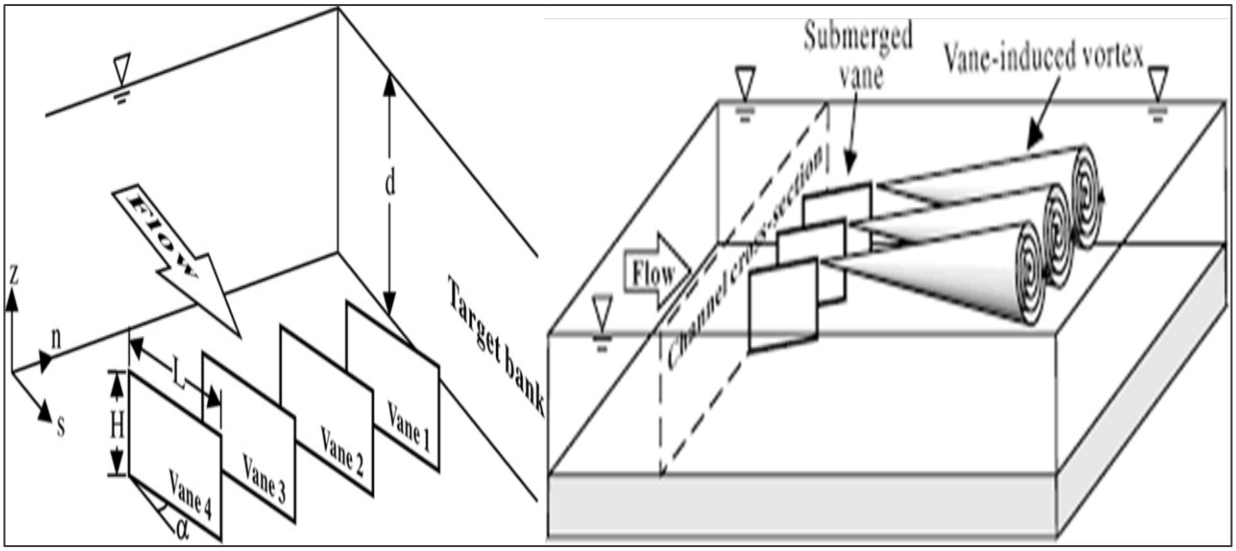
Definition

Submerged vanes are an unobtrusive and cost-effective way for river engineers to address many problems associated with river management. The vanes are small flow-training structures designed and installed on the riverbed to modify the near-bed flow pattern and redistribute flow and sediment transport within the channel cross section. The structures are laid out so they create and maintain a flow and bed topography that is consistent with that of a stable channel creating optimum conditions for managing the river. A relatively new technology, submerged vanes are a low-impact method for restoring river banks, stabilizing or re-meandering river reaches previously modified (straightened) by humans, increasing flood flow capacity, reducing sediment deposits, and helping maintain or enhance the ecosystem in and around rivers.

Working Principles

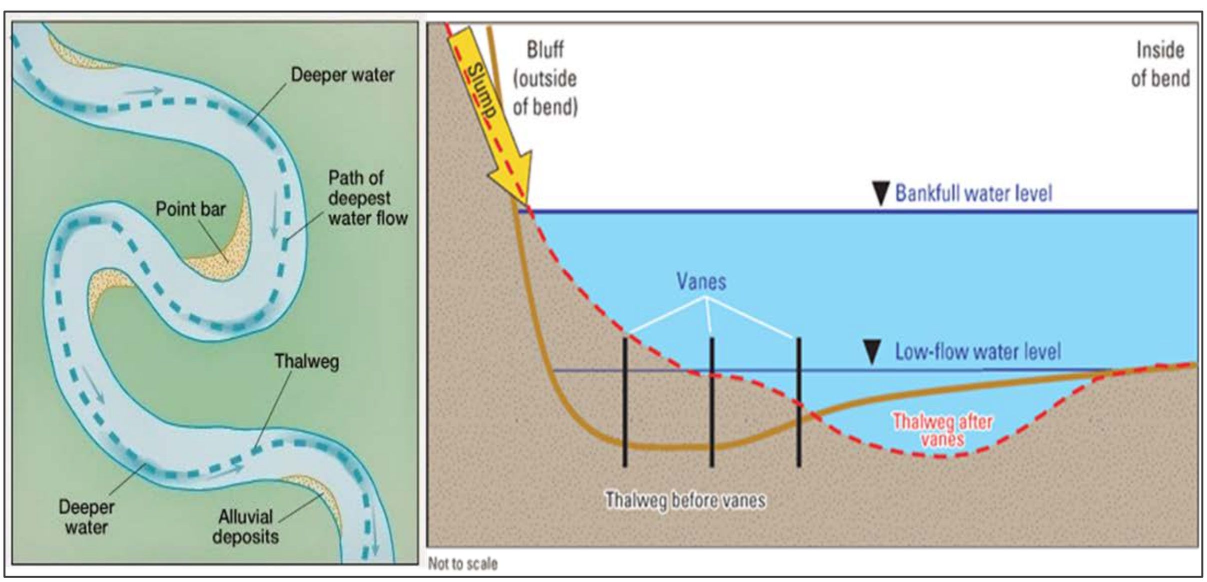
The Submerged Vanes Submerged vanes are under-water permeable type bank protection measures. These vanes are kept at an appropriate angle with the bank and at appropriate height with intention to induce optimum siltation near the bank. Orientation of submerged vanes should be decided after the model study to get their desired results. The vanes located intelligently can deflect the bank hugging flows to the center of the channel so that the flow gets shifted to the desired channel and sedimentation happens in the shadow. The Figure 3.41 indicates the location of the vanes for shifting the flow away from the target bank and making sedimentation happens along the target bank akin to one shown in the Figure 3.42

Figure 3. 41: Principles Of Working Of The Submerged Vanes



The submerged vanes are intelligently located along the concave banks so that the flow concentration shifts to the central portion of the channel due to bed aggradation and flow redistribution. Figure 3.42 indicates a meandering river along with the eroded and the sediment deposited banks. Post installation of the submerged vanes, the flow gets better distributed and deposition on the eroded bank happens.

Figure 3. 42: Effects Of Submerged Vanes On The Target Banks



Applicable Areas

Research indicates that the vane concept is an effective flow control device and a realistic alternative to other generally used techniques for streambank protection and flow channelization. The design in the river bend produced a reduction of the high-flow transverse bed slope of at least 50 percent and a reduction of the near-bank velocity of generally, 10 to 20 percent moving the velocity maximum toward the center of the channel.

Monitoring over a period of time on pilot projects in various periods indicated encouraging findings. In most cases, the channel alignment did not change measurably, despite several record floods through the channel. Overall, the top edge of the bank retreated on the average of about 2 m, with a maximum of about 6 m near apex of the bend. The toe of the bank showed no substantial movement along most of the bank. Over a 60-m long reach around apex, a 1-2 m retreat of the toe was noted. Comparisons with the past records indicated that, the floods of this period would have produced a bank retreat of at least 20 m if vanes had not been installed. (The outer bank of the bend immediately upstream from the vaned bend retreated 20-30 m during the same period). The system did not cause any measurable change in the longitudinal slope of the water surface, nor in the average depth for a given discharge.
Most alternative bank protection techniques produce significant changes of both slope and average depth surmising to the effectiveness of these techniques.

However, the design of the vanes and the installation must be immaculate and based on flow regime and geometry. Because of the sensitivity of vane performance to the approach-flow angle, correct number of vanes should be installed at the crossover between this and the upstream bend to maintain the correct approach angle to the uppermost vanes in the system, or better yet, the upstream bend should have been stabilized.

Following laboratory research and feedback from field installations, guidelines are now available for designs that are effective and sustainable. The experience summarized herein suggests that vanes are an attractive technology for managing streams of all sizes ranging from small creeks to large, braided rivers like Brahmaputra.

For the present case, these could be deployed to a limited extent on the eroding bends near Kasheli for example. However, these locations would have to be carefully chosen and designed for the local requirements once the waterway gets functional.

3.4.2 Dredging

3.4.2.1 Definition

Dredging is the most effective method for creating navigable depth artificially. Dredging is an excavation activity usually carried out underwater, in shallow seas or freshwater areas with the purpose of gathering up bottom sediments and widening the channel. This technique is often used to keep waterways navigable and creates an anti-sludge pathway for boats. It is also used as a way to replenish sand on some public beaches, where sand has been lost because of coastal erosion. Fishing dredges are used as a technique for catching certain species of edible clams and crabs. The dredging can be broadly divided in to the following three types,

i. **Capital**: Dredging carried out to create a new harbor, berth or waterway, or to deepen existing facilities in order to allow larger ships access. Because capital works usually involve hard material or high-volume works, the work is usually done using a cutter suction dredge or suction dredgers; but for rock works, drilling and controlled blasting along with mechanical excavation may be used. As the water depth is low and quantities are only about 25,904 cu m, breaking the rocks by hammers/backhoes and scooping may an effective method. Using smaller fully-certified field-tested dredgers means the vessel is transportable on the back of a lorry and can 'walk' itself into the water. Launching is quick and economical – no extra machinery is needed, this would ensure faster commencement. In the Indian scenario, Crawl cat series of dredgers can be very effective for Capital and maintenance dredging of Inland waterways and irrigation canals. These are amphibious hydraulic cutter suction dredgers, offering tremendous potential for capital and maintenance dredging.

ii. **Preparatory**: Work and excavation for future bridges, piers or docks/wharves, often connected with foundation work.

iii. **Maintenance**: Dredging to deepen or maintain navigable waterways or channels, which are threatened to become silted with the passage of time, due to sedimented sand and mud, possibly making them too shallow for navigation. This is often carried out with a grab dredger when the dredging is less or a trailing suction dredger of Crawl Cat series when the dredging quantity is more. In the present waterway, Grab dredgers would be enough for the maintenance job of the channel. Most dredging is for this purpose, and it may also be done to maintain the holding capacity of reservoirs or lakes.

Without the many and almost non-stop dredging operations worldwide, much of the world's commerce would be impaired, often within a few months, since much of world's goods travel by ship, and need to access harbors or seas via channels.

3.4.2.2 Types Of Dredging

A. Suction

These operate by sucking through a long tube, like some vacuum cleaners but on a larger scale. A plain suction dredger has no tool at the end of the suction pipe to disturb the material. This is often the most commonly used form of dredging.

Figure 3. 43: Dredge Drag Head Of A Suction Dredge Barge On A River

B. Trailing Suction

A trailing suction hopper dredger (TSHD) trails its suction pipe when working. The pipe, which is fitted with a dredge drag head, loads the dredge spoil into one or more hoppers in the vessel. When the hoppers are full, the TSHD sails to a disposal area and either dumps the material through doors in the hull or pumps the material out of the hoppers. Some dredges also self-offload using drag buckets and conveyors.

The largest trailing suction hopper dredgers in the world are currently Jan De Nul's Cristobal Colon (launched 4 July 2008) and its sister ship Leiv Eriksson (launched 4 September 2009. Main design specs for the Cristobal Colon and the Leiv Eriksson are: 46,000 cubic meter hopper and a design dredging depth of 155 m. Next largest is HAM 318 (Van Oord) with its 37,293 cubic meter hopper and a maximum dredging depth of 101 m.

Figure 3. 44: Trailing Suction Dredger Working On A Canal In Netherland

C. Cutter-Suction

A cutter-suction dredger's (CSD) suction tube has a cutting mechanism at the suction inlet. The cutting mechanism loosens the bed material and transports it to the suction mouth. The dredged material is usually sucked up by a wear-resistant centrifugal pump and discharged either through a pipe line or to a barge. Cutter-suction dredgers are most often used in geological areas consisting of hard surface materials (for example gravel deposits or surface bedrock) where a standard suction dredger would be ineffective. In recent years, dredgers with more powerful cutters have been built in order to excavate harder rock without the need for blasting.

The two largest cutter suction dredgers in the world are currently (as at August 2009) DEME's D'Artagnan (28,200 kW total installed power) and Jan De Nul's J.F.J. DeNul (27,240 kW) both built by IHC Merwede.

Figure 3. 45: Trailing Suction Dredger Working On A Canal In Netherland

D. Auger Suction

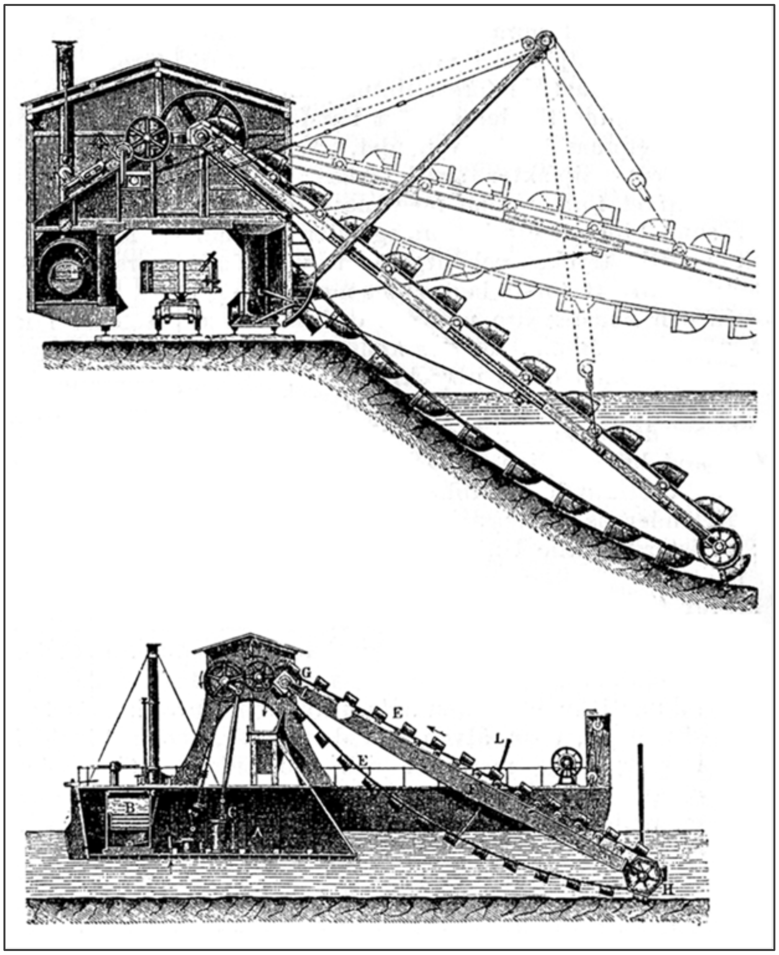
This process functions like a cutter suction dredger, but the cutting tool is a rotating Archimedean screw set at right angles to the suction pipe. The first widely used auger dredges were designed in the 1980s by Mud Cat Dredges, which was run by National Car Rental, but is now a Division of Ellicott Dredges. In 1996, IMS Dredges introduced a self-propelled version of the auger dredge that allows the system to propel itself without the use of anchors or cables. During the 1980s and 1990s auger dredges were primarily used for sludge removal applications from waste water treatment plants. Today, auger dredges are used for a wider variety of applications including river maintenance and sand mining.

The most common auger dredge on the global market today is the Versi-Dredge. The turbidity shroud on auger dredge systems creates a strong suction vacuum, causing much less turbidity than conical (basket) type cutter heads and so they are preferred for environmental applications. The vacuum created by the shroud and the ability to convey material to the pump faster makes auger dredge systems more productive than similar sized conical (basket) type cutter head dredges.

E. Bucket

A bucket dredger is equipped with a bucket dredge, which is a device that picks up sediment by mechanical means, often with many circulating buckets attached to a wheel or chain. Some bucket dredgers and grab dredgers are powerful enough to rip out coral to make a shipping channel through coral reefs.

Figure 3. 46: Bucket Dredger



F. Jet-lift

These use the Venturi effect of a concentrated high-speed stream of water to pull the nearby water, together with bed material, into a pipe.

G. Air-lift

An airlift is a type of small suction dredge. It is sometimes used like other dredges. At other times, an airlift is handheld underwater by a diver. It works by blowing air into the pipe, and that air, being lighter than water, rises inside the pipe, dragging water with it.

H. Clamshell

A grab dredger picks up seabed material with a clam shell bucket, which hangs from an onboard crane or a crane barge, or is carried by a hydraulic arm, or is mounted like on a dragline. This technique is often used in excavation of bay mud. Most of these dredges are crane barges with spuds.

Figure 3. 47: Clamshell Dredging In Progress

I. Backhoe/Dipper

A backhoe/dipper dredger has a backhoe like on some excavators. A crude but usable backhoe dredger can be made by mounting a land-type backhoe excavator on a pontoon. The six largest backhoe dredgers in the world are currently the Vitruvius, the Mimar Sinan, Postnik Jakovlev (Jan De Nul), the Samson (DEME), the Simson and the Goliath (Van Oord).[citation needed] They featured barge-mounted excavators. Small backhoe dredgers can be track-mounted and work from the bank of ditches. A backhoe dredger is equipped with a half-open shell. The shell is filled moving towards the machine. Usually dredged material is loaded in barges. This machine is mainly used in harbors and other shallow water.

J. Water Injection

A water injection dredger uses a small jet to inject water under low pressure (to prevent the sediment from exploding into the surrounding waters) into the seabed to bring the sediment in suspension, which then becomes a turbidity current, which flows away down slope, is moved by a second burst of water from the WID or is carried away in natural currents. Water injection results in a lot of sediment in the water which makes measurement with most hydrographic equipment (for instance: single beam echo sounders) difficult.

K. Pneumatic

These dredgers use a chamber with inlets, out of which the water is pumped with the inlets closed. It is usually suspended from a crane on land or from a small pontoon or barge. Its effectiveness depends on depth pressure.

L. Bed Leveler

This is a bar or blade which is pulled over the seabed behind any suitable ship or boat. It has an effect similar to that of a bulldozer on land. The chain-operated steam dredger Bertha, built in 1844 to a design by Brunel and now the oldest operational steam vessel in Britain, was of this type.

M. Krabbelaar

This is an early type of dredger which was formerly used in shallow water in the Netherlands. It was a flat-bottomed boat with spikes sticking out of its bottom. As tide current pulled the boat, the spikes scraped seabed material loose, and the tide current washed the material away, hopefully to deeper water. Krabbelaar is Dutch for "scratcher".

N. Snag Boat

A snag boat is designed to remove big debris such as dead trees and parts of trees from rivers and canals.

O. Amphibious

Dredgers that can operate almost everywhere i.e. Land as well as water.
Some of these are any of the above types of dredger, which can operate normally, or by extending legs, also known as spuds, so it stands on the seabed with its hull out of the water.
Some forms can go on land as well. Some of these are land-type backhoe excavators whose wheels are on long hinged legs so it can drive into shallow water and keep its cab out of water. Some of these may not have a floatable hull and, if so, cannot work in deep water. Oliver Evans (1755–1819) in 1804 invented an amphibious dredger which was America's first steam-powered road vehicle.

P. Submersible

These are usually used to recover useful materials from the seabed. Many of them travel on continuous track. A unique variant is intended to walk on legs on the seabed.

Q. Fishing

Fishing dredges are used to collect various species of clams, scallops, oysters or crabs from the seabed. These dredges have the form of a scoop made of chain mesh, and are towed by a fishing boat. Careless dredging can be destructive to the seabed. Nowadays some scallop dredging is replaced by collecting via scuba diving.

R. Crawl Cat Amphibious Dredgers

Manufactured by an Indian Shipyard, is an amphibious hydraulic suction dredger, offers tremendous capability for capital as well as the maintenance dredging of Inland waterways and irrigation canals. These dredgers and similar ones of its ilk, can be moved through road and they have the ability to walk in to the water, without much ado about the launching them in to the water. These dredgers have jacking capability above water level, which enables them to over come the extreme wave and current forces. Is a very safe dredger to work in estuaries and sand bars. The absence of winch and winch wires, the ability to work continuously, easy handling by one operator, good maneuverability contributes to its higher productivity.

3.4.2.3 Applicable Areas

The dredging of the areas in the Channel which is shallow and sedimented would be taken up using suction dredgers, a type close to Crawl cat or similar type. In this case the width of the channel to be fixed up later in the chapter and the widening at the bends to be included in the design of the channel and computation of the quantities, as described in the Para 3.2.1.

The dredging of the shoals areas has been worked out and given in Table 3.11 and 3.12 for North and south channels respectively.

The top level of the entire channel consists of mostly sedimented sand or silt and therefore the dredging could be completed by a suction dredger. Part of the good quality sand could be used for reclamation near the terminal areas and the low lying swampy areas to be developed as utility areas. The exact areas of disposal have been marked on the chart and given separately in section 3.4.2.5.

3.4.2.4 Calculation Of The Dredging Volumes

In order to compute the dredging volume for creation of the channel Dredging volumes for 3 different depths are calculated in the following table based on the current bathymetry. Though the initial developments would be planned with 3 m dredging, other options would give the necessary perspectives for future considerations.

Table 3.10 gives the general river slope along the existing creek/river, which follows the computation of the dredging quantity in Table 3.11 and 3.12. Table 3.12 gives the computation of the dredging in the southern secondary channel. The total dredging quantity would be the summation of the both.

Table 3. 10: River Slopes Along The Proposed Channel

Reach		River / Canal Bed Level Change (m)	Distance (km)	Slope (A/B)
From	To			
0	1.0	7.4	893	0.008
1	2.0	8.8	489	0.018
2	3.0	9	616	0.015
3	4.0	1.5	371	0.004
4	5.0	4.3	915	0.005
5	6.0	14.8	332	0.045
6	7	8.1	758	0.011
7	8	2.3	789	0.003
8	9	1.7	792	0.002
9	10	4	604	0.007
10	11	1.3	540	0.002
11	12	7	559	0.013
12	13	2.2	312	0.007
13	14	0.9	577	0.002
14	15	2.3	925	0.002
15	16	3.8	971	0.004
16	17	4.8	690	0.007
17	18	11	728	0.015
18	19	29.8	165	0.180
19	20	28.8	112	0.257
20	21	25.2	781	0.032
21	22	23.2	955	0.024
22	23	5.6	234	0.024
23	24	5	242	0.021
24	25	2.6	978	0.003
25	26	4.8	188	0.026
26	27	5	646	0.008
27	28	6.4	952	0.007
28	29	4.4	344	0.013
29	30	0.4	347	0.001

Reach		River / Canal Bed Level Change (m)	Distance (km)	Slope (A/B)
From	To			
30	31	3.8	653	0.006
31	32	3.9	673	0.006
32	33	0.2	484	0.000
33	34	11.1	77	0.145
34	35	10.8	956	0.011
35	36	4.2	385	0.011
36	37	5	685	0.007
37	38	11.2	688	0.016
38	39	6.3	529	0.012
39	40	5.3	122	0.043
40	41	9.2	107	0.086
41	42	8.9	184	0.048
42	43	7.5	493	0.015
43	44	2.9	468	0.006
44	45	9.8	403	0.024
45	46	6.3	102	0.062
46	47	10.2	353	0.029
47	48	8.2	765	0.011
48	49	6.3	675	0.009
49	50	8.1	209	0.039
50	51	12.1	505	0.024
51	52	14.1	410	0.034
S0.160	S1.0	7.1	615	0.012
S2.0	S3.0	5.9	896	0.006
S3.0	S4.0	0.7	745	0.0009
S4.0	S5.0	0.8	592	0.001
S5.0	S6.0	1.2	959	0.001
S6.0	S7.0	1.8	590	0.003
S7.0	S8.0	2.9	605	0.004
S8.0	S9.0	1.2	513	0.002
S9.0	S10.0	1.7	892	0.002

Reach		River / Canal Bed Level Change (m)	Distance (km)	Slope (A/B)
From	To			
S10.0	S11.8	0.5	305	0.001

Table 3. 11: Dredging Volumes For Different Depths Of Channel Depth Along The 100 M Wide Channel To The North

CHAINAGE (Km)	Existing Average Depth	Dredging Volume (Cu m)					
		Design Depth 3m below CD		Design Depth 4m below CD		Design Depth 5m below CD	
		Soft	Hard	Soft	Hard	Soft	Hard
0-0.5	2.0	32425.5	Nil	66516.7	Nil	101160.7	Nil
0.5-1.0*	5.5	32.4	Nil	2041.2	Nil	11353.5	Nil
1-2	4.0	0.00	Nil	0.00	Nil	719.48	Nil
2-3	5.2	0.00	Nil	0.00	Nil	0.00	Nil
3-4	5.9	0.00	Nil	0.00	Nil	0.00	Nil
4-5	6.4	0.00	Nil	0.00	Nil	0.00	Nil
5-6	2.4	2151.47	Nil	4778.74	Nil	9068.21	Nil
6-7	4.2	0.00	Nil	0.00	Nil	3152.77	Nil
7-8	4.1	0.00	Nil	0.00	Nil	26985.40	Nil
8-9	4.7	0.00	Nil	0.00	Nil	3305.27	Nil
9-10	3.4	0.00	Nil	346.07	Nil	10558.13	Nil
10-11	3.1	0.00	Nil	30650.63	Nil	126648.87	Nil
11-12	3.4	0.00	Nil	1347.47	Nil	71799.20	Nil
12-13	2.5	3998.33	Nil	36961.47	Nil	131118.33	Nil
13-14	2.0	64882.60	Nil	162986.60	Nil	261090.60	Nil
14-15	2.5	2091.47	Nil	41722.53	Nil	125834.47	Nil
15-16	4.3	0.00	Nil	0.00	Nil	8266.20	Nil
16-17	6.4	0.00	Nil	0.00	Nil	0.00	Nil
17-18	8.6	0.00	Nil	0.00	Nil	0.00	Nil
18-19	13.7	0.00	Nil	0.00	Nil	0.00	Nil
19-20	10.2	0.00	Nil	0.00	Nil	0.00	Nil
20-21	16.8	0.00	Nil	0.00	Nil	0.00	Nil
21-22	7.5	0.00	Nil	0.00	Nil	0.00	Nil
22-23	4.8	0.00	Nil	0.00	Nil	15.13	Nil
23-24	3.7	0.00	Nil	338.85	Nil	16648.12	Nil

CHAINAGE (Km)	Existing Average Depth	Dredging Volume (Cu m)					
		Design Depth 3m below CD		Design Depth 4m below CD		Design Depth 5m below CD	
		Soft	Hard	Soft	Hard	Soft	Hard
24-25	4.3	0.00	Nil	0.00	Nil	15916.73	Nil
25-26	6.10	0.00	Nil	0.00	Nil	0.00	Nil
26-27	4.8	0.00	Nil	0.00	Nil	99.80	Nil
27-28	5.7	0.00	Nil	0.00	Nil	0.00	Nil
28-29	8.9	0.00	Nil	0.00	Nil	0.00	Nil
29-30	7.4	0.00	Nil	0.00	Nil	0.00	Nil
30-31	5.7	0.00	Nil	0.00	Nil	0.00	Nil
31-32	5.6	0.00	Nil	0.00	Nil	0.00	Nil
32-33	5.6	0.00	Nil	0.00	Nil	0.00	Nil
33-34	5.4	0.00	Nil	0.00	Nil	0.00	Nil
34-35	3.6	0.00	Nil	19.41	Nil	3397.41	Nil
35-36	1.9	10470.93	Nil	59028.79	Nil	148364.93	Nil
36-37	2.9	1.13	Nil	5633.20	Nil	33204.12	Nil
37-38	5.2	0.00	Nil	0.00	Nil	0.00	Nil
38-39	5.1	0.00	Nil	0.00	Nil	0.00	Nil
39-40	5.9	0.00	Nil	0.00	Nil	0.00	Nil
40-41	5.00	0.00	Nil	0.00	Nil	0.00	Nil
41-42	5.60	0.00	Nil	0.00	Nil	0.00	Nil
42-43	5.90	0.00	Nil	0.00	Nil	0.00	Nil
43-44	4.80	0.00	Nil	0.00	Nil	49.67	Nil
44-45	4.70	0.00	Nil	0.00	Nil	5.50	Nil
45-46	5.30	0.00	Nil	0.00	Nil	0.00	Nil
46-46.5	6.0	0.00	0.00	0.00	0.00	0.00	0.69
46.5-47#	8.5	0.00	0.00	43.00	0.00	546.8	0.00
47-48	1.20	14107.67	104.55	45445.42	1813.08	103427.79	5448.71
48-49	-0.98	121094.76	652.54	206804.30	1824.87	302070.91	4140.82
49-50	-1.51	77680.15	4509.31	145551.28	7887.41	232061.97	11332.20
50-51	-0.87	57125.18	20587.23	92866.69	30845.68	139697.41	42621.86
51-52	2.10	109.50	50.01	1619.88	941.23	8772.37	2843.23
TOTAL		**386171.099**	**25903.644**	**904702.233**	**43312.27**	**1895339.795**	**66387.51**

Note: Volume calculations were done based on Bathymetry and Geophysical survey data collected during the survey by using Hypack software.

0.5-1.0* The average value is only indicative, shallow depths below 3m,4m&5m are also observed in the channel.

46.5-47# The average value is only indicative, shallow depths below 4m&5m are also observed in the channel

Table 3. 12: Dredging Volumes For Different Depths Of Channel Depth - 100 M Wide Channel To The South (Secondary)

CHAINAGE (Km)	Existing Average Depth	Dredging Volume (Cu m)					
		Design Depth 3m below CD		Design Depth 4m below CD		Design Depth 5m below CD	
		Soft	Hard	Soft	Hard	Soft	Hard
0.160-1	12.15	0.0	Nil	0.0	Nil	0.0	Nil
1-2	4.10*	18745.0	Nil	59234.7	Nil	122987.8	Nil
2-3	1.81	116743.7	Nil	215151.7	Nil	313559.7	Nil
3-4	1.66	132488.0	Nil	231674.0	Nil	330860.0	Nil
4-5	2.79	26801.5	Nil	120361.7	Nil	219541.7	Nil
5-6	4.44	0.0	Nil	6561.5	Nil	57848.9	Nil
6-7	5.12	0.0	Nil	0.0	Nil	16654.5	Nil
7-8	5.54	0.0	Nil	0.0	Nil	1106.6	Nil
8-9	4.70	0.0	Nil	169.9	Nil	41329.1	Nil
9-10	3.62	0.0	Nil	37771.2	Nil	136516.7	Nil
10-11	5.08	0.0	Nil	218.6	Nil	27213.4	Nil
11-12	7.16	0.0	Nil	0.0	Nil	0.0	Nil
		294778.2	**Nil**	**671143.3**	**Nil**	**1267618.4**	**Nil**
Total North + South		**680949.3**	**25903.6**	**1575845.5**	**43312.27**	**3163018.2**	**66387.5**
		Grand Total For North&South Channels (Soft +Hard) 706852.90		**Grand Total For North&South Channels (Soft +Hard) 1619157.77**		**Grand Total For North&South Channels (Soft +Hard) 3229405.70**	

Note: Volume calculations were done based on Bathymetry and Geophysical survey data collected during the survey by using Hypack software.

1-2 * The average value is only indicative, shallow depths below 3m,4m&5m are also observed in the channel.

3.4.2.5 Dredge Spoil Disposal Areas

The bathymetry in the navigational channel is proposed to be maintained at 3.0 m CD. The dredgeable quantities have been worked out based on the bathymetry, seismic survey and geotechnical investigations and shown in tables 3.11 and 3.12

The total dredged quantities to be disposed are 0.71 million cu.m. Based on borehole data the good useable dredged material is about 0.43 million cu.m, which will be used during construction of the nearest IWT terminal. The balance disposable material is only 0.28 million cu.m which is proposed to be disposed as follows:

a. Area 1 – Disposal of 0.1 million cu.m on Panju Island eastern tip as shown in figure 3.48 below

Figure 3. 48: Disposal Area 1

b. Area 2 – Disposal of 0.05 million cu.m on eroding zone upstream of Kolshet bridge as shown in figure 3.49 below

Figure 3. 49: Disposal Area 2

c. Area 3 – Disposal of 0.08 million cu.m on the eroding bank north of Anjurdive (Chaninage 36.00 to 36.5 km) as shown in figure 3.50 below

Figure 3. 50: Disposal Area 3

d. Area 4 – Disposal of 0.05 million cu.m on the eroding zone north-east of Saatpul bridge on north bank of Ulhas river as shown in figure 3.51 below

Figure 3. 51: Disposal Area 4

About 25,904 cu m of hard material is to be removed by dredging. It is proposed to utilize the hard material for bank protection/terminal construction at the nearest location

3.4.3 River Training

3.4.3.1 Methods of River Training

The most important types of river training works, i.e., (1) Embankments, (2) Guide Banks or Bell Bunds, (3) Spurs or Groynes, (4) Impermeable Groynes, (5) Permeable Groynes, (6) Bed Pitching and Bank Revetment, and (7) Dredging of River. In addition, other river training works such as bandalling and submerged vanes are also deployed which has been described earlier.

A. Embankments:

The floods may be prevented from submerging the country by constructing earth embankments. They are generally constructed up to a height of 12 m. They are designed and constructed in the same way as an earth dam. The embankments are generally constructed parallel to the river channel. These embankments in a tidal river such as Ulhas, serves two purposes,

1. Prevention of the tidal water/Flood water from entering the fields and properties along the coastline
2. Provide approach to the river through motorable way

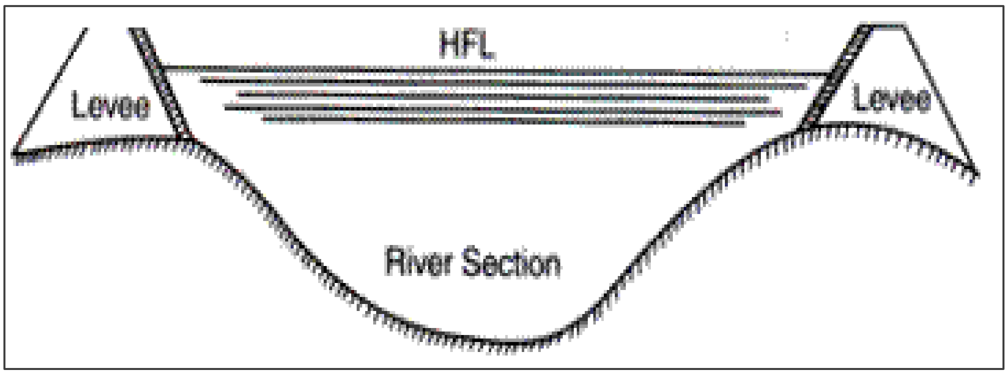
In the state of Maharashtra, these embankments are constructed and maintained by the Kharland department.

Depending upon the position of the embankments subdivisions made are:

i. Marginal embankments or dykes or levees
ii. Retired embankments

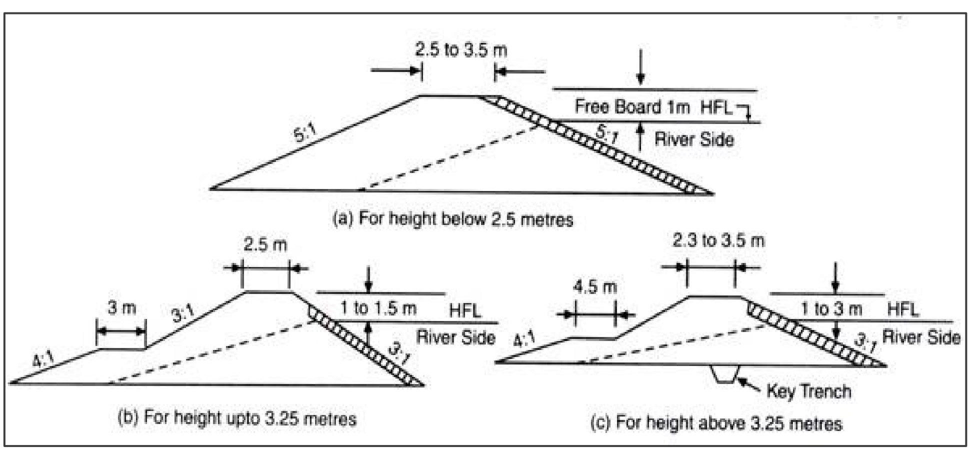
The marginal embankments are constructed as close to the banks as possible to restrict the flood/tidal water from submerging the area behind them. Figure 3.48 shows the position of marginal embankments.

Figure 3. 52: Marginal Embankments Or Levees



They are designed to hold up the water up to a maximum anticipated HFL without the possibility of overtopping and with a view to withstand all external pressures. This condition is met with by providing sufficient free board, bed width, top width and stone protection on adequate slopes. As the height of the embankment increases it becomes necessary to provide key trench, zoned section etc., to make the embankment stable. Like earth dams, embankments are also likely to fail due to overtopping, piping, rat holes, seepage and caving in of river side sloping face. It is therefore necessary to adopt adequate sections for various heights. The following sections are generally adopted for various heights.

Figure 3. 53: Sections Of The Marginal Embankments (Typical)



Advantages of Embankments:

1. They are very widely used river training work.
2. It is cheaper and quick as well as simple in construction. They can be constructed with locally available material.
3. Maintenance of embankments is similar to canal bank maintenance and does not involve intricate methods.
4. Embankment can be constructed reach by reach to extend extent of protection.
5. They protect large areas by comparatively small investment.

Disadvantages of Embankments:

i. By restricting the waterway, it raises the flood levels.
ii. Unpredictable flood flows attack the embankment and hence chances of its failure are quite high.
iii. During flood constant vigil is required on the embankments. It increases cost of maintenance.
iv. They interfere in laying irrigation canal system and also reduce cultivable area.

Retired embankments are constructed at a distance from the river banks. Thus, retired embankments are the intermediate type between the case of marginal embankments and river with no embankments. Retired embankments are generally constructed on a lower ground away from the banks.

Though they are costly due to increased height and risky, they have some mentionable advantages:

i. They do not interfere in the process of raising of the ground by deposition of silt.
ii. They make it possible to store more water for longer period.
iii. They provide wider waterway in times of high floods.

B. Guide Banks or Bell's Bunds:

Rivers in flood plains submerge very large areas during flood periods. Naturally when some structure is to be constructed across such a river (for example, bridge, weir, etc.), it is very expensive to construct the work spanning whole width of the river. To economies some training work may be constructed to confine the flow of water within a reasonable waterway.

Guide banks are meant for guiding and confining the flow in a reasonable waterway at the site of the structure. The design of the guide banks is based on the theory developed by Mr. Bells. Hence, guide banks are also known as Bell's bunds. This river training work has been devised from a study of the natural river channel in alluvial reach.

The river has a tendency to meander over large width of low lying land thereby flooding it occasionally. But it was observed that the same stream passes through narrow and deep sections where high and stiff permanent banks are available on either side without appreciable afflux or abnormal velocity.

The guide banks guide the river flow past a bridge or any other hydraulic structure without causing damage to the work and its approaches. The guide banks are constructed parallel or approximately parallel to the direction of flow. They extend both upstream and downstream of the abutments of the hydraulic structure. The guide banks may be provided on either side of the hydraulic structure or on one side as required.

The guide banks consist of four parts mainly:

i. Upstream curved head or impregnable head
ii. Downstream curved head
iii. Shank or a straight portion which joins the two curved heads
iv. Slope and bed protection, it includes apron

Generally, the core of the bund is built with sand. The sloping faces are protected with stones. An apron is also provided for protecting the bed against scouring. Sufficient freeboard and top width are also provided. The curved heads are laid with adequate curvature.

Guide banks mainly serve two purposes:

i. They protect the approach embankment for the bridge from attack of the water. Approach embankments extend from the bank of the river to the guide banks generally in perpendicular direction to both.
ii. They control the river and induce it to flow through the bridge more or less axially.

Selection of Site and Section of Guide Banks:

The site for guide banks should be selected in such a way that there is no side channel flowing parallel to the guide banks. The side channel if present may breach the approach embankment. The guide banks should be so designed that no swirls are produced.

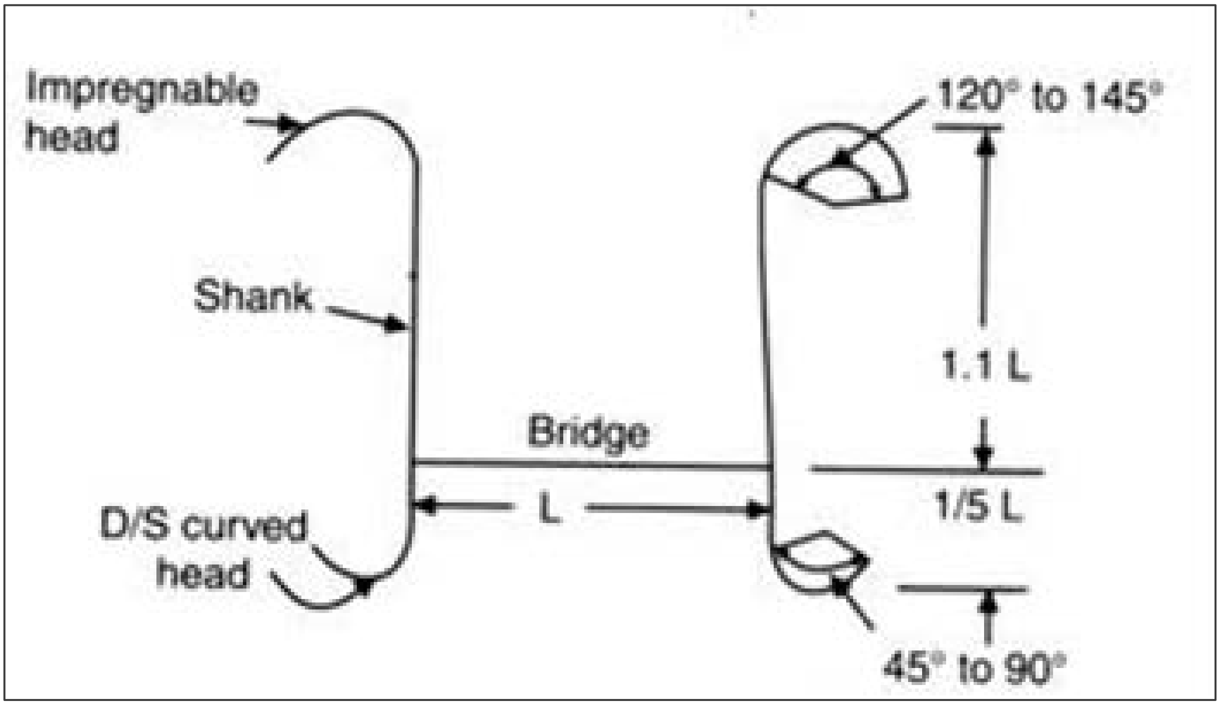
The top width of bank should not be less than 3 m. Side slopes should be 2:1 and free board 1.25 to 1.50 meters. While providing the free board due weightage should be given for heading up of the water and also for settlement of banks (generally 10 per cent of height). The inside slope should be protected with stone pitching and outside slope with good earth.

The waterway is given by Lacey's regime perimeter formula:

Pw= 4.825 Q1/2

where Pw is waterway in meters and Q is discharge in cubic meters/sec. The length of upstream part of the guide bank should be 10 per cent more than the length of a bridge or any other structure between the abutments. The length of downstream part of the guide bank should be 1/5 of the structure. (Fig. 3.50).

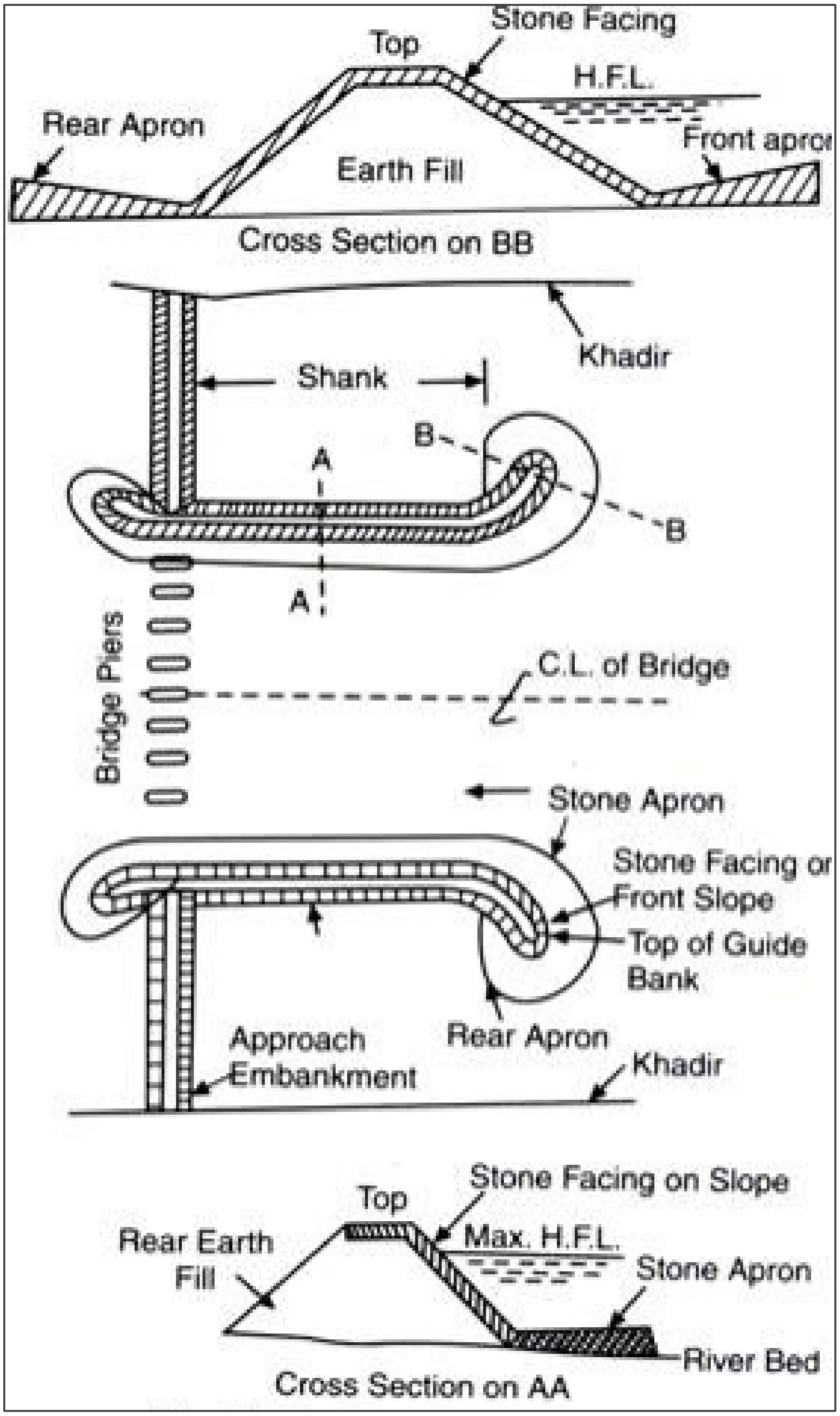
Figure 3. 54: Dimensions Of Guide Bunds (Typical)



The radius of curvature of the upstream curved head should be such as not to cause intense eddies. The radius of downstream curved head may be kept half that of upstream curved head. The heads should be curved well round to the back of the guide bank. Upstream curved head generally subtends an angle from 120° to 145° to the center and downstream head from 45° to 90°. The upstream curved head is also called “impregnable head”.

To protect the face of the guide bank at the river bed level a thick stone cover is laid on the bed. It is called an apron. When the scour undermines the river bed the apron comes down or launches to cover the face of the scour. Hence it is called Launching apron also. The quantity of stone in the apron should be adequate to insure complete protection of the scoured face. Figure 3.51 shows the details of a guide bank. After launching, the apron does not remain uniform in thickness.

Figure 3. 55: Details of Guide Bunds (Typical)



Generally, apron thickness is kept 1.25 times thickness of the pitching. For rivers in which deep scour is likely to take place thickness of the apron may be increased to 1.5 times.

C. Spurs or Groynes:

They are the structures constructed transverse to the river flow. They extend from the bank into the river. Groynes serve following purposes:

a. They protect the river bank by keeping the flow away from it.
b. They create still pond along a particular bank with the aim of silting up the area in the vicinity.
c. They train the river to flow along a desired course by attracting, deflecting or repelling the flow.
d. They contract the wide river channel for improving the navigation depth.

Classification of Groynes:

Various classifications of spurs or groynes may be given as mentioned below:

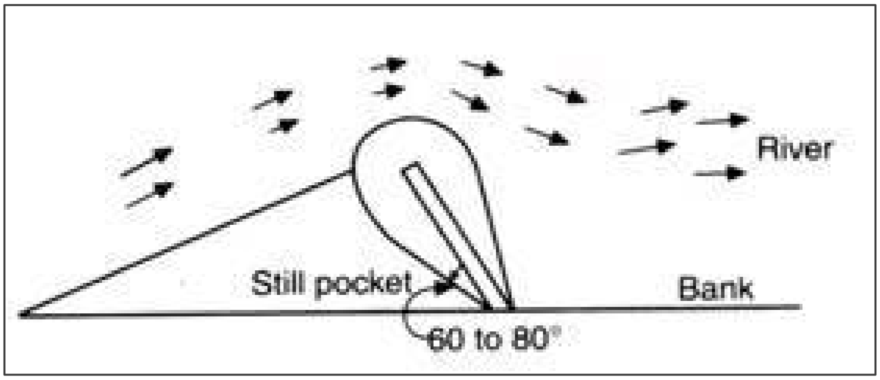
1. **Classification according to the method of construction.**
   a. Permeable
   b. Impermeable
2. **Classification according to the height of the spur below high water.**
   a. Submersible
   b. Non-submersible
3. **Classification according to the functions served.**
   a. Attracting type
   b. Deflecting type
   c. Repelling type
   d. Sedimenting type
4. **Special type:**

For example, Denehy's "T" headed groynes. Hockey spurs, etc. When a river is to be confined to a definite channel impermeable type of groyne is most suitable. For excessively silt-laden rivers permeable groynes are suitable. The groynes may be used singly or in series or in combination with other training work depending upon the problem in hand. When training or protection is to be given over a long and straight river reach groynes are used in series. Spacing of 2 to 2.5 times the length of groynes is a general practice. In a curved reach river can be trained by limited number of spurs. They can also be used in combination with other training measures.

5. **Impermeable Groynes:**

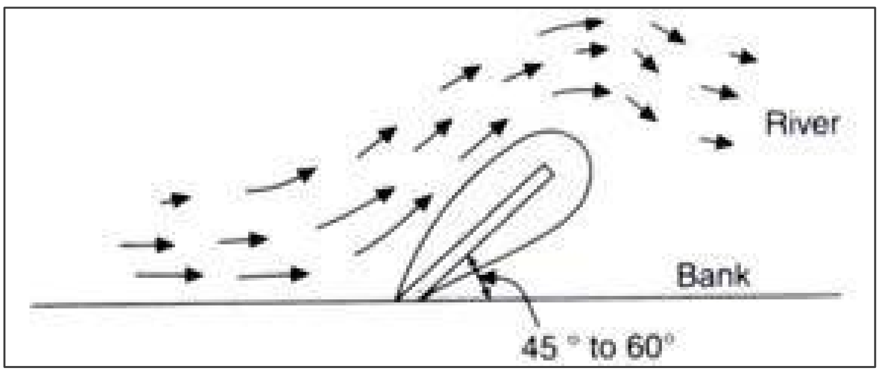
The groynes may be aligned either perpendicular to the bank or inclined, pointing upstream or downstream. When a groyne points upstream then it is called a repelling groyne. The reason being, this type has a property of repelling the river flow away from the bank (Fig 3.52). This is accomplished by creation of a still pond on the upstream. Obviously, the river starts following beyond the still pond and in the process the river flow goes away from the bank.

Figure 3. 56: Repelling Groyne (Typical)



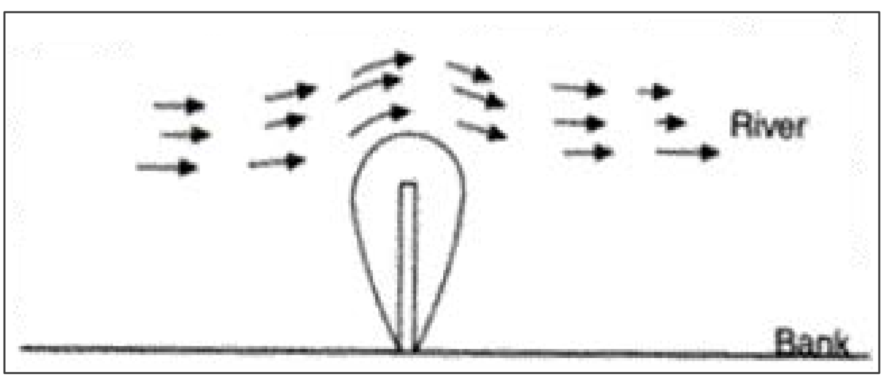
On the contrary, when a groyne points downstream it is called an attracting groyne as. It attracts the river flow towards the bank from which it takes off (Figure 3.53).

Figure 3. 57: Atrracting Groynes (Typical)



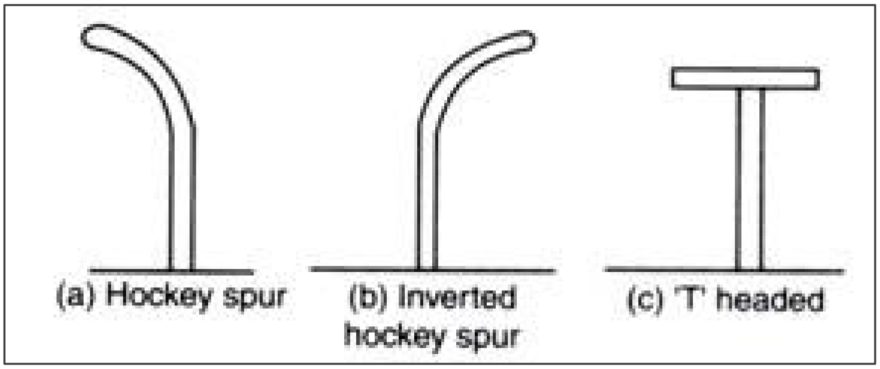
In this case the groyne actually provides a body against which the river current keeps hugging. The river flow thus remains along the bank permanently. When a groyne of short length is taken perpendicular to the bank, it only deflects the flow locally. Hence, it is called deflecting groyne

Figure 3. 58: Deflecting Groyne (Typical)



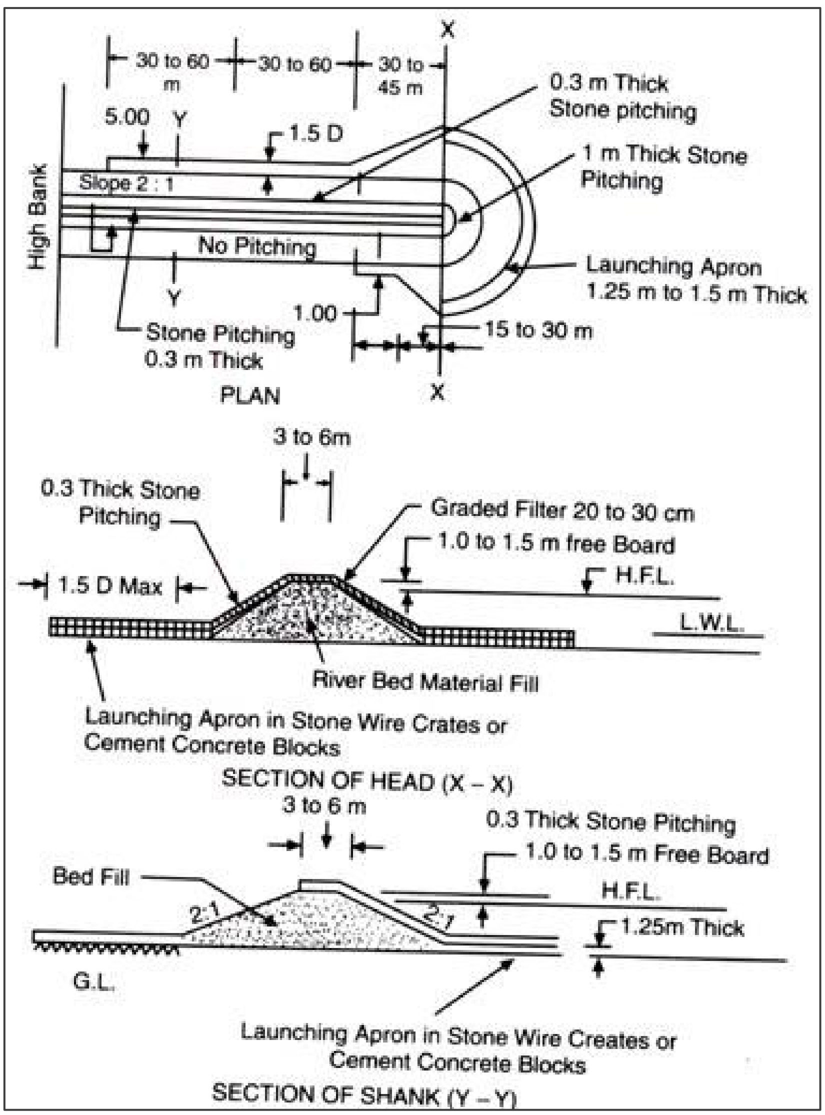
After successfully conducting model experiments various designs for groyne heads have been evolved. A groyne with head normal to the groyne direction of called 'T' headed groyne (Fig. 3.55).

Figure 3. 59: Special Types Of Spurs Or Groynes (Typical)



From this it is clear that deflecting, repelling, attracting, T headed, hockey type, etc., all come under the impermeable type of groynes.

Figure 3. 60: Details Of Spurs Or Groynes (Typical)



The section of groyne is like a guide bund or an embankment (Fig. 3.56). It is protected on both sides by stone pitching or concrete blocks etc. At the river bed launching apron is also provided. Top of spur is generally kept 3 m wide. Side slopes of 2:1 is general practice. The spurs are built by sand, gravel and boulders.

6. **Permeable Groynes:**

Common type of permeable groynes are tree groynes and pile groynes. They are temporary in nature and get washed away during floods. Therefore, they are constructed every time before floods. A tree groyne consists of a thick wire rope (2.5 cm diameter) firmly anchored at one end to the bank and tied at the other to a heavy buoy. Sometimes this wire may be stretched across the river and anchored at its ends. It may be supported at intermediate points on tripods.

Entire leafy trees are taken and about 30 cm up the stem a hole is drilled through each tree. Then an iron ring is drawn through the whole and attached to the wire rope. Dimensions of trees may vary from 6 to 12 m in height and 0.50 to 1.2 m in girth.

A pile groyne consists of a series of piles driven 6 to 9 m into the bed 2.5 m to 3 m apart. There may be two or three rows. The rows are spaced 1 to 2 m apart. Each row is closely intertwined by brushwood branches. For stability upstream row is braced to the downstream row by transverse laterals and diagonals.

The permeable groynes lower the velocity of flow. As a result, sedimentation occurs. Hence permeable groynes may be said to be of segmenting type according to the function served. The cost of construction of this type is about 40 per cent that of impermeable type of same length. This type of groynes may be constructed even if there is flow in the river. Thus construction is easy and rapid. To summarise, the factors which influence the choice and design of groynes are:

a. Fall and velocity of flow in the river.
b. Character of bed load carried by the river.
c. Depth of waterway, maximum HFL and nature of flood hydrograph.
d. Width of waterway, at high water, low water, and mean water.
e. Availability of funds and construction materials.

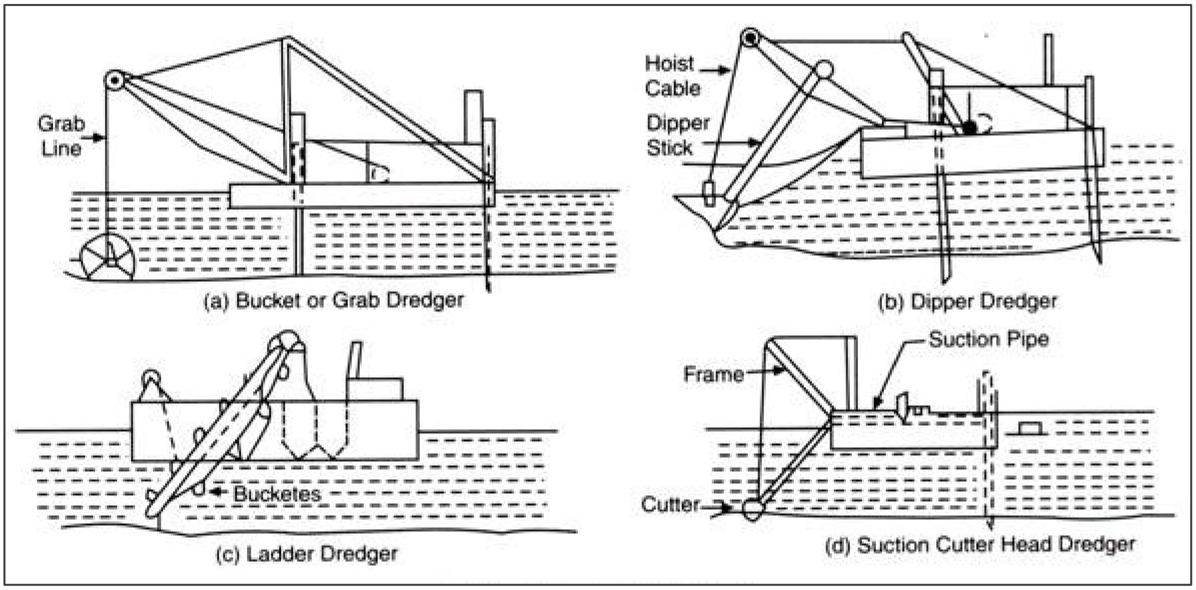
D. Bed Pitching and Bank Revetment:

Sometimes to protect the bed and bank against action of water, protection is provided by laying a closely packed stone blocks or boulders or even concrete blocks. This permanent revetment and pitching counteracts the general tendency of the water to notch away the material from bed and banks.

E. Dredging of River:

As described earlier, the dredging is necessary to improve navigability of the river channel needing to be excavated. This excavation is carried out to increase the depth of flow even when there is flow in the river. The process of underwater excavation is termed dredging. The machinery used for the purpose is called a dredger. Various types of dredgers are in use for example, dipper dredger, grab dredger, bucket dredger, suction dredger etc. Figure 3.57 shows various types of dredgers. Although a detailed discussion ensued earlier, a small discussion is also included here for contextuality.

Figure 3. 61: Types Of Dredgers (Typical)



Types of Dredgers for the Proposed Waterway:

1. Bucket or grab dredger:

It is essentially a stiff leg derrick, or crane fitted with bucket and these are mounted on a barge or a self-propelled vessel. The buckets are of various weight for different kind of material to be dredged. These also have two types of cutting edges (plain and toothed). The material is either loaded in the hopper in the vessel (in case of large dredger) or dumped in hopper barges or flat barges for transporting to dumping places. The dredgers are kept in desired place with the help of anchors and three spuds provided in the dredger.

The capacity of bucket varies from one cubic meter to eight cubic meter. This is extensively used at locations where the dredging quantity is small and bigger dredgers could not be mobilized due to lack of depths or head room. Though the process is slow, it could be profitably deployed for the present waterway. Since the quantity is low multiple equipment could be mobilsed for completing the Job quicker.

2. Dipper dredger:

This consists of a floating power shovel and except for the dragging equipment; it is same as a Grab dredger. It is used when material is hard such as soft rock, boulders and requires breaking. Not suitable for this waterway as they are not available commonly.

3. Ladder dredger:

This consists of a series of buckets attached to an endless chain operating around sheaves at each end of the frame. This type of dredger is suitable for dredging silt, mud and sand. When self-propelled and provided with hopper the material is filled in hopper and carried away for dumping. Generally, two units of hopper barges and tugs are used to carry the material when continuous operation is necessary and the dumping ground is far off. Generally, these dredgers are not provided with hoppers so that draft could be reduced. This is an old dredging principle where the output is likely to be small.

4. Suction cutter head dredger:

It has a rotary cutter head which carves clay, breaks off chunks of soft rock such as coral and shale and stirs up gravel and sand so that the pipe carries material to its capacity. The cutter diameter ranges from 1 to 3 m and the cutter speed is 25 to 30 rpm.
Impeller diameter of the pump range from 75 cm to 240 cm and pump power 100 HP to 5000 HP with pump speed varying 600 rpm to 140 rpm. The dredger is provided with large spuds round or square for anchoring.

Figure 3. 62: Crawler Cat At The Field (Typical)

This equipment could move in to narrow stretches of water area where the dredging is limited. Their productivity and the size can vary according to site.

For this waterway, Crawler Cat or similar dredger and grab bucket dredger could be deployed. The disposal of the dredged spoils would be carried out preferably in the sea. However, since the distance of travel for disposal is very large, it was considered necessary to squat for areas inside the creek.

There are several locations inside the creek, which could be evaluated, depending on the type of material. By examining the solid qualities, it was ascertained that the dredged material is mostly sandy or part of hard rocky strata. These materials could be used for reclamation around the terminal locations. Since the material obtained from dredging is not substantial, the reclamation need could consume the entire material. In addition, the low lying areas at the terminal locations could be reclaimed using the dredged soils.

A typical river in the planes with various river conservancy methods is shown in the Figure 3.59 below. The conservancy shown in the figure are typical and are provided for various requirements, namely flow channelization, prevention of erosion and protection of the banks.

Figure 3. 63: Typical River Showing Various River Training Works (Typical)

The river has groynes for shore protection and accretion of the shore line, pitching of the banks, Guide bunds for tributaries and distributaries etc.

Vasai Creek/Ulhas River system, unlike this river is a tidal river, where groynes would be mostly ineffective. For example, a repelling type the groyne becomes attractive type under flow reversal. The requirements of the river training works in this water way is not likely to be much due to the following reasons;

1. Since the creek/river is tidal in nature, the Groyne are likely to be very ineffective due to flow reversals. In a unidirectional flow, mostly these structures are more effective.
2. There are no large scale inundation and crossing of banks due to high flood or tidal flows
3. The erosion areas are mostly local and global river training works are not desirable.

4. For flow channelization local temporary schemes as described above could be adopted.

F. Requirements of River Training Works

After thorough examination of the waterway it was decided that River training would be provided in the following areas as observed or indicated in various other studies apart from the field investigation, viz. Mathematical model studies.

1. Local erosion in form of bank protection
2. Coastal embankments at the areas of the terminals for preventing inundation in 1:200 years flood or monsoon events
3. Bank protection near the terminal in order to prevent erosion due to wakes and vessel working
4. Local flow control regimes in shallow areas near Kalyan.

The details of the bank protection/river training are given in the next section.

3.5 Bank Protection / Embankment Strengthening

3.5.1 Bank Protection

Bank protections are required for the rivers with high flood discharges, because of the large differences in the discharge in the monsoon and the lean periods. In case of low discharge rivers these requirements reduce. In the tidal affected rivers often times the river flows get drowned and the tide prevails. In such case, since the flow reversals. In the extant river with tide dominating flow regime, the banks are not attacked that much as could be seen from the description above that barely 6 to 7 places are subjected to low scale erosion, mostly due to the deposition and erosions of the shoals. Hence, in the considered opinion of the consultants, large-scale bank protections may not be required. As suggested above, the only bank protection for prevention of erosion would not require any hard structures and only temporary flow deflector structure would do the trick. To this extent, bandalling with local available materials. This apart from saving valuable resources, would do the required trick.

3.5.2 Embankment Strengthening

The rivers in the planes are subjected to the high discharges like in the River Ganga or Brahmaputra. This is because of the fact that the rivers in the planes have low river banks and high flood discharges are not contained in the flood plains. In order to prevent flooding of the banks and bring in consequent devastations in loss of life and property, these rivers are provided high embankments to contain the flows in the flood plains. These embankments are designed for large return periods and therefore ordinarily capable of preventing floods.

In the Ulhas river with a limited catchment, the fresh water flows are low and regulated, therefore the fear of floods in these kinds of rivers are almost nil. Hence these rivers are not completely provided with embankments. No embankment strengthening is warranted nor provided.

3.6 Navigation Markings / Navigation Aids

3.6.1 Fairway Marking And Positioning Systems

3.6.1.1 Fairway Marking

Pairs of buoys are arranged on either side of the fairway to indicate the maneuverable zone. In general, light buoys or beacons are placed to enable night navigation. The clearance between two buoys in the direction perpendicular to the ship's course should be determined with consideration of the design ships, their transiting speed and the visibility (such as the frequency of fog occurrence). Fairway markings should also be placed in the region of a bend and leading lights/lines and other guide marking may be required in a fairway with successive bends.

Buoys and Markers

There are many types of Buoys and markers that are used to demarcate the navigation channel in order to aid the vessels ply safely in the confines of the deep channel waters as shown in Figure 3-60 to Figure 3-65 below as prescribed by the International Association for Marine Aid to Navigation and Lighthouse Authorities. The Figure 3.60 and 3.61 shows the channel marker buoys and the preferred channel markers.

Figure 3. 64: Typical River Channel Marker bouys (Typical)

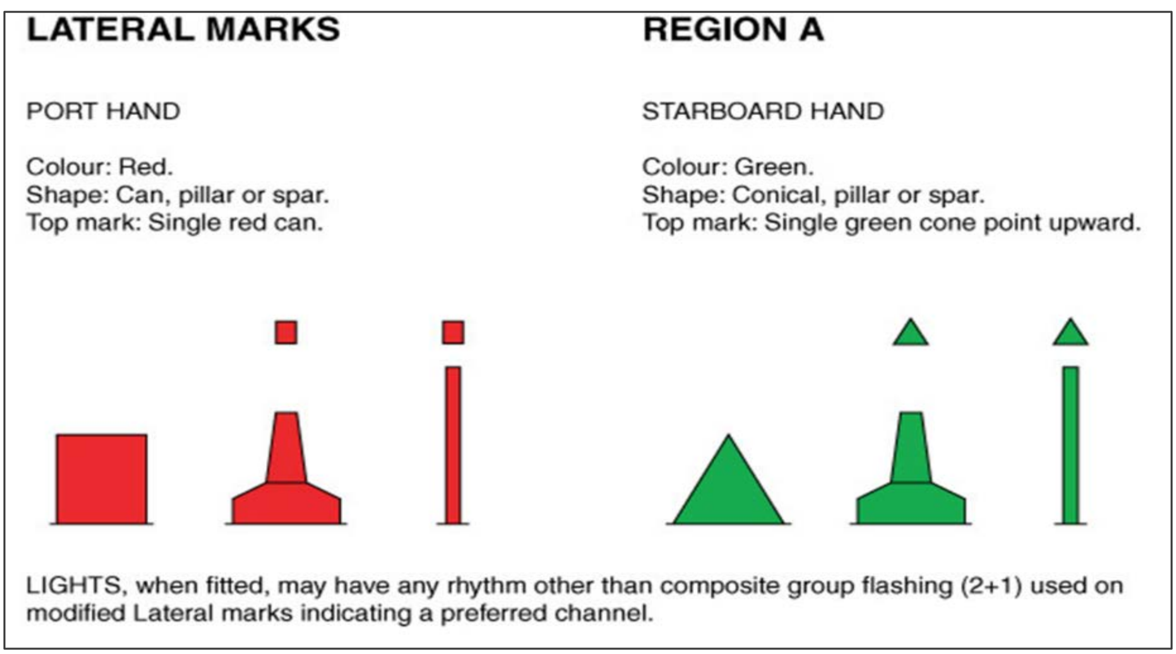
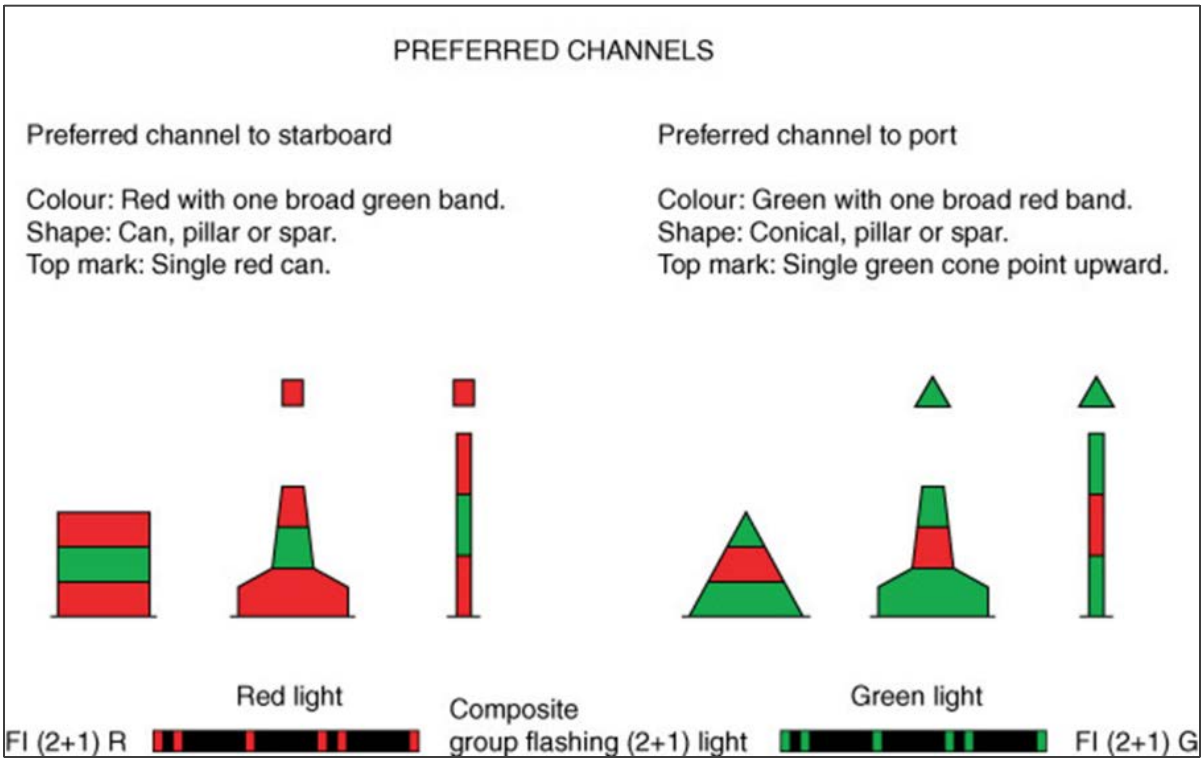


Figure 3. 65: Typical River Channel Marker bouys (Typical) – Continued



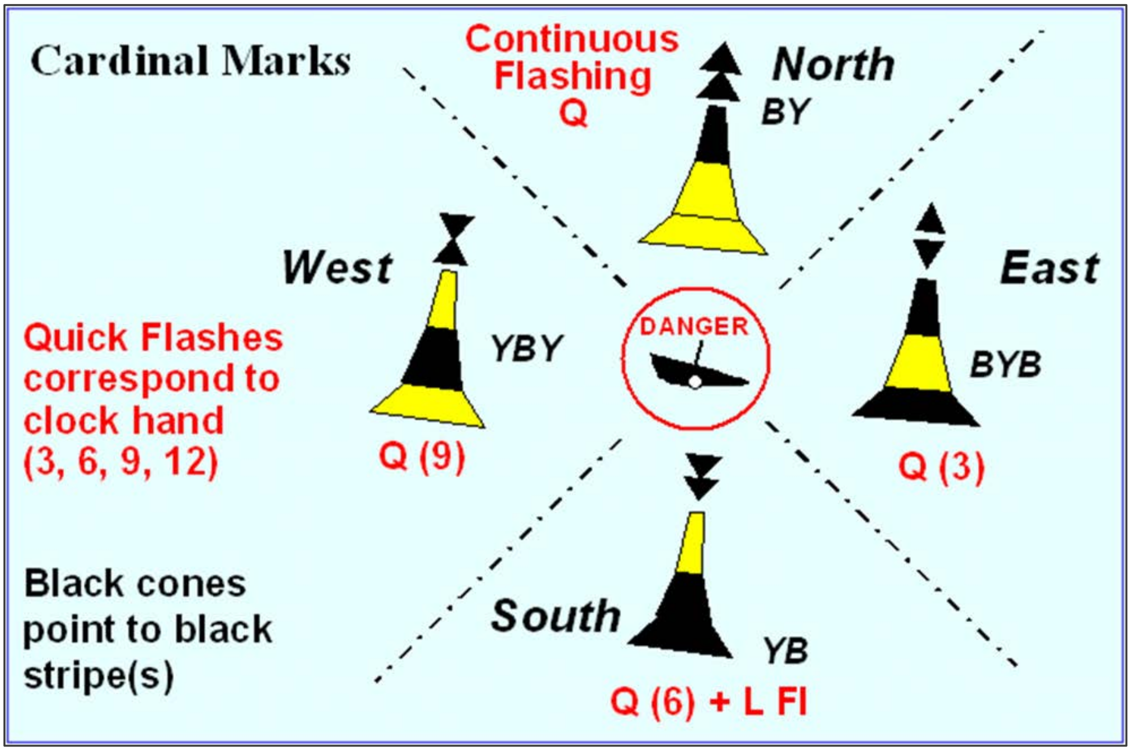
While the Figure indicates the Buoys, which marks the edge of the Channels, the Figure 3.61 shows the channel markers which indicates the seafarers the preferred channel.

Cardinal Buoys: Indicates the deepest water occurs at the side of the marks name. They are placed to the North, South, East or West from a point of interest, like a wreck. They are painted in horizontal yellow and black stripes and are of four types. North Cardinal, East Cardinal, South Cardinal and West Cardinal buoy.

A North cardinal buoy has deepest water North of the buoy, and so a ship must always pass North of the buoy, keeping it to the South. Same for the others.

The Figure 3.62 gives details of all the cardinal buoys with a central point of interest (a wreck). The direction of North is up the page. The colours, top marks and lights (at night) of each are distinctive. One should therefore, pass North of the North cardinal buoy, East of the East Cardinal buoy, and so on.

Figure 3. 66: Typical River Channel Marker Bouys (Typical) - Continued

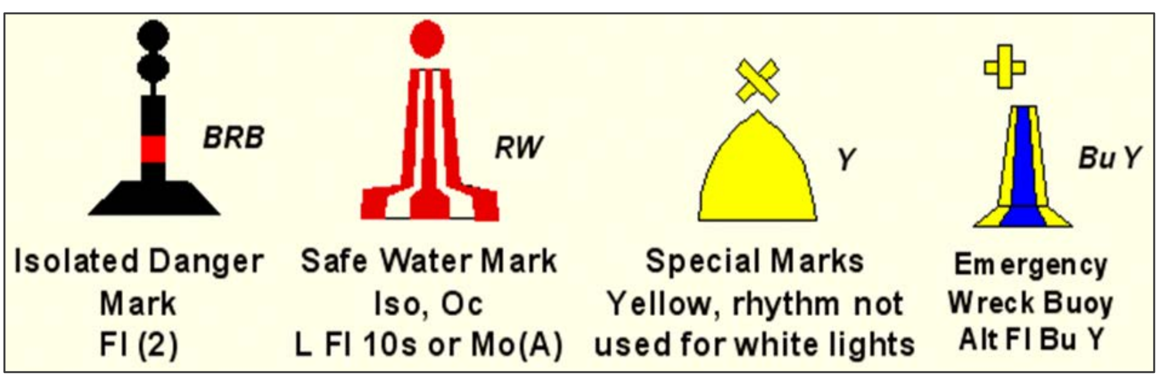


An isolated danger buoy (left) indicates there is a danger in the immediate vicinity of the buoy, like a wreck. Ships should keep well clear of it. (Refer Figure 3.63).

A **safe water buoy (2nd from left)** tells us that there is safe (deep) water all-round the buoy. A ship can pass any side of it.

A **special buoy (3rd from left)** indicates a special area or an object mentioned on charts or in other nautical documents and publications. On their own, they may not have great navigational significance.

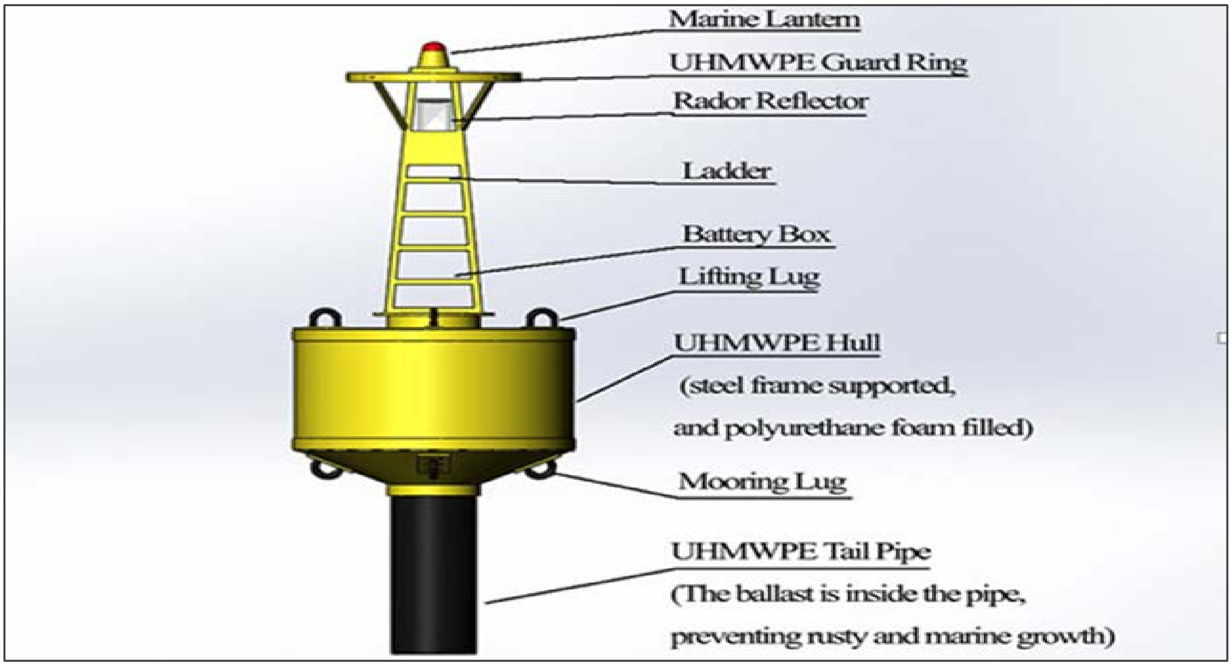
Figure 3. 67: Typical River Channel Marker Bouys (Typical) - Continued



Inland water obstruction Marker: Marks the obstructions to navigation. Not permitted to pass between these buoys and these buoys and the nearest shore.

Mooring Buoys: White with a blue band, usually placed at marinas or other areas, where the vessels are allowed to anchor. These are the only buoys where one can legally tie up.

Figure 3. 68: Typical Mooring Buoys (Typical)



Other Markers: There are also other markers that give information other than the edges of safe waters. Most are white with orange markings and black lettering. They are used to give direction and information, warn of hazards and destructions, mark controlled areas, and mark off-limits areas. These ATONs do not mark traffic channels.

On non-lateral markers, there are some shapes that show certain things:

Squares: show information, including places to find food, supplies, and repairs. They sometimes show directions.

Diamonds: warn about dangers like rocks, construction, dams, or stumps.

Circles: mark a controlled area such as no wake, idles speed, speed limit, or ski zone.

Crossed diamonds: show areas off limits to all boats, like swimming areas and dams.

ATONs are often integrated with Automatic Identification System (AIS), e.g. a lighthouse can be equipped with an AIS transmitter. Sometimes it is impractical to equip the ATON with an AIS transponder; in this case an AIS shore station can be assigned to transmit AIS messages on behalf of the ATON. This is known as a synthetic ATON.

In other cases, such as marking a wreck until a physical buoy can be deployed, a so-called virtual ATON is created: A shore-based AIS system is configured to transmit AIS messages indicating the existence of an ATON at a specified location.

Lead marks (as in "leading a ship into a safe place") and lights are fixed markers that are laterally displaced to allow a mariner to navigate a fixed channel along the preferred route. They are also known as "channel markers".

They can normally be used coming into and out of the channel. When lit, they are also usable at night. Customarily, the upper mark is up-hill from the lower (forward) mark.

The mariner will know the geometry of the marks/lights from the navigational chart and can understand that when "open" (not one above the other) the ship needs to be navigated to "close" the marks (so one is above the other) and be in the preferred line of the channel.

In some cases, the lead marks/lights are provided by lasers, as in the laser channel under the Tasman Bridge on the Derwent River at Hobart, Tasmania.

A typical channel with the markers is shown on Figure 3.65.

Figure 3. 69: Typical River Channel Marker Bouys (Typical) – Continued

Positioning Systems

Ship positioning systems, such as GPS or DGPS with electronic charts are widely utilised nowadays in ship handling operations. However, although electronic charts are increasingly found on board ships, some may not be official ECDIS but ENCs and, therefore, come with a warning that they must not be used for navigation. Ship-handlers judge and recognise the ship's position by an image of GPS information on the display of the electronic chart. However, there are two kinds of errors that can occur with respect to GPS utilisation. One is the perception error on the electronic chart display, where the image information on the electronic chart is definitely presupposed to be sufficiently accurate but positioning of the ship is made solely by perceiving ship movement on the display by the naked eye. For this reason, some perception error (a half of a ship's beam or so) should be taken into account in the design of the maneuvering lane. The other is the error of GPS information itself, for which an error of at least 3 m may be assumed, subject to future developments in GPS systems. Due to the improved accuracy of DGPS, no error needs be considered for ship positioning, although there are errors to be considered, such as the accuracy of the antenna installation and calibration. Note that

GPS is not the only method for determining ship position. The channel configurations, consisting of the width and nomenclature is discussed in the earlier sections.

River Information Systems

The Indian Government proposes to launch a River Information System (RIS) on lines of Air Traffic Control. RIS is a combination of tracking and meteorological equipment with specialized software designed to optimize traffic and transport processes in inland navigation.

The system enables swift electronic data transfer between mobile vessels and shore (base stations) through advance and real-time exchange of information so as to ensure navigation safety in inland waterways. It also provides virtual navigational aids to guide the vessel during navigation.

About RIS

RIS does not deal principally with internal commercial activities between companies but is available for interfacing with commercial processes. RIS streamlines information exchange between public and private parties participating in inland waterborne transport. The information is shared on the basis of information and communication standards. The information is used in different applications and systems for enhanced traffic or transport processes.

The need for RIS

Modern logistics management requires extensive information exchange between partners in supply chains. Implementation of communications and information technologies in organizational and operational processes is a crucial prerequisite to increase operational efficiency and safety in today's market.

RIS facilitates the inland waterway transport organisation and management. Through effective information exchange, transport operations (such as trip schedules and terminal/lock operation plans) could easily be optimised, providing advantages for inland navigation and enabling it to be integrated into the intermodal logistic chains.

Working Principles of RIS

RIS is built on modern information technology and telecommunication infrastructure. The key RIS related technological innovations introduced in the inland waterway sector during the last decade are:

Inland Electronic Navigational Charts (IENC) and Inland Electronic Chart Display Information System (Inland ECDIS) for visualisation of fairway and ship position information.

- IENCs are to be made available for large parts of the inland waterway network.
- Internet applications for Notices to Skippers in different languages and machine-readable format.
- Electronic ship reporting systems for information collection and distribution on voyage-related data (ship and cargo).
- Vessel tracking and tracing technologies such as Automatic Identification System (AIS) for automatic reporting of the position of ships and other safety relevant data.
- Radar systems with ENC underlay for navigation and traffic monitoring.
- Route and voyage planning applications.
- Applications for optimising fuel consumption.

Lending Support to services

These new information technologies support the following:

Fairway Information Service (FIS): FIS contains geographical, hydrological and administrative data that are used by skippers and fleet managers to plan, execute and monitor a journey. FIS provides dynamic information as well as static information about the use and status of the inland waterway infrastructure, and thereby supports tactical and strategic navigation decision-making. FIS contains data on the waterway infrastructure only – excluding data on vessel movements – and therefore consists of one-way information from shore to ship/office. Traditionally these services are provided through nautical paper charts and one or more of the following services in national formats and in the national language: Notices to Skippers, TV and radio broadcasts, internet, VHF nautical information radio, e-mail subscription services and fixed telephones situated on locks. RIS will provide standardised electronic charts and standardised Notices to Skippers in a machine readable format and in different languages.

Traffic Information Service (TI): The information provided in a Tactical Traffic Image (TTI)supports the ship’s master in the immediate navigation decisions in the actual traffic situation. The TTI allows skippers also to make navigational arrangements with other vessels. The TTI contains information on the position of vessels, speed, heading and specific vessel information of all targets identified by radar and – if available – AIS or compatible automatic vessel tracking and tracing systems. The TTI is displayed on a standardised electronic chart; the Inland ECDIS. • The Strategic Traffic Image (STI)on the other hand provides a general overview of the traffic situation over a relatively large area. The STI is used mainly for planning and monitoring. The STI will provide the user with information about intended voyages of vessels, (dangerous) cargo and Requested Times of Arrival (RTA) at defined points (e.g. locks, terminals).

Traffic Management (TM): TM is carried out by waterway administrations aiming at optimal utilisation of the infrastructures and assurance of safe navigation by:

Local Traffic Management: Vessel Traffic Service (VTS), whose centers are currently installed at some critical points along the European waterway network, are implemented by a Competent Authority to improve the safety and efficiency of vessel traffic, and to protect the environment. The service has the capability to interact with the vessel traffic and to respond to traffic situations developing in the VTS area. The information required by VTS centers is basically gathered by means of permanent shore-based radar stations. AIS could, in the future, provide additional information, such as the vessel's identity and main dimensions. • Navigational Support: Vessel tracking technology, such as AIS, provides individual skippers with the information needed to take navigational decisions.

Lock and Bridge Management (LBM): RIS facilitates the planning of lock and bridge operations. RIS supports lock/bridge operators in their medium term decisions by providing a strategic traffic image. RIS thereby assists the operators in the calculation of ETAs/ RTAs (Estimated/ Requested Time of Arrival) of vessels. By means of optimal planning of locking operations, the smooth passage of vessels through the locks and bridges, which are considered as inland waterways’ bottlenecks, can be realised. Lock planning can reduce waiting times significantly. In turn, lock operators can inform the individual skipper of his RTA, enabling him to adapt his speed and possibly save on fuel.

Calamity Abatement service (CA): CA registers vessels and their transport data at the beginning of a journey and updates the data during the voyage. In the event of an accident, the authorities are capable of providing data immediately to the rescue and emergency teams. The electronic charts and the traffic image provide the basis for the coordination of rescue forces and nautical measures.

Information for Transport Logistics • Voyage Planning (VP): VP includes the planning of the optimal route, the draught and the ETA of the vessel. Skippers and fleet managers need fairway information for these planning activities. • Transport Management (TM):TM means the management of the transport chain beyond the scope of the navigation and is driven by freight brokers and transport service quality managers. It is aimed at improving the overall performance of the contracted fleet and terminals, at controlling the progress of the contracted transports, at monitoring unexpected threats to the reliability of these transports, and at finalising the transport (delivery and invoice). • Intermodal Port and Terminal Management (PTM): Terminal and port operators need ETA information in order to plan resources for terminal operations. ETA information of approaching vessels supports the overall terminal utilisation and allows smooth passage of vessels through the terminal facilities.

As a result, the trans-shipment time can be reduced. In situations when there is insufficient terminal capacity, the terminal operator can inform the individual skipper of his RTA. Better slot management is possible as a result of the exchange of ETA and RTA data.

Cargo and Fleet Management (CFM): CFM is based on information on the loaded and the available empty vessels; the fleet including the actual vessel positions and their RTAs and ETAs; detailed information on the cargo transported and the cargo to be shipped and information on the terminals.

Information for Law-enforcement (ILE): Law enforcement ensures that people within a given jurisdiction adhere to the laws of that jurisdiction. RIS supports law enforcement in inland navigation in the fields of cross-border management (e.g. the movement of people controlled by the immigration service, customs), compliance with the requirements for traffic safety, and compliance with the environmental requirements. It will also reduce waiting times at borders.

Statistics (ST): RIS can be used to collect relevant inland waterway freight statistics. Since data already collected for other services can be used, then skippers, terminal and lock operators no longer need to provide special statistics. Electronic data collection will facilitate the process for data providers and statistical offices. The statistics are of interest to the waterway authorities, international organisations and companies engaged in inland navigation for strategic planning and monitoring.

Waterway Charges and Harbour Dues (CHD): RIS can assist in levying charges for the use of infrastructure tolls. The travel data of the ship can be used to automatically calculate the charge and initiate invoicing, thus facilitating the process for waterway users and authorities.

So once in place the RIS is capable of taking whole gamut of services listed above. The RIS is operational partly in NW 1, and deployment of the same on the countrywide network is on the anvil. Till then if this waterway is functional before, discrete positioning systems could be used.

3.7 Modification Requirement In Existing Bridges / Cables / Dams / Barrages / Locks / Weirs / Anicuts / Aqueducts

There are no barrages, Locks, Weirs, Anicuts or aqueducts in the stretch under evaluation.
Even the existing cable supports are not found to be impediment in the navigation and hence are excluded from this discussion.

In order to make the navigation in the waterway possible, the old Bhayander rail bridge with a horizontal clearance of 18.70 m between piers and vertical clearance of 3.43 m from the HFL is to be dismantled, at least in the navigation spans, if not completely.

3.8 Proposed Dams / Barrages / Locks / Weirs To Improve Depth

No Dams, Barrages, Locks and Weirs are required to improve the depth and hence the navigation in the proposed waterway between Vasai and Kalyan.

3.9 Land Acquisition

3.9.1 General

The Land requirement with regard to the following activities would be desirable.

1. Terminal and allied activities like
   a. Water Front land for the Jetty
   b. Terminal Building
   c. Toilet facilities
   d. Parking for Passenger cars
   e. Ticketing counters
   f. Waiting area
   g. Waste Disposal including STP
   h. Restaurants and Shopping arcades
   i. Children play area
   j. Parks and activities area
   k. Banks and ATM
   l. Fueling station facilities with Diesel, Petrol, CNG, LNG and Electricity charging station
   m. Bunkering facilities at select locations
   n. Truck Parking for Ro-Ro cargo

o. Unitised cargo area
2. Approach to the Terminal
3. Space for ship repair and rehabilitation
4. Areas for allied activities if any.

The total land requirements can be assessed as given in table no

Table 3. 13: Land Requirement locationwise

NO.	Site	Onshore Total Area	Offshore Total Area	Ship Yard Area
1	Vasai Fort	21500	2706	-
2	Mira Bhayander	7525	3020	-
3	Ghod Bunder	20000	2740	-
4	Nagla Bunder	12400	2883	-
5	Kolshet	19300	4081	17120
6	Kalher	10200	2882	-
7	Anjurdive	10075	3781	-
8	Parsik Bunder	14000	3315	-
9	Dombivali	7200	2740	-
10	Kalyan	20500	2740	-
	Total	142700	30877	
	Grand Total	190707 m² (19.07 ha, Say 20 ha)		

3.9.2 Status Of The Land

Though, efforts have been made to select the locations with maximum of land belonging to the Government, minimal land acquisition may have to be made for the allied activities at locations. In addition, the peripheral lands should be classified by the government as areas reserved for development of activities directly and indirectly connected to the navigation and its development. The land requirement for different terminals is given above. The ownership and other details shall be discussed in the chapter 5.

3.10 Fairway Costing

3.10.1 Capital Cost

Based on the discussion above the main capital outlay for the fairway development would be consists of following;

1. Dredging
2. Dismantling of the old bridge at Bhayander
3. Erosion control measures at 6 identified locations
4. Reclamation and bank protection at the Terminal locations.

3.10.2 Cost Of Dredging

The cost of the dredging of the channel would depend on the depth of dredging that would be necessitated on account of the waterway functionality. For the purpose of this report, 3 m dredging is considered for this stage of development to be enough for seamless operation of the vessels and ro-ro vessels.

Though lesser depth may be sufficient for the present operations it was considered necessary to maintain a minimum depth of about 3 m as LAD for standardization purposes.

Table 3. 14: Capital Cost of Dredging

Sl. No	Dredging Quality & Quantity		Rate In ₹	Amount in Million ₹.
1	Soft Material	680546.6	450*	306
2.	Hard Material	25903.64	2200*	57
Total for dredging				363

* : Cost is inclusive of the cost of disposal at the closest terminal banks

3.10.3 Cost Of Dismantling Of The Old Bhayander Bridge

Exact details of the Old Bhayander bridge sub structure and super structures are not available. The bridge was built, used and maintained by the Indian Railways and logically the Railways should be asked to remove the old bridge as well. However, since the removal of the bridge is central to the navigability of the waterway, an amount of about ₹50/- million is provided for the dismantling and removal of debris of the Bridge up to the founding levels.

3.10.4 Cost Of Erosion Control At Locations Of Soil Erosion

There are totally 6 locations along the entire waterway which is exposed to low level of erosion. These areas do not require any hard protections in terms of bank pitching/Groynes or any such similar structures. Only local temporary erosion control, such as bandalling would allow natural accretion of soil and prevent any further erosion. Such structures are made up of locally available materials. Total length of erosion control is about 1500 m and about ₹5 million is provided for this purpose. Provisions for yearly maintenance will be provided.

3.10.5 Cost Of Bank Protection Near The Terminal Locations

Several places along the waterway the chosen locations of terminals consist of high banks. Either side of the terminal would have to be reclaimed and straightened bank to enable tying of other crafts and vessels near the terminals. This cost would be considered along with the cost of the terminals.

3.10.6 Total Cost Of Fairway Development

The total cost of the fairway development is as given in Table 3.14

Table 3. 15: Capital Cost Of Fairway Development

Sl. No	Details	Amount in Million ₹.
1	Dredging	363.00
2.	Bridge Dismantling	50.00
3.	Erosion Control	5.00
Total		**418.00**

3.10.7 O&M Cost

The operation and maintenance cost of the above structures and activities are as follows;

3.10.7.1 Maintenance Dredging

As per the mathematical model studies the maintenance dredging would be about 50000 m3. The allotted cost for the same is ₹25 million.

3.10.7.2 Erosion Control

10% of the capital cost are in general sufficient for the yearly maintenance for the erosion control. The total O&M cost is given in Table 3.15

Table 3. 16: O & M Cost Of Fairway Development

Sl. No	Details	Amount in Million ₹.
1	Dredging	25.00
2.	Bridge Dismantling	-
3.	Erosion Control	0.50
Total		**25.50**

4 Traffic Study

4.1 Need Of Traffic Study

The scope of the present report is limited to examining the feasibility of handling passenger and Ro-Ro service only. However, it was considered necessary, to give a perspective with regard to cargo traffic so that in case at any time in future, the MMR needs to be decongested by removing the road cargo traffic to the naturally interconnected waterways in the region, study of the cargo handling in the region would come handy. Hence, though may appear superfluous, a brief writeup on traffic of the region including that of the waterway under consideration was considered apt. Therefore, it was considered necessary for providing completeness.

4.2 General

4.2.1 Trade In Maharashtra

The trade pattern in Maharashtra involving the water transport could broadly involve the following;

1. River Movement
2. Complimenting Ports
3. Coastal Shipping

4.2.1.1 River Movement

There could have been prospects of moving cargo in the river from one location to another. However, due to shorter length of the river, and existence of mountainous terrain along the rivers, prospects of development of the river for cargo movement on a large scale locally may have less potential. The movement of cargo and passengers across creeks for short distances and at location with no bridges could be highly feasible. In crowded areas with a well-developed waterway, men and material could be shifted with rapidity and volume with ease and economically. This mode is least intrusive and could supplement the other modes effectively.

4.2.1.2 Complementing Ports

An opportunity could be explored for ports with poor connectivity with the hinterland. But this may be associated with the following problems;

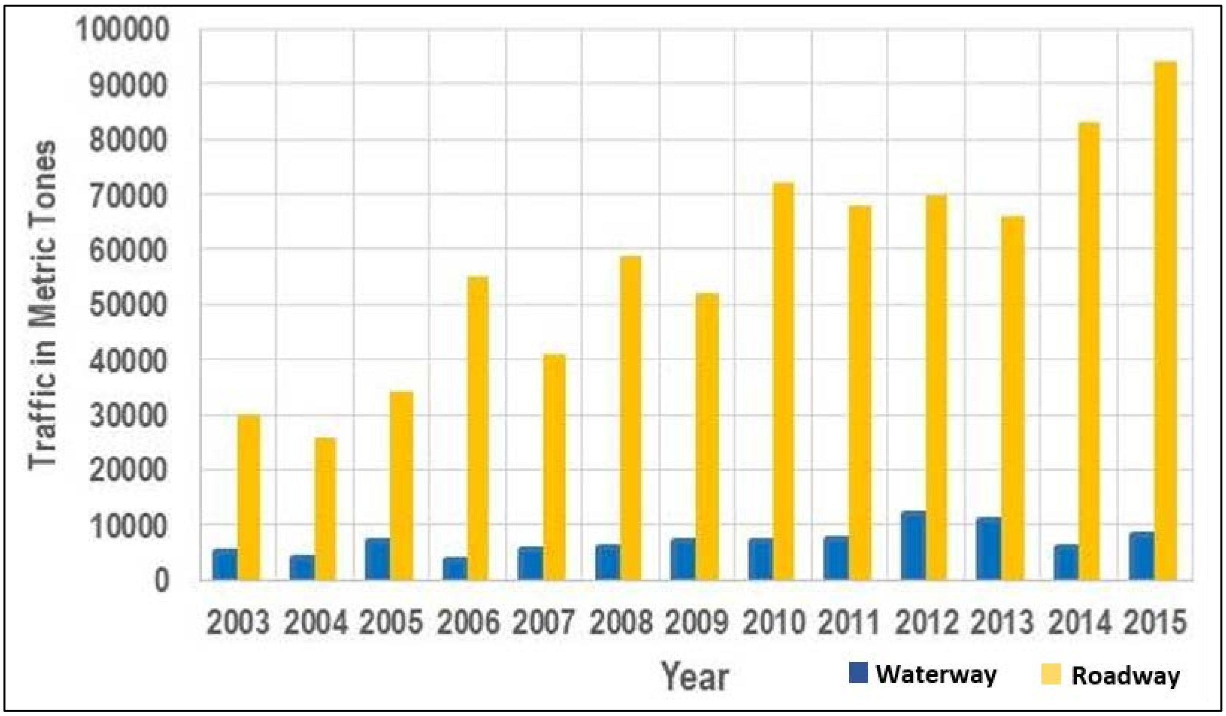
1. Multiple handling involved in multi-modal transport increases the cost of the transportation making it uneconomical/unviable.

2. High river banks make the evacuation of the cargo difficult almost rendering it impossible from the river landing point without specialised equipments.

4.2.1.3 Coastal Movement

With implementation of the new River-Sea regulation, and ready adaptation by the industry, there exists potential for coastal movement of cargo from other coastal states to the final industrial destination near the river. Hence, mapping of movement of cargo to industrial areas along the river would be explored.

Figure 4. 1: Trade In Maharashtra By Road And Waterways



It can be seen from the Figure 4.1, which shows the quantum of trade occurred during the year 2003-15 via Land and Waterway, the quantum of trade via waterway is found to be in increasing trend, though there is no exact correlation. Needless to say, the road traffic is still increasing multiple times more than the waterway traffic, which is about 10% of the road traffic in the year 2015.

4.2.1.4 Inter State Trade – Coastal Waterways

Gujarat, Karnataka and West Bengal are the major importers of commodities from Maharashtra. Major commodities being exported from the state are Sugar, Fertilizer and Animal & feeder. Gujarat accounts for more than 70% import of animal & feeder from the state. It also imports a substantial amount of sugar from the state.

Goa, Tamil Nadu and Andhra Pradesh do not have much import from the state. Karnataka majorly imports fertilizer and mineral oil & products. Orissa mainly imports mineral oil & products. There is export of a number of commodities to West Bengal including agriculture products, animal & feeder, food products, sugar etc.

However, the volume is quite low which collectively adds to 1.6 Million Tonnes. Table 4.1 shows list of major commodities exported from Maharashtra to other states by coastal waterways.

Table 4. 1: Commodity Wise O-D Pair Exports Of Maharashtra By Coastal Waterways

(in '000 Tonnes)

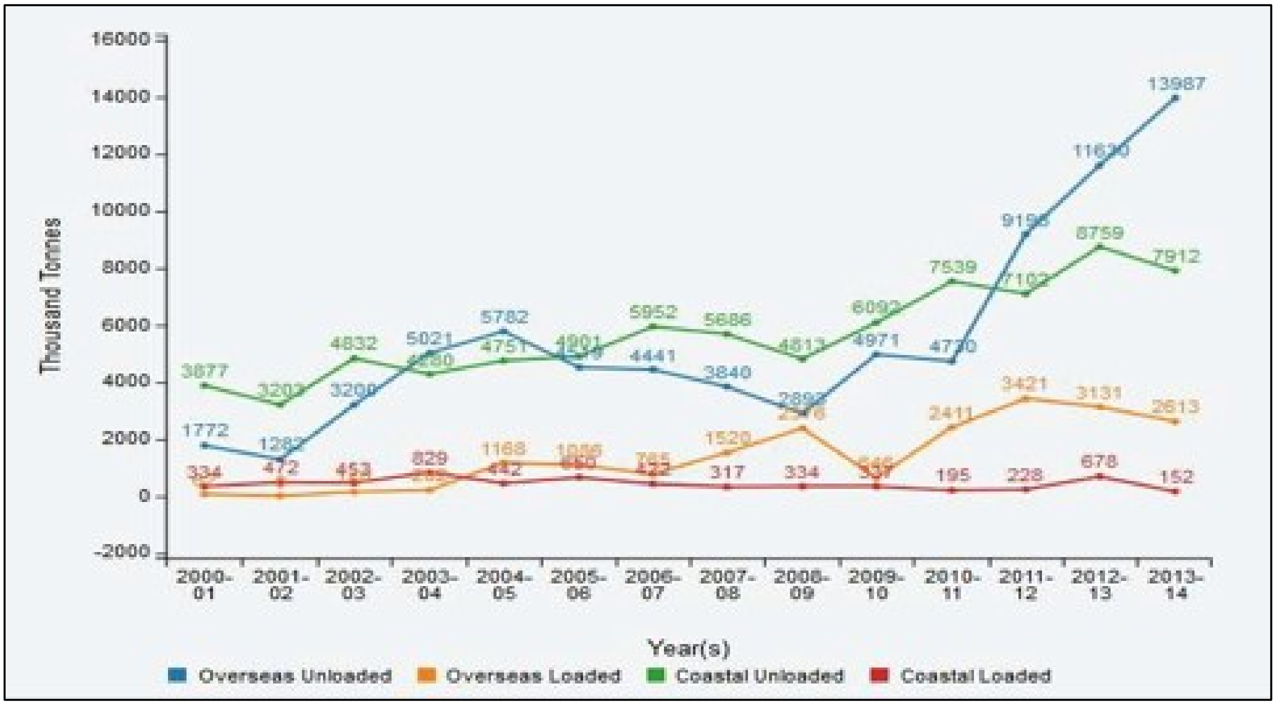
Commodities	Gujarat	Goa	Karnataka	Tamil Nadu	Andhra Pradesh	Orissa	West Bengal
Agri Products	-	12,200	-	-	-	-	19,165
Animal & Feeder	1,02,650	-	-	-	-	2,454	40,965
Cereals & Pulses	-	-	-	-	-	-	303
Chemicals	-	-	-	-	-	1,260	-
Coal & Coke	-	-	11,843	-	-	-	-
Fertilizers	13,290	-	92,799	6,534	-	-	7,607
Food Products	28,024	-	-	-	-	-	19,608
Forest Products	-	-	-	-	-	-	243
Mineral Oil & Products	-	-	79,826	-	38,649	26,591	-
Oil	-	-	1,729	-	-	-	-
Ores	-	-	-	-	-	2,835	-
Others	-	-	924	-	-	4,969	28,755
Sugar	1,18,551	25,515	-	-	-	2,664	39,388
Total	**2,62,515**	**37,715**	**1,87,121**	**6,534**	**38,649**	**40,773**	**1,56,034**

4.2.2 Trade via Waterways

4.2.2.1 Total Traffic Handled

Maharashtra has been using its waterways for movement of its industrial cargo as well as passenger traffic. There are total 48 identified minor ports in Maharashtra. Out of them, 14 are currently active. These ports collectively handled an amount of 24.8 million tons in the year 2014. This includes the coastal movement as well as overseas. Bulk forms the major share of the traffic mainly – Iron ore, Cement and Coal. A large part of cargo is meant for the industries located within a radius of 50 km from the ports. Fig. 4.2 shows the quantum of Cargo Handled at Non-Major Ports of Maharashtra.

Figure 4. 2: Quantum Of Cargo Handled At Non Major Ports Of Maharashtra



4.3 Influence Area / Hinterland

4.3.1 Population In The Influence Area

The proposed waterway extends from the Arabian Sea on the west to Kalyan in the East, consisting of the Vasai/Bassein Creek and the Ulhas River. The creek/river have the following Municipal corporations/Areas/Cities or localities as one moves from the seaward end landwards (Left bank is defined as the bank when one goes from inland towards the sea)

1. Left Bank
   a. Mira-Bhayander
   b. Ghodbunder
   c. Part of North Mumbai
   d. Kolshet
   e. Thane
   f. Parsik Nagar

g. Dombivli

h. Ambarnath

i. Ulhasnagar

j. Kalyan

2. Right Bank

a. Vasai/Nalasopara/Virar

b. Naigaon

c. Navghar

d. Bhiwandi

e. Anjur Dive

f. Surai

g. Kongaon

The population living on the left bank is about 50.00 lakhs and on the right bank it is about 25.00 lakhs. However, if the 25 km aspect (from the waterway) is taken, then the population would exceed 1.5 crores as it will include the population of the part of Municipal Corporation of Greater Mumbai (MCGM). With a CAGR of 8%, the population is likely to double by the year 2030. In addition, to this the waterway could be a conduit of transport for the out bound traffic from the city, bypassing the congested roads and railways.

4.4 Traffic Study Carried Out As Part Of This Study

4.4.1 General

As per the web site of Maharashtra Maritime Board (MMB), about 18 million passengers in the state use the water mode annually. These include river crossings, ro-ro movements and others. There is no good record of traffic movement in the Vasai creek and accordingly it was considered necessary to carry out a separate study to ascertain the potential of the Vasai creek for development of the waterway through Public Private Participation (PPP) mode, which requires financial viability as a pre-condition.

The detailed study of the traffic was carried out as a part of this study, which discusses market analysis for Vasai Creek-Ulhas River catchment area and constitutes

1. Analysis of existing and potential waterway traffic for passenger and cargo
2. Existing trends of passenger flow between origin and destination

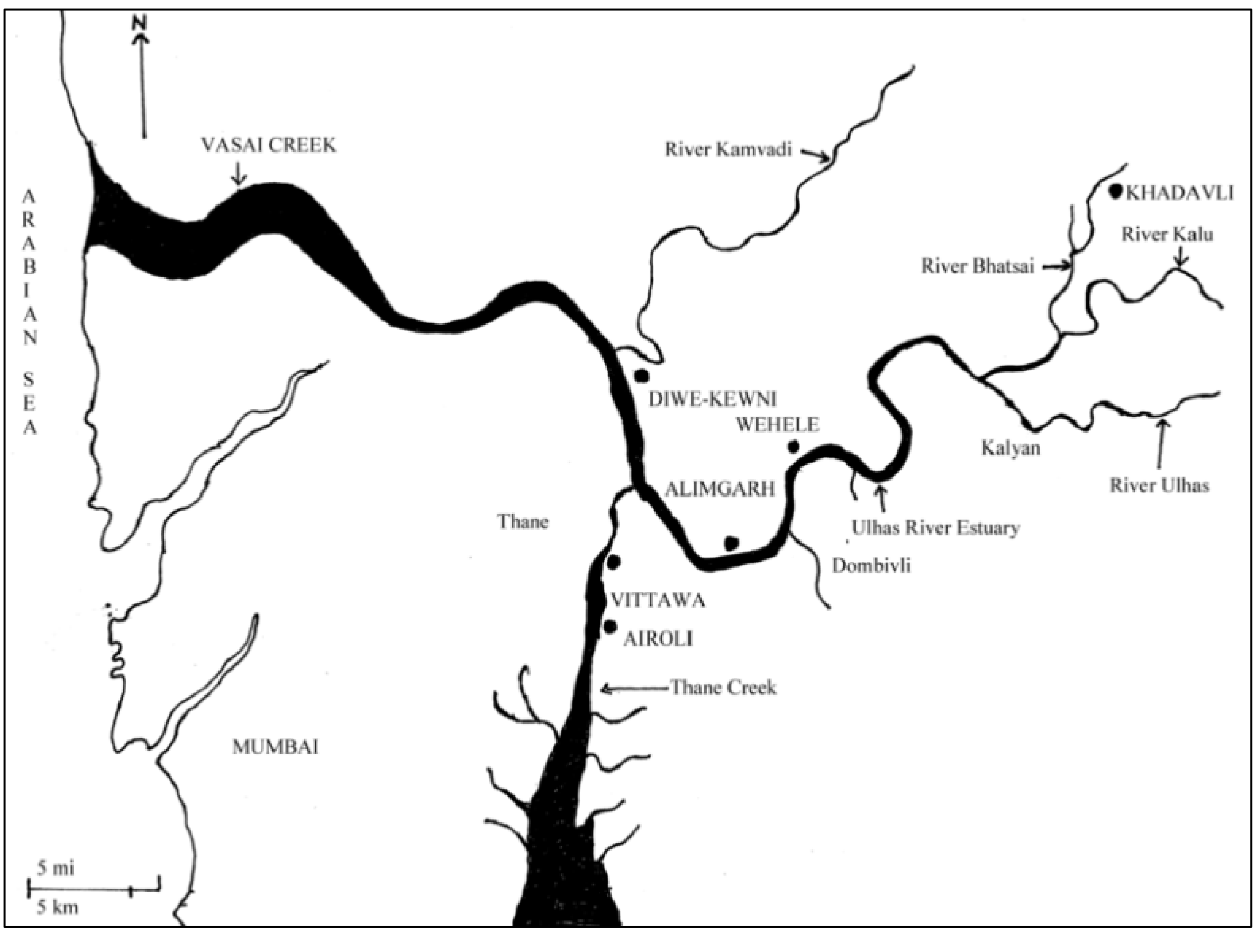
3. The feasibility of diversion of passenger traffic from existing land-based transport modes to waterways.

The highlight and the findings of the report is discussed in the following sections.

4.4.2 The Waterway

The length of the Vasai (Bassein) Creek Sections of waterway is approximately 50 Km, which could be split in to two sections at Kasheli (upstream of Thane Bridge) namely Vasai (Bassein)- Kasheli section (Creek entrance) and Kasheli – Kalyan – the upstream section. Vasai Creek takes off from the Arabian Sea with the Vasai fort located near the entrance of the creek on the right bank. Two small creeks emerge from the creek near Ghodbander village to move towards Kashimira village. The creek turns at Kharbao to move to northeast for about a distance of 10 km from the main creek. However, the creek remains confined to its narrow stretches with low draft. This part of the creek forms part of Ulhas River.

Figure 4. 3: Vasai Creek Overview



Ulhas River originates from Rajmachi hills, a part of Sahyadri range located near Lonavala. The main Ulhas River coming from Kalyan area meets the creek at Majiwada. However, the width and draft of the river is very less up to Kalyan. The depth gradually increases as one moves towards Vasai creek.

The creek can act as an alternate route for movement of passengers and cargo to nearby destinations especially for the habitation and industries located along the river/creek banks.

There is huge industrialization near Vasai creek, which may prompt number of organisations to opt for moving their cargo through the waterways. This is because the roads are highly congested as the industries fall in contiguity of densely populated cities. The waterways will also provide an alternate mode of travel to the population staying in the cities. Additionally, the cargo from JNPT and Mumbai Ports, in form of containers, project cargo and over dimensional cargo can also be conveniently diverted to the waterways with least intrusions in road transport. Hence, if this creek is properly developed, it shall unveil the underutilized potential of a cheap, efficient, pollution free mode of transport.

4.4.3 Influence Area / Hinterland Analysis

Vasai Creek which lies between latitude 19.315°N longitude 72.875°E, forms the northern boundary of Salsette Island, and empties west into the Arabian Sea. There is a fishing jetty on the left bank, with a distinct sandbar splitting the entrance into two with the main channel hugging the north bank. As one moves inside the creek, there is a ferry terminal located at a distance of 2 km from Naigaon Railway Station. Panju Island is a village located in the middle of the creek at a distance of nearly 500 metres from the main land on the right bank. A large part of the area of the village is swampy and mostly covered with mangroves. More than 1,300 people, majority of whom are fishermen, live on the island. Their residences are mostly confined to the dry patches of the island.

Densely populated Mira-Bhayander Municipal Corporation is located on the left bank of the creek. The area has the required infrastructure with low-level industrialisation. Sopara creek, a small water flow from Pelhar lake area meets the creek near the railway track. Gaimukh gaon is a village located near the state highway (SH) 48 on the left bank of the creek. There is existence of mangroves along the river/creek slopes up to Gaimukh gaon. Bharati Defence and Infrastructure Limited shipyard is located just downstream of the state highway bridge across the creek near Ghodbander village. It is a privately-operated ship building facility spread over 12 acres of land. It is equipped with four slipways for building ships up to 125 m length. It acts as a feeder yard to Ratnagiri yard. Reti bunder is just beside the shipyard towards Vasai end. It stretches to a length of 1 km along the creek. Ghodbander village is located at a distance of 1 km from Retibunder.

4.4.3.1 Demography Profile of Hinterland

The demographic characteristics i.e. the emerging trend in population growth, its characteristics, spatial distribution are sure to have profound influence on the structure and size of the city.

An official Census 2011 detail of Thane, a district of Maharashtra has been released by Directorate of Census Operations in Maharashtra. The census data reveals that the population of Thane has increased continuously since 1931. The increase was 68.6% during the decade 1941-51 and by 59% during 1951-61. The rate of growth was noticed to be 50.1% during 1961 -71. The annual growth rate during the decade 1971-81 works out to be 8.12% which was the highest in the MMR. The rate of growth works out to be 6.78% during the decade 1981 -91 while the annual growth rate during the last decade was about 5.85%. As per provisional reports of Census India, population of Thane in 2011 is 1,818,872; of which male and female are 966,293 and 852,579 respectively. As per census 2011, it is seen that the average female to male ratio in the city stands at 882 females per 1000 males. Average literacy rate of Thane city is 91.36 percent (1,491,552) of which male and female literacy is 94.19 % (817,828) and 88.14 % (673,724). Total children (0-6) in Thane city are 186,259 as per figure from Census India report on 2011. There were 98,017 boys while 88,242 are girls. Child sex ratio of girls is 900 per 1000 boys.

Table 4. 2: District-Wise Population Around Vasai-Creek

District	No. Of Tehsils/Talukas	Population	Population Density (Per Square km)	Population Division	
				Rural	Urban
Thane	15	8128833	850	27.4	72.6

4.4.3.2 Economic Profile of Maharashtra

GSDP of Maharashtra in FY 16 was the highest among all other states of India. Maharashtra's contribution to GSDP of India is 13%; GSDP in FY16 was US $300.51 billion. Mumbai & Pune are the two major cities and the contribution of these cities to GSDP is comparatively higher than other cities in the state. Maharashtra is considered as an industrialized state due to the dominating existence of many small-scale industries. Following table shows Gross state domestic product prices of Maharashtra. The table 4.3 shows historic GSDP of the three sectors.

Table 4. 3: Historic GSDP Of Maharashtra

Year	Primary	Secondary	Tertiary	GSDP
2005	48418	119531	247531	415480
2009	81001	230921	442048	753970
2010	93988	249698	512065	855751
2011	134356	306571	608223	1049150
2012	140314	325096	704711	1170121
2013	148710	367979	805534	1322222
2014	176016	405002	929115	1510132

Source: GoM, Directorate of Planning, Statistics, Evaluation

Table 4.4 shows sector wise annual growth rates of GSDP. Whereas growth rate has declined in secondary sector, the tertiary sector's growth remains stagnant.

Table 4. 4: Sectoral Annual Growth Rates Of GSDP

Sector	2013(%)	2014(%)	2015(%)
Primary	0.5	7.7	-8.5
Secondary	9.2	4.5	4
Tertiary	8.1	8.6	8.1

Source: DES, GoM

4.4.3.3 Economic Profile of Thane

The city of Thane has been the key center of industrial activities which are considered as the engines of the economic growth. The demographic profile shows continuous growth in the population of the city which mainly attributes to the industrial, commercial, administrative and strategic development of the city. The overall economy is versatile and the city does not have a predominant economic base.

A. Agriculture

Rice is the main crop of the district. Rice is grown in all the talukas of the district but mainly in Palghar, Bhiwandi, Murbad, Shahapur, Vada and Vikramgad, whereas Dahanu taluka is famous for fruits.

B. Industries

Thane District ranks third amongst the industrially developed districts of Maharashtra. There are 1548 large and medium scale and 18,480 small scale industries in the district. The main products of these industries are Drugs, Textiles, Adhesives, Plastics, Rubber, Steel, Pharmaceuticals, Engineering, Fertilizers, Electronics, Chemicals and Iron & Steel. The Thane Belapur-Kalyan industrial belt is the centre of highly sophisticated modern industries. In Ambarnath, Bhiwandi, Badlapur, Tarapur and Murbad there are nearly 4000 industries which contribute towards the industrialisation of the district. The medium and large industries manufacturing chemicals and chemical products are Pfizer, Lubrizol India Ltd., Polyolefins Industries Ltd., NOCIL, Herdillia Chemicals Ltd., BASF (India) Ltd., Star Chemicals, Indofil Chemicals Ltd., and Phoenix Chemical Works. The cotton and non-cotton power looms are mainly located at Bhiwandi, Thane and Kalyan. Fisheries constitute an important industry in Thane district. It is carried out in sea as well as in creeks and estuaries on the western coast. Marine fishery predominates over inland fishery in the district and provides employment to about 75% of the persons engaged in the fishing industry. Raptakos, Brett and Co., Pfizer Ltd., Cadbury (India) Ltd. which produce modified milk food and high protein food are some of the large and medium companies in the district. The Tarapur Atomic Power Station which has raised the utilisation of nuclear energy for electricity generation is also situated in the district. Bank of Maharashtra is one of the leading Public Sector Banks of the thane district, having 60 branches.

4.4.3.4 Infrastructure Analysis

Infrastructure is crucial in the development of a region. It is also essential to understand various types of existing and upcoming infrastructure around Vasai Creek, as they would provide support and connectivity for waterway with other modes of transportation. It becomes backbone for any new development.

4.4.3.5 Connectivity Analysis

Railway, roadway and airports around the waterway help in evacuation of passengers and cargo. It helps to determine best multimodal route for evacuation. The strong local & regional connectivity of rail & road network can be a competition to inland water transport, unless effectively utilized for IWT mobility. Maharashtra state has four international & seven domestic airports.

A. Road Infrastructure

The road length in Mumbai is about 2,000 km, comprising of about 1,950 km of MCGM maintained roads and about 50 km of State Highways (23.55 km of Eastern Express Highway from Sion to Thane and 25.33 km of Western Express Highway from Bandra to Dahisar). All the roads in the city are surfaced, with about 17.5% concretized and the rest blacktopped. The structural condition of the roads is generally very good, though the riding surface deteriorates during monsoons as witnessed during the unprecedented rains and flooding during the rains. The road transport accounts for about

27% of the total traffic, commuting about 5.5 million passengers daily, generating about 45 million passenger kilometers.

B. Rail Infrastructure

The rail network operated by Central and Western divisions of Indian Railways, Government of India cater to over 6 million one-way passenger trips per day. The rail based system caters to north-south traffic and has longer trip lengths than the bus system (average trip length of 15 to 20 km). The total passenger traffic in suburban rail system of Mumbai has increased six-folds since its inception, while capacity has been augmented by only about 2.3 times. As a result, each train on an average carries 4,500 passengers as against the desired average capacity of 1,750 passengers.

C. Intermediate Public Transport

Intermediate public transport modes like taxi cars and auto rickshaws largely serve as collectors and distributors of traffic to the suburban railway system, with average trip lengths of about 3 to 5 km. As per Transport Commissioner, Government of Maharashtra vehicle registration statistics, there were 54,809 registered taxi cars and 246,000 registered auto rickshaws in Mumbai.

D. Ferry Services

The following ferry services are in vogue in the Metropolitan area of Mumbai;

- From Vashi (in Navi Mumbai) to the Gateway of India.
- From Gateway of India to Elephanta Caves, JNPT and to nearby places such as Alibaug, Rewas and Mandwa.
- From Ferry wharf to Mora/Uran, Rewas
- In Northern Mumbai across the Manori creek. The ferries operate at regular intervals across the shallow creek linking Manori to Marve, Marve to Esselworld and Borivili, Borivili to Gorai and Esselworld
- From Versova to Madh Island Malad creek
- From Arnala to Dhatiware in Vaitarna river/Arnala creek
- From Naigaon to Panju Island in Vasai creek

E. Water Transport

With a modest growth rate of about 4 to 5 % in the private carriers, not accounted in the above discussions and a CAGR growth rate of 7-8% *(Source: Comprehensive Transportation Study for Mumbai Metropolitan Region,2010)*, the transportation needs will double by 2030, hence would need an integrated and vibrant approach to the planning. Recognizing that expansion of the surface transport is rather limited; augmentation by adaptation and integration of the water transport would help in alleviating the situation considerably. Water transport, though a slower mode, has the advantage of shortening the travel distance and a higher carrying capacity at a lesser cost per kilometer vis-à-vis other modes of travel. Water transport is environment friendly and is less polluting than other modes of travel.

4.4.4 Passenger Traffic

There are ferry services operating from Naigaon to Panju Island to meet the needs of people staying on Panju Island. The ferry network has the potential of connecting densely populated areas like Vasai, Mira Bhayander, Naigaon, Varsova and other populated areas along the waterway. Landing points for lightweight ferry operations require at least 3-4 meters depth, which is considered relatively safe depth for this kind of operations.

However, the depth in the creek is more than 4 meters in majority of the navigable stretch. Since, the depth of creek varies from 1 meter to 4 meters at and near the potential passenger jetty sites, there is a requirement of some dredging near jetty areas for the smooth operations of ferries. Hence, as part of this study, new landing points and analysis of existing jetties/sloping ramps has been undertaken in order to obtain strategic advantage to attract passenger traffic.

This existing jetty/terminal could be upgraded and if the existing jetty/terminal lacks the required connectivity and does not fulfil other criteria, then a new landing point would be suggested.

The Mumbai Port Trust is developing/upgrading the terminal for inland passengers near Ferry Wharf. The budget of this project is about ₹140 crores. This proposed new/upgraded terminal will provide facilities like safe navigation for Raigad district and to the Elephanta Caves. Such development would help to increase passenger traffic in near future. The traffic has witnessed growth in last 5 years in the Vasai Creek, which is one of the prominent creeks of Maharashtra.

4.4.5 Data Collection

To carry out the analysis of travel behavior data collection was employed through the traditional passenger interview survey. Travel behavior data has been collected through predesigned questionnaire which aimed at providing the data to meet the objectives of the present study. The questionnaire consisted of three sections namely

- Household information

- Personal information
- Trip information.

Household information captured aspects like household income. Under personal information age and gender was sought for. Both household information and personal information was used to characterize the socio demographic attributes of the commuters. Travel distance (Home to work) consisting of, travel time, access time, waiting time, transfer time, parking time, travel cost and preferred mode of travel was pursued under travel information. Rating questions regarding soft factors of travel information were also included in the questionnaire. A sample questionnaire is enclosed as Annexure D.

Survey samples have been collected from locations including Bhiwandi, Bhayander, Diva, Dombivli, Kalwa, Kalyan, Mumbra, Naigaon, Nalasopara, Thane, Vasai and Virar.

Figure 4.4 shows the survey locations indicated below, consisting of a total of 50,000 samples.

The data was preprocessed for better assessment and simplified interpretation of the results. Correlation analysis was carried out to find the correlation between the various parameters. Highly correlated parameter was removed from being used further in the analysis.

Figure 4. 4: User Survey Locations

Preprocessing of data also involves preparation of input data according to NLOGIT format for mode choice analysis.

NLOGIT is a full information maximum likelihood estimator for a variety of multinomial choice models. NLOGIT includes the discrete estimators in LIMDEP, an estimation tool, plus model extensions for multinomial logit (many specifications), random parameters mixed logit, random regret logit, WTP space specifications in mixed logit, scaled multinomial logit, nested logit, multinomial probit, heteroscedastic extreme value, error components, heteroscedastic logit and latent class models. The program derives its name from the Nested LOGIT model.

With the additions of the multinomial probit model and the mixed logit model among several others, NLOGIT became a self standing superset of LIMDEP. LIMDEP is an econometric and statistical software package with a variety of estimation tools. In addition to the core econometric tools for analysis of cross sections and time series, LIMDEP supports methods for panel data analysis, frontier and efficiency estimation and discrete choice modeling.

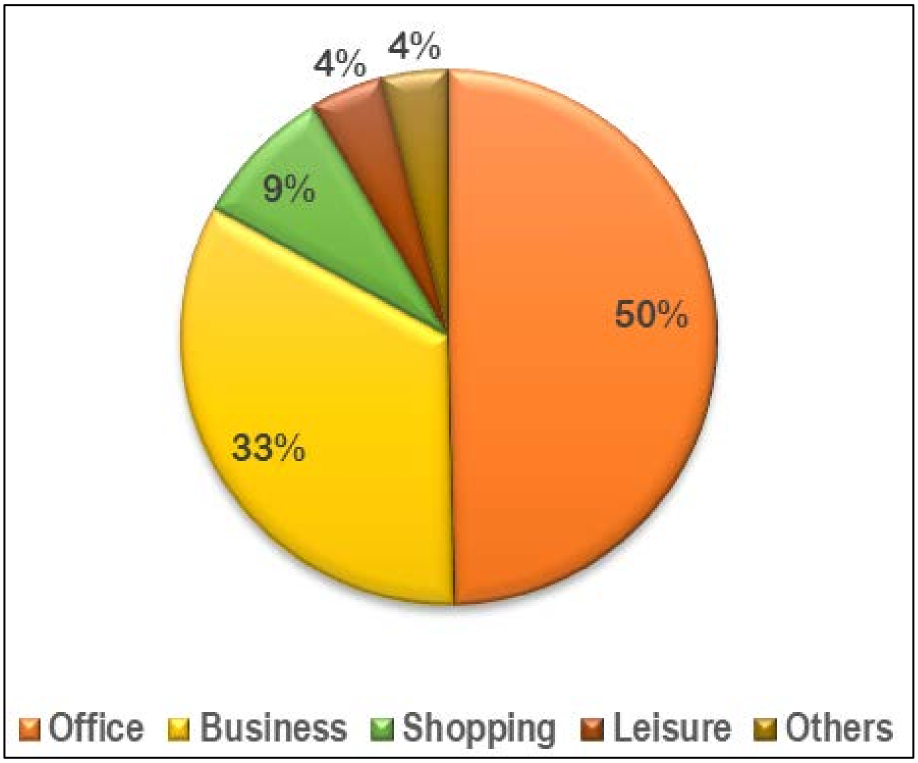
NLOGIT is typically used to analyse individual, cross section data on consumer choices and decisions from multiple alternatives. Analysis may also include market shares or frequency data, data on rankings of alternatives, and panel data from repeated observation of choice situations.

The inference tools for hypothesis testing include the Wald, likelihood ratio and Lagrange multiplier tests and tools for discrete choice analysis, including built-in procedures for testing the assumption of the multinomial logit model. The models estimated by NLOGIT can be used in 'what if' analyses using the model simulation package. The base case model produces fitted probabilities data that aggregate to a prediction of the sample shares for the alternatives in the choice set. The simulator is then used, with the estimation data set or any other compatible data set, to recompute these shares under specified scenarios, such as a change in the price of a particular alternative or a change in household incomes. Nlogit works on multiline format, one for each choice option. All the mentioned parameters above are analysed.

4.4.5.1 Trip Characteristics

Trip Purpose: Different trips were made based on purposes; these are presented in Figure 4.5. The largest share of transport is driven by the purpose of making office trips. From the figure it can be observed that 50% of the trips are work related, followed by business, shopping and recreational trips.

Figure 4. 5: Percentage Distribution Of Trips By Purpose



Trip Length: From the data it was observed that the average trip distance is 30 km. The percentage distribution of respondents by distance to respective destinations is presented in Figure 4.6.

Figure 4. 6: Distribution Of Respondents By Trip Length

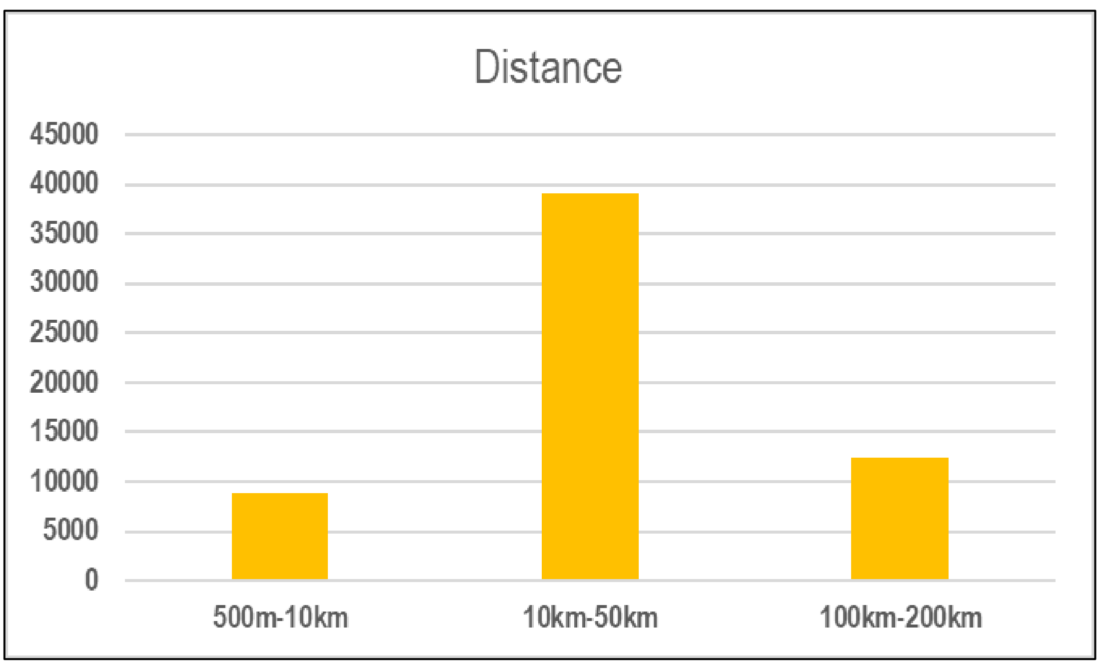
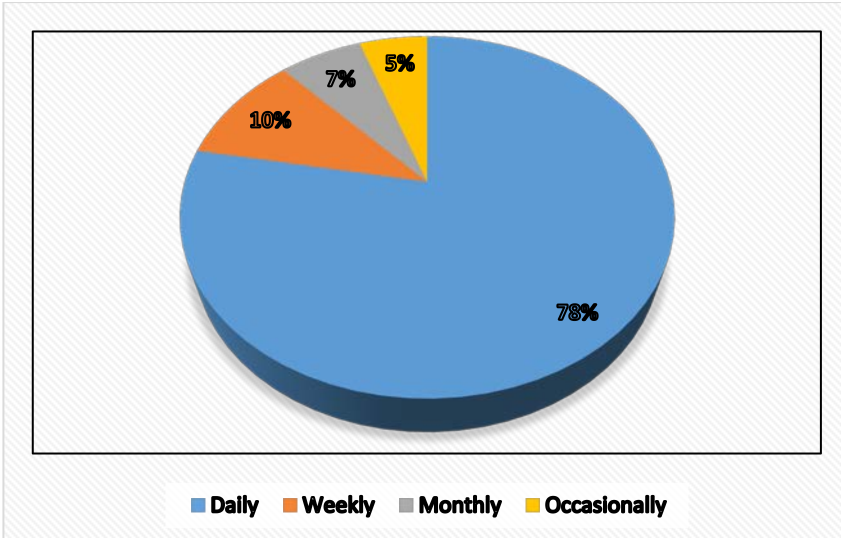
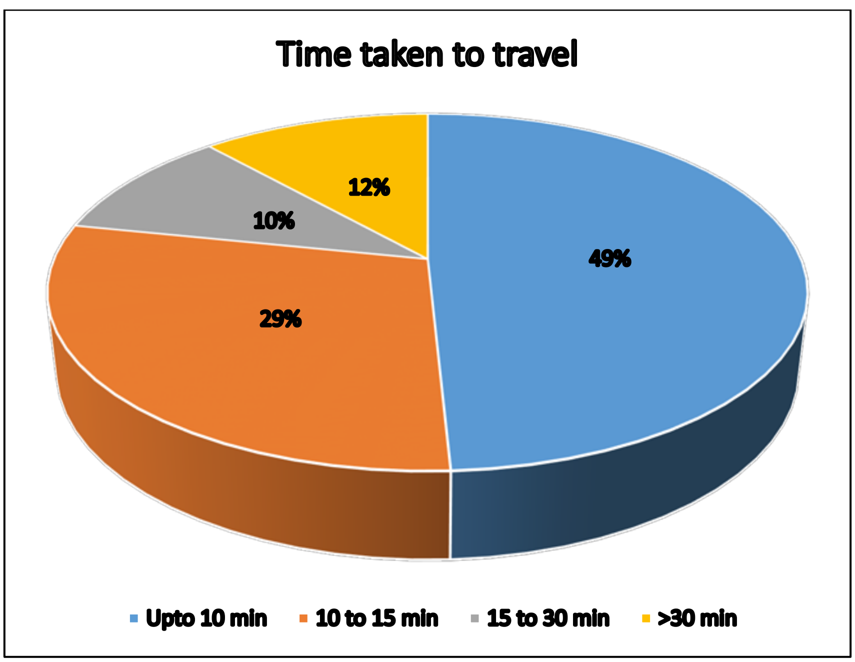


Figure 4. 7: Percentage Distribution Of Respondents By Frequency Of Visit



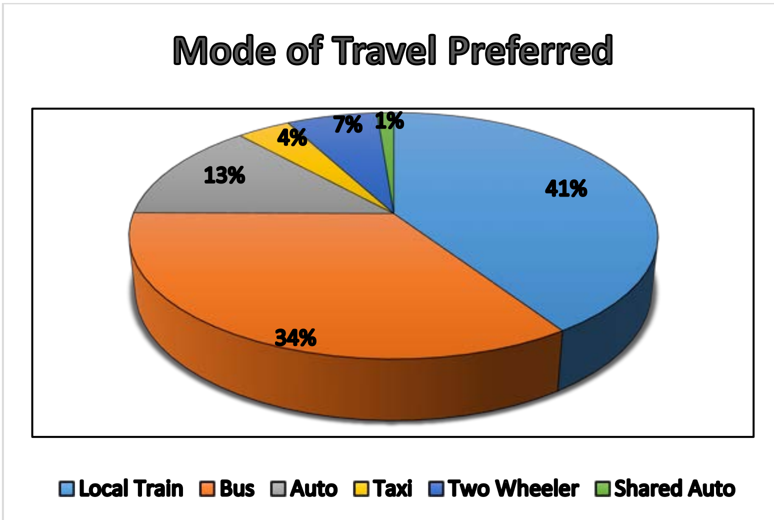
Travel Time to reach the Transport System terminal: After analysing the response from the respondents, its seen that almost half of the commuters take less than 10 minutes to reach transport terminal. This clearly shows how daily commuters choose to stay close to the transport facility.

Figure 4. 8: Percentage distribution of Respondents for time taken to travel



Mode of Travel Preferred: The data shows that majority of the respondents opted the local train service as their preferred mode of commuting (amounting to 41%) and the second most opted mode were the bus services.

Figure 4. 9: Percentage Distribution of the Mode of Travel preferred by Respondents



4.4.5.2 Person Information

Age: The largest commuter share of travelers comes from the age group of 20 to 35 years as shown in Figure 4.8. This dominant age group of commuters prefer public vehicle for their mobility with approximately 32%, 15%, 15% of them using train and bus respectively. The effect of age on mode choice is presented in Figure 4.9.

Figure 4. 10: Percentage Distribution Of Respondents By Age Group

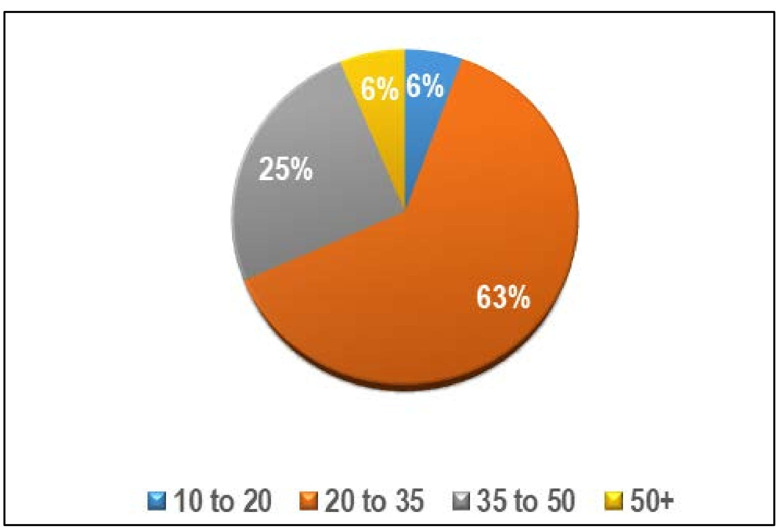
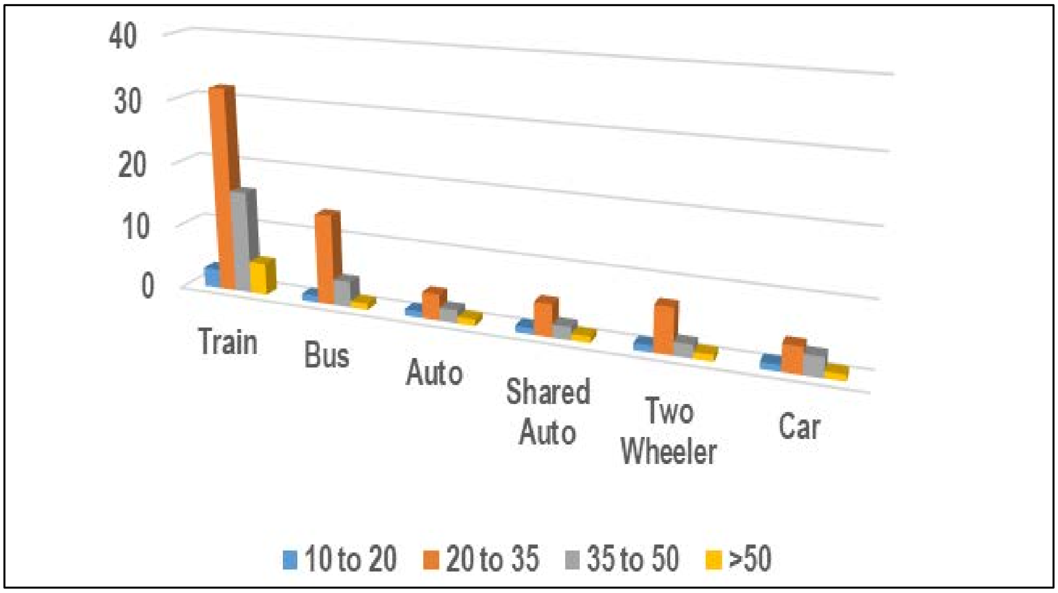
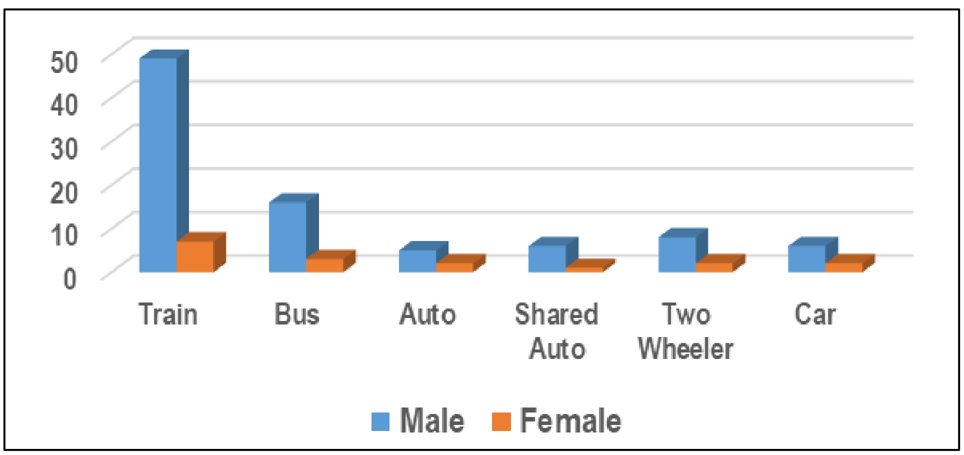


Figure 4. 11: Mode Choice Preference Based On Age Group



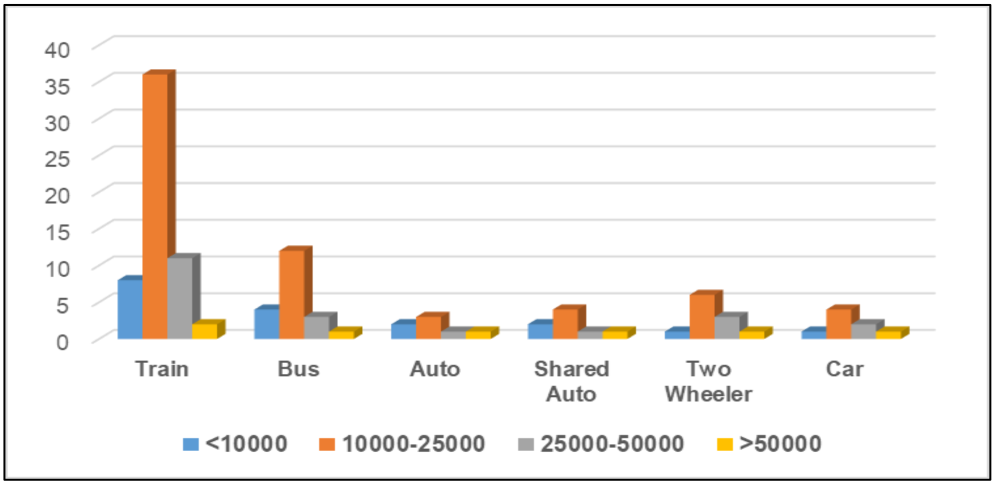
Gender: The influence of gender on mode choice can be viewed in Figure 4.10. The female commuter's most preferred mode of travel is train. While they prefer private cars and two wheelers over other modes which definitely provides higher security and privacy to women. While a major percentage of males prefer trains followed by buses. Auto rickshaw is not as popular with them as private modes.

Figure 4. 12: Mode Choice Preference Based On Gender



The income revealed by the passengers during the survey can't be trusted to be very accurate or very reliable as this information is very sensitive for the people to disclose in a country like India. But somehow the income was grouped and categorised into different classes to ease the passenger and to get the as accurate results as possible. Figure 4.11 represents the mode choice preference based on Household (HH) Income. Figure clearly shows that irrespective of the HH income, train is the most preferred mode followed by bus. The higher middle income group show greater preference towards use of car and two wheelers.

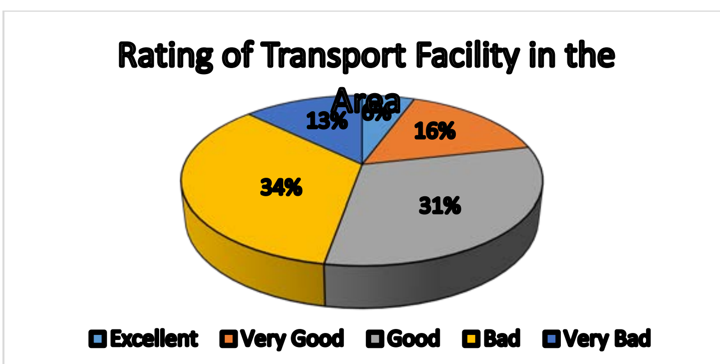
Figure 4. 13: Mode Choice Preference Based On Income



4.4.5.3 Transportation System Characteristics

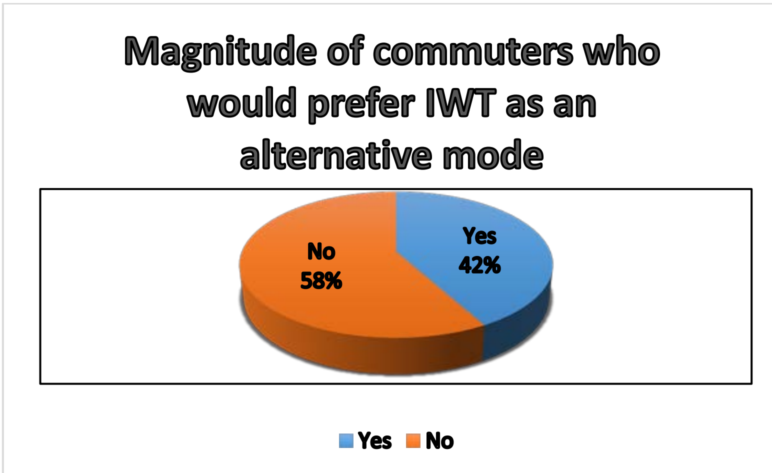
Rating of transport facility: The overall rating of the transport facilities in the area was enquired among the respondents and it was seen that the majority of them felt that the facilities made available for commuting were not up to par.

Figure 4. 14: Percentage Distribution of Rating chosen by the Respondents



Preference to Inland Water Transport as a mode of transport: After analysing the response regarding the public's opinion on whether they would prefer Inland water transport as a mode, the pie chart showed that around 42% of the respondents will prefer to shift to the IWT if the fares are equivalent to the train fares.

Figure 4. 15: Percentage distribution of preference of IWT by the Respondents



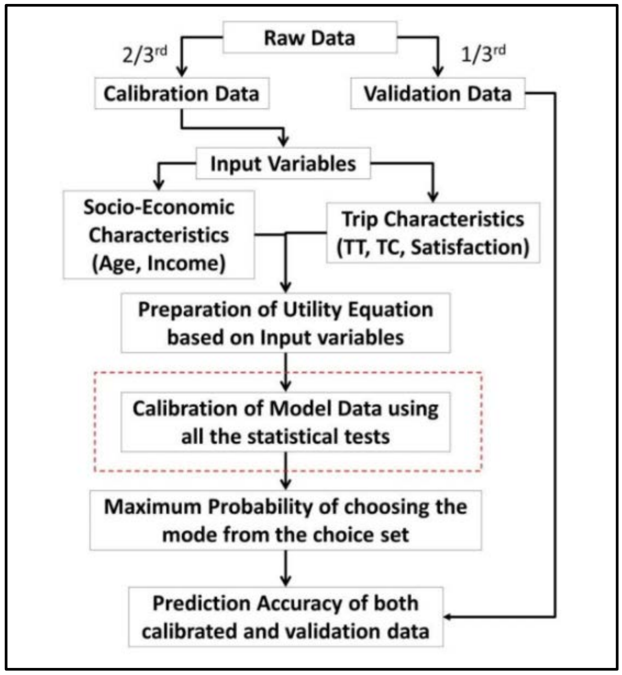
4.5 Development Of Mode Choice Model

The study is aimed to assess the potential shift of commuters presently traveling by local trains, bus, auto, two wheeler and car within Mumbai where a new mode of transport i.e. Inland Water Transport is to be introduced. An extensive primary survey was conducted to study the existing mode choice behaviour of passengers for travel within Mumbai.

The N-Logit (Limdep 4) software has been used for development of utility equation for each mode and the statistical significance of various parameters in each model was evaluated through various tests like Standard Error of Estimates, T-value test, P-value test, Log Likelihood test, Chi-square value and Prediction Table were also tested. In order to obtain the most accurate results, the R square values were analysed each time the new model has been developed.

A major concern with development of models is that whether the results of the model can be extended to the entire population from where the sample was drawn. Application of modeling techniques without subsequent performance analysis of the obtained models can result in poorly fitted results that inaccurately predict outcomes on new subjects (Giancristofaro, et al.2003). To investigate the fact that whether the fitted model is dependent on the data or whether it can perform equally well with a subset of data, 20% of the data was used to validate the model. The validation process was done by using NLOGIT5 software. During validation the model was not re-estimated but the already obtained model fit was applied to validation data. Figure 4.16 shows the methodology for model development.

Figure 4. 16: Methodology For Logit Model Development



As clear from methodology above, initially the total samples from the raw data were divided in a ratio of 2/3rd and 1/3rd that is calibration data and validation data. The calibration data was used in model development and the remaining of the validation data was used to test and validate the model. To identify the significant parameters, the model was developed taking all the variables into the account and then the statistical tests were performed to assess its significance. This process of model development was repeated many times with the combination of different variables. For model development, the final parameters used were Travel Time, Travel Cost and were found to be significant for the purpose of mode choice.

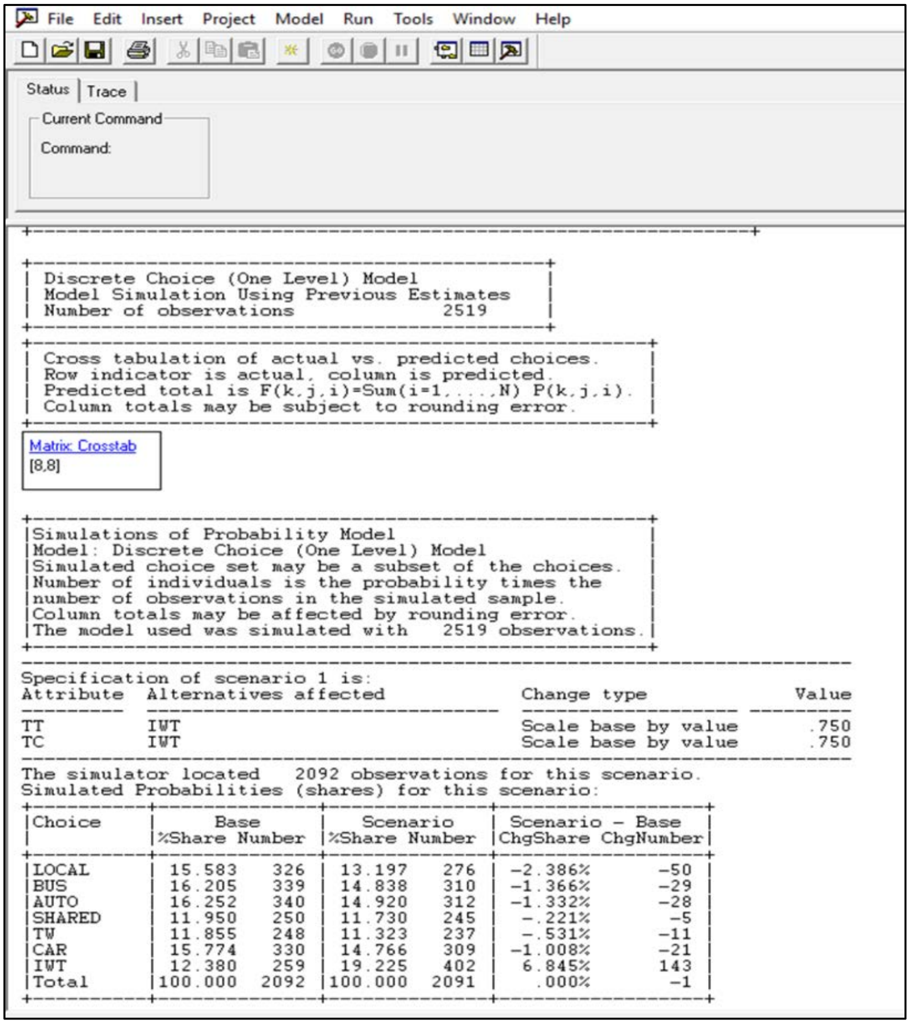
A certain base value for the proposed mode that is Inland Water Transport has been assumed from the secondary sources. In this case we have assumed that the proposed mode will be having lesser travel cost and the reduction in the time will be more from the exiting modes. As per the stated preference survey data, passengers were allowed to choose one of the seven options towards there discrete choice.

$$P_{IWT} = \frac{e^{U_{IWT}}}{e^{U_{Train}} + e^{U_{Bus}} + e^{U_{Auto}} + e^{U_{Shared}} + e^{U_{TW}} + e^{U_{Car}} + e^{U_{IWT}}}$$

The mode with the maximum probability has been chosen and hence the total samples with the probability of same mode are being added to estimate the total shift from the exiting mode to the IWT.

The sample result obtained from the N-Logit software package is shown below in Figure 4.17.

Figure 4. 17: Sample Result From The N-Logit Software



Choice	Base %Share	Base Number	Scenario %Share	Scenario Number	Scenario - Base ChgShare	Scenario - Base ChgNumber
LOCAL	15.583	326	13.197	276	-2.386%	-50
BUS	16.205	339	14.838	310	-1.366%	-29
AUTO	16.252	340	14.920	312	-1.332%	-28
SHARED	11.950	250	11.730	245	-.221%	-5
TW	11.855	248	11.323	237	-.531%	-11
CAR	15.774	330	14.766	309	-1.008%	-21
IWT	12.380	259	19.225	402	6.845%	143
Total	100.000	2092	100.000	2091	.000%	-1

The mode with the maximum probability is chosen. The total samples with the probability of same mode are being added to estimate the total shift from the exiting mode to the IWT.

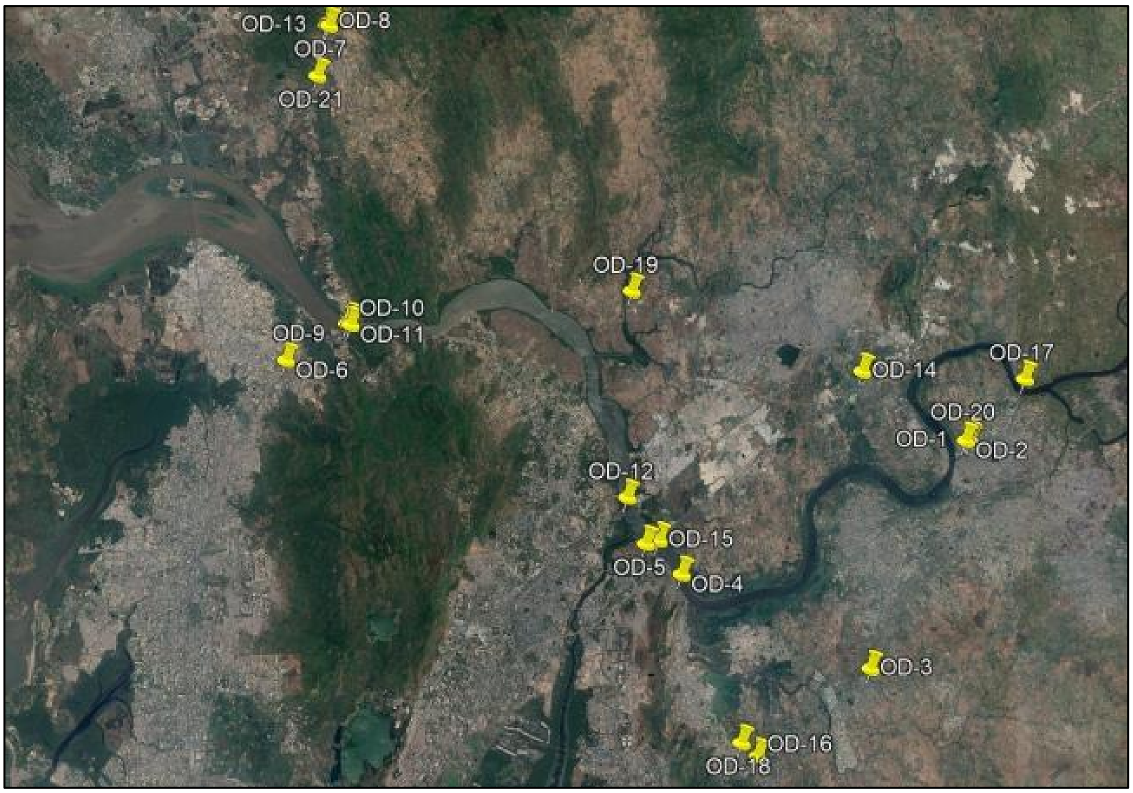
It has been found from the model that about 17.4%, 16.3%, 14.15%, 47.10%, 19.02%, 7%, 19.9%, 52.75% of the people travelling from Bhayander, Mira Road, Mumbra, Naigaon, Nalasopara, Thane, Vasai and Virar respectively shifted to IWT from the present modes in the realistic scenario.

Combining these model results with the OD survey data of each jetty location, OD expansion was carried out to get the actual values of traffic. For further analysis, these values were projected for future scenarios considering growth rate of 7.8% per year, according to the CMP-2016, Mumbai. The calculations for Jetty capacity are given in Table 4.6 and are explained in detail in following section.

4.5.1 Traffic Forecasting

The accuracy of traffic data collection and the subsequent predictions are of paramount importance in the fulfilment of an appropriate planning, design, maintenance monitoring and management of the transport network. The concept of forecasting the future use of the network in terms of traffic flow, is most accepted approach. To obtain detailed picture of travel pattern and for further analysis, valuable data related to trip was obtained from OD survey. OD survey was done at 21 locations, shown in Figure 4.18 and listed in Table 4.5. The peak hour traffic volume in each direction was obtained from video graphic survey. Using these data Origin-Destination matrix was derived.

Figure 4. 18: OD Survey Locations



The modal shift values attained for each Jetty location from NLOGIT was applied to this OD matrix to obtain the base year traffic volume at each jetty location.

The operation of the service is considered for year 2018, therefore an estimation of the demands for starting year is important. Table 4.5 shows the peak hour traffic volume expected at each jetty location. Considering 15 hours of operation of jetty, per day volume count was calculated as represented in Figure 4.19. Assuming 1 year of construction and 20 years as a period of economic evaluation, this data was forecasted at the growth rate of 7.8% per year according to CMP-2016, Mumbai. Capacity of each jetty location so arrived for base year and future year is attached in Tables 4.6 to 4.12.

Table 4. 5: OD Survey Locations

Present (per hour)										
UP	Anjur Dive	Kalher	Jasal Park	Ghod bunder	Nagla Bunder	Dombivli	Parsik Bunder	Kalyan	Kolshet	Vasai
Anjur Dive	1	1	294	44	44	7	12	62	270	181
Kalher	1	1	294	44	44	7	12	62	270	181
Jasal Park	54	54	1	1	1	1	15	23	423	1
Ghodbunder	8	8	1	1	1	1	2	3	63	1
Nagla Bunder	8	8	1	1	1	1	2	3	63	1
Dombivli	1	1	1	2	1	1	44	18	7	1
Parsik Bunder	2	2	2	2	2	17	195	34	95	1
Kalyan	16	16	15	2	2	45	47	0	87	8
Kolshet	140	140	596	89	89	20	325	169	0	1171
Vasai	28	28	466	70	70	31	21	71	779	147
DOWN										
Anjur Dive	1	1	286	43	43	5	24	56	337	37
Kalher	1	1	286	43	43	5	24	56	337	37
Jasal Park	33	33	1	1	1	1	9	19	220	61
Ghodbunder	33	33	1	1	1	1	1	3	33	9
Nagla Bunder	4	4	1	1	2	1	1	3	33	9
Dombivli	3	3	2	2	1	1	28	53	33	10
Parsik Bunder	37	37	13	2	2	45	54	22	195	9
Kalyan	81	81	17	3	3	47	55	0	101	3
Kolshet	133	133	121	18	18	54	27	70	0	416
Vasai	267	1	364	55	55	12	36	144	587	137

Figure 4. 19: Base Year Traffic At Each Jetty Location Per Year

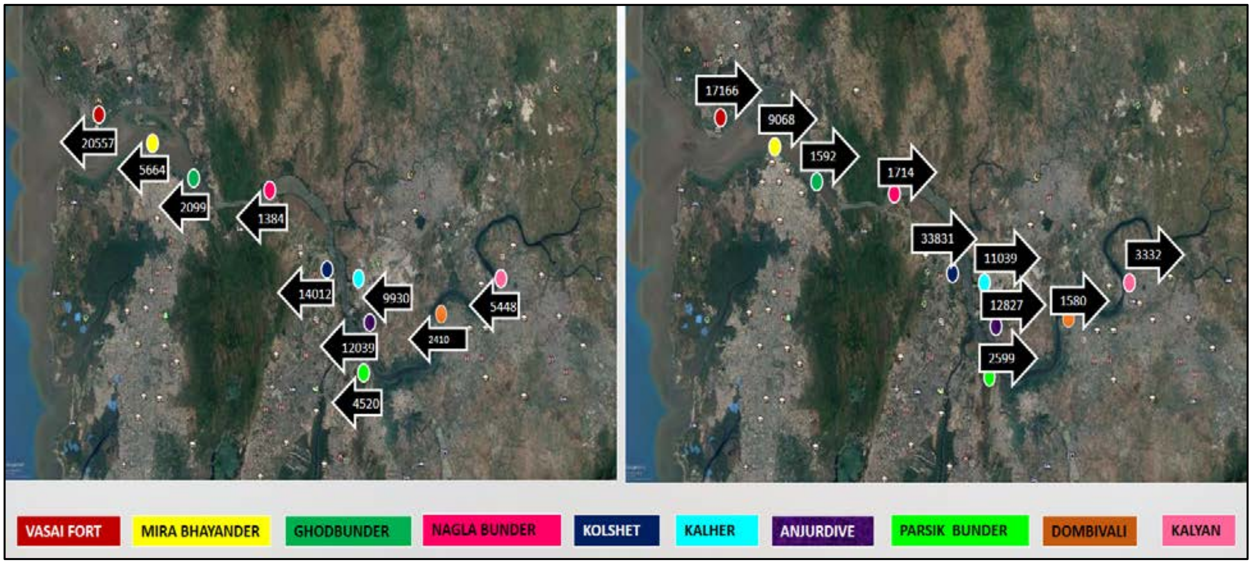


Table 4. 6: Traffic Volumes At Various Jetty Locations Year 2019

(Year: 2019)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
Vasai	Jasal Park	538	4842		**Vasai**	Jasal Park	421	5048
	Ghodbunder	81	851			Ghodbunder	63	851
	Nagla Bunder	81	1094			Nagla Bunder	63	567
	Kolshet	900	8100			Kolshet	678	8136
	Kalher	32	288			Kalher	10	120
	Anjur Dive	32	336			Anjur Dive	308	3234
	Parsik Bunder	24	252			Parsik Bunder	42	441
	Dombivli	35	420			Dombivli	14	168
	Kalyan	82	984			Kalyan	166	1992
Total Jetty Capacity		**1805**	**17167**		**Total Jetty Capacity**		**1765**	**20557**
Jasal Park	Ghodbunder	10	135		**Jasal Park**	Ghodbunder	10	135
	Nagla Bunder	10	90			Nagla Bunder	10	120
	Kolshet	489	6601			Kolshet	254	3429

(Year: 2019)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Kalher	62	837			Kalher	38	342
	Anjur Dive	62	651			Anjur Dive	38	399
	Parsik Bunder	17	178.5			Parsik Bunder	10	120
	Dombivli	10	120			Dombivli	10	120
	Kalyan	27	364			Kalyan	22	264
	Vasai	10	90			Vasai	70	735
Total Jetty Capacity		**697**	**9066.5**		**Total Jetty Capacity**		**462**	**5664**
Ghodbunder	Nagla Bunder	10	135		**Ghodbunder**	Nagla Bunder	10	105
	Kolshet	73	767			Kolshet	38	399
	Kalher	10	105			Kalher	38	456
	Anjur Dive	10	90			Anjur Dive	38	513
	Parsik Bunder	10	90			Parsik Bunder	10	105
	Dombivli	10	90			Dombivli	10	135
	Kalyan	10	120			Kalyan	10	135
	Vasai	10	105			Vasai	11	116
	Jasal Park	10	90			Jasal Park	10	135
Total Jetty Capacity		**153**	**1592**		**Total Jetty Capacity**		**175**	**2099**
Nagla Bunde	Kolshet	73	769		**Nagla Bunder**	Kolshet	38	457
	Kalher	10	135			Kalher	10	90
	Anjur Dive	10	105			Anjur Dive	10	105
	Parsik Bunder	10	120			Parsik Bunder	10	105
	Dombivli	10	135			Dombivli	10	135
	Kalyan	10	135			Kalyan	10	120
	Vasai	10	105			Vasai	11	132
	Jasal Park	10	120			Jasal Park	10	135
	Ghodbunder	10	90			Ghodbunder	10	105
Total Jetty Capacity		**153**	**1714**		**Total Jetty Capacity**		**119**	**1384**
Kolsh	Kalher	161	1936		**Kolshet**	Kalher	154	1848

(Year: 2019)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Anjur Dive	161	1449			Anjur Dive	154	1617
	Parsik Bunder	376	4512			Parsik Bunder	31	372
	Dombivli	23	276			Dombivli	62	837
	Kalyan	195	2633			Kalyan	81	1094
	Vasai	1353	14207			Vasai	480	6480
	Jasal Park	688	6192			Jasal Park	140	1260
	Ghodbunder	103	1236			Ghodbunder	21	221
	Nagla Bunder	103	1391			Nagla Bunder	21	284
Total Jetty Capacity		**3163**	**33832**		**Total Jetty Capacity**		**1144**	**14013**
Kalher	Anjur Dive	10	90		**Kalher**	Anjur Dive	10	90
	Parsik Bunder	14	189			Parsik Bunder	28	252
	Dombivli	10	120			Dombivli	10	90
	Kalyan	72	756			Kalyan	65	878
	Vasai	210	1890			Vasai	42	441
	Jasal Park	340	3570			Jasal Park	330	2970
	Ghodbunder	51	536			Ghodbunder	50	675
	Nagla Bunder	51	612			Nagla Bunder	50	450
	Kolshet	312	3276			Kolshet	389	4085
Total Jetty Capacity		**1070**	**11039**		**Total Jetty Capacity**		**974**	**9931**
Anjur Dive	Parsik Bunder	14	147		**Anjur Dive**	Parsik Bunder	28	297
	Dombivli	10	135			Dombivli	10	135
	Kalyan	72	648			Kalyan	65	878
	Vasai	210	2835			Vasai	42	441
	Jasal Park	340	4080			Jasal Park	330	3960
	Ghodbunder	51	459			Ghodbunder	50	600
	Nagla Bunder	51	689			Nagla Bunder	50	450
	Kolshet	312	3744			Kolshet	381	5144
	Kalher	10	90			Kalher	10	135
Total Jetty Capacity		**1070**	**12827**		**Total Jetty Capacity**		**966**	**12040**

(Year: 2019)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
Parsik Bunde	Dombivli	20	243		**Parsik Bunder**	Dombivli	52	708
	Kalyan	39	527			Kalyan	25	338
	Vasai	10	105			Vasai	10	90
	Jasal Park	10	135			Jasal Park	15	158
	Ghodbunder	10	120			Ghodbunder	10	135
	Nagla Bunder	10	90			Nagla Bunder	10	90
	Kolshet	110	1155			Kolshet	226	2034
	Kalher	10	105			Kalher	43	452
	Anjur Dive	10	120			Anjur Dive	43	516
Total Jetty Capacity		**229**	**2600**		**Total Jetty Capacity**		**434**	**4521**
	Kalyan	21	279		**Dombivl**	Kalyan	61	820
	Vasai	10	105			Vasai	12	126
	Jasal Park	10	120			Jasal Park	10	90
	Ghodbunder	10	105			Ghodbunder	10	105
	Nagla Bunder	10	120			Nagla Bunder	10	90
	Kolshet	10	90			Kolshet	38	513
	Kalher	10	120			Kalher	10	135
	Anjur Dive	10	105			Anjur Dive	10	135
	Parsik Bunder	51	536			Parsik Bunder	33	396
Total Jetty Capacity		**142**	**1580**		**Total Jetty Capacity**		**194**	**2410**
Kalya	Vasai	10	90		**Kalyan**	Vasai	42	504
	Jasal Park	18	243			Jasal Park	20	270
	Ghodbunder	10	105			Ghodbunder	10	120
	Nagla Bunder	10	135			Nagla Bunder	10	90
	Kolshet	100	900			Kolshet	116	1044
	Kalher	19	171			Kalher	94	987
	Anjur Dive	19	257			Anjur Dive	94	1128
	Parsik Bunder	54	729			Parsik Bunder	64	576
	Dombivli	52	702			Dombivli	54	729

(Year: 2019)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
Total Jetty Capacity		292	3332		Total Jetty Capacity		504	5448

Seasonal variation taken into account for computing 15-hour traffic

Table 4. 7: Traffic Volumes At Various Jetty Locations Year 2024

(Year: 2024)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
Vasai	Jasal Park	783	9398		Vasai	Jasal Park	612	7349
	Ghodbunder	118	1415			Ghodbunder	92	963
	Nagla Bunder	118	1415			Nagla Bunder	92	1238
	Kolshet	1310	15722			Kolshet	987	13325
	Kalher	47	559			Kalher	15	131
	Anjur Dive	47	489			Anjur Dive	448	5381
	Parsik Bunder	35	367			Parsik Bunder	92	825
	Dombivli	51	535			Dombivli	20	245
	Kalyan	119	1432			Kalyan	242	3262
Total Jetty Capacity		2628	31332		Total Jetty Capacity		2600	32719
Jasal Park	Ghodbunder	15	197		Jasal Park	Ghodbunder	15	131
	Nagla Bunder	15	131			Nagla Bunder	15	197
	Kolshet	712	6407			Kolshet	370	3328
	Kalher	90	1083			Kalher	55	747
	Anjur Dive	90	812			Anjur Dive	55	581
	Parsik Bunder	25	297			Parsik Bunder	15	197
	Dombivli	15	175			Dombivli	15	131
	Kalyan	39	472			Kalyan	32	288
	Vasai	15	175			Vasai	102	1070
Total Jetty Capacity		1016	9749		Total Jetty Capacity		674	6670

(Year: 2024)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
Ghodbunder	Nagla Bunder	15	153		Ghodbunder	Nagla Bunder	15	153
	Kolshet	106	1435			Kolshet	55	664
	Kalher	15	175			Kalher	55	664
	Anjur Dive	15	153			Anjur Dive	55	747
	Parsik Bunder	15	131			Parsik Bunder	15	175
	Dombivli	15	153			Dombivli	15	175
	Kalyan	15	175			Kalyan	15	197
	Vasai	15	197			Vasai	16	192
	Jasal Park	15	131			Jasal Park	15	197
Total Jetty Capacity		**226**	**2703**		**Total Jetty Capacity**		**256**	**3164**
Nagla Bunder	Kolshet	107	1280		Nagla Bunder	Kolshet	55	749
	Kalher	15	175			Kalher	15	197
	Anjur Dive	15	197			Anjur Dive	15	197
	Parsik Bunder	15	197			Parsik Bunder	15	197
	Dombivli	15	197			Dombivli	15	131
	Kalyan	15	175			Kalyan	15	175
	Vasai	15	175			Vasai	16	144
	Jasal Park	15	197			Jasal Park	15	131
	Ghodbunder	15	175			Ghodbunder	15	153
Total Jetty Capacity		**227**	**2768**		**Total Jetty Capacity**		**176**	**2074**
Kolshet	Kalher	235	2818		Kolshet	Kalher	224	3027
	Anjur Dive	234	2461			Anjur Dive	224	2018
	Parsik Bunder	547	4926			Parsik Bunder	45	474
	Dombivli	33	301			Dombivli	90	812
	Kalyan	284	2981			Kalyan	118	1061
	Vasai	1970	26590			Vasai	699	7337
	Jasal Park	1002	12019			Jasal Park	204	2140
	Ghodbunder	150	2024			Ghodbunder	31	275

(Year: 2024)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Nagla Bunder	150	1350			Nagla Bunder	31	321
Total Jetty Capacity		**4605**	**55470**		**Total Jetty Capacity**		**1666**	**17465**
Kalher	Anjur Dive	15	175		**Kalher**	Anjur Dive	15	153
	Parsik Bunder	20	275			Parsik Bunder	41	428
	Dombivli	15	175			Dombivli	15	197
	Kalyan	105	1415			Kalyan	95	1277
	Vasai	306	3210			Vasai	61	642
	Jasal Park	495	5940			Jasal Park	480	5765
	Ghodbunder	74	1002			Ghodbunder	73	655
	Nagla Bunder	74	1002			Nagla Bunder	73	983
	Kolshet	454	6132			Kolshet	566	7645
Total Jetty Capacity		**1558**	**19326**		**Total Jetty Capacity**		**1419**	**17745**
Anjur Dive	Parsik Bunder	20	214		**Anjur Dive**	Parsik Bunder	41	371
	Dombivli	15	131			Dombivli	15	131
	Kalyan	105	1415			Kalyan	95	852
	Vasai	306	3210			Vasai	61	825
	Jasal Park	495	6682			Jasal Park	480	6485
	Ghodbunder	74	780			Ghodbunder	73	983
	Nagla Bunder	74	1002			Nagla Bunder	73	983
	Kolshet	454	4088			Kolshet	555	7488
	Kalher	15	131			Kalher	15	131
Total Jetty Capacity		**1558**	**17653**		**Total Jetty Capacity**		**1408**	**18249**
Parsik Bunder	Dombivli	29	309		**Parsik Bunder**	Dombivli	76	802
	Kalyan	57	511			Kalyan	36	382
	Vasai	15	153			Vasai	15	197
	Jasal Park	15	197			Jasal Park	22	262
	Ghodbunder	15	175			Ghodbunder	15	175
	Nagla Bunder	15	175			Nagla Bunder	15	197

(Year: 2024)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Kolshet	160	1681			Kolshet	329	2961
	Kalher	15	131			Kalher	63	845
	Anjur Dive	15	175			Anjur Dive	63	657
Total Jetty Capacity		**336**	**3507**		**Total Jetty Capacity**		**634**	**6478**
Dombivli	Kalyan	30	406		**Dombivli**	Kalyan	88	1194
	Vasai	15	175			Vasai	17	210
	Jasal Park	15	197			Jasal Park	15	197
	Ghodbunder	15	175			Ghodbunder	15	175
	Nagla Bunder	15	175			Nagla Bunder	15	153
	Kolshet	15	153			Kolshet	55	747
	Kalher	15	131			Kalher	15	197
	Anjur Dive	15	197			Anjur Dive	15	131
	Parsik Bunder	74	891			Parsik Bunder	48	649
Total Jetty Capacity		**209**	**2500**		**Total Jetty Capacity**		**283**	**3653**
Kalyan	Vasai	15	131		**Kalyan**	Vasai	61	734
	Jasal Park	26	275			Jasal Park	29	262
	Ghodbunder	15	153			Ghodbunder	15	131
	Nagla Bunder	15	197			Nagla Bunder	15	197
	Kolshet	146	1310			Kolshet	169	1773
	Kalher	28	373			Kalher	137	1437
	Anjur Dive	28	373			Anjur Dive	204	2140
	Parsik Bunder	79	1061			Parsik Bunder	31	413
	Dombivli	76	681			Dombivli	31	367
Total Jetty Capacity		**428**	**4554**		**Total Jetty Capacity**		**692**	**7454**

**Seasonal variation taken into account for computing 15-hour traffic*

Table 4. 8: Traffic Volumes At Various Jetty Locations Year 2029

(Year: 2029)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
Vasai	Jasal Park	1140	15392		**Vasai**	Jasal Park	892	9361
	Ghodbunder	172	2060			Ghodbunder	134	1802
	Nagla Bunder	172	2317			Nagla Bunder	134	1402
	Kolshet	1907	20027			Kolshet	1437	17242
	Kalher	68	814			Kalher	21	286
	Anjur Dive	68	916			Anjur Dive	653	6854
	Parsik Bunder	51	687			Parsik Bunder	89	935
	Dombivli	74	1001			Dombivli	30	356
	Kalyan	174	1564			Kalyan	352	4222
Total Jetty Capacity		**3826**	**44778**		**Total Jetty Capacity**		**3742**	**42460**
Jasal Park	Ghodbunder	21	254		**Jasal Park**	Ghodbunder	21	223
	Nagla Bunder	21	223			Nagla Bunder	21	191
	Kolshet	1036	13990			Kolshet	538	4845
	Kalher	131	1380			Kalher	81	1087
	Anjur Dive	131	1183			Anjur Dive	81	966
	Parsik Bunder	36	378			Parsik Bunder	21	254
	Dombivli	21	286			Dombivli	21	286
	Kalyan	57	515			Kalyan	47	559
	Vasai	21	286			Vasai	148	1780
Total Jetty Capacity		**1475**	**18495**		**Total Jetty Capacity**		**979**	**10191**
Ghodbunder	Nagla Bunder	21	191		**Ghodbunder**	Nagla Bunder	21	191
	Kolshet	155	2089			Kolshet	81	725
	Kalher	21	286			Kalher	81	725
	Anjur Dive	21	254			Anjur Dive	81	846
	Parsik Bunder	21	254			Parsik Bunder	21	223
	Dombivli	21	286			Dombivli	21	286
	Kalyan	21	223			Kalyan	21	254

(Year: 2029)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Vasai	21	223			Vasai	23	245
	Jasal Park	21	286			Jasal Park	21	223
Total Jetty Capacity		**323**	**4092**		**Total Jetty Capacity**		**371**	**3718**
Nagla Bunder	Kolshet	155	1631		**Nagla Bunder**	Kolshet	81	727
	Kalher	21	191			Kalher	21	286
	Anjur Dive	21	254			Anjur Dive	21	286
	Parsik Bunder	21	254			Parsik Bunder	21	286
	Dombivli	21	191			Dombivli	21	254
	Kalyan	21	191			Kalyan	21	223
	Vasai	21	286			Vasai	23	245
	Jasal Park	21	254			Jasal Park	21	254
	Ghodbunder	21	286			Ghodbunder	21	286
Total Jetty Capacity		**323**	**3538**		**Total Jetty Capacity**		**251**	**2847**
Kolshet	Kalher	342	4103		**Kolshet**	Kalher	326	3427
	Anjur Dive	341	3071			Anjur Dive	326	3916
	Parsik Bunder	797	9562			Parsik Bunder	66	591
	Dombivli	49	512			Dombivli	131	1577
	Kalyan	413	4959			Kalyan	172	1802
	Vasai	2867	38710			Vasai	1017	9155
	Jasal Park	1458	19684			Jasal Park	297	4005
	Ghodbunder	218	2619			Ghodbunder	45	401
	Nagla Bunder	218	2619			Nagla Bunder	45	467
Total Jetty Capacity		**6703**	**85839**		**Total Jetty Capacity**		**2425**	**25341**
Kalher	Anjur Dive	21	254		**Kalher**	Anjur Dive	21	254
	Parsik Bunder	30	401			Parsik Bunder	59	801
	Dombivli	21	286			Dombivli	21	223
	Kalyan	153	1831			Kalyan	138	1860
	Vasai	445	4005			Vasai	89	935
	Jasal Park	721	6485			Jasal Park	699	8392

(Year: 2029)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Ghodbunder	108	1297			Ghodbunder	106	1431
	Nagla Bunder	108	1135			Nagla Bunder	106	954
	Kolshet	661	5951			Kolshet	824	8656
Total Jetty Capacity		**2268**	**21645**		**Total Jetty Capacity**		**2063**	**23506**
Anjur Dive	Parsik Bunder	30	312		**Anjur Dive**	Parsik Bunder	60	629
	Dombivli	21	254			Dombivli	21	191
	Kalyan	153	2060			Kalyan	138	1653
	Vasai	445	5341			Vasai	89	1202
	Jasal Park	721	6485			Jasal Park	699	8392
	Ghodbunder	108	973			Ghodbunder	106	1272
	Nagla Bunder	108	1297			Nagla Bunder	106	1431
	Kolshet	661	7935			Kolshet	807	7267
	Kalher	21	191			Kalher	21	223
Total Jetty Capacity		**2268**	**24848**		**Total Jetty Capacity**		**2047**	**22260**
Parsik Bunder	Dombivli	43	450		**Parsik Bunder**	Dombivli	111	1501
	Kalyan	83	992			Kalyan	53	556
	Vasai	21	286			Vasai	21	191
	Jasal Park	21	191			Jasal Park	32	286
	Ghodbunder	21	254			Ghodbunder	21	286
	Nagla Bunder	21	254			Nagla Bunder	21	254
	Kolshet	233	3147			Kolshet	479	4311
	Kalher	21	223			Kalher	91	820
	Anjur Dive	21	254			Anjur Dive	91	1094
Total Jetty Capacity		**485**	**6051**		**Total Jetty Capacity**		**920**	**9299**
Dombivli	Kalyan	44	460		**Dombivli**	Kalyan	129	1352
	Vasai	21	286			Vasai	25	343
	Jasal Park	21	286			Jasal Park	21	286
	Ghodbunder	21	286			Ghodbunder	21	254

(Year: 2029)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Nagla Bunder	21	286			Nagla Bunder	21	286
	Kolshet	21	223			Kolshet	81	1087
	Kalher	21	254			Kalher	21	191
	Anjur Dive	21	286			Anjur Dive	21	191
	Parsik Bunder	108	1459			Parsik Bunder	70	734
Total Jetty Capacity		**299**	**3826**		**Total Jetty Capacity**		**410**	**4724**
Kalyan	Vasai	21	223		**Kalyan**	Vasai	89	1068
	Jasal Park	38	343			Jasal Park	42	381
	Ghodbunder	21	286			Ghodbunder	21	223
	Nagla Bunder	21	223			Nagla Bunder	21	191
	Kolshet	212	2861			Kolshet	246	2581
	Kalher	40	423			Kalher	199	2391
	Anjur Dive	40	483			Anjur Dive	199	2391
	Parsik Bunder	114	1202			Parsik Bunder	136	1221
	Dombivli	110	1157			Dombivli	114	1545
Total Jetty Capacity		**617**	**7201**		**Total Jetty Capacity**		**1067**	**11992**

**Seasonal variation taken into account for computing 15-hour traffic*

Table 4. 9: Traffic Volumes At Various Jetty Locations Year 2034

(Year: 2034)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
Vasai	Jasal Park	1660	14938		**Vasai**	Jasal Park	1298	17521
	Ghodbunder	250	417			Ghodbunder	194	1749
	Nagla Bunder	250	3374			Nagla Bunder	194	2624
	Kolshet	2777	24990			Kolshet	2092	18826
	Kalher	99	1333			Kalher	31	278

(Year: 2034)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Anjur Dive	99	889			Anjur Dive	950	9977
	Parsik Bunder	74	889			Parsik Bunder	130	1749
	Dombivli	108	1134			Dombivli	43	389
	Kalyan	253	2277			Kalyan	512	5377
Total Jetty Capacity		**5570**	**58491**		**Total Jetty Capacity**		**5444**	**58490**
Jasal Park	Ghodbunder	31	417		**Jasal Park**	Ghodbunder	31	324
	Nagla Bunder	31	278			Nagla Bunder	31	278
	Kolshet	1509	18104			Kolshet	784	10579
	Kalher	191	2008			Kalher	117	1055
	Anjur Dive	191	2295			Anjur Dive	117	1231
	Parsik Bunder	52	472			Parsik Bunder	31	417
	Dombivli	31	417			Dombivli	31	370
	Kalyan	83	750			Kalyan	68	713
	Vasai	31	278			Vasai	216	2592
Total Jetty Capacity		**2150**	**25019**		**Total Jetty Capacity**		**1426**	**17559**
Ghodbunder	Nagla Bunder	31	417		**Ghodbunder**	Nagla Bunder	31	324
	Kolshet	225	3040			Kolshet	117	1231
	Kalher	31	324			Kalher	117	1055
	Anjur Dive	31	370			Anjur Dive	117	1231
	Parsik Bunder	31	278			Parsik Bunder	31	417
	Dombivli	31	370			Dombivli	31	278
	Kalyan	31	417			Kalyan	31	278
	Vasai	31	324			Vasai	34	305
	Jasal Park	31	324			Jasal Park	31	417
Total Jetty Capacity		**473**	**5864**		**Total Jetty Capacity**		**540**	**5536**
Nagla Bunder	Kolshet	226	2035		**Nagla Bunder**	Kolshet	118	1058

(Year: 2034)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Kalher	31	417			Kalher	31	324
	Anjur Dive	31	417			Anjur Dive	31	370
	Parsik Bunder	31	278			Parsik Bunder	31	324
	Dombivli	31	417			Dombivli	31	324
	Kalyan	31	417			Kalyan	31	278
	Vasai	31	278			Vasai	34	458
	Jasal Park	31	324			Jasal Park	31	324
	Ghodbunder	31	370			Ghodbunder	31	324
Total Jetty Capacity		**474**	**4953**		**Total Jetty Capacity**		**369**	**3784**
Kolshet	Kalher	498	5973		**Kolshet**	Kalher	475	4277
	Anjur Dive	497	5216			Anjur Dive	475	4989
	Parsik Bunder	1160	15660			Parsik Bunder	96	861
	Dombivli	71	958			Dombivli	191	2295
	Kalyan	602	5415			Kalyan	250	2624
	Vasai	4174	50091			Vasai	1481	19992
	Jasal Park	2123	19103			Jasal Park	432	4535
	Ghodbunder	318	3337			Ghodbunder	65	875
	Nagla Bunder	318	2860			Nagla Bunder	65	875
Total Jetty Capacity		**9761**	**108613**		**Total Jetty Capacity**		**3530**	**41323**
Kalher	Anjur Dive	31	370		**Kalher**	Anjur Dive	31	417
	Parsik Bunder	43	454			Parsik Bunder	86	1037
	Dombivli	31	278			Dombivli	31	278
	Kalyan	222	2332			Kalyan	201	1805
	Vasai	648	8747			Vasai	130	1361
	Jasal Park	1049	14161			Jasal Park	1018	9163
	Ghodbunder	157	1888			Ghodbunder	154	1851
	Nagla Bunder	157	2124			Nagla Bunder	154	2083
	Kolshet	963	10107			Kolshet	1200	12601
Total Jetty Capacity		**3301**	**40461**		**Total Jetty Capacity**		**3005**	**30596**

(Year: 2034)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
Anjur Dive	Parsik Bunder	43	455		**Anjur Dive**	Parsik Bunder	87	1178
	Dombivli	31	370			Dombivli	31	417
	Kalyan	222	2999			Kalyan	201	2707
	Vasai	648	8747			Vasai	130	1166
	Jasal Park	1049	9441			Jasal Park	1018	12217
	Ghodbunder	157	2124			Ghodbunder	154	1620
	Nagla Bunder	157	1652			Nagla Bunder	154	1388
	Kolshet	963	11551			Kolshet	1175	15869
	Kalher	31	278			Kalher	31	324
Total Jetty Capacity		**3301**	**37617**		**Total Jetty Capacity**		**2981**	**36886**
Parsik Bunder	Dombivli	62	748		**Parsik Bunder**	Dombivli	162	1942
	Kalyan	120	1444			Kalyan	77	694
	Vasai	31	278			Vasai	31	417
	Jasal Park	31	278			Jasal Park	46	417
	Ghodbunder	31	417			Ghodbunder	31	324
	Nagla Bunder	31	370			Nagla Bunder	31	370
	Kolshet	339	4072			Kolshet	697	9413
	Kalher	31	370			Kalher	133	1194
	Anjur Dive	31	370			Anjur Dive	133	1592
Total Jetty Capacity		**707**	**8347**		**Total Jetty Capacity**		**1341**	**16363**
Dombivli	Kalyan	64	574		**Dombivl**	Kalyan	187	2531
	Vasai	31	417			Vasai	37	444
	Jasal Park	31	417			Jasal Park	31	324
	Ghodbunder	31	417			Ghodbunder	31	370
	Nagla Bunder	31	417			Nagla Bunder	31	370
	Kolshet	31	278			Kolshet	117	1407
	Kalher	31	324			Kalher	31	324

(Year: 2034)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Anjur Dive	31	417			Anjur Dive	31	278
	Parsik Bunder	157	2124			Parsik Bunder	102	916
Total Jetty Capacity		**438**	**5385**		**Total Jetty Capacity**		**598**	**6964**
Kalyan	Vasai	31	278		**Kalyan**	Vasai	130	1555
	Jasal Park	56	500			Jasal Park	62	555
	Ghodbunder	31	278			Ghodbunder	31	417
	Nagla Bunder	31	278			Nagla Bunder	31	278
	Kolshet	309	2777			Kolshet	358	4831
	Kalher	59	703			Kalher	290	2610
	Anjur Dive	59	615			Anjur Dive	290	3480
	Parsik Bunder	167	1999			Parsik Bunder	197	2369
	Dombivli	160	1444			Dombivli	167	1999
Total Jetty Capacity		**903**	**8872**		**Total Jetty Capacity**		**1556**	**18094**

**Seasonal variation taken into account for computing 15-hour traffic*

Table 4. 10: Traffic Volumes At Various Jetty Locations Year 2039

(Year: 2039)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
Vasai	Jasal Park	2416	25371		**Vasai**	Jasal Park	1889	19838
	Ghodbunder	364	3820			Ghodbunder	283	2547
	Nagla Bunder	364	3274			Nagla Bunder	283	3395
	Kolshet	4042	42443			Kolshet	3045	31974
	Kalher	144	1509			Kalher	45	472
	Anjur Dive	144	1509			Anjur Dive	1383	18675
	Parsik Bunder	108	1455			Parsik Bunder	189	2547

(Year: 2039)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Dombivli	157	1886			Dombivli	63	566
	Kalyan	368	3867			Kalyan	746	6710
Total Jetty Capacity		**8107**	**85134**		**Total Jetty Capacity**		**7926**	**86724**
Jasal Park	Ghodbunder	45	606		**Jasal Park**	Ghodbunder	45	404
	Nagla Bunder	45	404			Nagla Bunder	45	472
	Kolshet	2196	23061			Kolshet	1141	15401
	Kalher	278	3759			Kalher	171	2048
	Anjur Dive	278	2924			Anjur Dive	171	2048
	Parsik Bunder	76	1031			Parsik Bunder	45	404
	Dombivli	45	606			Dombivli	45	404
	Kalyan	121	1637			Kalyan	99	1334
	Vasai	45	404			Vasai	314	2830
Total Jetty Capacity		**3129**	**34432**		**Total Jetty Capacity**		**2076**	**25345**
Ghodbunder	Nagla Bunder	45	539		**Ghodbunder**	Nagla Bunder	45	404
	Kolshet	328	3443			Kolshet	171	1792
	Kalher	45	539			Kalher	171	1792
	Anjur Dive	45	472			Anjur Dive	171	1792
	Parsik Bunder	45	472			Parsik Bunder	45	472
	Dombivli	45	404			Dombivli	45	404
	Kalyan	45	539			Kalyan	45	539
	Vasai	45	539			Vasai	49	519
	Jasal Park	45	539			Jasal Park	45	539
Total Jetty Capacity		**688**	**7486**		**Total Jetty Capacity**		**787**	**8253**
Nagla Bunder	Kolshet	329	4443		**Nagla Bunder**	Kolshet	171	2311
	Kalher	45	539			Kalher	45	472
	Anjur Dive	45	472			Anjur Dive	45	404
	Parsik Bunder	45	539			Parsik Bunder	45	606

(Year: 2039)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Dombivli	45	606			Dombivli	45	606
	Kalyan	45	606			Kalyan	45	404
	Vasai	45	606			Vasai	49	593
	Jasal Park	45	606			Jasal Park	45	606
	Ghodbunder	45	472			Ghodbunder	45	606
Total Jetty Capacity		**689**	**8889**		**Total Jetty Capacity**		**535**	**6608**
Kolshet	Kalher	725	7608		**Kolshet**	Kalher	692	6226
	Anjur Dive	723	9762			Anjur Dive	692	8300
	Parsik Bunder	1689	22798			Parsik Bunder	139	1671
	Dombivli	103	1085			Dombivli	278	3342
	Kalyan	876	7882			Kalyan	364	4366
	Vasai	6077	54691			Vasai	2156	22636
	Jasal Park	3090	41715			Jasal Park	629	5659
	Ghodbunder	463	5551			Ghodbunder	94	1132
	Nagla Bunder	463	4857			Nagla Bunder	94	990
Total Jetty Capacity		**14209**	**155949**		**Total Jetty Capacity**		**5138**	**54322**
Kalher	Anjur Dive	45	472		**Kalher**	Anjur Dive	45	606
	Parsik Bunder	63	755			Parsik Bunder	126	1320
	Dombivli	45	606			Dombivli	45	606
	Kalyan	323	4366			Kalyan	292	3941
	Vasai	943	11318			Vasai	189	2547
	Jasal Park	1527	13743			Jasal Park	1482	15562
	Ghodbunder	229	2405			Ghodbunder	225	2695
	Nagla Bunder	229	3092			Nagla Bunder	225	3032
	Kolshet	1401	18917			Kolshet	1747	15724
Total Jetty Capacity		**4805**	**55674**		**Total Jetty Capacity**		**4376**	**46033**
Anjur Dive	Parsik Bunder	63	756		**Anjur Dive**	Parsik Bunder	127	1334
	Dombivli	45	539			Dombivli	45	606
	Kalyan	323	2910			Kalyan	292	2627

(Year: 2039)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Vasai	943	12733			Vasai	189	2264
	Jasal Park	1527	13743			Jasal Park	1482	13339
	Ghodbunder	229	2405			Ghodbunder	225	2021
	Nagla Bunder	229	2749			Nagla Bunder	225	3032
	Kolshet	1401	12612			Kolshet	1711	23101
	Kalher	45	539			Kalher	45	539
Total Jetty Capacity		**4805**	**48986**		**Total Jetty Capacity**		**4341**	**48863**
Parsik Bunder	Dombivli	91	1225		**Parsik Bunder**	Dombivli	236	3181
	Kalyan	175	2102			Kalyan	112	1011
	Vasai	45	539			Vasai	45	606
	Jasal Park	45	606			Jasal Park	67	707
	Ghodbunder	45	539			Ghodbunder	45	606
	Nagla Bunder	45	539			Nagla Bunder	45	539
	Kolshet	494	4446			Kolshet	1015	10658
	Kalher	45	606			Kalher	193	2318
	Anjur Dive	45	472			Anjur Dive	193	1738
Total Jetty Capacity		**1030**	**11074**		**Total Jetty Capacity**		**1951**	**21364**
Dombivli	Kalyan	93	975		**Dombivl**	Kalyan	273	3275
	Vasai	45	404			Vasai	54	566
	Jasal Park	45	472			Jasal Park	45	606
	Ghodbunder	45	539			Ghodbunder	45	539
	Nagla Bunder	45	606			Nagla Bunder	45	472
	Kolshet	45	472			Kolshet	171	1792
	Kalher	45	472			Kalher	45	472
	Anjur Dive	45	539			Anjur Dive	45	539
	Parsik Bunder	229	2405			Parsik Bunder	148	2001
Total Jetty Capacity		**637**	**6884**		**Total Jetty Capacity**		**871**	**10262**
Kalyan	Vasai	45	539		**Kalyan**	Vasai	189	2264
	Jasal Park	81	970			Jasal Park	90	1213

(Year: 2039)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Ghodbunder	45	472			Ghodbunder	45	472
	Nagla Bunder	45	472			Nagla Bunder	45	606
	Kolshet	449	6063			Kolshet	521	5470
	Kalher	85	1024			Kalher	422	3800
	Anjur Dive	85	1152			Anjur Dive	422	5700
	Parsik Bunder	243	3274			Parsik Bunder	287	3449
	Dombivli	234	3153			Dombivli	243	2547
Total Jetty Capacity		**1312**	**17119**		**Total Jetty Capacity**		**2264**	**25521**

**Seasonal variation taken into account for computing 15-hour traffic*

Table 4. 11: Traffic Volumes At Various Jetty Locations Year 2044

(Year: 2044)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
Vasai	Jasal Park	3518	36934		**Vasai**	Jasal Park	2750	37132
	Ghodbunder	530	7150			Ghodbunder	412	4943
	Nagla Bunder	530	5561			Nagla Bunder	412	5561
	Kolshet	5885	61788			Kolshet	4433	46547
	Kalher	209	1883			Kalher	65	883
	Anjur Dive	209	2825			Anjur Dive	2014	24166
	Parsik Bunder	157	1883			Parsik Bunder	275	2883
	Dombivli	229	3089			Dombivli	92	824
	Kalyan	536	7238			Kalyan	1085	9768
Total Jetty Capacity		**11803**	**128351**		**Total Jetty Capacity**		**1153**	**132707**
Jasal Park	Ghodbunder	65	785		**Jasal Park**	Ghodbunder	65	588
	Nagla Bunder	65	687			Nagla Bunder	65	588

(Year: 2044)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Kolshet	3197	38367			Kolshet	1661	22420
	Kalher	405	4256			Kalher	248	2981
	Anjur Dive	405	5473			Anjur Dive	248	2981
	Parsik Bunder	111	1167			Parsik Bunder	65	883
	Dombivli	65	588			Dombivli	65	687
	Kalyan	177	2383			Kalyan	144	1726
	Vasai	65	785			Vasai	458	5492
Total Jetty Capacity		**4555**	**54491**		**Total Jetty Capacity**		**3019**	**38346**
Ghodbunder	Nagla Bunder	65	785		**Ghodbunder**	Nagla Bunder	65	687
	Kolshet	477	4296			Kolshet	248	2236
	Kalher	65	883			Kalher	248	2981
	Anjur Dive	65	883			Anjur Dive	248	3354
	Parsik Bunder	65	883			Parsik Bunder	65	785
	Dombivli	65	785			Dombivli	65	785
	Kalyan	65	785			Kalyan	65	687
	Vasai	65	687			Vasai	72	647
	Jasal Park	65	883			Jasal Park	65	785
Total Jetty Capacity		**997**	**10870**		**Total Jetty Capacity**		**1141**	**12947**
Nagla Bunder	Kolshet	479	5749		**Nagla Bunder**	Kolshet	249	2617
	Kalher	65	785			Kalher	65	785
	Anjur Dive	65	883			Anjur Dive	65	883
	Parsik Bunder	65	588			Parsik Bunder	65	785
	Dombivli	65	588			Dombivli	65	687
	Kalyan	65	883			Kalyan	65	785
	Vasai	65	785			Vasai	72	647
	Jasal Park	65	687			Jasal Park	65	588
	Ghodbunder	65	883			Ghodbunder	65	687

(Year: 2044)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
Total Jetty Capacity		**999**	**11831**		**Total Jetty Capacity**		**776**	**8464**
Kolshet	Kalher	1055	12658		**Kolshet**	Kalher	1007	12085
	Anjur Dive	1053	9474			Anjur Dive	1007	13593
	Parsik Bunder	2458	29501			Parsik Bunder	203	1824
	Dombivli	150	1579			Dombivli	405	3648
	Kalyan	1275	15300			Kalyan	530	5561
	Vasai	8846	106157			Vasai	3138	42369
	Jasal Park	4498	53981			Jasal Park	915	10984
	Ghodbunder	673	9092			Ghodbunder	137	1442
	Nagla Bunder	673	8081			Nagla Bunder	137	1236
Total Jetty Capacity		**20681**	**245823**		**Total Jetty Capacity**		**7479**	**92742**
Kalher	Anjur Dive	65	687		**Kalher**	Anjur Dive	65	883
	Parsik Bunder	92	1236			Parsik Bunder	183	2197
	Dombivli	65	687			Dombivli	65	687
	Kalyan	471	5649			Kalyan	425	5737
	Vasai	1373	12358			Vasai	275	2883
	Jasal Park	2223	20007			Jasal Park	2158	29128
	Ghodbunder	333	3001			Ghodbunder	327	4413
	Nagla Bunder	333	4502			Nagla Bunder	327	3433
	Kolshet	2040	18360			Kolshet	2543	30521
Total Jetty Capacity		**6995**	**66487**		**Total Jetty Capacity**		**6368**	**79882**
Anjur Dive	Parsik Bunder	92	963		**Anjur Dive**	Parsik Bunder	185	2496
	Dombivli	65	785			Dombivli	65	883
	Kalyan	471	5649			Kalyan	425	3825
	Vasai	1373	16477			Vasai	275	2883
	Jasal Park	2223	30011			Jasal Park	2158	29128
	Ghodbunder	333	4001			Ghodbunder	327	4413
	Nagla Bunder	333	4502			Nagla Bunder	327	4413

(Year: 2044)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Kolshet	2040	24480			Kolshet	2491	33630
	Kalher	65	687			Kalher	65	883
Total Jetty Capacity		**6995**	**87555**		**Total Jetty Capacity**		**6318**	**82554**
Parsik Bunder	Dombivli	132	1784		**Parsik Bunder**	Dombivli	343	4117
	Kalyan	255	3060			Kalyan	163	1962
	Vasai	65	883			Vasai	65	785
	Jasal Park	65	883			Jasal Park	98	1324
	Ghodbunder	65	883			Ghodbunder	65	883
	Nagla Bunder	65	588			Nagla Bunder	65	785
	Kolshet	719	9709			Kolshet	1478	13299
	Kalher	65	785			Kalher	281	2530
	Anjur Dive	65	883			Anjur Dive	281	2530
Total Jetty Capacity		**1496**	**19458**		**Total Jetty Capacity**		**2839**	**28215**
Dombivli	Kalyan	135	1217		**Dombivli**	Kalyan	397	4172
	Vasai	65	588			Vasai	78	706
	Jasal Park	65	588			Jasal Park	65	883
	Ghodbunder	65	588			Ghodbunder	65	588
	Nagla Bunder	65	883			Nagla Bunder	65	883
	Kolshet	65	785			Kolshet	248	2236
	Kalher	65	588			Kalher	65	588
	Anjur Dive	65	687			Anjur Dive	65	687
	Parsik Bunder	333	3501			Parsik Bunder	216	2589
Total Jetty Capacity		**923**	**9425**		**Total Jetty Capacity**		**1264**	**13332**
Kalyan	Vasai	65	883		**Kalyan**	Vasai	275	3295
	Jasal Park	118	1236			Jasal Park	131	1569
	Ghodbunder	65	785			Ghodbunder	65	588
	Nagla Bunder	65	687			Nagla Bunder	65	687
	Kolshet	654	8827			Kolshet	758	10239

(Year: 2044)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Kalher	124	1491			Kalher	615	5531
	Anjur Dive	124	1677			Anjur Dive	615	8297
	Parsik Bunder	353	3707			Parsik Bunder	418	5021
	Dombivli	340	3570			Dombivli	353	3178
Total Jetty Capacity		**1908**	**22863**		**Total Jetty Capacity**		**3295**	**38405**

**Seasonal variation taken into account for computing 15-hour traffic*

Table 4. 12: Traffic Volumes At Various Jetty Locations – Year 2049

(Year: 2049)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
Vasai	Jasal Park	5121	69131		Vasai	Jasal Park	4004	48049
	Ghodbunder	771	8095			Ghodbunder	600	8095
	Nagla Bunder	771	10408			Nagla	600	5397
	Kolshet	8567	77099			Kolshet	6453	67761
	Kalher	305	3198			Kalher	95	999
	Anjur Dive	305	3655			Anjur Dive	2932	39577
	Parsik Bunder	228	2399			Parsik	400	3598
	Dombivli	333	3998			Dombivli	133	1599
	Kalyan	781	9366			Kalyan	1580	21331
Total Jetty Capacity		**17182**	**187349**		**Total Jetty Capacity**		**16797**	**196406**
Jasal Park	Ghodbunder	95	857		**Jasal Park**	Ghodbunder	95	999
	Nagla Bunder	95	857			Nagla	95	1285
	Kolshet	4654	62836			Kolshet	2418	21759
	Kalher	590	6196			Kalher	362	3255
	Anjur Dive	590	7967			Anjur Dive	362	4883

(Year: 2049)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Parsik Bunder	162	1456			Parsik	95	1142
	Dombivli	95	999			Dombivli	95	857
	Kalyan	257	2313			Kalyan	209	2827
	Vasai	95	999			Vasai	666	5997
Total Jetty Capacity		**6633**	**84480**		**Total Jetty Capacity**		**4397**	**43004**
Ghod bunde	Nagla Bunder	95	1285		**Ghodbund er**	Nagla Bunder	95	857
	Kolshet	695	9380			Kolshet	362	3255
	Kalher	95	1142			Kalher	362	3798
	Anjur Dive	95	1142			Anjur Dive	362	4883
	Parsik Bunder	95	999			Parsik	95	857
	Dombivli	95	857			Dombivli	95	857
	Kalyan	95	1142			Kalyan	95	857
	Vasai	95	1142			Vasai	105	1256
	Jasal Park	95	999			Jasal Park	95	1142
Total Jetty Capacity		**1455**	**18088**		**Total Jetty Capacity**		**1666**	**17762**
Nagla Bunde	Kolshet	697	8370		**Nagla Bunder**	Kolshet	363	4354
	Kalher	95	999			Kalher	95	857
	Anjur Dive	95	1285			Anjur Dive	95	1142
	Parsik Bunder	95	999			Parsik	95	857
	Dombivli	95	857			Dombivli	95	999
	Kalyan	95	857			Kalyan	95	999
	Vasai	95	1285			Vasai	105	942
	Jasal Park	95	999			Jasal Park	95	1142
	Ghodbunder	95	1285			Ghodbunder	95	999
Total Jetty Capacity		**1457**	**16936**		**Total Jetty Capacity**		**1133**	**12291**
Kolsh	Kalher	1536	16124		**Kolshet**	Kalher	1466	13195
	Anjur Dive	1532	20688			Anjur Dive	1466	19789
	Parsik Bunder	3579	48315			Parsik	295	3983

(Year: 2049)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Dombivli	219	2299			Dombivli	590	7082
	Kalyan	1856	16705			Kalyan	771	9252
	Vasai	12878	115905			Vasai	4569	47973
	Jasal Park	6549	78584			Jasal Park	1333	13992
	Ghodbunder	980	11765			Ghodbunder	200	2399
	Nagla Bunder	980	11765			Nagla	200	2099
Total Jetty Capacity		**30109**	**322150**		**Total Jetty Capacity**		**10890**	**119764**
Kalher	Anjur Dive	95	999		**Kalher**	Anjur Dive	95	1142
	Parsik Bunder	133	1599			Parsik	267	2399
	Dombivli	95	1142			Dombivli	95	1285
	Kalyan	685	9252			Kalyan	619	8352
	Vasai	1999	26985			Vasai	400	5397
	Jasal Park	3236	38835			Jasal Park	3141	37693
	Ghodbunder	485	5097			Ghodbunder	476	4997
	Nagla Bunder	485	6553			Nagla	476	5711
	Kolshet	2970	40091			Kolshet	3703	49986
Total Jetty Capacity		**10183**	**130553**		**Total Jetty Capacity**		**9272**	**116962**
Anjur Dive	Parsik Bunder	134	1202		**Anjur Dive**	Parsik Bunder	269	3230
	Dombivli	95	999			Dombivli	95	999
	Kalyan	685	9252			Kalyan	619	8352
	Vasai	1999	17990			Vasai	400	5397
	Jasal Park	3236	38835			Jasal Park	3141	42404
	Ghodbunder	485	5825			Ghodbunder	476	4997
	Nagla Bunder	485	5825			Nagla	476	5711
	Kolshet	2970	35637			Kolshet	3627	43518
	Kalher	95	1142			Kalher	95	1142
Total Jetty Capacity		**10184**	**116707**		**Total Jetty Capacity**		**9198**	**115750**
Parsik Bunde	Dombivli	192	2597		**Parsik Bunder**	Dombivli	499	5244

(Year: 2049)								
Up					Down			
To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *		To	From	Peak Hour Traffic	15 Hour Operational Traffic in a Day *
	Kalyan	371	5011			Kalyan	238	2856
	Vasai	95	999			Vasai	95	999
	Jasal Park	95	1142			Jasal Park	143	1285
	Ghodbunder	95	857			Ghodbunder	95	999
	Nagla Bunder	95	1285			Nagla	95	1285
	Kolshet	1047	12564			Kolshet	2151	25814
	Kalher	95	857			Kalher	409	5525
	Anjur Dive	95	857			Anjur Dive	409	3684
Total Jetty Capacity		**2180**	**26169**		**Total Jetty Capacity**		**4134**	**47691**
	Kalyan	197	1771		**Dombivli**	Kalyan	578	5206
	Vasai	95	999			Vasai	114	1542
	Jasal Park	95	857			Jasal Park	95	1285
	Ghodbunder	95	999			Ghodbunder	95	999
	Nagla Bunder	95	1142			Nagla	95	857
	Kolshet	95	999			Kolshet	362	3255
	Kalher	95	1285			Kalher	95	999
	Anjur Dive	95	1142			Anjur Dive	95	999
	Parsik Bunder	485	6553			Parsik	314	3298
Total Jetty Capacity		**1347**	**15747**		**Total Jetty Capacity**		**1843**	**18440**
Kalya	Vasai	95	1285		**Kalyan**	Vasai	400	4797
	Jasal Park	171	2313			Jasal Park	190	1713
	Ghodbunder	95	1142			Ghodbunder	95	857
	Nagla Bunder	95	999			Nagla	95	857
	Kolshet	952	8567			Kolshet	1104	14906
	Kalher	181	2441			Kalher	895	10737
	Anjur Dive	181	1899			Anjur Dive	895	12079
	Parsik Bunder	514	5397			Parsik	609	5483
	Dombivli	495	5939			Dombivli	514	6939
Total Jetty Capacity		**2279**	**29982**		**Total Jetty Capacity**		**4797**	**58368**

**Seasonal variation taken into account for computing 15-hour traffic*

4.5.2 Possibility Of OD Pairs For Stand-Alone Operation

Before discussing the possible OD pairs and their financial viability, it is natural to discuss the other aspects of the waterway transport in order to provide right perspective. Since, waterway transport can not serve door to door customers, last mile connectivity of the terminals determines its success or lack of it. The Table 4.13, shows the connectivity to the proposed IWT terminals, by both rail and the road modes. The table indicates that the terminals are well connected, but the quality of connection may have to be improved.

Table 4. 13: Connectivity To The Proposed IWT Stations

IWT Terminal Site	Distance to nearest local rail station	Distance to nearest Bus Stop	Distance to nearest road (to be constructed)
Vasai	4.0 km - Naigaon Station (Western Railway)	575 m – Chimaji Appa (VMMT)	0.0 m
Jasal Park	1.0 km - Bhayander Station (Western Railway)	1 km – Bhayander Station East (BEST & VMMT)	15 m
Godhbunder Village	4.0 km - Mira Road Station (Western Railway)	250 m – Ghodbunder Village (BEST)	70 m
Nagla Bunder	10.0 km – Mira Road Station (Western Railway)	1 km – Nagla Bund (BEST & TMT)	50 m
Kolshet	5.0 km – Kalwa Station (Central Railway)	700 m – Air Force (TMT)	70 m
Kalher	4.0 km – Bhiwandi Station (Central Railway)	1 km – Pipe Line Kalher (TMT)	380 m
Parsik Bunder	3.0 km – Kalwa Station (Central Railway)	500 m – Pipe Line Kalwa (TMT)	20 m
Anjur Dive	4.0 km – Kalwa Station (Central Railway)	1.7 km – Diva Gaon (TMT)	180 m
Dombivli	1.5 km – Dombivli Station (Central Railway)	1 km – Retibunder Nakka (KDMT)	50 m
Kalyan	1.71 km – Kalyan Station (Central Railway)	700 m – Durgadi Chowk (KDMT)	50 m

The traffic study carried out as a part of this study also identified certain OD pairs and compared them with the other existing modes of transport. The computation given in table 4.14, indicates the mode of travel, whether across or linear, the speed of travel by the vessel/rail/road, to indicate the aptness of each mode. It could be seen that there are mix of cross and linear travel. The cross water routes are considered to be for immediate implementation, so that the river route works as an alternative mode of transport. The viability of each terminal on a stand-alone basis shall be examined in the financial analysis chapter.

Possible pairing of the terminals and their likely comparison is given in Table 4.14. It is proposed that, the cross services should be made to commence in the initial phase.

Table 4. 14: Possible Routes And Comparison With Alternate Modes Of Travel

Sr	Description	Linear/ Cross Ferry	By Water way					By Road		By Train	
			Distance		Speed		Time	Distance	Time	Distance	Time
			Kms	NM	Knots	Kms	Min	Kms	Min	Kms	Min
1	Vasai to Mira Bhayandar	Cross	4.1	2.21	6	11.112	22.14	30.5	57	12	9
2	Mira Bhayandar to Ghodbunder	Linear	4.72	2.54	8	14.816	19.11	8	25	-	-
3	Ghodbunder to Naglabunder	Linear	6.53	3.52	10	18.52	21.16	10	35	-	-
4	Naglabunder to Kolshet	Linear	10.25	4.87	10	18.52	33.21	10	35	-	-
5	Kolshet to Kalher	Cross	0.66	0.35	6	11.112	3.56	7	30	-	-
6	Kolshet to Parsik	Linear	4.3	2.32	10	18.52	13.93	8	27	-	-
7	Parsik to Anjur Dive	Cross	0.7	0.37	6	11.112	3.78	6.5	20	-	-
8	Parsik to Dombivli	Linear	9	4.62	8	14.816	36.45	21.5	48	14	10
9	Dombivli to Kalyan	Linear	6.95	3.75	6	11.112	37.53	9	30	7	9
10	Vasai to Naigaon	Linear	2.62	1.41	6	11.112	14.15	2	17	-	-
11	Naigaon to Ghodbunder	Cross	8.17	4.41	6	11.112	44.11	31	62	25	60
12	Naigaon to Nagla Bunder	Cross	14.12	7.62	8	14.816	57.18	43	84	-	-

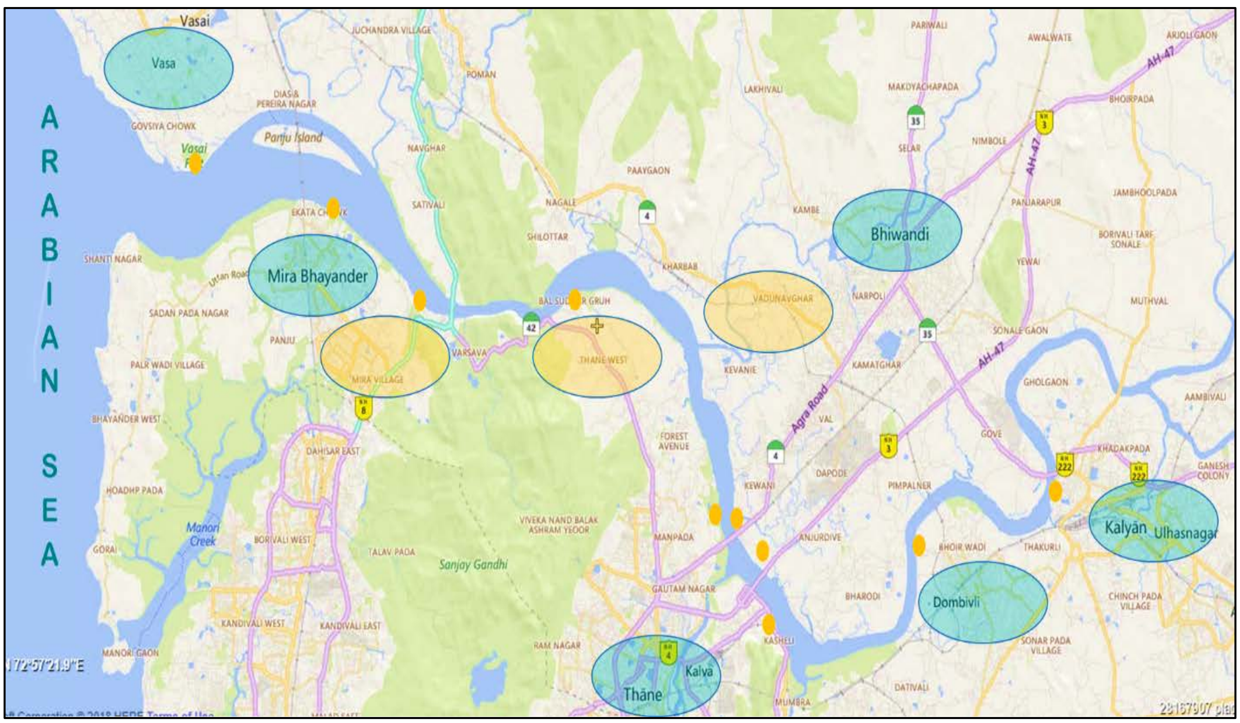
Sr	Description	Linear/ Cross Ferry	By Water way					By Road		By Train	
			Distance		Speed		Time	Distance	Time	Distance	Time
			Kms	NM	Knots	Kms	Min	Kms	Min	Kms	Min
13	Naigaon to Kolshet	Cross	23.42	12.65	8	14.816	94.84	51	95	-	-
14	Naigaon to Parsik Bunder	Cross	26.77	14.45	8	14.816	108.41	56	119	47	126
15	Naigaon to Dombivli	Cross	35.77	19.31	8	14.816	144.86	62	149	42	113
16	Naigaon to Kalyan	Cross	42.72	23.07	8	14.816	173.00	69	162	48	123
17	Ghodbunder to Kalher	Cross	15.44	8.34	10	18.52	50.02	24	52	-	-
18	Nagla Bunder to Kalher	Cross	8.91	4.81	10	18.52	28.87	18	49	-	-
19	Parsik Bunder to Kalher	Cross	3.45	1.86	8	14.816	13.97	14	42	-	-
20	Kolshet to Anjur Dive	Cross	3.42	1.85	6	11.112	18.47	19	59	-	-
21	Nagla Bunder to Anjur Dive	Cross	13.67	7.38	10	18.52	44.29	24	78	-	-
22	Dombivli to Anjur Dive	Cross	9	4.86	8	14.816	36.45	26	82	-	-

5. Terminals

5.1 General Review

Terminals are the points of interchange. In all Ten (10) terminals are proposed on the proposed waterway. These locations are chosen close to the population centers so that they could be accessible with ease. Figure 5.1 shows the main population centers along the waterway. The ellipses are indicative of the population centers. The blue ones indicate the main and the orange ones the secondary population centers and the yellow dots the location of the terminals.

Figure 5. 1: Population Centers And The Proposed Terminals



In general, the locations of the terminals are prima-facie correct, through the dynamics of the operation over the years may allow more number of terminals. The present study is confined to the requirements of the passenger movements, however, as and when the cargo handling becomes imperative in the waterway, separate terminals or terminals with additional facilities may have to be developed for the purpose. For the present, the location of the terminals looks apt.

5.2 Identification And Site Location

5.2.1 Identification Of Terminal Locations

The terminal locations in general depends on the following main factors,

1. Population Centers
2. Accessibility

3. Land availability
4. Depths availability
5. Environmental Impact

A brief recount of the above criteria is given as under;

5.2.1.1 Population Centers

The population centers along the waterway is shown in Figure 5.1 above. The population centers in general require the terminal nearby for easy accessibility and use. In addition, the population centers are also centers of trade and commerce, making the waterway the main conduit for the trade.

5.2.1.2 Accessibility

Approach to the terminals is the second most important factor, which determines the success and failures of the terminal operation, as door to door delivery of people and material would obviously depend on other modes as well. Hence, road approach is an essential part of the overall terminal development.

5.2.1.3 Land Availability

Land availability for the present and future developments is essential to the selection of the location for the terminal. Future requirements should be forecast and earmarked at the initial stage itself for change in land use. Land requirement should never be the constraint for establishment and expansion of the terminal.

5.2.1.4 Depth Availability

Natural depth availability close to the shore is required to make the waterfront functional over the year without the fear of siltation. Though depths could be created through dredging, it would be ideal to have natural depths near the proposed location of the terminal.

5.2.1.5 Environmental Impact

The terminal area should be bereft of any mangroves or any such plants and habitats that could potentially be in danger due to the operation of the terminal. In general, terminals must be away from the mangrove areas, and areas of marine swamps.

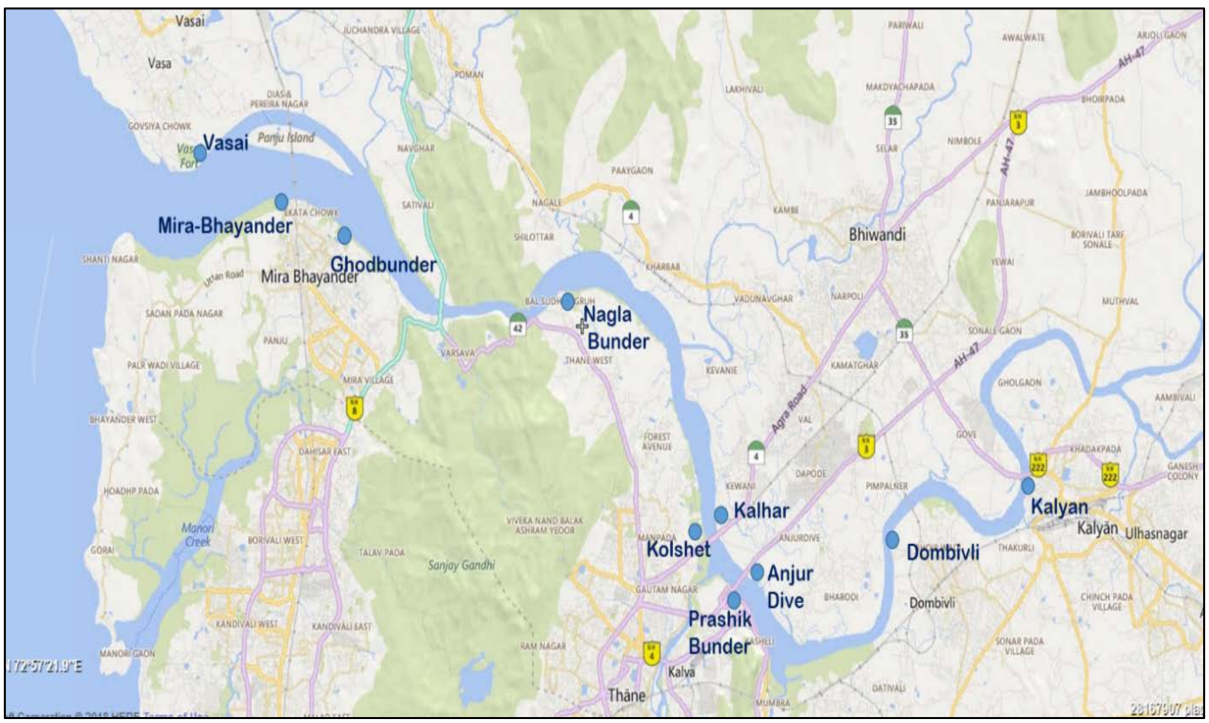
Based on the above requirements the following Terminal locations were selected along the water way. There are 7 terminals on the left and 3 on the right bank.

1. Vasai Fort
2. Mira-Bhayander

3. Ghodbunder
4. Nagla Bunder
5. Kolshet
6. Kalher
7. Parsik
8. Anjur Dive
9. Dombivli
10. Kalyan

The locations of the terminals are shown in Figure 5.2.

Figure 5. 2: Terminal Locations



The individual terminal potential and selection criteria as per the above criterions and given in the following paragraphs;

A. Vasai Terminal

The Vasai terminal is located near the Vasai Fort on the right bank, closer to the Vasai-Virar population center and is on the Arabian Sea. The terminal would be designed for handling passenger and passenger ro-ro service as a part of the Vasai-Ulhas river waterway system.

Adequate depths of around 3 m to 4 m is available around the area proposed to be developed for berthing, handling and mooring of the floating crafts.

Though the current project is for passenger and Ro-Ro services, the site has great potential for development as the biggest cargo hub for the entire region and receiving terminal for the container traffic from the JNPT/MbPT at a later stage.

B. Mira-Bhayander Terminal

Close to the Mira-Bhayander municipal region, main terminal for passenger and passenger ro-ro service on the left bank. Being upstream of the old Bhayander bridge, this could host bigger vessels from the Arabian Sea, albeit after dismantling of old railway bridge. Depths at the terminal location is more than 3.0 m and therefore terminal construction could be taken up independent of dredging.

C. Ghodbunder Terminal

This is located near the Ghodbunder region and is a Secondary terminal for Passenger and ro-ro service. The depths are more than adequate as depths of 7.0 m or more are noticed quite close to the shoreline.

D. Nagla Bunder

This is a secondary terminal, located near the new construction locations and beginning of the sanctuary region. Could be the passenger amenities center and mark the region of amusement and tourism. The depths are good for the terminal development and dredging is not necessary for berthing of vessels. Depths are more than 6.0 m way above the required designed depths of 3.0 m.

E. Kolshet & Kalher Terminals

Kolshet is near the notified industrial region. Located on the down-stream of the Old Agra bridge, this is a main terminal. But since located near an industrial area and looking at the availability of Government land this could host the ship repair and maintenance yard. In fact, this could also locate the retrofitting and engine upgrade facilities for the vessels wanting to change over to cleaner fuel. Kalher is the complementary terminal on the right bank and could aid in the passenger and vehicle transfer through passenger and Ro-Ro services.

Kolshet terminal has shallow depths of around 2.0 m and some dredging may be required for the terminal to function at full capacity. Kalher has the required depths of more tha 3.0 m.

F. Parsik Bunder & Anjur Dive

Parsik Bunder and Anjur Dive are close to population centers and are secondary terminals for mainly passenger and passenger ro-ro services. Parsik Bunder has shallow depth between 2.0 and 3.0 m and some dredging may be required. Anjur Dive has adequete depths which are more than 3.0 m.

G. Dombivli

Located near Thakurli village, Dombivli terminal could be a main terminal and is suitable for operating passenger services as well as Ro-Ro services. The water depths are more than 6.0 m.

H. Kalyan

Kalyan terminal is closest to the Kalyan and an ideal place for main terminal subject to the availability of land. Water depths at the location is more than 7 m and hence the location on that count is very good. There is a shipyard and a landing facility upstream of the Kalyan bridges, however there exists a dump yard right behind the existing landing facility and a foul smell is present in the atmosphere. The proposed site will also avoid crossing two road

5.3 Terminal Layout / Master Planning-Phases Of Development

5.3.1 Terminal Nomenclature

In the above paragraph three types of terminals are described, namely;

1. Main Terminal
2. Secondary Terminal
3. Special Terminal

These terminals are envisaged to have the following facilities;

5.3.1.1 Main Terminal

Vasai, Mira-Bhayander, Kolshet, Kalher and Kalyan are the likely main terminals in the waterway. These terminals would have the following facilities;

1. **Water Front**
    a. Dolphins for berthing of the Vessels up to 40 m length initially and progressively upto 100 m with addition of extra dolphins.
    b. Floating Pontoon and the Link Span
    c. Concrete platform for turning and handling up to 40’ Containers trucks
    d. Approach adequate for passenger and container trucks
2. **Foreshore**
    a. Passenger amenities like
        i. Waiting area
        ii. Restaurants
        iii. Children’s’ Play area
        iv. Shopping areas
        v. Banks/ATMS
        vi. Space for Parking Facility for Commercial and Private vehicles/Motor Cycles
        vii. Space for Passenger handling for Public Transport

b. Terminal Amenities
    i. Terminal Office
    ii. Ticketing Area
    iii. Staff and others waiting area
    iv. Baggage Storage Facility
    v. Public toilets
c. Cargo Amenities (To be developed later)
    i. Container marshaling yard
    ii. Covered storage area
    iii. Cold Storages
    iv. Loading and unloading areas
d. Other Facilities
    i. Sewage Treatment Facility
    ii. Medical Facility/First Aid facility
    iii. Connectivity to the terminal
    iv. Protected waterfront for shoreline stability
    v. Garbage, waste oil, grey water, bilge water recepetion facilities

5.3.1.2 Secondary Terminal

Ghodbunder, Nagla Bunder, Parsik Bunder, Anjur Dive, and Dombivli terminals are to be designed as secondary terminals. The following amenities are proposed at the secondary areas;

1. Water Front

a. Dolphins for berthing of the Vessels up to 40 m length initially and progressively upto 100 m with addition of extra dolphins.
b. Floating Pontoon and the Link Span
c. Concrete platform for turning and handling up to 40’ Containers trucks
d. Approach adequate for passenger and container trucks

2. Foreshore

a. Passenger amenities like
    i. Waiting area
    ii. Restaurants
    iii. Children’s’ Play area
    iv. Shopping areas
    v. Banks/ATMS
    vi. Parking facilities for Public and Private vehicles
    vii. Handling of Public transport passengers
b. Terminal Amenities

i. Terminal Office
ii. Ticketing Area
iii. Staff and others waiting area
iv. Baggage storage facility
v. Public toilets

c. Other Facilities
i. Sewage Treatment Plant
ii. Medical and First aid facility
iii. Connectivity to the terminal
iv. Protected waterfront for shoreline stability
v. Garbage, waste oil, grey water, bilge water recepetion facilities

5.3.1.3 Special Terminal

At the Kolshet terminal additionally the facilities for the ship repair and building including the slipway for repairing vessels up to 110 m would be provided.

In the following paragraphs the terminal layouts of the individual terminals shall be described based on the parameters defined above.

5.3.2 Terminal Layouts

5.3.2.1 Terminal Layouts And Mathematical Model Studies

The terminal layouts, especially the water front was tested in the mathematical model for evaluating the following;

1. Whether there is any flow concentration near the terminals leading to accretion/erosion
2. Whether the flow vectors are aligned to the berthing face.

The first aspect would predict any likely effects of the flow concentration near the jetty terminal including eddies, that may affect the navigation and sedimentation criteria and the second aspect would examine whether the berthing face is aligned to the flow vectors, so that no set off of vessels, endangering the moorings, happen. In the following paragraphs the mathematical model study for each of the terminal locations would be described briefly.

Once the layouts are tested in the mathematical model, the authenticity of the alignment could be ascertained with surety. In case the terminals are not aligned to the current vectors with in the permissible limits, the vessels may not stay along the berth and there would be constant disbalance. There could be unnecessary movement of the vessels that may cause discomfort to the occupying passengers. In addition, the mooring lines would be stressed perpetually.

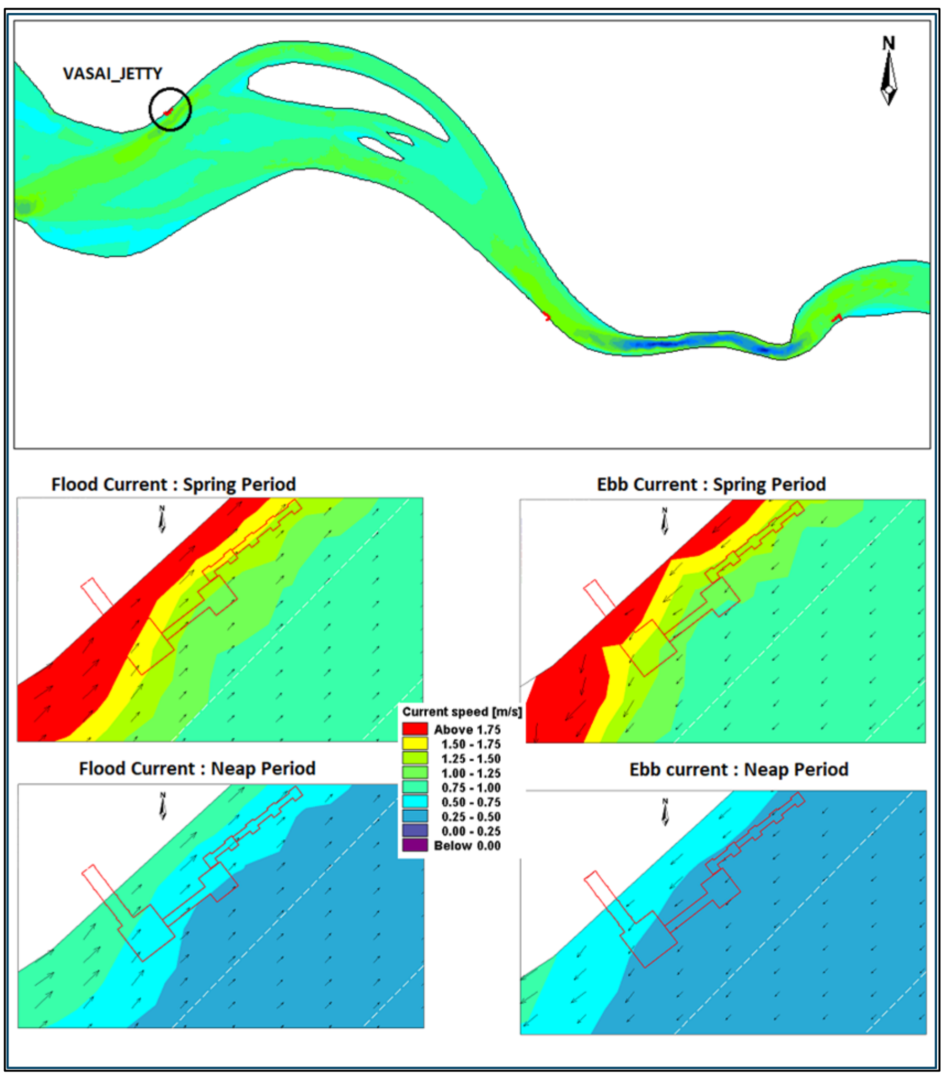
Further the current velocities near shore the terminal location would help determining the protection along the bank preventing any erosion of the shoreline/bankline.

A detailed discussion on the model studies has been included in the Chapter 3. In this chapter the flow vectors superimposed on the proposed layout would be produced to illustrate pictorially that there is no flow concentration near the terminals nor there is any angle between the predominant flow direction and the berthing face. In the illustrations below, the current vectors, the terminal layout and the current speeds are shown and discussed briefly in the following paragraphs.

Vasai Terminal

This is the first terminal from the seaward end and is exposed to open sea waves, though fairly attenuated by the sand bars at the entrance. Maximum wave heights of 0.3 to 0.4 m are noticed at this terminal. The location is also marked in the figure for ready refence. The Vasai terminal is located on the right bank of the river.

Figure 5. 3: Vasai Terminal Location And The Flow Hydrodynamics Around The Terminal

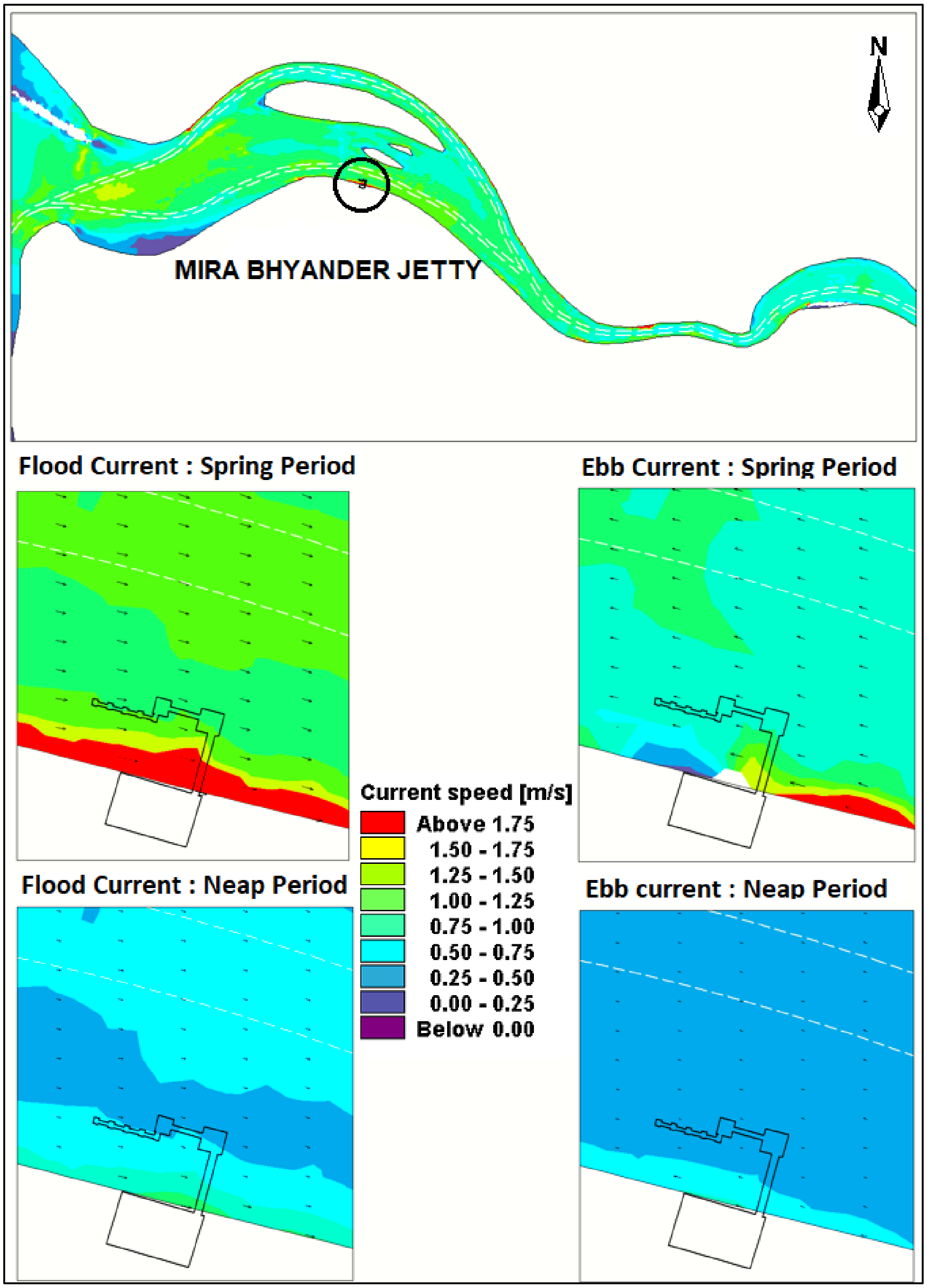


By virtue of its location the flood currents are intense. Speeds up to 1.75 m/s is reached at certain stage of the tide, near shore. Along the berthing face the currents are milder and about 1.50 m/s is noted. There are no flow concentrations near this terminal.

Mira Bhayander Terminal

This is the second terminal from the seaward end and is partially exposed to open sea waves, though fairly attenuated by the sand bars at the entrance and the railway bridges. The location is also marked in the figure for ready refence. The Mira Bhayander terminal is located on the left bank of the river.

Figure 5. 4: Mira Bhayander Terminal Location And The Flow Hydrodynamics Around The Terminal

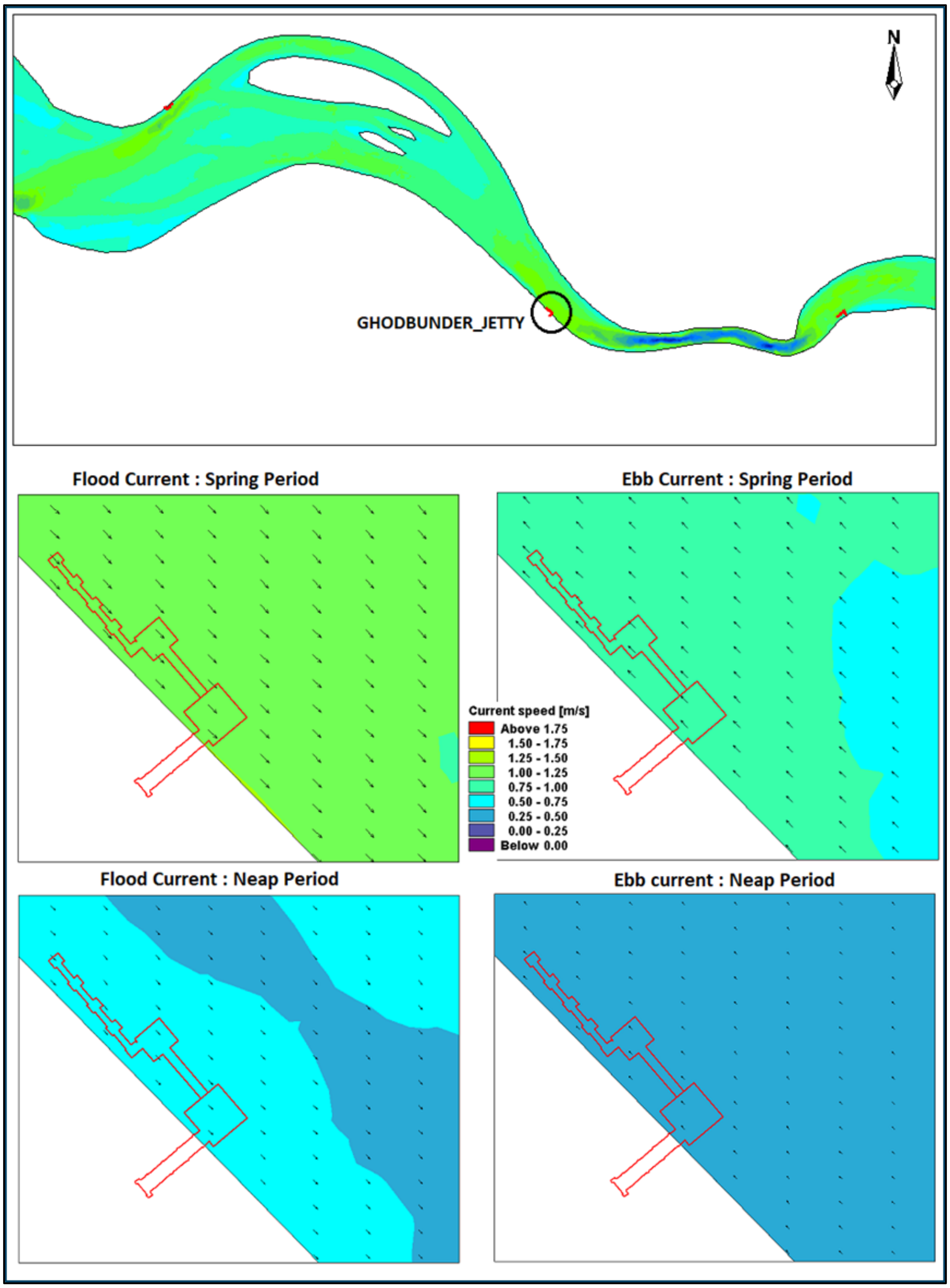


By virtue of its location the flood currents are intense. Speeds up to 1.75 m/s is reached at certain stage of the tide, near shore. Along the berthing face the currents are milder and about 1.50 m/s is noted. There are no flow concentrations near this terminal.

Ghodbunder Terminal

Located on the upstream of Vasai, is well protected and wave heights are much lower. The Figure 5.5 shows the existing flow regime around the Ghodbunder terminal

Figure 5. 5: Ghodbunder Terminal Location And The Flow Hydrodynamics Around The Terminal

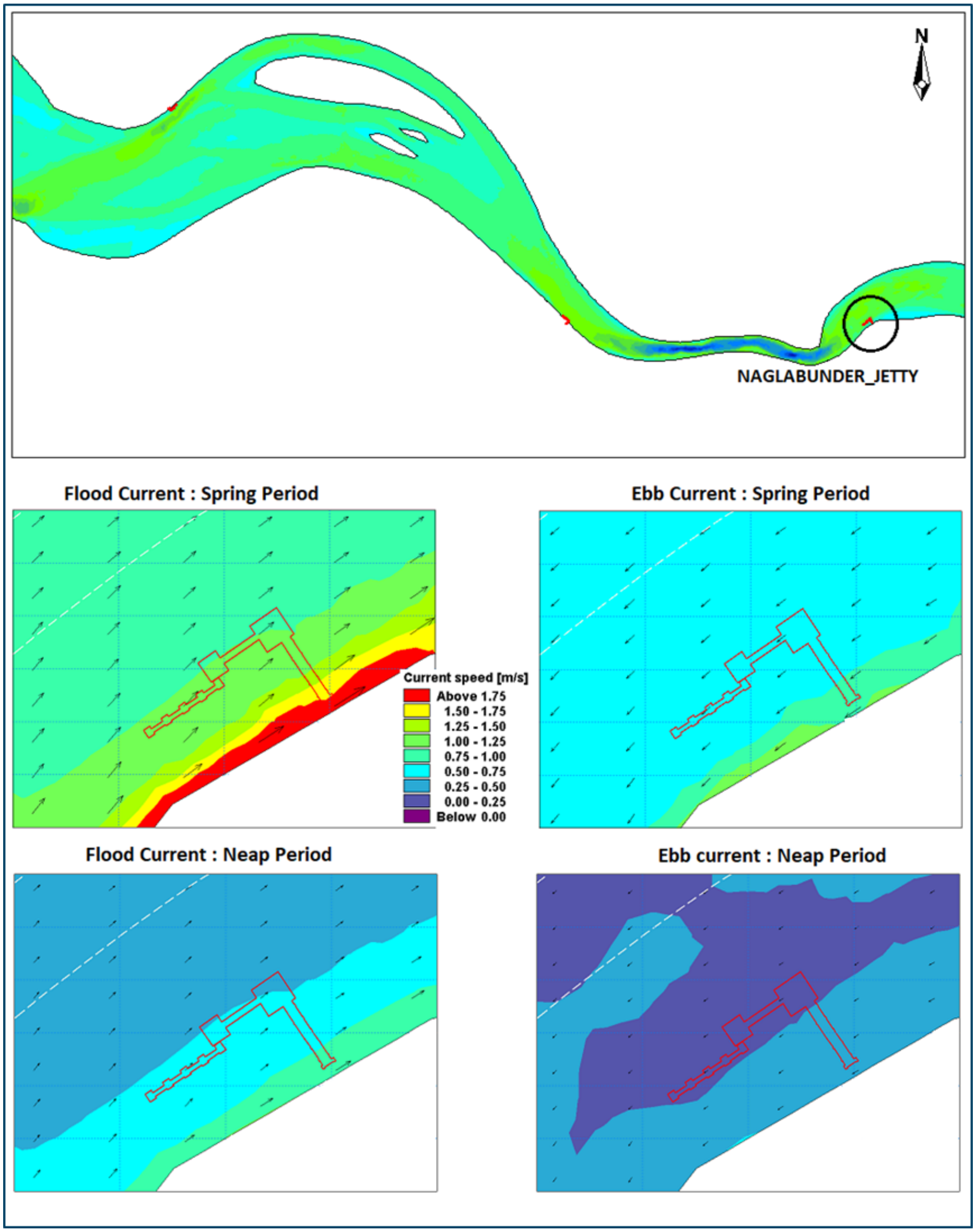


The above figure indicates that the flow vectors are in general parallel to the berthing face, the velocities are much lower and maximum current speed of around 1.0 to 1.25 m/s occurs at the terminal. No flow concentrations are observed.

Naglabunder Terminal

Located on the upstream of Ghodbunder, is well protected and wave heights are much lower. The location is just after the flow contractions, but due to the higher depths, the velocities are still in the manageable range. Figure 5.6 shows the existing flow regime around the Naglabunder terminal

Figure 5. 6: Naglabunder Terminal Location And The Flow Hydrodynamics Around The Terminal

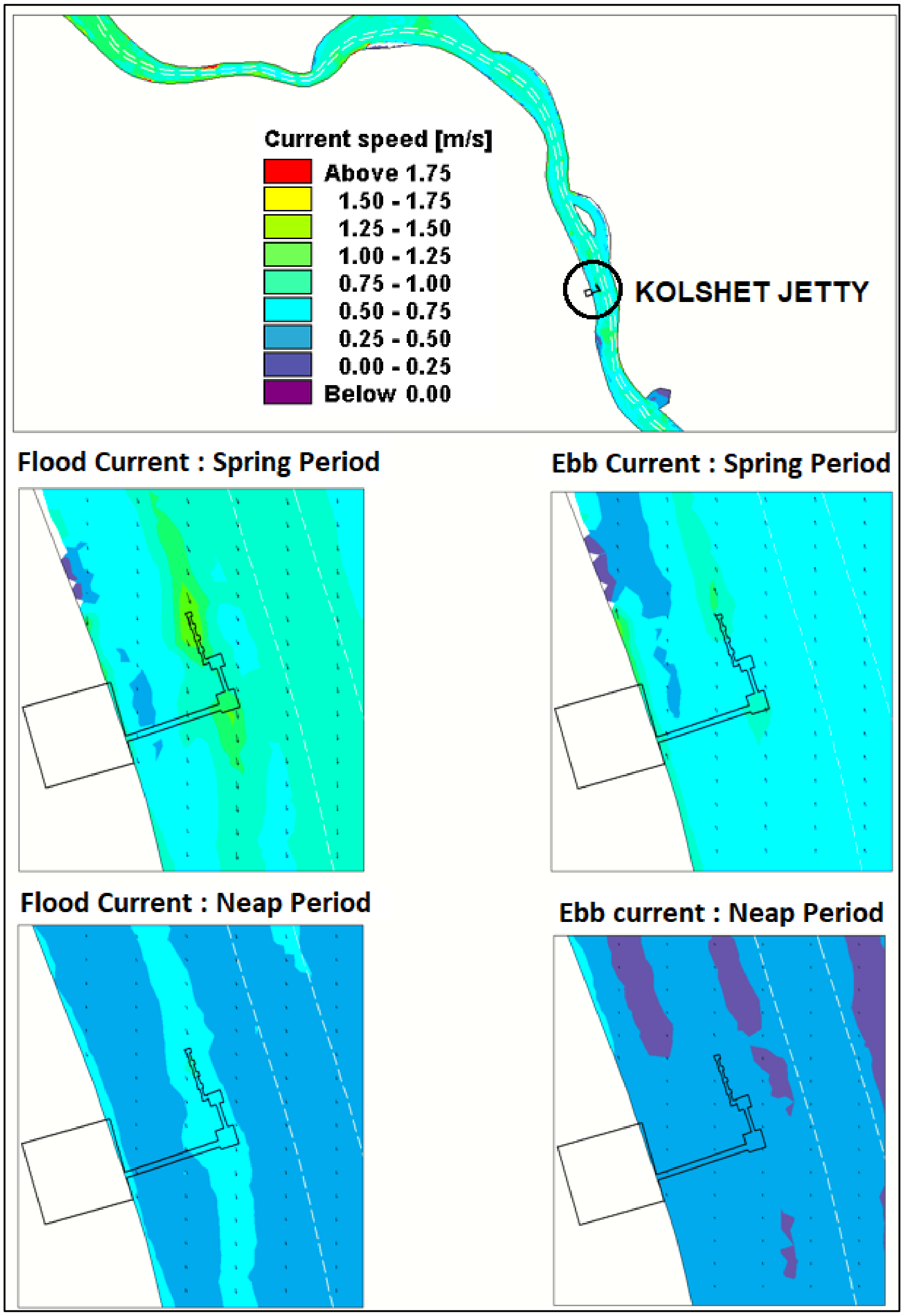


The above figure indicates that the flow vectors are in general parallel to the berthing face, the velocities are much lower and maximum current speed of around 1.5 to 1.75 m/s occurs at the terminal in the near shore region flood tide. No flow concentrations are observed.

Kolshet Terminal

Located on the upstream of Naglabunder on the left bank, is well protected and wave heights are insignificant. Figure 5.7 shows the existing flow regime around the Kolshet terminal

Figure 5. 7: Kolshet Terminal Location And The Flow Hydrodynamics Around The Terminal

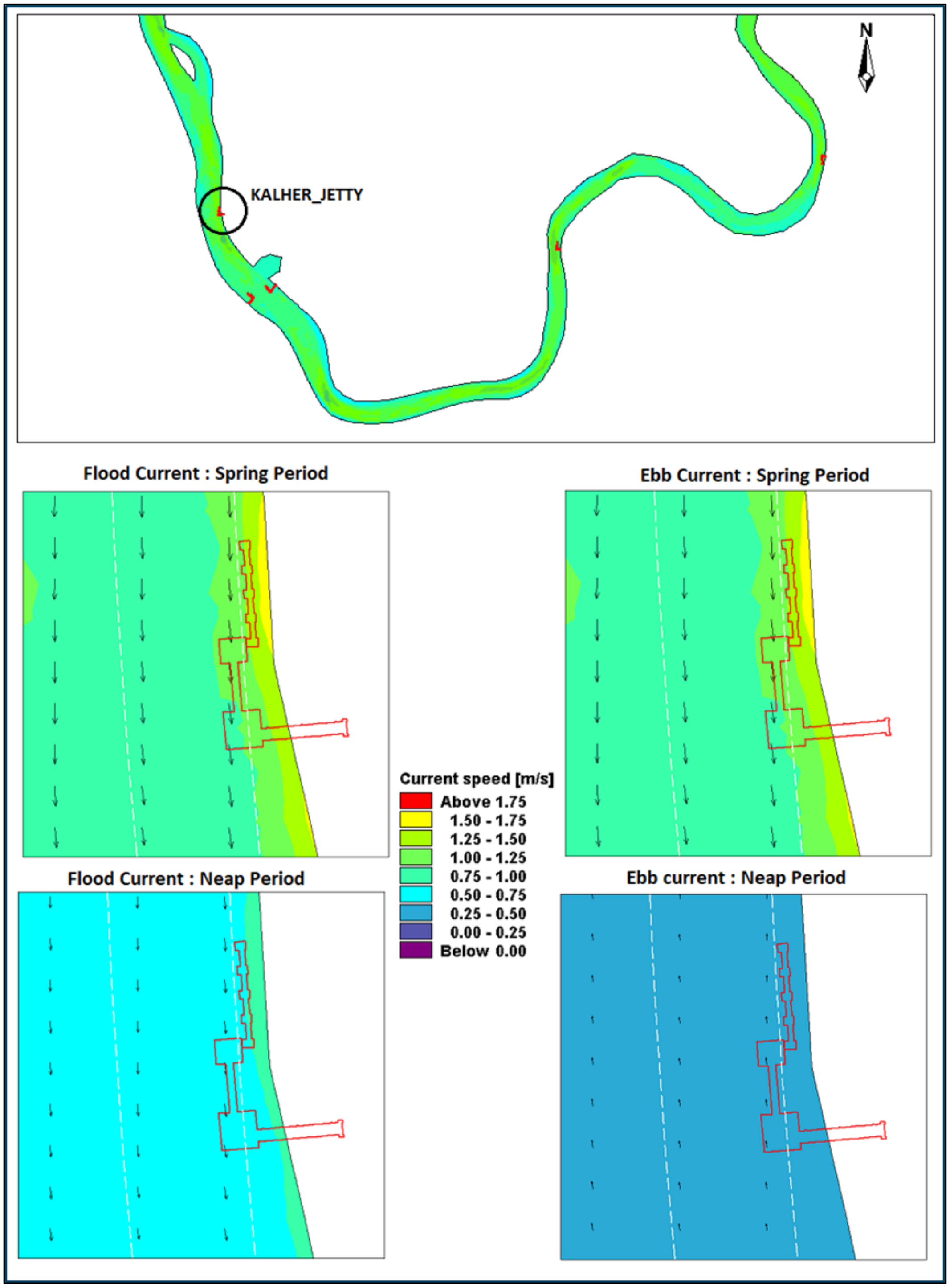


The flows are more benign, wave heights less and absence of flow concentrations makes the terminal layout perfect.

Kalher Terminal

Located on the upstream of Naglabunder on the right bank, is well protected and wave heights are insignificant. Figure 5.8 shows the existing flow regime around the Kalher terminal

Figure 5. 8: Kalher Terminal Location And The Flow Hydrodynamics Around The Terminal

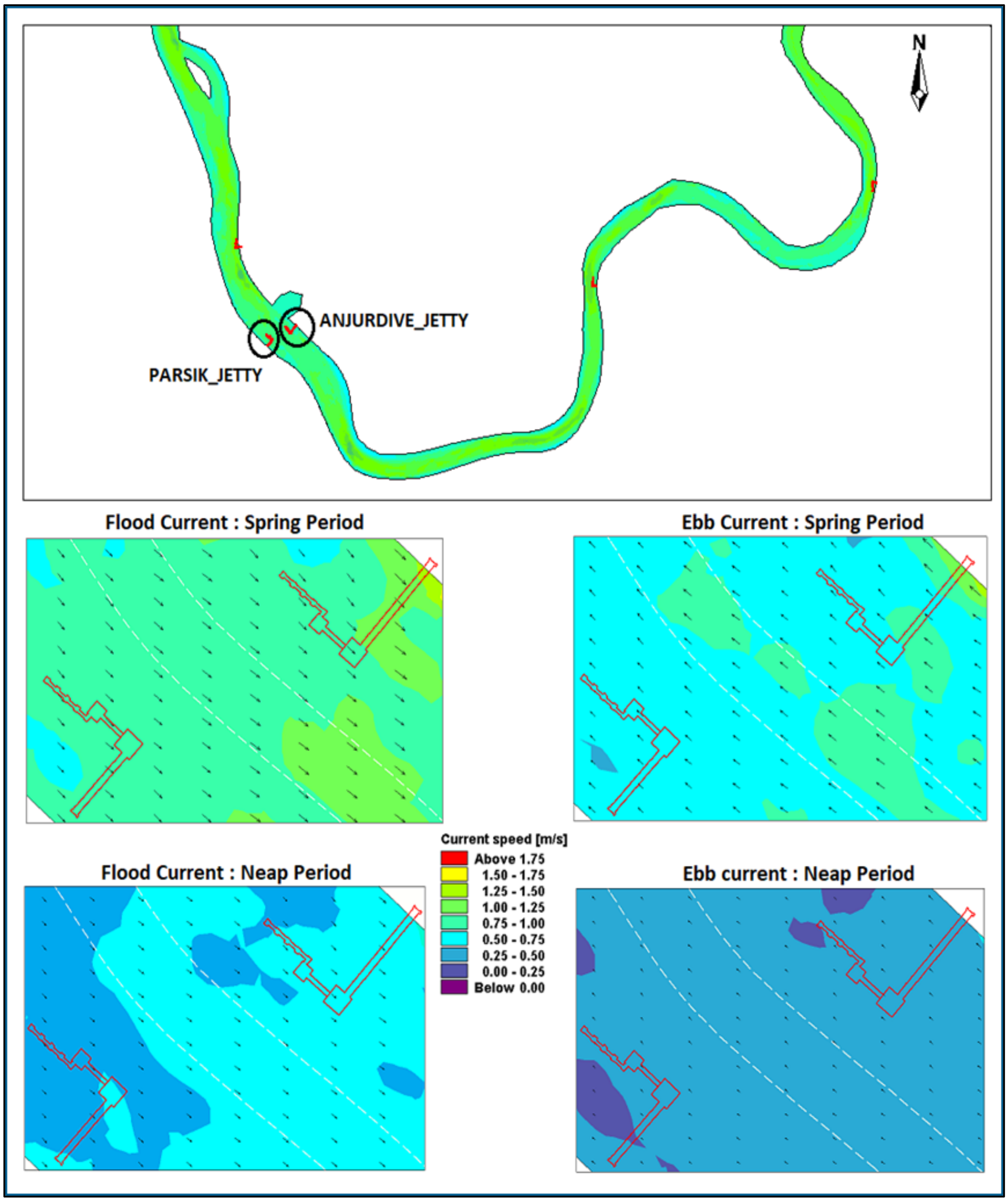


The flows are more benign, wave heights less and absence of flow concentrations makes the terminal layout perfect.

Parsik & Anjur Dive Terminal

Located on the upstream of Kalher on the left and right bank, is well protected and wave heights are insignificant. These are complementary terminals. Figure 5.9 shows the existing flow regime around these two terminals and indicating it's the benign current and wave climate.

Figure 5. 9: Parsik & Anjur Dive Terminal Location And The Flow Hydrodynamics Around The Terminal

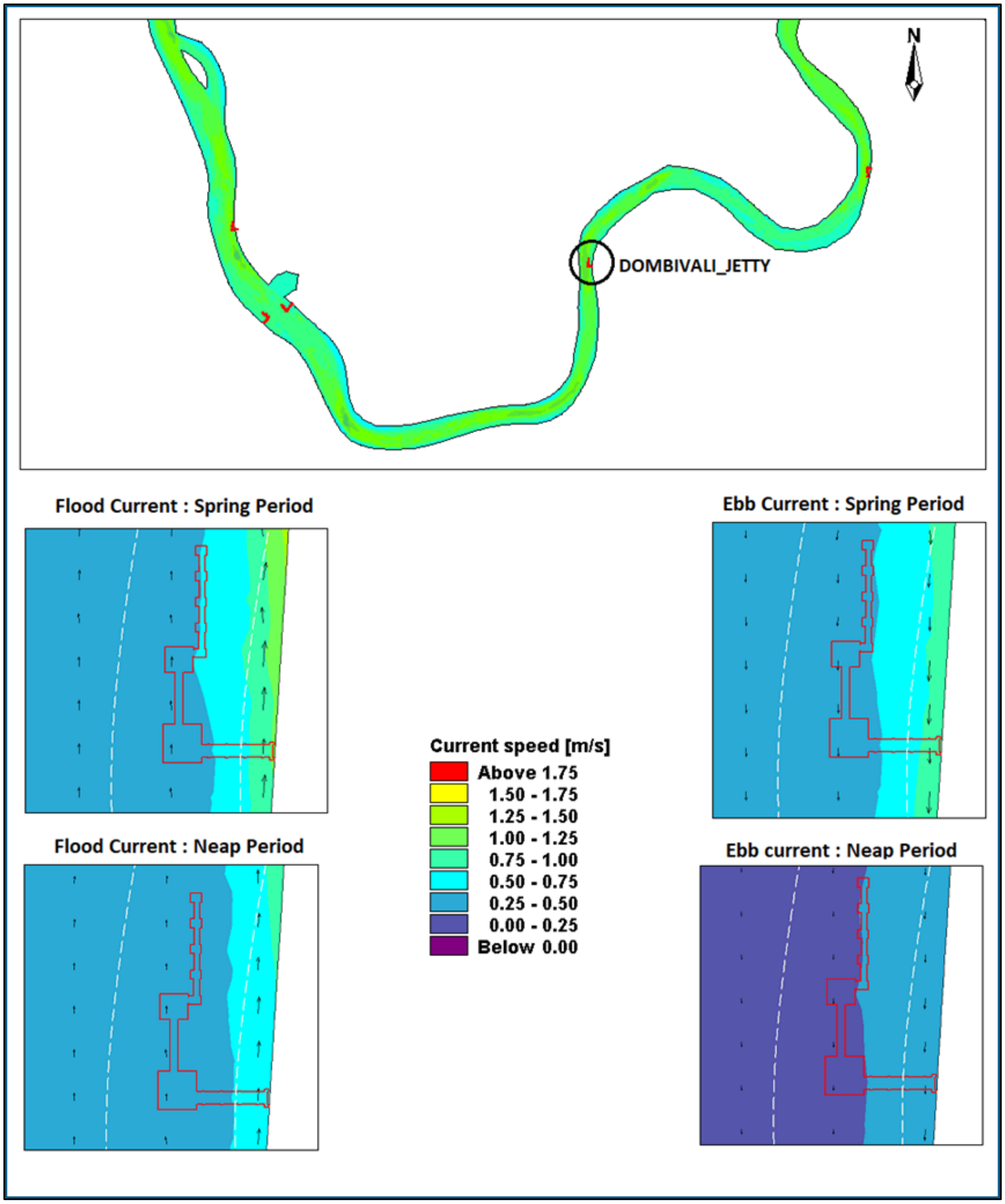


Flow velocities are reaching maximum of about 0.75 to 1.00 m/s in the spring tides. The neap tides are much more calm. No flow concentrations are seen in the area and the flow vectors are having the flow vectors parallel to the berthing face.

Dombivli Terminal

Located on the upstream of Parsik on the left bank, is well protected and wave heights are insignificant. Figure 5.10 shows the existing flow regime around this terminal and indicating it's the benign current and wave climate.

Figure 5. 10: Dombivli Terminal Location And The Flow Hydrodynamics Around The Terminal

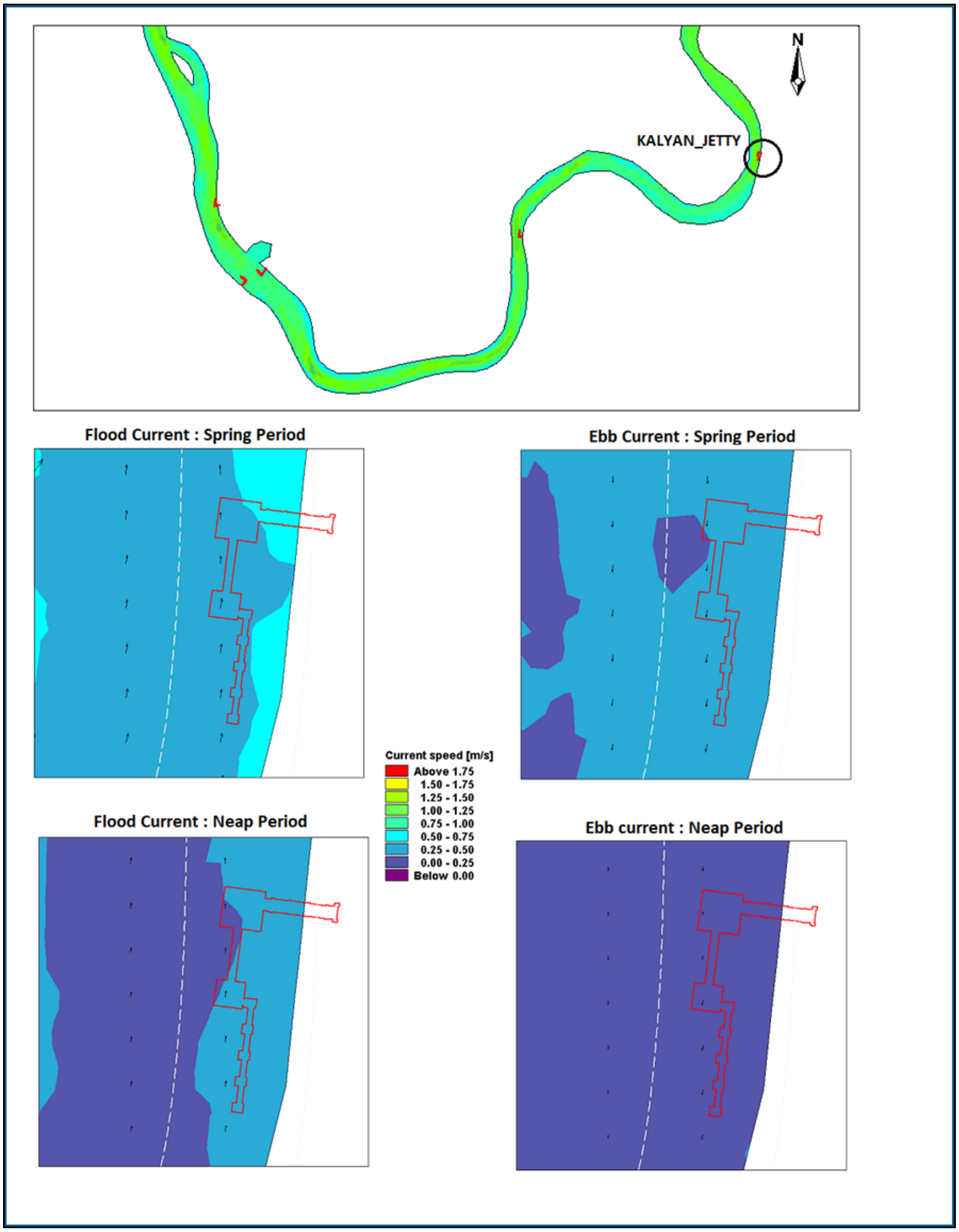


Current speeds are higher near shore and along the berthing head the maximum velocity is about 0.5 m/s. No flow concentrations seen.

Kalyan Terminal

Located on the upstream of Dombivli on the left bank, is well protected and wave heights are insignificant. Figure 5.11 shows the existing flow regime around this terminal and indicating it's the benign current and wave climate.

Figure 5. 11: Kalyan Terminal Location And The Flow Hydrodynamics Around The Terminal



Current speeds are higher near shore and along the berthing head the maximum velocity is about 0.5 m/s. No flow concentrations seen.

The above discussions indicate that the layouts are generally aligned correctly and hydraulically there would be no difficulty on this count. In the following paragraphs, the structural layout of the elements of the terminal would be discussed based on the land availability and connectivity.

5.3.2.2 Terminal Layout And Design

Based on the model study results, the berth alignment was determined. Based on the water side alignment and the logical requirements of the terminals, detailed layout for all the terminal locations were prepared. The terminal designs and the philosophy is discussed in the following sections and the layout is enclosed as Annexure E. The necessary excerpts from the detailed drawings where ever required has been reproduced for better understanding.

5.3.2.3 Vasai Terminal

The Vasai terminal which is probably the most important terminal of the waterway, and likely to serve, a bigger role than is envisaged at the present. The potential is immense as are the possibilities. As the terminal is located on the entrance of the waterway (from the seaward side) and has reasonably good depths, this terminal will be used for passenger and Ro-Ro services. The terminal has potential to be used for cargo handling in future.

The Figure 5.12 shows the present condition of the foreshore as well as the near shore areas at the proposed terminal.

It could be seen that the MMB Jetty is connected through the Vasai Fort to the mainland area. The MMB Jetty is presently used for small craft landing and fishermen of the area, but to a limited extent. The Foreshore area between the tidal highs and lows are covered with mangroves. Behind this mangrove habitat to the landward side, there exists an embankment constructed by the Khar Bund Department, ostensibly for preventing salt water ingress in to the land area. The passenger amenities, such as parking, amusement areas, parks and children play area, the terminal building consisting of the like waiting area for passengers, ATMs, ticket counters, canteens and rest rooms would be located on the landward side of the embankment as shown. In addition, the northern part of the land would be reserved for the future cargo related activities if any, in form of Ro-Ro service. However, the requirement of facilities for the Ro-Ro facilities would be evaluated based on the demand and the availbility of land.

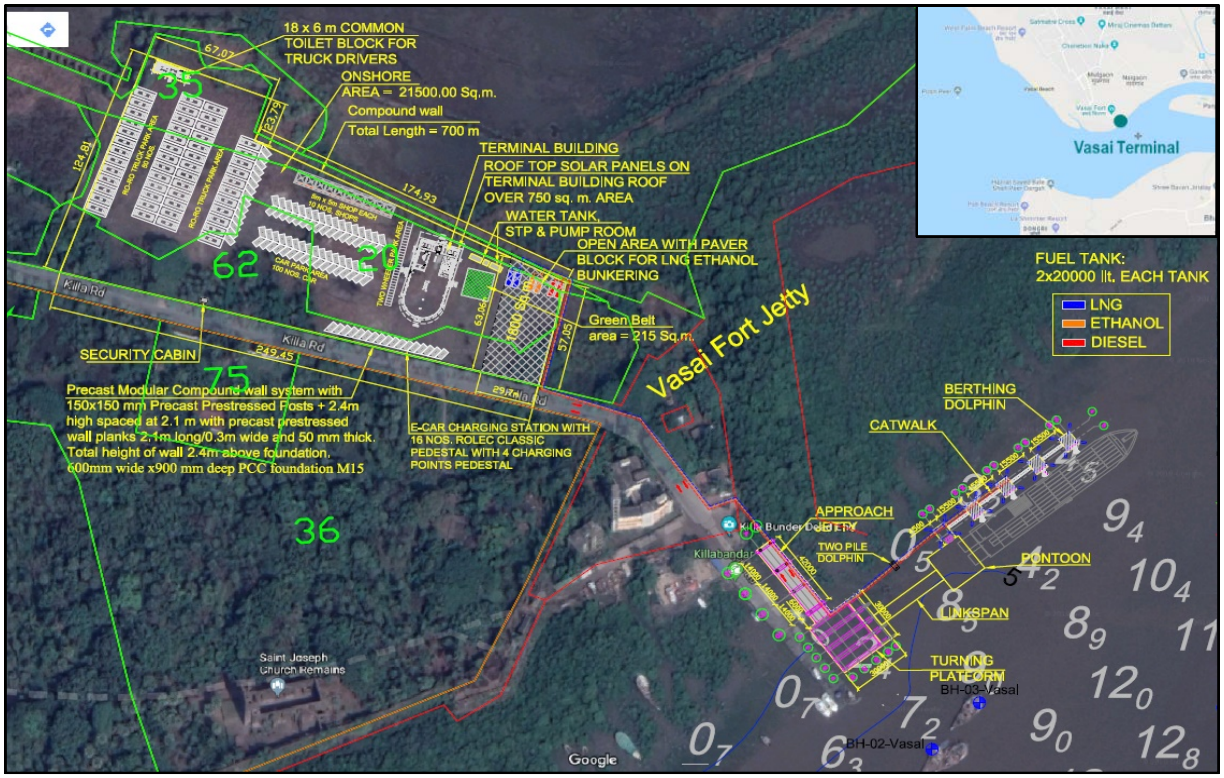
Figure 5. 12: Layout Of The Available Land Area Near The Proposed Vasai Terminal

Additional facilities such as electrical car charging points, fueling stations and solar panels are other fcailities for integration in to the green initiatives of the Government.

The terminal is designed as a Main terminal, meaning thereby, that the facilities would be created for berthing of the largest craft that may be expected to use the waterway in future. The facility would be designed for vessels up to 10000 DWT vessels.

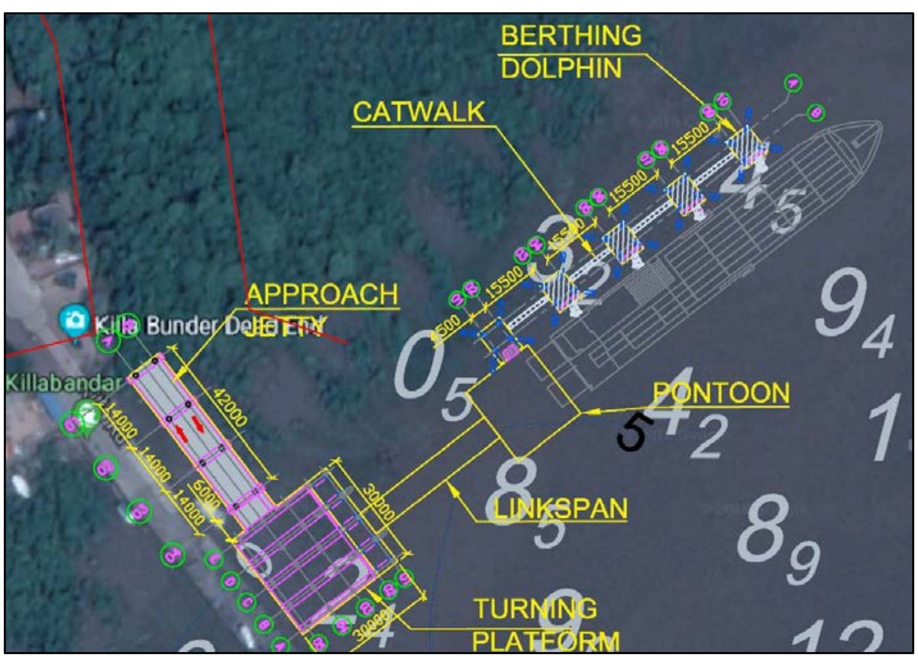
For detailed informations on the terminal layout, terminal location on the waterway, details of the foreshore development, water front development and terminal buildings please refer Annexure – E.

Figure 5. 13: Layout Of The Proposed Facility At Vasai Fort



In the layout superimposed on the google map shown in Figure 5.14, the berthing facility below consists of the components that would be designed in addition to the designed vessel (10000 DWT), the superimposed loads due to the passenger cars, passenger busses, loaded trucks and such other things as mentioned in Chapter 6 on designs.

Figure 5. 14: Layout Of The Proposed Berthing And Other Facilities For Vasai Terminal



The facilities on the water side shown above would constitute the following structural elements;

1. Jetty Approach: 50 m long and 10 m wide, carrying a 7.5 m wide carriage way, 1.5 m wide walk way on one side (to the right on this case). (Refer Drawing No. KE-1138-VF-GA-151, 152 and 153 in Annexure E). Excerpts from the above is reproduced in Figure 5.15 and 5.16 for better understanding.

Figure 5. 15: Layout Of The Beams For The Approach (Typical)

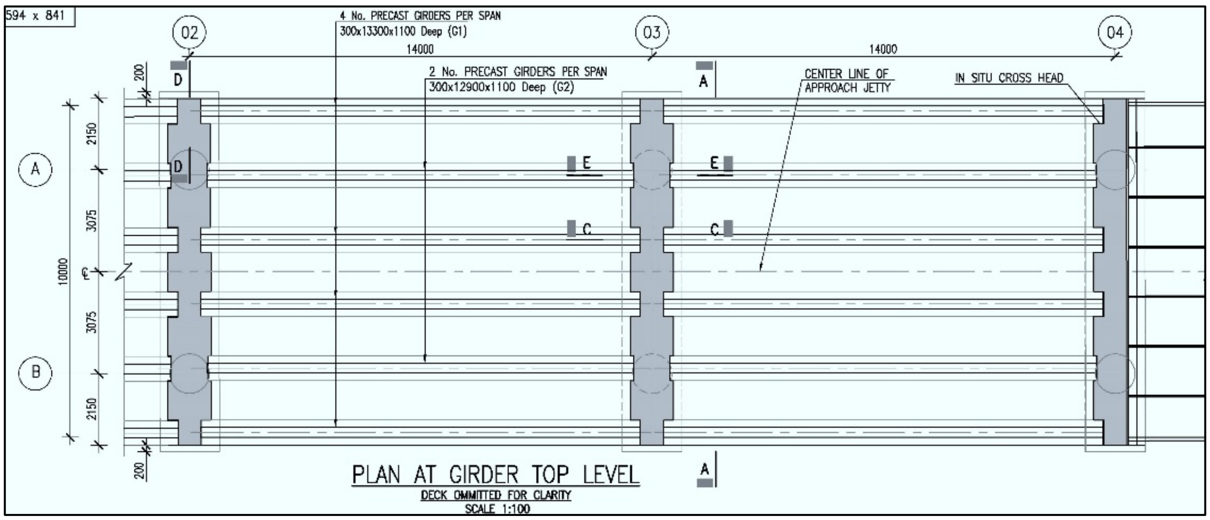
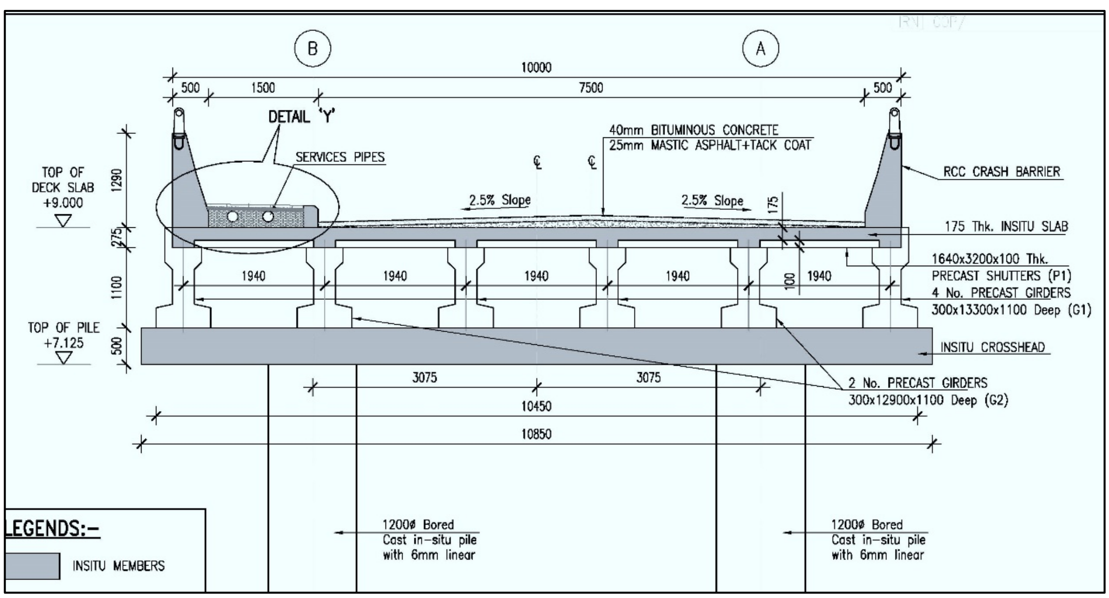


Figure 5. 16: Section Showing The Details Of The Approach (Typical)



2. A 30 m x 30 m Turning platform for allowing the turning of the loaded trucks carrying up to 40' Container. The turning platform shall also support the hinge of support for the floating pontoon. (Refer Drawing No. KE-1138-VF-GA-154)
3. A floating Pontoon of 20 m x 22 m size, connected by a 6.5 m wide pathway to the turning basin forming a part of it. The Pontoon is hinged on the turning platform with a moving swivel

joint, with a fender protection at the tip, for exigencies. On the end the Pontoon is connected to Dolphin with a Guide Pile platform. The Link span takes care of the gap between the pontoon and the Turning Plant form. Refer Drawing No. KE-1138-VF-156, 158 and 159.

4. There will be 5 berthing/mooring Dolphins, one of them for locating the Guide Pole. The Dolphins are connected by a series of walks ways. Refer Drawing No. KE-1138-VF-155, and 156

On the Foreshore side for these terminals (main terminals), there will be facilities for;

A. **Terminal Building** – Refer Drawing KE-1138-GA-VF-101-00
   a. Office Facility
   b. Fire/Life Guard Cabin
   c. Waiting Area
   d. Refreshment Area
   e. Canteen and Kitchen area
   f. Rest Area
   g. Wash Rooms
   h. Infirmary
   i. Ticketing Counter
   j. Store Room
   k. DG Room

B. **Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-117-01**

C. **Banks/ATM**

D. **Fueling Station with facilities for**
   a. Diesel/MDO/IFO/Ethanol and reception facility (waste oil / bilge water)
   b. LNG/CNG
   c. Charging Point for Electric Vehicles

E. **Areas for Future Expansion**
   a. Areas for Storage including ware houses
   b. Container Parking
   c. Container stuffing/De-stuffing facility
   d. Marshalling Yard
   e. Storage and handling of other cargo

F. **Solar Panels on the Terminal Building for Green Energy for Future Expansion**

5.3.2.4 Mira-Bhayander Terminal

Mira Bhayander terminal, is the first terminal on the left bank. Located fronting the Mira-Bhayander municipal area, the land availability may be a factor needs consideration and to be factored in the planning process. As could be seen from the Figure 5.17, below, the location is upstream of the existing Mira-Bhayander bridges. The area chosen for the proposed terminal is roughly 125 m wide, and spreads approximately for 650 m along the bank, refer Figure 5.17.

Figure 5. 17: Location And Foreshore Areas Of The Proposed Mira-Bhayander Terminal

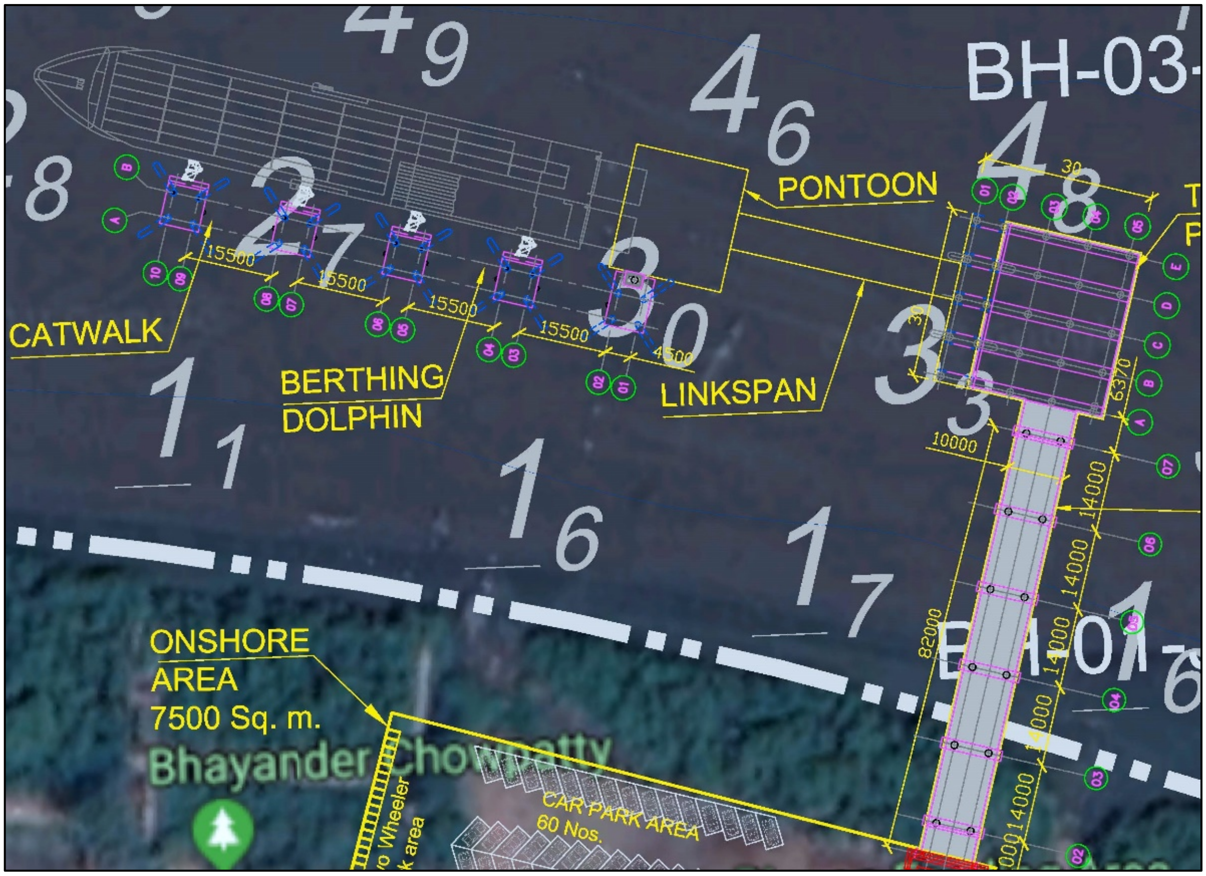
However, the area is partly covered with mangroves, houses the Jogger's Park, Playground etc. It is however, possible to plan the terminal complementing the existing infrastructure without much ado. The planning however need a certain degree of innovation and deft engineering. At a later stage the river front could be reclaimed with the dredged material to locate the cargo handling facilities if required. Figure 5.18 shows the proposed layout of the water and the foreshore facilities. As could be seen from the figure, the Joggers Park, the play area and the other infrastructures are interwoven with the terminal layout. The park and the play area are envisaged to be used as the amusement area for the passengers as well. In fact, the parking area could be shared by the terminal users as well as the park users. The play area and the Flower garden as it is popularly known has also been utilised for enhancing the appeal of the foreshore facility.

As indicated earlier this terminal would be designed as a main terminal with facilities for cargo handling in the later phase of the development.

The Water Side Facilities for this terminal would be similar to that of the Vasai Terminal, with an about 80 m of approach up to the design depth of greater than 3 m as shown in Figure 5.19.

Figure 5. 18: Layout Of Proposed Facilities At Mira-Bhayander Terminal

Figure 5. 19: Layout Of The Water Side Facilities At The Proposed Mira-Bhayander Terminal



The following are the details as shown in Figure 5.19;

A. Water Side Facilities

1. Jetty Approach: 80 m long and 10 m wide, carrying a 7.5 m wide carriage way, 1.5 m wide walk way on one side (to the right on this case). (Refer Drawing No. KE-1138-VF-GA-251, 252 and 253)
2. A 30 m x 30 m Turning platform for allowing the turning of the loaded trucks carrying up to 40' Container. The turning platform shall also support the hinge of support for the floating pontoon. (Refer Drawing No. KE-1138-VF-GA-254)
3. A floating Pontoon of 20 m x 22 m size, connected by a 6.5 m wide pathway to the turning basin forming a part of it. The Pontoon is hinged on the turning platform with a moving swivel joint, with a fender protection at the tip, for exigencies. On the end the Pontoon is connected to a Dolphin with a Guide Pile platform. The Link span takes care of the gap between the pontoon and the Turning Plant form. Refer Drawing No. KE-1138-VF-256, 258 and 259.
4. There will be 5 berthing/mooring Dolphins, one of them for locating the Guide Pole. The Dolphins are connected by a series of walks ways. Refer Drawing No. KE-1138-VF-255, and 256

5. On the Foreshore side for these terminals (main terminals), there will be facilities for;

B. Terminal Building – Refer Drawing KE-1138-GA-VF-201-00

a. Office Facility
b. Fire/Life Guard Cabin
c. Waiting Area
d. Refreshment Area
e. Canteen and Kitchen area
f. Rest area
g. Wash Rooms
h. Infirmary
i. Ticketing Counter
j. Store Room

C. Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-217-01

D. Banks/ATM

E. Fueling Station with facilities for

i. Diesel/MDO/IFO/Ethanol and reception facility (waste oil / bilge water)
ii. LNG/CNG
iii. Charging Point for Electric Vehicles

F. Areas for Future Expansion

i. Areas for Storage including ware houses
ii. Container Parking
iii. Container stuffing/De-stuffing facility
iv. Marshalling Yard
v. Storage and handling of other cargo

G. Solar Panels on the Terminal Building for Green Energy

It must however be remembered that the cargo operation is subjected to the land availability/creation by reclamation. Unless land is available this function may have to be shifted to a lesser habituated area like Ghodbunder/Nagla bunder.

5.3.2.5 Ghodbunder Terminal

Ghodbunder terminal is designated as a secondary terminal unless partial activity of the Mira-Bhayander terminal is shifted to this location. The water front is generally flat and used for small scale boat repairs and beaching in foul weather.

The potential developable waterfront is about 100 m wide and 600 m long. Number of boats could be seen along the waterfront area many beached and many with minor repairs. In order to locate and develop the terminal operations in this area, the existing activities needs to be segregated. These activities are proposed to be concentrated on the southern side, while on the northern side the terminal could be developed as shown in Figure 5.20.

Figure 5. 20: Location And Foreshore Areas Of The Proposed At Ghodbunder Terminal

The Proposed layout of the terminal is shown in Figure 5.14. As can be seen very deep contours are seen quite close to the shoreline. Hence the water side facility would have a very short approach of about 30 m. Since this is a secondary terminal, the turning platforms and the pontoon could be designed for passenger cars only. The biggest vessel for such terminals could be 7-8 passenger vehicles. Hence the size of the turning platform and the Pontoons also could be suitably reduced.

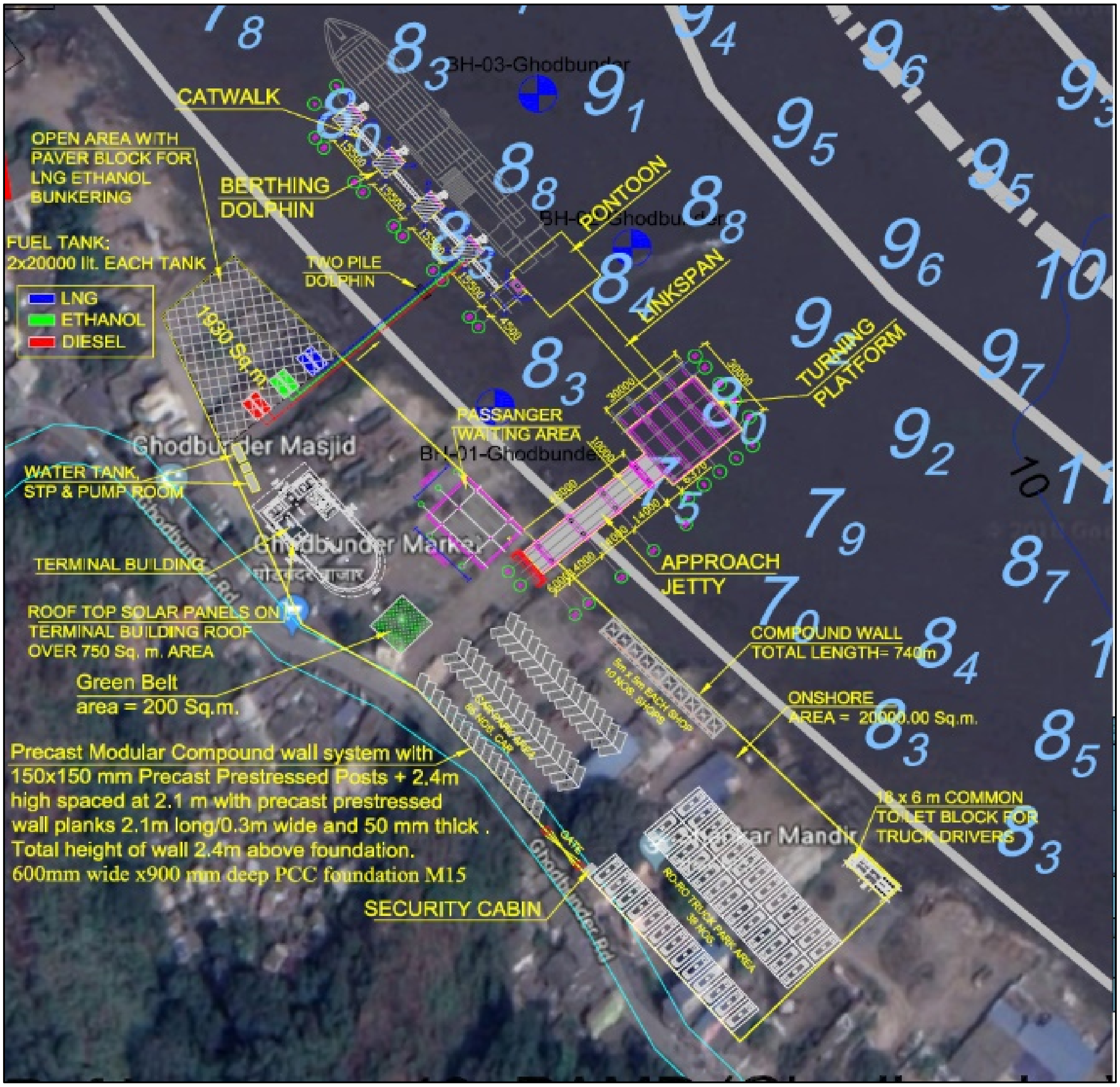
Alternatively, it will be ideal to adopt a scalable model, so that the terminal is upgradable keeping pace with the traffic, in this way the construction would be of similar nature, and the facilities would not be infructuous.

It is proposed that the size of the approach, turning platform, the pontoon, link span and the berthing dolphins would be kept same, but the lay out and the extent would be altered. This would enable the facility to handle bigger size vessels at a later date with modifications without affecting the services.

Accordingly, the proposed layout on the waterfront is shown in Figure 5.21 and 5.22. Figure 5.21 gives the layout superimposed on the Google imagery and Figure 5.22 on the hydrographic chart. The facility created is capable of handling vessels up to 60 m in the first phase and up to 110 m long vessels in the final phase, in which case more dolphins may have to be added.

However, it must be remembered that bigger vessels are likely to be confined to the lower reaches of the waterway where adequate maneuvering bend radius is available. Therefore, for greater coverage of the channel and better use of resources smaller vessels of the design indicated under the vessel design shall be followed. However, depending on the future demands, the length could be decided and accordingly, the required flexibility is built up in to the system.

Figure 5. 21: Water Side Layout Of The Proposed At Ghodbunder Terminal



The facility created is capable of handling vessels up to 60 m in the first phase and up to 110 m long vessels in the final phase, in which case more dolphins may have to be added.

However, it must be remembered that bigger vessels are likely to be confined to the lower reaches of the waterway where adequate maneuvering bend radius is available. Therefore, for greater coverage of the channel and better use of resources smaller vessels of the design indicated under

the vessel design shall be followed. However, depending on the future demands, the length could be decided and accordingly, the required flexibility is built up in to the system. The descriptions of the facility are given in the following paragraphs,

A. Water Side Facilities

1. Jetty Approach: 30 m long and 10 m wide, carrying a 7.5 m wide carriage way, 1.5 m wide walk way on one side (to the right on this case). (Refer Drawing No. KE-1138-VF-GA-351, 352 and 353)
2. A 30 m x 30 m Turning platform for allowing the turning of the busses and passenger cars. The turning platform shall also support the hinge of support for the floating pontoon. (Refer Drawing No. KE-1138-VF-GA-354)
3. A floating Pontoon of 20 m x 22 m size, connected by a 6.5 m wide pathway to the turning basin forming a part of it. The Pontoon is hinged on the turning platform with a moving swivel joint, with a fender protection at the tip, for exigencies. On the end the Pontoon is connected to a Dolphin with a Guide Pile platform. The Link span takes care of the gap between the pontoon and the Turning Plant form. Refer Drawing No. KE-1138-VF-356, 358 and 359.
4. There will be 5 berthing/mooring Dolphins, one of them for locating the Guide Pole. The Dolphins are connected by a series of walks ways. Refer Drawing No. KE-1138-VF-255, and 256.

The Figure 5.22 shows the existing and the future facilities for the Ghodbunder Terminal.

Figure 5. 22: Water Side Layout Of The Proposed At Ghodbunder Terminal On Depth Contours

On the Foreshore side for these terminals (secondary terminals), there will be facilities for;

B. Terminal Building – Refer Drawing KE-1138-GA-VF-331-00

- i. Office Facility
- ii. Fire/Life Guard Cabin
- iii. Waiting Area
- iv. Refreshment Area
- v. Canteen and Kitchen area
- vi. Rest area
- vii. Wash Rooms
- viii. Infirmary
- ix. Ticketing Counter
- x. Store Room

C. Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-317-01

D. Banks/ATM

E. Fueling Station with facilities for

- i. Diesel/MDO/IFO/Ethanol and reception facility (waste oil / bilge water)
- ii. LNG/CNG
- iii. Charging Point for Electric Vehicles

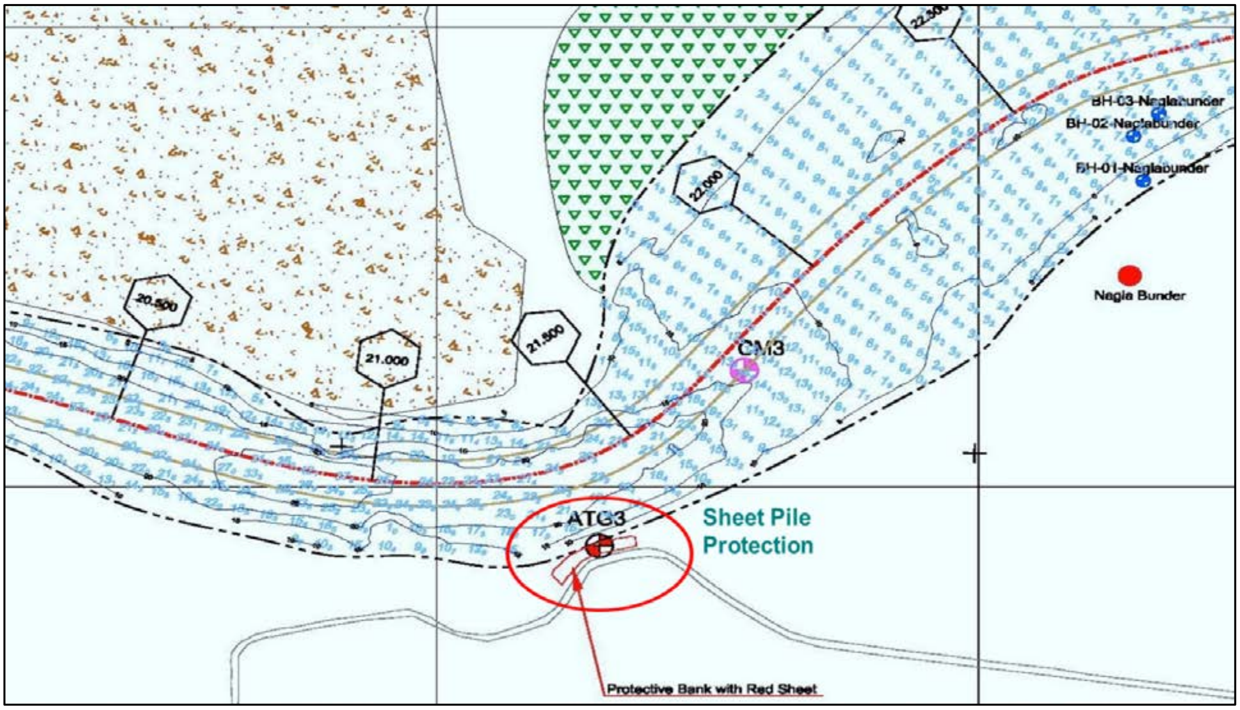
F. Solar Panels on the Terminal Building for Green Energy

As the traffic grows progressively additional dolphins could be added so that the largest design vessel could be handled at the peak traffic conditions.

5.3.2.6 Nagla Bunder Terminal

Nagla Bunder located upstream of the Gaimukh area which is being protected by sheet piles. Deep depths could be found in this region which is both serene and calm. Refer Figure 5.23 for details of depths near Gaimukh and Nagla Bunder.

Figure 5. 23: Depths Near Gaimukh And Nagla Bunder Area



As the creek/river crosses this almost 700 turn the flow spreads and the velocity drops. The area near the proposed Nagla Bunder terminal is shallower near shore, with the 5 m contour around 40-50 m away from the shore.

The foreshore is barren and generally free of vegetation. Enough area is available for present and future developments. This is a special terminal as far as the nature of this terminal is concerned. This terminal is proposed to be developed to facilitate and encourage tourism in the creek, between this terminal and Kolshet terminal primarily and for the entire creek generally.

Figure 5. 24: Area Proposed To Be Earmarked For Nagla Bunder Terminal

The waterfront facilities at this location would be similar to that of the Ghodbunder terminal except that additional facilities for the tourists and water sports enthusiasts. The Water front facilities at the Nagla Bunder Terminal is as under.

The descriptions of the facility are given in the following paragraphs,

A. Water Side Facilities

1. Jetty Approach: 50 m long and 10 m wide, carrying a 7.5 m wide carriage way, 1.5 m wide walk way on one side (to the right on this case). (Refer Drawing No. KE-1138-VF-GA-451, 452 and 453)
2. A 30 m x 30 m Turning platform for allowing the turning of the busses and passenger cars. The turning platform shall also support the hinge of support for the floating pontoon. (Refer Drawing No. KE-1138-VF-GA-454)
3. A floating Pontoon of 20 m x 22 m size, connected by a 6.5 m wide pathway to the turning basin forming a part of it. The Pontoon is hinged on the turning platform with a moving swivel joint, with a fender protection at the tip, for exigencies. On the end the Pontoon is connected to a Dolphin with a Guide Pile platform. The Link span takes care of the gap between the pontoon and the Turning Plant form. Refer Drawing No. KE-1138-VF-456, 458 and 459.
4. There will be 5 berthing/mooring Dolphins, one of them for locating the Guide Pole. The Dolphins are connected by a series of walks ways. Refer Drawing No. KE-1138-VF-455, and 456.
5. In the later years keeping pace with the growth additional dolphins could be added.

The Figure 5.25 shows the existing and the future facilities for the Nagla Bunder Terminal.

Figure 5. 25: Water Front Facilities At Nagla Bunder Terminal

On the Foreshore side for these terminals (secondary terminals), there will be facilities for;

B. Terminal Building – Refer Drawing KE-1138-GA-VF-431-00

i. Office Facility
ii. Fire/Life Guard Cabin
iii. Waiting Area
iv. Refreshment Area
v. Canteen and Kitchen area
vi. Rest area
vii. Wash Rooms
viii. Infirmary
ix. Ticketing Counter
x. Store Room

C. Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-417-01

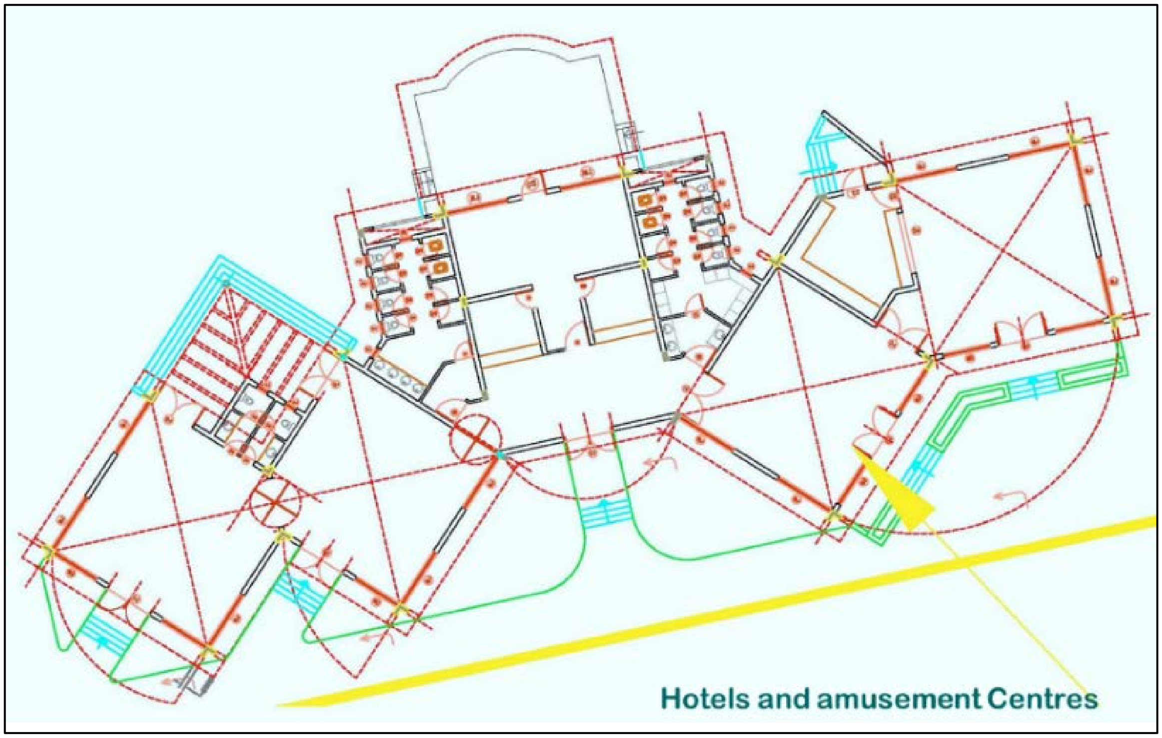
Figure 5. 26: Layout Of Parking And The Terminal Building At Nagla Bunder Terminal

D. Banks/ATM

E. Solar Panels on the Terminal Building for Green Energy

F. Restaurants, Resorts and Amusement areas for the Tourists as shown below

Figure 5. 27: Layout Of Tourist Amenities Likes Restaurants And Pubs At Nagla Bunder



G. Parks and gardens

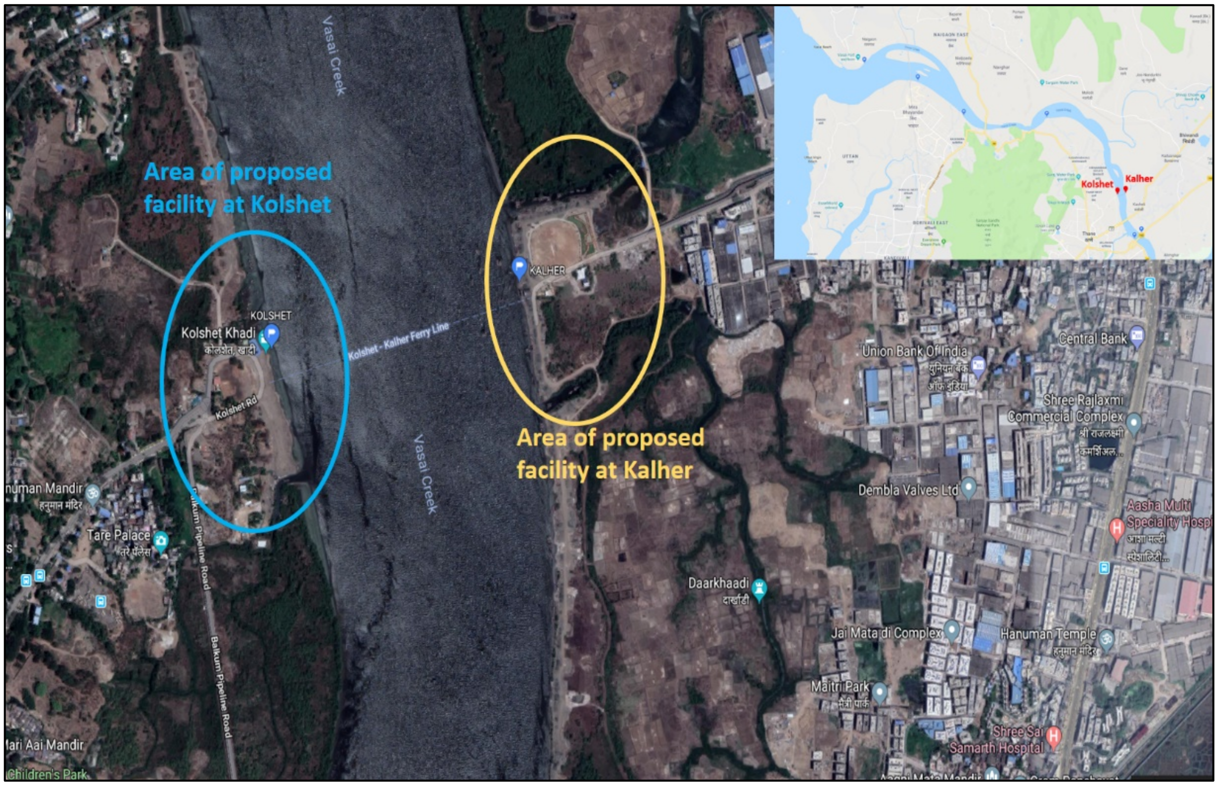
As the traffic grows progressively additional dolphins could be added so that the largest design vessel could be handled at the peak traffic conditions. The terminal also supports Seaplane operations, by providing necessary embarkations/disembarkations facilities.

5.3.2.7 Kolshet Terminal

Kolshet is a Special Terminal. This terminal apart being a main terminal is envisaged to locate, the repair and fitment yard for the vessels. The primary advantage of the location is the proximity to the industrial area of Kolshet which would provide adequate ambience. The Kolshet waterfront is fronted by an area of Mangroves, which could be avoided while planning the facilities.

Figure 5.28, shows the waterfront at Kolshet on the left bank of the creek which about 180-200 m wide and about 900 m along the river/creek. About 18 ha land is available for the development enough for the requirements of the terminal housing and ancillaries.

Figure 5. 28: Layout Of The Water Front Showing The Location Of The Kolshet And Kalher Terminals

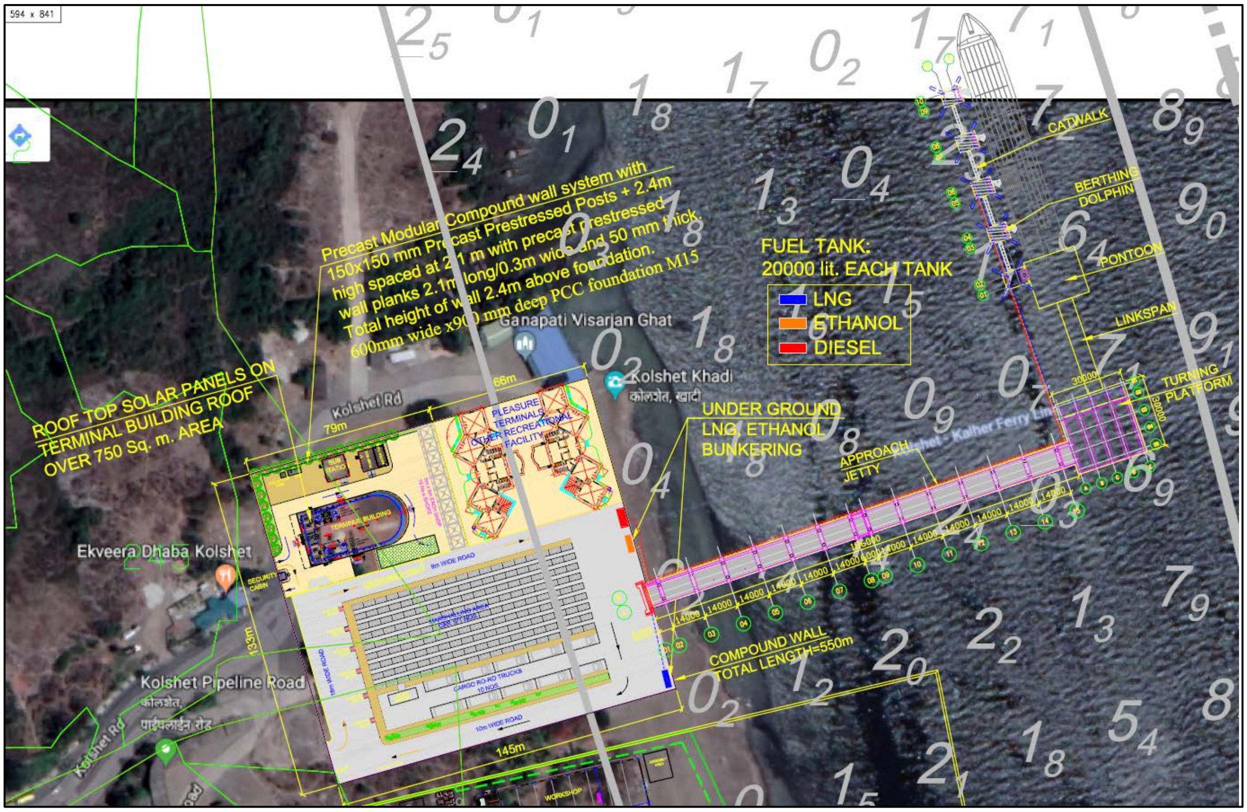


The Proposed Facilities at Kolshet is as follows;

A. Water Front Facilities for the Terminal

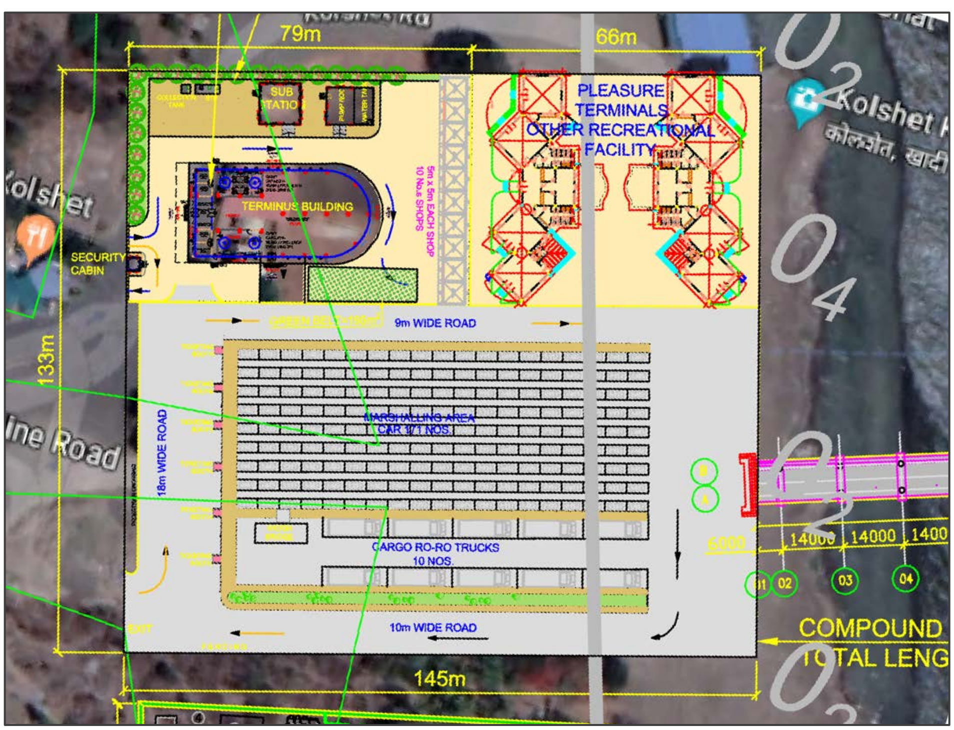
1. Jetty Approach: 110 m long and 10 m wide, carrying a 7.5 m wide carriage way, 1.5 m wide walk way on one side (to the right on this case). (Refer Drawing No. KE-1138-VF-GA-551, 552 and 553)
2. A 30 m x 30 m Turning platform for allowing the turning of the busses and passenger cars. The turning platform shall also support the hinge of support for the floating pontoon. (Refer Drawing No. KE-1138-VF-GA-554)
3. A floating Pontoon of 20 m x 22 m size, connected by a 6.5 m wide pathway to the turning basin forming a part of it. The Pontoon is hinged on the turning platform with a moving swivel joint, with a fender protection at the tip, for exigencies. On the end the Pontoon is connected to a Dolphin with a Guide Pile platform. The Link span takes care of the gap between the pontoon and the Turning Plant form. Refer Drawing No. KE-1138-VF-556, 558 and 559.
4. There will be 5 berthing/mooring Dolphins, one of them for locating the Guide Pole. The Dolphins are connected by a series of walks ways. Refer Drawing No. KE-1138-VF-555, and 556.

Figure 5. 29: Layout Of The Water Front Showing The Location Of The Kolshet Terminal



Similar to Nagla Bunder, there will be general amusement areas at Kolshet as well as shown in Figure 5.30.

Figure 5. 30: Layout Of The Water Front Foreshore Area Showing The Proposed Facilities



B. **Water Front Facilities for the Vessel repairs**

1. Slipway facility for retrieving the vessel to the yard and letting the vessel to the water. The other associated facilities as indicated in Figure 5.31 below.

Figure 5. 31: Layout Of The Ship Repair Facility At Kolshet

C. **Terminal Building – Refer Drawing KE-1138-GA-VF-531-00**

i. Office Facility
ii. Fire/Life Guard Cabin
iii. Waiting Area
iv. Refreshment Area
v. Canteen and Kitchen area
vi. Rest area
vii. Wash Rooms
viii. Infirmary
ix. Ticketing Counter
x. Store Room

D. **Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-517-01**

E. **Banks/ATM**

F. **Fueling Station with facilities for**

i. Diesel/MDO/IFO/Ethanol and reception facility (waste oil / bilge water)
ii. LNG/CNG
iii. Charging Point for Electric Vehicles

G. **Solar Panels on the Terminal Building for Green Energy**

H. **Vessel Repair Facility**

I. **Restaurants, Resorts and Amusement areas for the Tourists**

J. **Parks and gardens**

5.3.2.8 Kalher Terminal

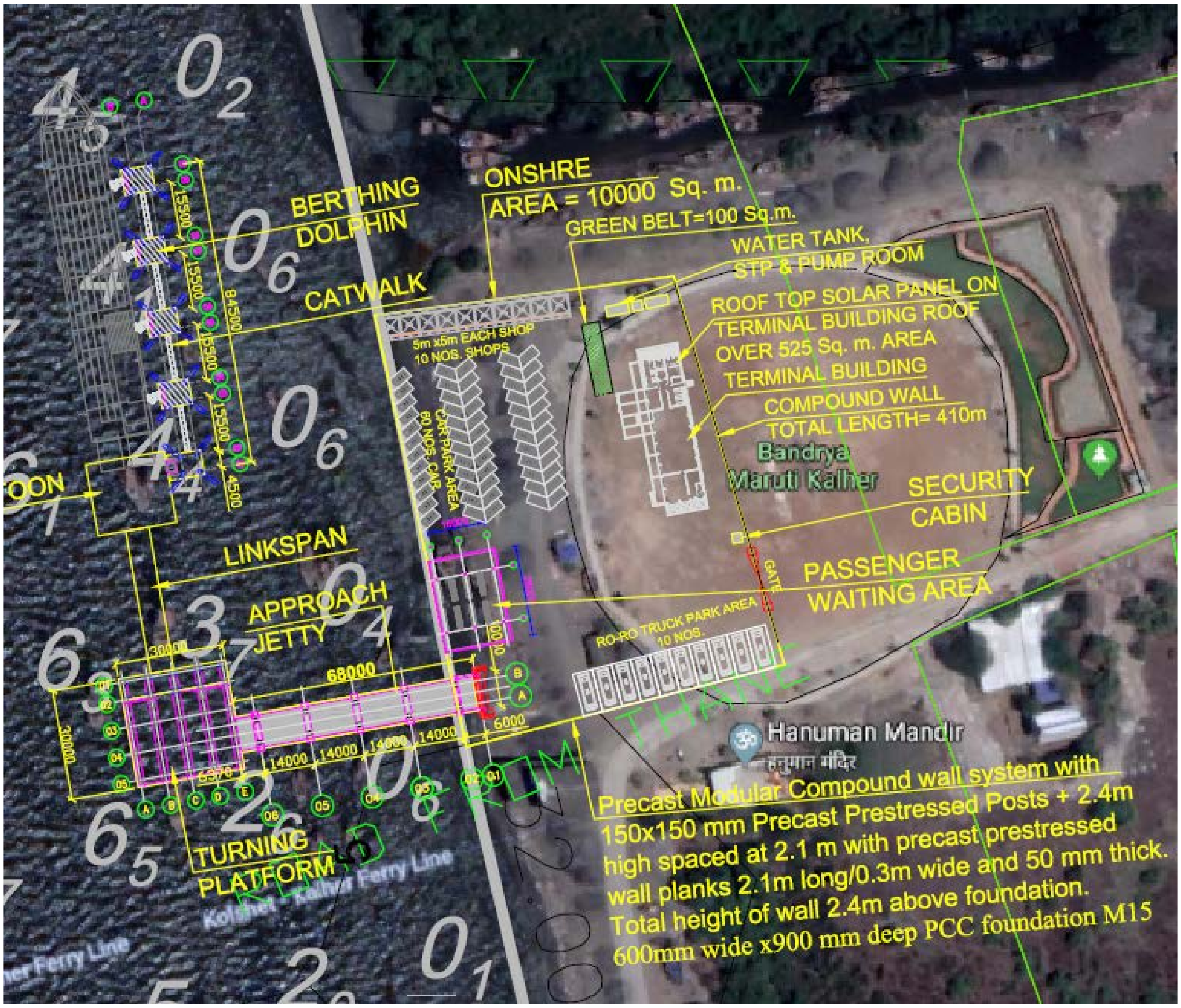
Kalher is a secondary terminal. This is also the complementary terminal for the Kolshet terminal located on the opposite bank. Though this terminal could be ideal for ro-ro cargo vehicles, for this stage only passenger ro-ro would be planned. The water front shown in Figure 5.32 had adequate space for locating the terminal. The facilities for this terminal is as under;

A. **Water Side Facilities**

1. Jetty Approach: 50 m long and 10 m wide, carrying a 7.5 m wide carriage way, 1.5 m wide walk way on one side (to the right on this case). (Refer Drawing No. KE-1138-VF-GA-651, 652 and 653)
2. A 30 m x 30 m Turning platform for allowing the turning of the busses and passenger cars. The turning platform shall also support the hinge of support for the floating pontoon. (Refer Drawing No. KE-1138-VF-GA-654)
3. A floating Pontoon of 20 m x 22 m size, connected by a 6.5 m wide pathway to the turning basin forming a part of it. The Pontoon is hinged on the turning platform with a moving swivel joint, with a fender protection at the tip, for exigencies. On the end the Pontoon is connected to a Dolphin with a Guide Pile platform. The Link span takes care of the gap between the pontoon and the Turning Plant form. Refer Drawing No. KE-1138-VF-656, 658 and 659.
4. There will be 5 berthing/mooring Dolphins, one of them for locating the Guide Pole. The Dolphins are connected by a series of walks ways. Refer Drawing No. KE-1138-VF-655, and 656.
5. In the later years keeping pace with the growth additional dolphins could be added.

The Figure 5.32 shows the existing and the future facilities for the Kalher Terminal.

Figure 5. 32:Water Front Facilities At Kalher Terminal



On the Foreshore side for these terminals (secondary terminals), there will be facilities for;

B. Terminal Building – Refer Drawing KE-1138-GA-VF-631-00 – Annexure E

i. Office Facility
ii. Fire/Life Guard Cabin
iii. Waiting Area
iv. Refreshment Area
v. Canteen and Kitchen area
vi. Rest area
vii. Wash Rooms
viii. Infirmary
ix. Ticketing Counter
x. Store Room

C. Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-617-01
D. Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-617-01
E. Banks/ATM
F. Solar Panels on the Terminal Building for Green Energy
G. Restaurants, Resorts and Amusement areas for the Tourists
H. Parks and gardens

5.3.2.9 Anjur Dive Terminal

Anjur Dive is located on the right bank of the creek/river downstream of the road bridge. An area practically flat, adjacent to the road bridge is identified for this development is shown in Figure 5.33.

Figure 5. 33: Water Front Area At The Proposed Anjur Dive Terminal

The waterfront has natural depths fairly close to the shoreline. This terminal provides connectivity to the Bhiwandi area as well as the other smaller areas recently very busy with residential as well as Industrial Township development.

The terminal is a secondary terminal, with passenger services alone. Accordingly, the following services are envisaged;

A. Water Side Facilities

1. Jetty Approach: 70 m long and 10 m wide, carrying a 7.5 m wide carriage way, 1.5 m wide walk way on one side (to the right on this case). (Refer Drawing No. KE-1138-VF-GA-751, 752 and 753)
2. A 30 m x 30 m Turning platform for allowing the turning of the busses and passenger cars. The turning platform shall also support the hinge of support for the floating pontoon. (Refer Drawing No. KE-1138-VF-GA-754)
3. A floating Pontoon of 20 m x 22 m size, connected by a 6.5 m wide pathway to the turning basin forming a part of it. The Pontoon is hinged on the turning platform with a moving swivel joint, with a fender protection at the tip, for exigencies. On the end the Pontoon is connected to a Dolphin with a Guide Pile platform. The Link span takes care of the gap between the pontoon and the Turning Plant form. Refer Drawing No. KE-1138-VF-756, 758 and 759.
4. There will be 5 berthing/mooring Dolphins, one of them for locating the Guide Pole. The Dolphins are connected by a series of walks ways. Refer Drawing No. KE-1138-VF-755, and 756.

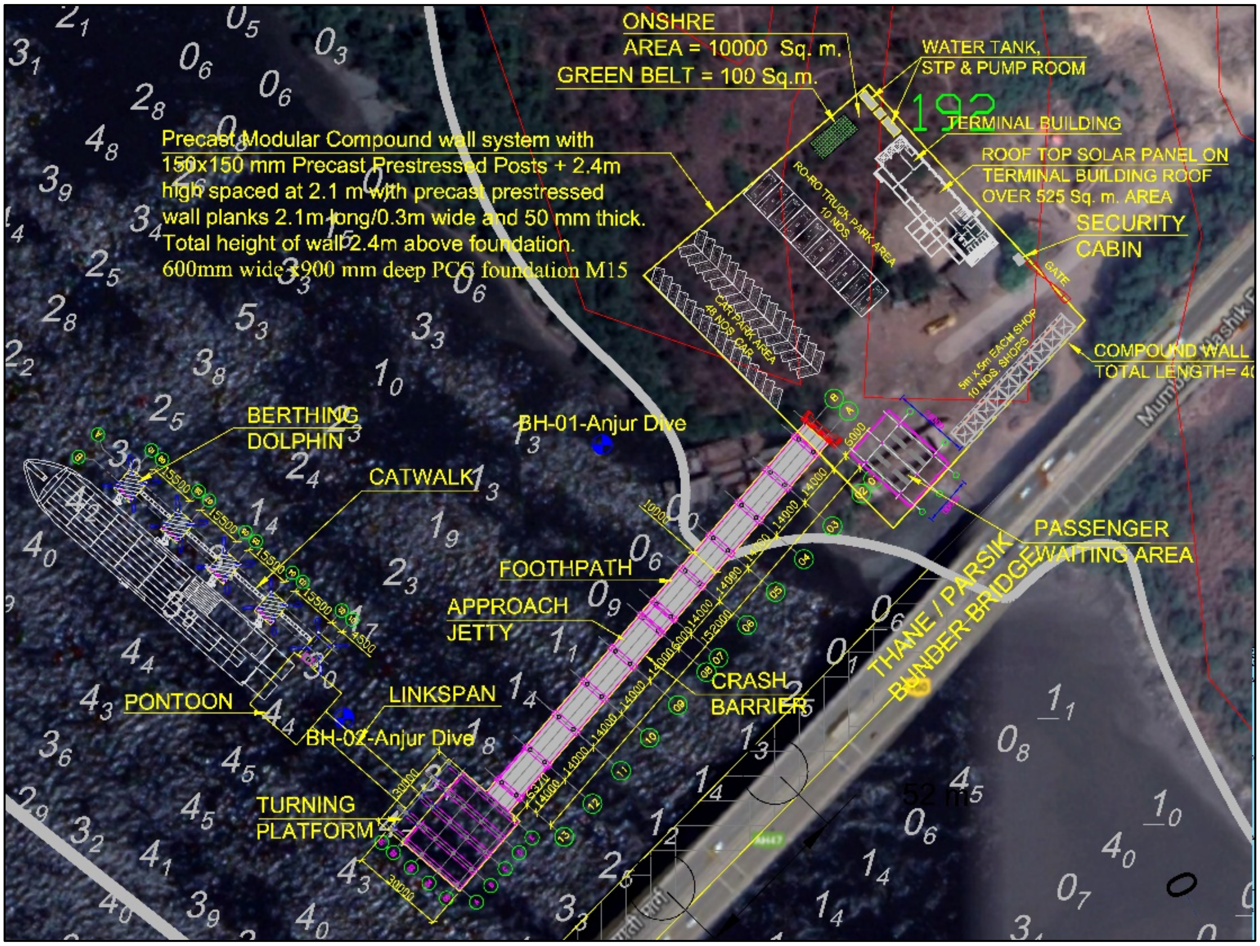
In the later years keeping pace with the growth additional dolphins could be added.

The Figure 5.34 shows the existing and the future facilities for the Anjur Dive Terminal.

B. Terminal Building – Refer Drawing KE-1138-GA-VF-731-00

i. Office Facility
ii. Fire/Life Guard Cabin
iii. Waiting Area
iv. Refreshment Area
v. Canteen and Kitchen area
vi. Rest area
vii. Wash Rooms
viii. Infirmary
ix. Ticketing Counter
x. Store Room

Figure 5. 34: Water Front Facilities At Anjur Dive Terminal



On the Foreshore side for these terminals (secondary terminals), there will be facilities for;

C. **Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-617-01**
D. **Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-617-01**
E. **Banks/ATM**
F. **Solar Panels on the Terminal Building for Green Energy**
G. **Restaurants, Resorts and Amusement areas for the Tourists**
H. **Parks and gardens**

5.3.2.10 Parsik Bunder Terminal

This area would locate a secondary terminal and would act as a complementary terminal to Anjur Dive terminal. The water front area is shown in Figure 5.35 below.

Figure 5. 35: Water Front Area At The Parsik Bunder Terminal

The facilities area akin to the facilities at the secondary terminals as under.

A. Water Side Facilities

1. Jetty Approach: 70 m long and 10 m wide, carrying a 7.5 m wide carriage way, 1.5 m wide walk way on one side (to the right on this case). (Refer Drawing No. KE-1138-VF-GA-751, 752 and 753)
2. A 30 m x 30 m Turning platform for allowing the turning of the busses and passenger cars. The turning platform shall also support the hinge of support for the floating pontoon. (Refer Drawing No. KE-1138-VF-GA-754)
3. A floating Pontoon of 20 m x 22 m size, connected by a 6.5 m wide pathway to the turning basin forming a part of it. The Pontoon is hinged on the turning platform with a moving swivel joint, with a fender protection at the tip, for exigencies. On the end the Pontoon is connected to a

Dolphin with a Guide Pile platform. The Link span takes care of the gap between the pontoon and the Turning Plant form. Refer Drawing No. KE-1138-VF-756, 758 and 759.

4. There will be 5 berthing/mooring Dolphins, one of them for locating the Guide Pole. The Dolphins are connected by a series of walks ways. Refer Drawing No. KE-1138-VF-755, and 756.

In the later years keeping pace with the growth additional dolphins could be added.

The Figure 5.36 shows the existing and the future facilities for the Parsik Bunder Terminal.

On the Foreshore side for these terminals (secondary terminals), there will be facilities for;

B. Terminal Building – Refer Drawing KE-1138-GA-VF-731-00

i. Office Facility
ii. Fire/Life Guard Cabin
iii. Waiting Area
iv. Refreshment Area
v. Canteen and Kitchen area
vi. Rest area
vii. Wash Rooms
viii. Infirmary
ix. Ticketing Counter
x. Store Room

C. Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-617-01

D. Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-617-01

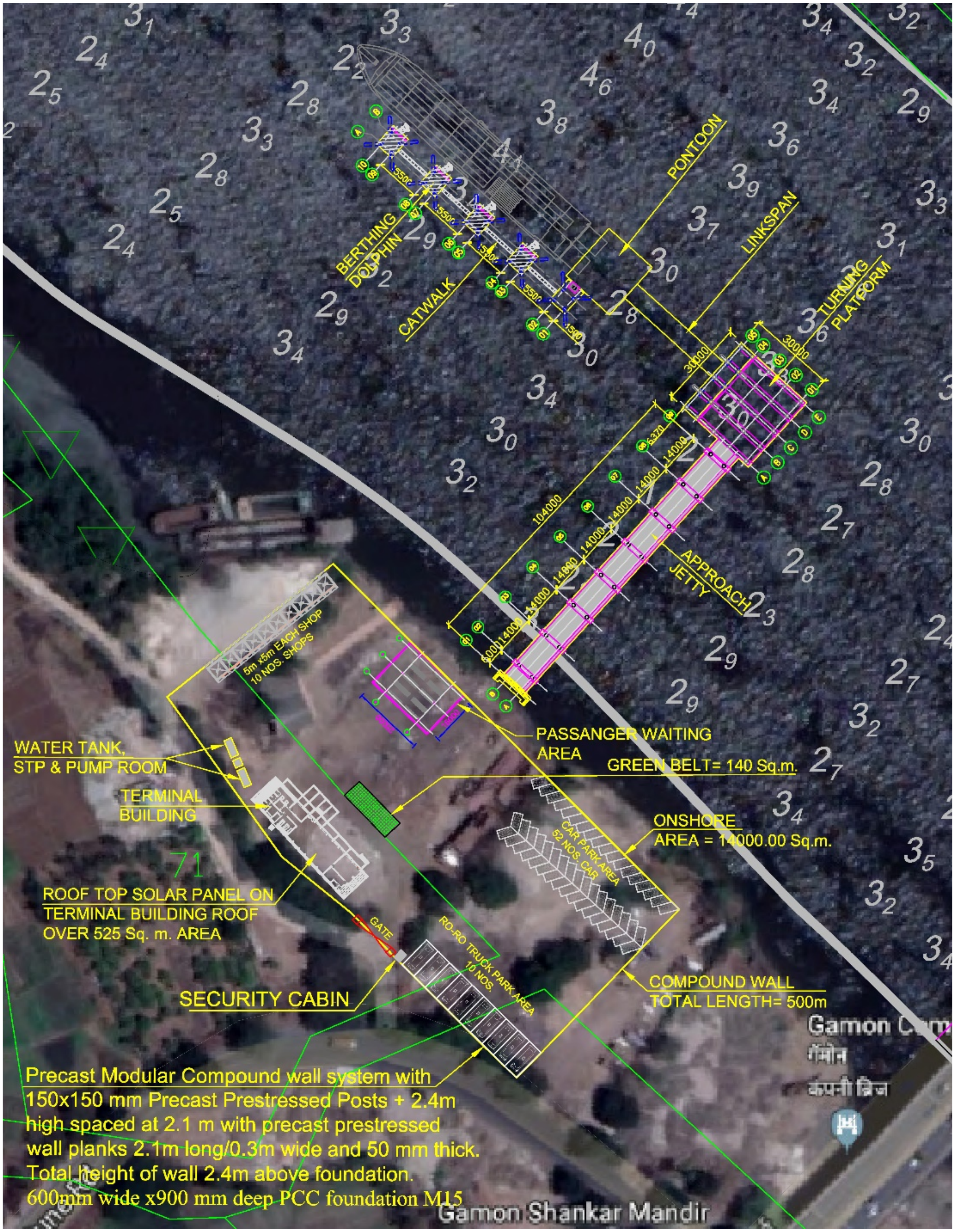
E. Banks/ATM

F. Solar Panels on the Terminal Building for Green Energy

G. Restaurants, Resorts and Amusement areas for the Tourists

H. Parks and gardens

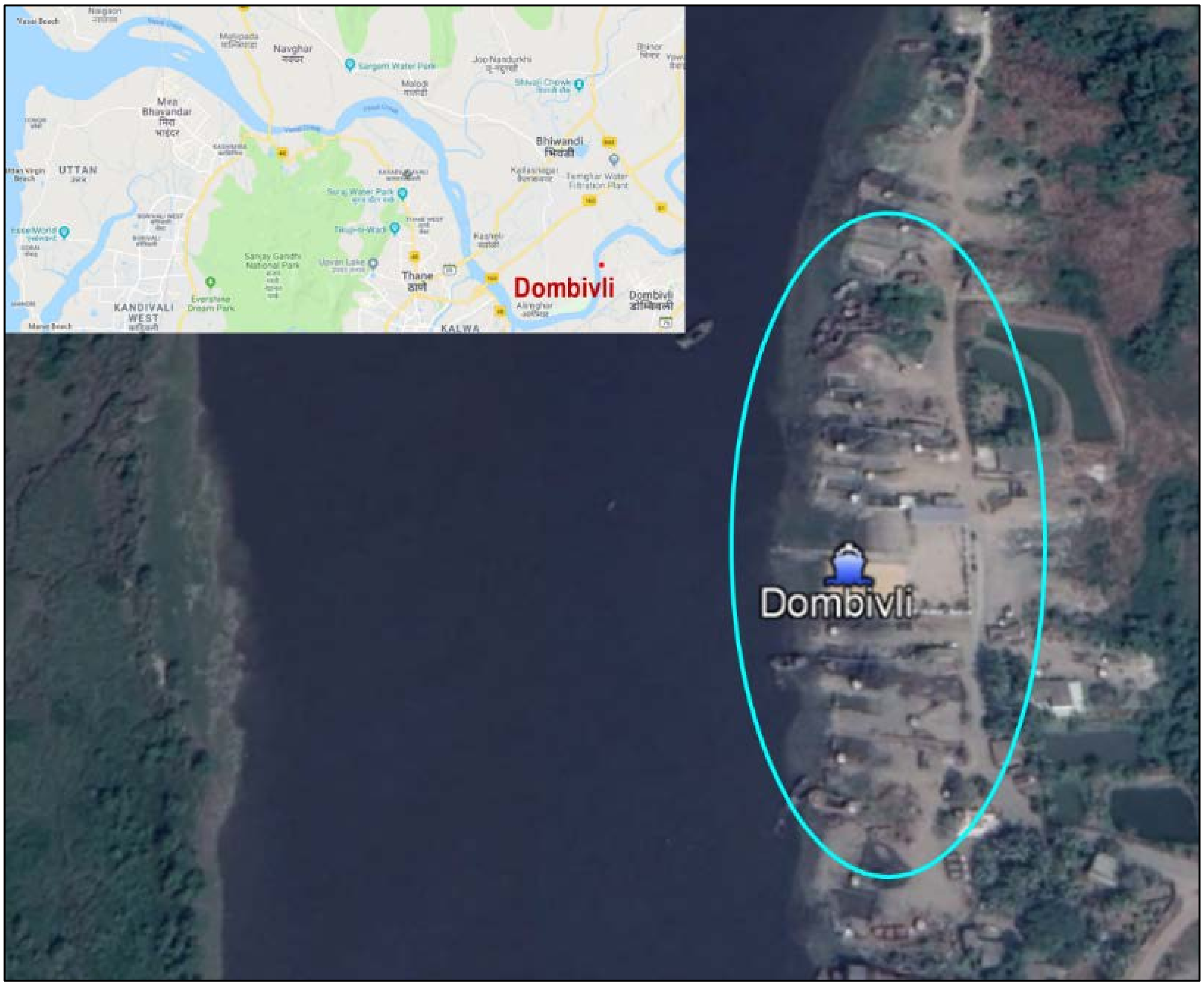
Figure 5. 36: Water Front Facilities At Parsik Bunder Terminal



5.3.2.11 Dombivli Terminal

This area would locate a secondary terminal and would act as a complementary terminal to Kalyan in case of congestion and lack of space there. The water front area is shown in Figure 5.37 below.

Figure 5. 37: Water Front Area At The Dombivli Terminal



The facilities area akin to the facilities at the secondary terminals as under.

A. Water Side Facilities

1. Jetty Approach: 70 m long and 10 m wide, carrying a 7.5 m wide carriage way, 1.5 m wide walk way on one side (to the right on this case). (Refer Drawing No. KE-1138-VF-GA-751, 752 and 753)
2. A 30 m x 30 m Turning platform for allowing the turning of the busses and passenger cars. The turning platform shall also support the hinge of support for the floating pontoon. (Refer Drawing No. KE-1138-VF-GA-754)
3. A floating Pontoon of 20 m x 22 m size, connected by a 6.5 m wide pathway to the turning basin forming a part of it. The Pontoon is hinged on the turning platform with a moving swivel joint,

with a fender protection at the tip, for exigencies. On the end the Pontoon is connected to a Dolphin with a Guide Pile platform. The Link span takes care of the gap between the pontoon and the Turning Plant form. Refer Drawing No. KE-1138-VF-756, 758 and 759.

4. There will be 4 berthing/mooring Dolphins, one of them for locating the Guide Pole. The Dolphins are connected by a series of walks ways. Refer Drawing No. KE-1138-VF-755, and 756.

In the later years keeping pace with the growth additional dolphins could be added.

The Figure 5.38 shows the existing and the future facilities for the Dombivli Terminal.

On the Foreshore side for these terminals (secondary terminals), there will be facilities for;

B. Terminal Building – Refer Drawing KE-1138-GA-VF-731-00

i. Office Facility
ii. Fire/Life Guard Cabin
iii. Waiting Area
iv. Refreshment Area
v. Canteen and Kitchen area
vi. Rest area
vii. Wash Rooms
viii. Infirmary
ix. Ticketing Counter
x. Store Room

I. Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-617-01

J. Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-617-01

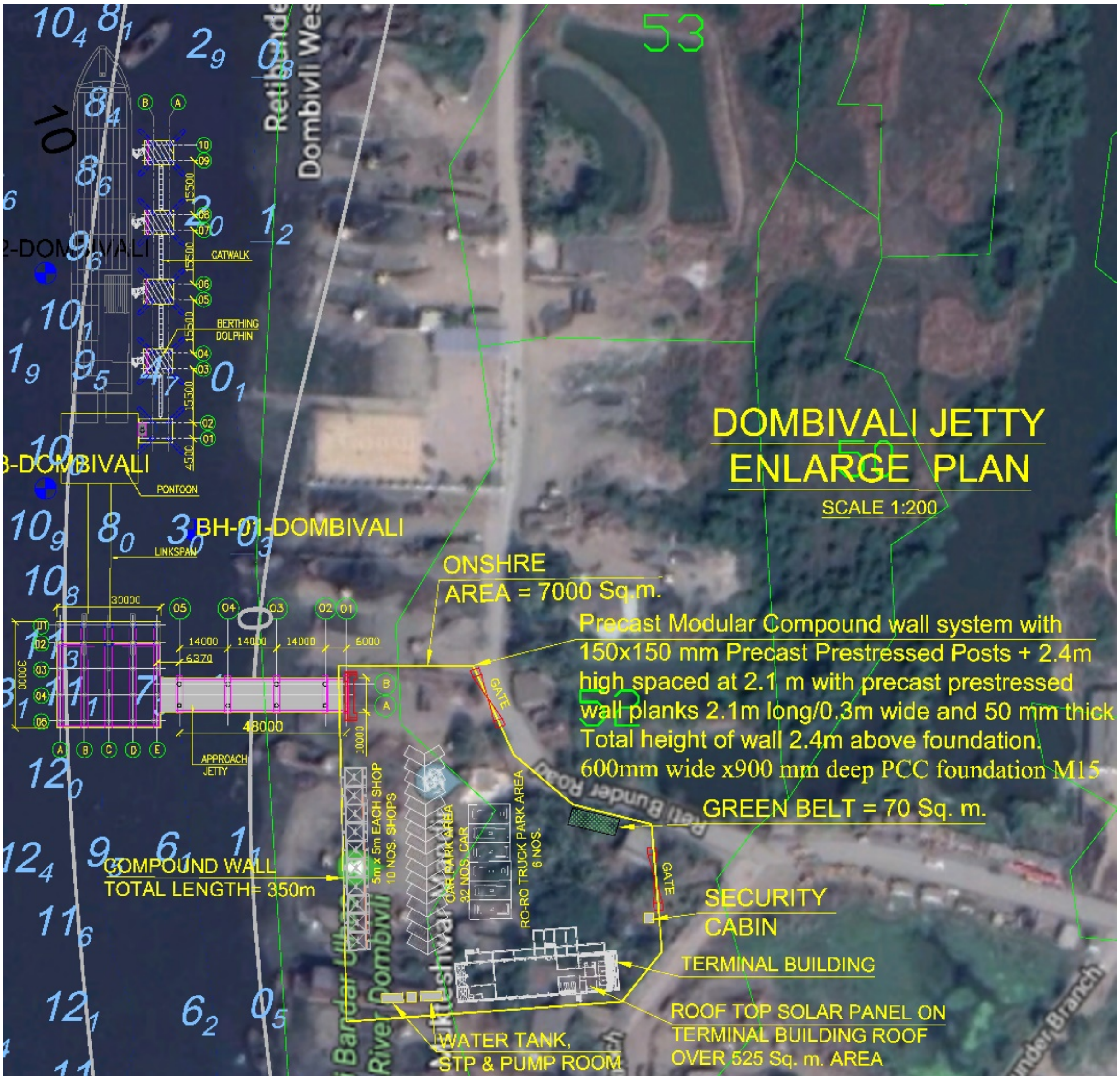
K. Banks/ATM

L. Solar Panels on the Terminal Building for Green Energy

M. Restaurants, Resorts and Amusement areas for the Tourists

N. Parks and gardens

Figure 5. 38: Water Front Facilities At Dombivli Terminal



5.3.2.12 Kalyan Terminal

The last terminal on the waterway on the landward side, and fronts the busy Kalyan area. The area downstream of the bridge is generally busy and is used by many barge users for repairs and trade. A fact easily verifiable from the figure 5.36 below.

A terminal is located on the downstream of the bridge. The existing activities needs to be confined to one side to give way to the new terminal. There is transportation of sands in this area as shown in the Figure 5.39.

This area would locate a main terminal build in stages with the pace in growth in demand.

Figure 5. 39: Water Front Area At The Kalyan Terminal

The facilities area akin to the facilities at the main terminals as under.

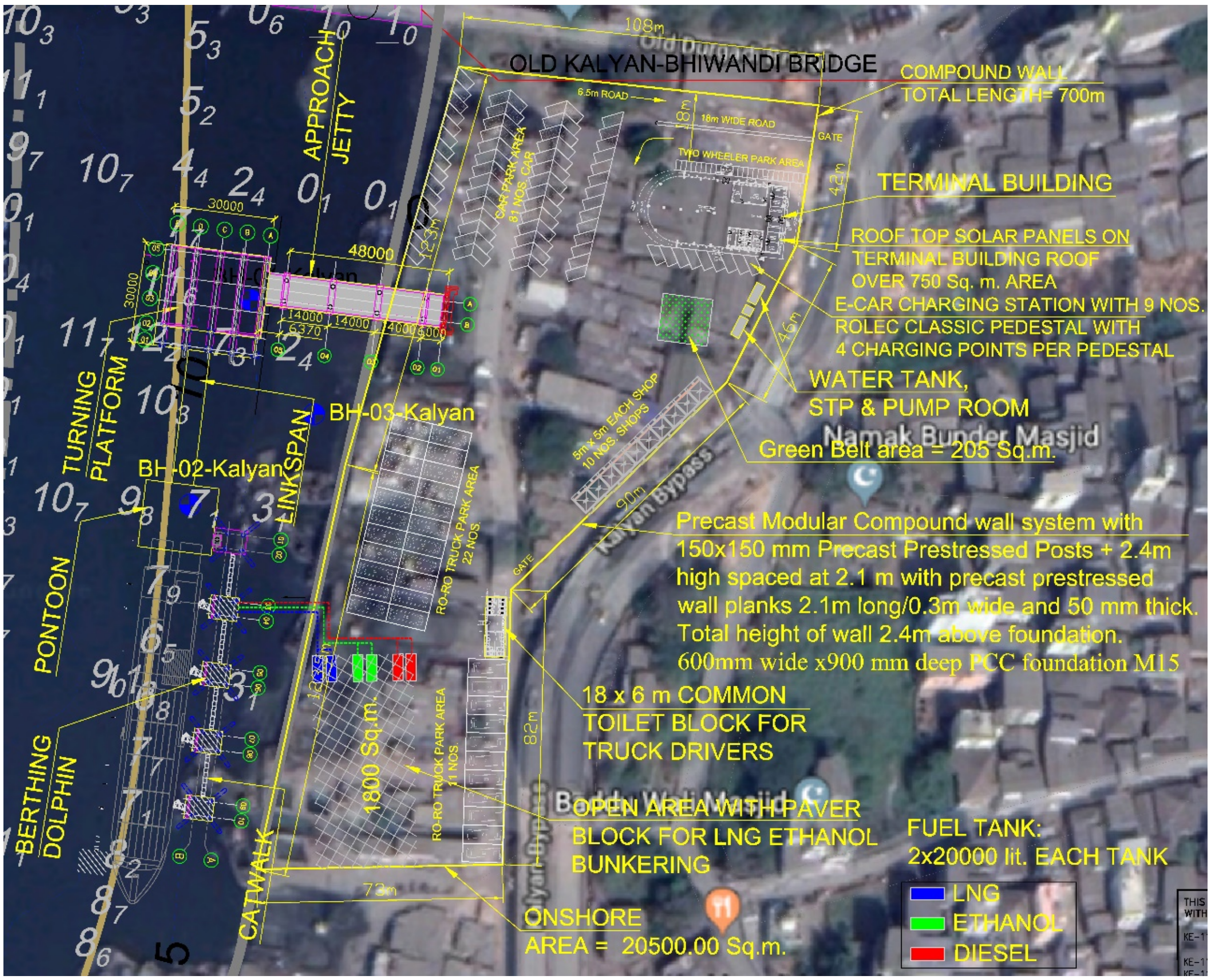
A. Water Side Facilities

1. Jetty Approach: 70 m long and 10 m wide, carrying a 7.5 m wide carriage way, 1.5 m wide walk way on one side (to the right on this case). (Refer Drawing No. KE-1138-VF-GA-1051, 1052 and 1053)
2. A 30 m x 30 m Turning platform for allowing the turning of the busses and passenger cars. The turning platform shall also support the hinge of support for the floating pontoon. (Refer Drawing No. KE-1138-VF-GA-1054)
3. A floating Pontoon of 20 m x 22 m size, connected by a 6.5 m wide pathway to the turning basin forming a part of it. The Pontoon is hinged on the turning platform with a moving swivel joint, with a fender protection at the tip, for exigencies. On the end the Pontoon is connected to a Dolphin with a Guide Pile platform. The Link span takes care of the gap between the pontoon and the Turning Plant form. Refer Drawing No. KE-1138-VF-1056, 1058 and 1059.

4. There will be 5 berthing/mooring Dolphins, one of them for locating the Guide Pole. The Dolphins are connected by a series of walks ways. Refer Drawing No. KE-1138-VF-1055, and 1056.

The Figure 5.40 shows the future facilities for the Kalyan Terminal.

Figure 5. 40: Proposed Development At Ahe Kalyan Terminal



On the Foreshore side for these terminals (main terminals), there will be facilities for;

C. Terminal Building – Refer Drawing KE-1138-GA-VF-1031-00

i. Office Facility
ii. Fire/Life Guard Cabin
iii. Waiting Area
iv. Refreshment Area
v. Canteen and Kitchen area
vi. Rest area
vii. Wash Rooms
viii. Infirmary

ix. Ticketing Counter

x. Store Room

B. Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-1017-01

C. Parking Facilities for Cars and other Commercial vehicles. Refer Drawing KE-1138-GA-VF-DE-1017-01

D. Banks/ATM

E. Fueling Station with facilities for

i. Diesel/MDO/IFO/Ethanol and reception facility (waste oil / bilge water)

ii. LNG/CNG

iii. Charging Point for Electric Vehicles

F. Solar Panels on the Terminal Building for Green Energy

G. Restaurants, Resorts and Amusement areas for the Tourists

H. Parks and gardens

5.4 Land Details

5.4.1 Land Requirement For The Terminals

As indicated in the section 3.8, the land for the terminal development is mostly planned around the area majorly owned by the State or the Central Government. The land holding pattern of the earmarked areas around the terminals are indicated in the layouts given in the drawings KE-1138-DB_GA_151 to KE-1138-DB_GA_1051. The land requirement for the various terminal area is given below; in table 5.1

Table 5. 1: Land Requirements Of Terminals Locationwise

NO.	Site	Onshore Total Area	Terminal Bldg. Area	Internal roads	Shops Area	STP,WT & sub station	Common Toilet Block Area	Passanger Waiting Area	Recr. Area	Security Cabin Area	Fuel Storage Area	Green Belt Area	Offshore Total Area	Jetty Area	Turning Platform Area	Dolphins Area	Linkspan + Dolphin Walkway	Ship Yard Area
1	Vasai Fort	**21500**	1050	17887.9	380	48	110	_	_	9.1	1800	215	**2706**	491	915	300	1000	-
2	Mira Bhayander	**7525**	1050	5962.9	380	48	_	_	_	9.1	_	75	**3020**	805	915	300	1000	-
3	Ghod Bunder	**20000**	1050	15908.9	380	48	110	494	_	9.1	1800	200	**2740**	525	915	300	1000	-
4	Nagla Bunder	**12400**	705	10287.9	380	48	_	_	850	9.1	_	120	**2883**	668	915	300	1000	-
5	Kolshet	**19300**	1050	13965.9	380	200	_	_	1700	9.1	1800	195	**4081**	1866	915	300	1000	17120
6	Kalher	**10200**	705	8463.9	380	48	_	494	_	9.1	_	100	**2882**	667	915	300	1000	-
7	Anjurdive	**10075**	705	8338.9	380	48	_	494	_	9.1	_	100	**3781**	1566	915	300	1000	-
8	Parsik Bunder	**14000**	705	12223.9	380	48	_	494	_	9.1	_	140	**3315**	1100	915	300	1000	-
9	Dombivali	**7200**	705	5987.9	380	48	_	_	_	9.1	_	70	**2740**	525	915	300	1000	-
10	Kalyan	**20500**	1050	16897.9	380	48	110	_	_	9.1	1800	205	**2740**	525	915	300	1000	-
		142700											30887					
	Total Land Requirement													**190707 m² 19.07 Ha (Say 20 Ha)**				

Hence the total land requirement would be ~ 20 ha (50 acres)

This is the bare requirement for the facilities proposed. As the green area shown in the table is very small, it is proposed to add additional green space in the Government land in and around the terminal at each location. It is however imperative to understand that land availability often times becomes the bane of many projects, at a later stage when the development has already taken place. Therefore, it must be endeavoured to acquire as much land as possible at the beginning itself, to cater to the additional facilities suggested in this report namely, potentials of cargo handling in future, solar power, water parks, and other extensions of the initial facility that may takes place in subsequent phases.

The land ownership details at the various terminals expected to be acquired is given in Table 5.2. The details and cost of land acquisition based on the ready reckoner price is also given in the table 5.2. As indicated above the cost of the total acquisition for the present requirement is about ₹ 710 Million. Part of this land acquisition cost could be reduced by using the TDR route by the respective Corporations. Since, part of the land is Government Owned and for a socially beneficially project such as this, land should be made available by the authorities at subsidized cost.

Table 5. 2: Cost Of Land Acquisition/Transfer of Development Rights (TDR) For The Water Front Facilities In INR (₹)

LA / TDR Requirement									
Sr no	District	Taluka	Village	Survey No	Area to be acquired by LA or TDR (Sq. m)	Rate of land (Rs/Sq.m)	LA Cost	Ownership	Reservation
Vasai Fort Jetty									
1	Palghar	Vasai	Malonde	62	6527.671	8610	56203247.31	Owned By Vasai Fort Revenue Dept.	Place of historical importance
2	Palghar	Vasai	Malonde	20	11704.199	8610	98315271.60		
3	Palghar	Vasai	Malonde	35	3132.215	8610	26968371.15		
4	Palghar	Vasai	Malonde	42	41.593	8610	349381.20		
Mira Bhayander Jetty									
1	Thane	Thane	Bhayander Pada	Creek Land	7520.94			Creek Land	Recreational land
Ghodbunder Jetty									
1	Thane	Thane	Ghodbunder	205	148.635	26030	3868969.05	Govt. Fort	Residential/ Housing
2	Thane	Thane	Ghodbunder	244	602.197	26030	15675187.91	Private Land	
3	Thane	Thane	Ghodbunder	Creek Land	18931.735			Creek Land	
Nagla Bunder Jetty									
1	Thane	Thane	Mogharpada	Creek Land	12376.018			Creek Land	Agricultural / Forest/ Green Zone
Kolshet Jetty									
1	Thane	Thane	Kolshet	287	5895.573	19000	112015887.00	BMC Land	Transportation
2	Thane	Thane	Kolshet	12	256.89	19000	4880910.00		
3	Thane	Thane	Kolshet	Creek Land	30267.028			Creek Land	
Kalher Jetty									
1	Thane	Thane	Kalher	Creek Land	10151.964			Creek Land	

LA / TDR Requirement									
Sr no	District	Taluka	Village	Survey No	Area to be acquired by LA or TDR (Sq. m)	Rate of land (Rs/Sq.m)	LA Cost	Ownership	Reservation
Parsik Bunder Jetty									
1	Thane	Thane	Parsik	71	3702.008	20600	76261364.80	Private Land	Agricultural/ other/ transportation
2	Thane	Thane	Parsik	70	578.467	20600	11916420.20	Private Land/TMC	
3	Thane	Thane	Parsik	Creek Land	9529.818			Creek Land	
Anjur Dive Jetty									
1	Thane	Thane	Dive	192	3652.038	211.1	770945.22	Private Land	
2	Thane	Thane	Dive	Creek Land	6409.445			Creek Land	
Dombivli Jetty									
1	Thane	Kalyan	Thakurli	52	4275.793	22800	97488080.40	Private Land	Public use
2	Thane	Kalyan	Thakurli	Creek Land	2895.336			Creek Land	
Kalyan Jetty									
1	Thane	Kalyan	Kalyan	309	111.787	14800	1654151.60	Private Land/KDMC	
2	Thane	Kalyan	Kalyan	310	205.74	22500	4629150.00	Private Land	
3	Thane	Kalyan	Kalyan	311,313	8058.085	22500	181306912.50	Private Land	
4	Thane	Kalyan	Kalyan	312	798.881	22500	17974822.50	Private Land	
5	Thane	Kalyan	Kalyan	Creek Land	11243.639			Creek Land	
				Total	20418.11		205565036.60		
				Grand Total	**159017.68**	**Sq. m**	**710279072.44**		

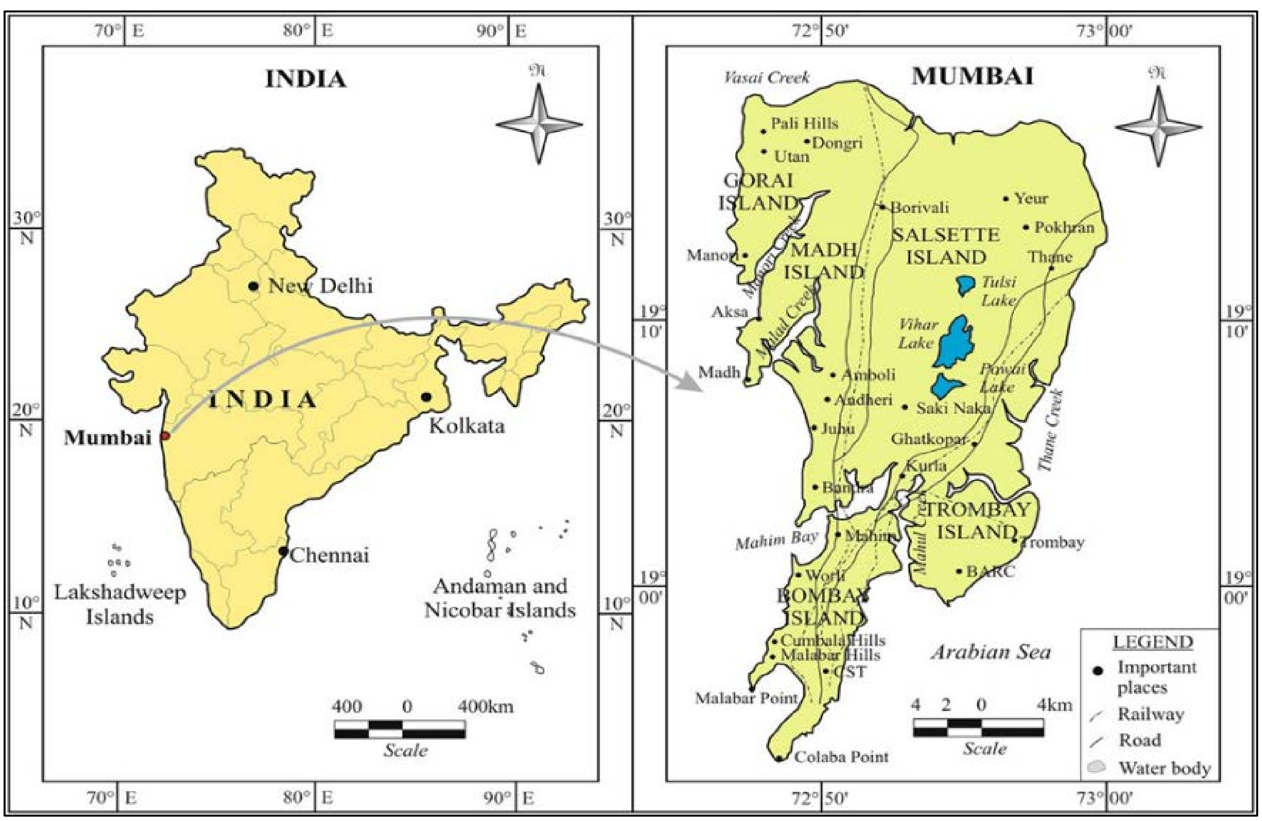
5.5 Geotechnical Investigations

5.5.1 Regional Geology

5.5.1.1 Study Area

Mumbai Island is located on the western coast of India (Figure 5.41) and experiences a tropical climate with copious rainfall. Geographically it lies between North latitudes 18°50° and 19°18° and East longitudes 72°45° and 73° 03°. Geomorphology of an area being dependent on the regional geology, the macro level study area is identified with respect to the geological similarity. Hence a reference to the macro level study area is necessary before the focus area is taken up. The Mumbai Island on the macro level is bounded by Vasai creek to the north, Thane creek to the east and Arabian Sea to the south and west. The creeks of Thane and Vasai separate this island from the mainland. Besides the Thane and Vasai creeks, Manori and Malad creeks are other smaller creeks on the west of Mumbai Islands. The creeks are the sites where six major streams which traverse the length and breadth of Mumbai Island debouch. The area is densely populated and highly urbanized and is characterized by industrial, commercial and residential land uses. Vast regions of the Mumbai Island are also covered by dense forests. Hilly areas are characterized by moderate to thick vegetation and many such areas have been designated as reserve forests. Three large reservoirs occur in this island like Tulsi, Vihar and Powai.

Figure 5. 41: Location Map Of The Study Area



Geological Set Up

Mumbai Island forms a part of Deccan Volcanic Province (DVP). DVP represents the remnants of one of the largest volcanic events on earth and is one of the best studied continental flood basalt provinces of the world. It originally covered an area of 1.5 million sq. km. (*Krishnan 1982*) with a total erupted volume of 2 x10^6 km^3 *(Krishnan 1960; Pascoe 1964; Rao et al. 1978*). The geological formations found in Mumbai include the Deccan Basalts and its acid variants, volcanic tuffs, intertrappean sediments, dykes, laterite and alluvium. The geology of Mumbai Island is rather unusual compared to that of the main Deccan flood basalt province, particularly the Western Ghats in several aspects (*Sukeshwala and Poldervaart 1958; Sethna 1981, 1999; Sheth et al. 2001*). Important differences include.

(1) The common occurrence of sedimentary intertrappeans, red boles and weathering profiles
(2) Sub-aqueous nature of the lava flows indicated by pillow structures, spilitic petrography and the presence of hyaloclastics (*Sethna 1999*)
(3) Representation of the intrusive phase of basic magma in the form of dyke swarms and plugs
(4) Association of acidic (rhyolite) and intermediate (trachyte) rock, often considered differentiates of the Deccan trap basaltic magma
(5) Occurrence of a large column of basic and acidic tuff
(6) Pronounced westerly (seaward) dips up to 25° unlike the horizontal lava pile of the Western Ghats (*Auden 1949; Sheth 1998*).

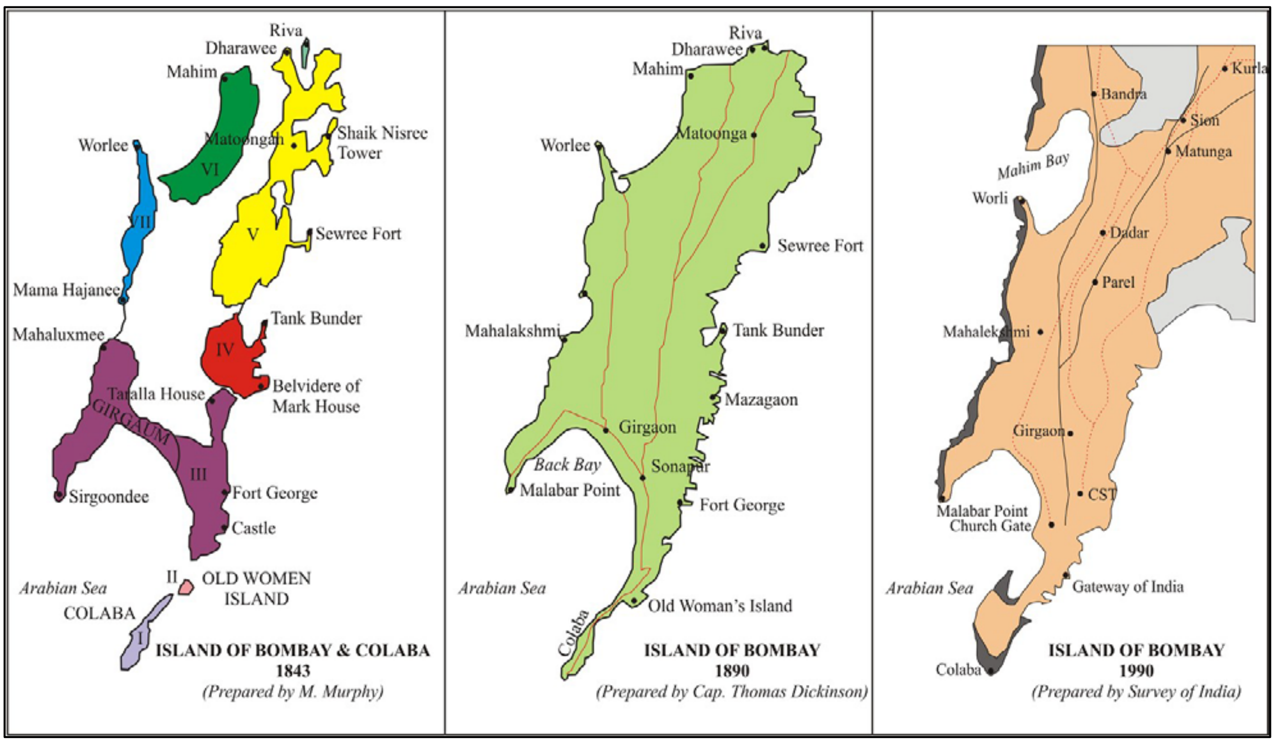
The Mumbai Island originally consisted of seven separate islands, separated from one another by swamps. These swamps were reclaimed, giving rise to a single landmass at the end of 18th century. This landmass is the old Mumbai city (Figure 5.42). The Salsette Island to the north and the Trombay Island to the east were separated from the Mumbai Island by the Mahim and Mahul creeks respectively. The Madh and Gorai Islands in the west were separated from the Salsette Island by the Malad and Manori Creek separated from the Salsette Island by the Malad and Manori Creek.

The Mumbai Island has ridges along its western and eastern sides running north–south, with broad intervening lowlands between the ridges. The eastern ridge exposes amygdaloidal basalt which in places is albitized and shows pillow structures, red ash, breccia, trachyte, rhyolite and green, black or brown stratified ash. Red ash breccias are lateritized at some places. On the other hand, the Western ridge mainly consists of stratified, coarse-grained acid tuff, stratified yellow–brown ash, massive lava flow of andesitic composition and columnar joints. Intertrappeans on Mumbai Island, especially at Worli Hill, have high yield of many fossil animals and plants (*Buist 1857; Carter 1857; Owen 1847; Williams 1953; Sukeshwala 1953)*.

The Salsette Island has a broad range of hills extending north–south along its center. The hills give way to tidal swamps towards the east and north-west and to a wide plain with a few hillocks towards the west. Amygdaloidal basalts occupy most of the eastern part of the island. The basalt of Gilbert Hill at Andheri has a prominent place in Mumbai geology on account of its spectacular columnar jointing. The rhyolitic flows outcrop in many areas. The basalts are intruded by sills and dykes of olivine, dolerite and trachyte

The Trombay Island is separated from Mumbai and Salsette Island by extensive tidal flats. The Trombay Island has pahoehoe type basaltic flows with dykes of andesite and dolerite. Most of the island consists of amygdaloidal basalts and mafic pyroclastic rocks dipping 7–12°W.

Figure 5. 42: Mumbai At Different Periods. It Was Created By Amalgamation Of Seven Different Islands



5.5.2 Physical Condition and Drainage

5.5.2.1 Macro Level Geomorphology

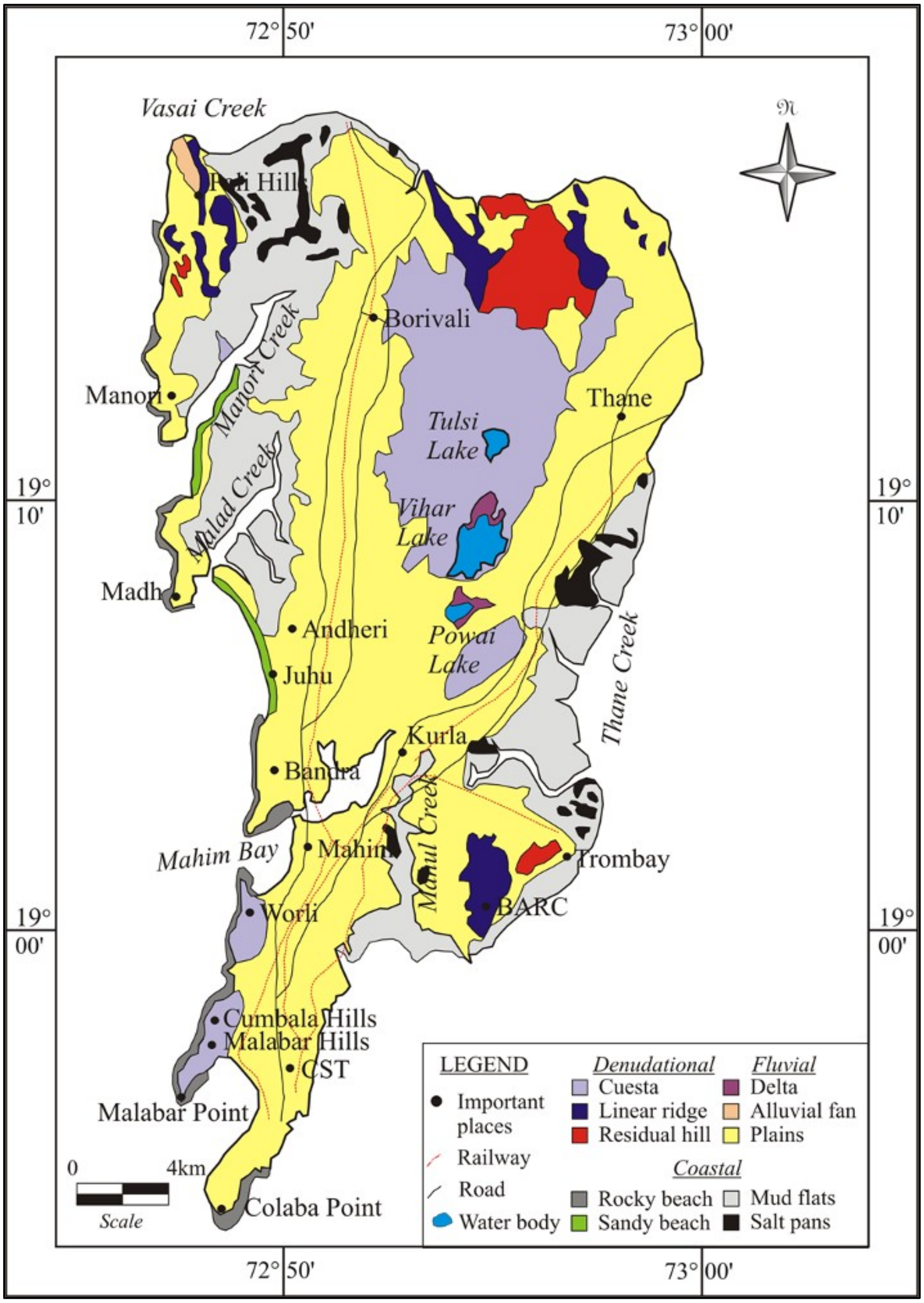
The Mumbai region is characterized by considerable variation in the lithological units of the Deccan Traps. This has resulted in different degrees of resistance to natural and artificial stresses (Shah and Parthasarathy,1982). Structural features such as joints, shear zones and intrusions have also affected the morphological setup of the entire Mumbai region. These effects are clearly reflected in the coastal geomorphology and in the naturally distinct land units of the region.

The landforms present in the study area are carved out by a combination of fluvial, denudational and marine processes (Figure 5.43). On the basis of different geomorphic features, the area has been divided into three distinct geomorphic land units and categorized as: (1) denudational, (2) fluvial and (3) coastal landform.

Denudational landforms are formed as a result of active processes of weathering, mass wasting and erosion due to the action of exogenic agents upon the exposed rocks. During these processes, the rocks on the land surface are worn away and the result is an overall lowering of the land surface. Cuesta, simple slope, residual hill and linear ridges are the different landforms of denudational origin. Cuestas are landforms with gentle dip slope on one side and an escarpment on other. Most of the hills of the Borivali National Park, Cumbala Hill and Malabar Hill are good examples of cuestas. Landforms with simple slope are produced by the wasting action of streams. This feature is seen in the north of the study area and in the Trombay region. Residual Hills are the end products of the process of peneplanation that reduces original mountain masses into a series of scattered knolls standing on the peneplain (Thornbury, 1990). These hills are seen in north of Gorai. Linear ridges are long hills or crests of land that stretch in a straight line. Such ridges may indicate the presence of some structural control. This structural feature affects very young and transient features, offsetting streams, fans and ridge spur. In the study area, this feature occurs in Trombay and in the northern part of Borivali National Park.

Fluvial landforms in the study area are developed due to the deposition of sediments carried by streams whenever its velocity is appreciably checked. Alluvial plains, alluvial fans and deltaic plains are the different fluvial landforms seen in the study area. Alluvial plains are stream deposited features and are relatively flat areas composed of alluvium. Extensive alluvial plains are confined to the area between the seacoast and hilly regions of Borivali National Park. They have also developed around the Mumbra–Belapur Hill ranges.

Figure 5. 43: Geomorphology Map Of Mumbai. The Landforms Are Carved Out By A Combination Of Fluvial, Denudational And Marine Processes



They are formed by the deposition of the six small rivers flowing out of the Borivali National Park towards west. Minor alluvial flood plains on the east of Borivali National Park are formed as a result of material brought out by the Ulhas River and also by the numerous small streams flowing down the Ghatkopar–Thane escarpment. Alluvial fans are the result of the deposition of the materials carried by streams and are formed on foot hill regions. Sediments are deposited due to change in depth and velocity in the foothill region. Alluvial fans occur on the foothills of Pali, on the northern part of Mumbai Island and are the only location where this feature is noted. Deltaic plains are formed where streams and rivers carrying an abundant supply of sediment enter a still body of water lacking extensive wave and current scour. The flow velocity is retarded and deposition occurs. Vihar and Powai Lakes exhibit this feature. These deltas are exposed only during summer months.

Coastal landforms are produced by the action of waves and tides. Marine waters erode the rock at the shore and this continued marine erosion results in considerable modifications of shoreline. Coastal landforms are common in the study area and include mudflats, salt pans, sandy and rocky beaches. Mudflats (also known as tidal flats), are covered by permanent and/or temporary salt water, and occur in the lowland area. Twice a day, water flows in and out with the tides, filling or draining the flats. Mudflats receive nutrients from the tidal flow from the nearby marsh, particularly when the vegetation in these marshes decays.

Mudflats thus have a rich plant and animal life. Mudflats are mainly seen around Thane, Manori and Malad. The widest mudflats occur around Thane Creek and support mangrove vegetation. Within the mudflats and beside the creeks, salt pans are observed. Salt pans here are artificial dry lakes that appear during summer season. They are ubiquitous in the study area and form the landforms of least relative relief. They are formed over a period of years and are found very close to coastal areas. The longer the water remains stagnant, the more concentrated minerals and salts contained in the water become. However, once the water evaporates fully, only the minerals and salts remain, forming a hard cracked surface. In the study area, it occurs in patches beside creeks. Beaches are loose unconsolidated deposits made by marine action near the shore. The lower margins of a beach are commonly beneath the waves whereas the upper margin is a few meters above the still area. Both sandy and rocky beaches are seen in the western coastal tract of the study area. Usually rocky beaches occur along the base of sea cliffs. They show a gradual change to sandy beaches. The most prominent ones are seen at Malabar hill and small patches occur along Bandra, Aksa and Gorai. Extensive sandy beaches are seen along the western shore of Mumbai, the most noticeable ones being the Worli-Bandra, Juhu, Aksa, Gorai and Uthan. At Madh, large patches of rocky exposures are seen. These sandy and rocky beaches occur as linear features enclosing the land and protecting it from further marine attack. Slope has direct control on surficial hydrologic phenomena such as runoff and infiltration.

Areas with steep slope experience high runoff and less infiltration and hence there is less chance of recharge and vice versa. Contour map of the study area was categorized into five groups(Rani 2004):

- Very low (5°): This corresponds to flat areas typical of erosional landscapes. In the study area, most of the area is occupied by pediments.

- Low (5°–15°): this area is almost plain and built-up as well as agricultural land occupies large parts of this area.
- Moderate (15°–30°): landscape that is neither plain nor steep.
- Steep (30°– 45°): this class can be considered to be uneconomic and requires special measures for cultivation
- Very steep (45°): areas which are mainly occupied by structural hills mainly escarpments.
- Alluvial fans are seen near foot hills and groundwater prospect in these units is moderate to good.

5.5.3 General Geology And Stratigraphy

Geology of Mumbai refers to the geology of the city of the island city of Mumbai. Back Bay and Bandra reclamation are the major reclamation areas of Mumbai in the Arabian sea. The predominant soil cover in Mumbai city is sandy, whereas in the suburban district, the soil cover is alluvial and loamy. The top layer is underlain by layers of rocks of igneous or sedimentary origin.

5.5.4 Sub-Surface Investigations

5.5.4.1 Location Of The Bore holes

A detailed soil invetigations consisting of 23 boreholes were carried out in the waterway. The bore hole locations are chosen based on the importance of the structures and/or to ascertain the dredgeability of the soil. The bore hole locations are marked in the Hydrographic Chart no GW-CBS-075-BA-01 to GW-CBS-075-BA-08. The geographical location is also indicated in the descriptions under the respective terminals. The detailed geotechnical study report is enclosed as Annexure F to this report. Excerpts from the report is given below for providing prespective and for better understanding.

5.5.4.2 Equipment

Sub-surface investigation was carried out in the water area by mobilizing marine spread of 7.5 m x 6 m size suitable anchored at the site, and centered at the location by using ‘Leica 420’ DGPS (direct Geographical Positioning System).

Two to three bore holes at each terminal locations were drilled and the results analysed, based on the site condition, for the soil profiling, laboratory tests to determine the soil characteristics

5.5.4.3 Boring In Soil

Boring was carried out in accordance with IS: 1892 -1979. A Shell and Auger rig was used for boring in the overburden strata (soil strata) with 150mm dia. boreholes. A standard shell and auger rig consists of a drum with rotating wheel where the wire rope was released and tight and one end is through pulley mounted on the tripod. Other end of the wire rope was fixed with sinker bar and shell to bore in the soil. Percussion method was used for boring in the overburden. The rig deployed was generally suitable for all Geotechnical Investigation work and had an arrangement for driving and extraction of casing, boring with percussion method. The boring was terminated and rock coring was commenced when SPT (N) >100.

5.5.4.4 Drilling In Rock

Once the Hard stratum or rock surface is encountered the size of the bore hole was reduced to NX size (76mm). Top of the rock surface was confirmed, either by the refusal from standard penetration test N value or through chiselling. In this rock stratum borehole was advanced by continuous rotary drilling technique using NX size Double Tube Core Barrel fitted with Diamond studded bits at its bottom.

The work was carried out as per IS: 6926-1973. The maximum length of the drill (run) was maintained as 1.50m or less as per the strata encountered. At the end of each run the drill rod string with core barrel was extracted from the bore hole and core was recovered from the core barrel. Recovered rock cores were numbered and labelled serially and carefully transferred to in good quality, sturdy, wooden core boxes and preserved. The core recovery percentage was recorded. Total Core Recovery percentage = {T.C.R. % = (Length of Core / Length of run) x 100}. Rock Quality Designation (RQD) was also recorded. Rock Quality.

Designation (RQD) = (Total Length of core pieces of 100mm & above in Length / length of run) x 100}. Solid Core Recovery (SCR) = (Total Length of core pieces of full diameter in Length / length of run) x 100}. TCR, SCR and RQD were computed for every drilled run based on the length of cores retrieved.

5.5.4.5 Standard Penetration Tests (SPT)

SPT's were carried out using a split spoon sampler complete with a drive shoe and drive head fitted with a non-return valve. The basis of the test consists of dropping a hammer of mass 63.5 kg (623N) on to a drive head from a height of 750 mm (as specified in I.S. Code of Practice). An auto trip hammer capable of dropping the weight freely on the anvil over a fixed height of 750 mm was used to assure the quality of the test. The number of such blows (SPT "N") necessary to achieve a penetration of the split spoon sampler of 300mm (after its penetration under gravity and below the seating drive) is regarded as the penetration resistance. The blow counts for each 150 mm penetration were recorded. Small disturbed samples were obtained from the split spoon sampler after completion of the tests.

5.5.4.6 Undisturbed Soil Samples

Undisturbed Soil Samples were collected in cohesive soil using thin walled Shelby tubes having nominal diameter of 100mm and minimum length of 450 mm.

5.5.4.7 Disturbed Soil Samples

Disturbed soil samples were collected from the bailer of the percussion boring.

5.5.4.8 Laboratory Test

Selected soil samples, collected during boring/drilling of boreholes were subjected to laboratory tests to determine the index and engineering characteristics as specified. The samples to be tested, type and number of laboratory tests to be carried out were decided so as to derive the maximum relevant information. Disturbed samples in SPT split spoons were collected from the boreholes. The soil samples were visually identified and described in accordance with relevant IS codes and thereafter packed, labelled, sealed and dispatched to the laboratory. The classification, index property, NMC, specific gravity, density and chemical tests were carried out on the soil samples and index properties and strength tests were carried out on rock specimen.

All these tests were carried out in accordance with relevant parts of Indian Standard Code of Practice. The list of IS and BS codes used is presented in Table 5.1 below.

The summary of the laboratory test results is presented on Appendix- B to the detailed report in Annexure F, in plates B1 through B2. A brief discussion on the laboratory tests conducted is presented in the following sections.

Table 5. 3: Applicable Codes For Soil Test And Analysis

Test on Soil Smaples Test Designation	Quantity	Applicable Standards	Results Presented in
Sieve Analysis	4	IS:2720 (Part – 4)	Plates C1 thru C2
Hydrometer Analysis	1	IS:2720 (Part – 4)	Plates C1 thru C2
Specific garvity	1	IS:2720 (Part – 3)	Plates B1
Tests on Rock Samples			
Point Load Strength Index Test	4	IS 8764	Plate B2
Porosity, Unit Weight, Water Absorption	4	IS 13030	Plate B2

A. Particle Size Distribution

The particle size distribution was determined for a total of four (4) soil samples in accordance with the method described in IS:2720 (Part 4). Compliance with the Standard, with respect to minimum sample quantity is dependent on the maximum sample available from the field test. For example SPT samples, the quantity of soil available for testing is typically about 100g. This sample quantity is considered representative where grain sizes range up to 4.75mm (i.e. to coarse sand size). Where significant quantities of coarser particles are present, the particle size distribution obtained from such samples should be regarded as indicative only.

B. Sedimentation/ Hydrometer Analysis

Sedimentation analyses have been performed for a total of one (1) soil sample in accordance with the hydrometer method described in IS: 2720 (Part 4). The analysis provides an estimate of the particle size distribution for the fine fraction (<75µm) of a soil sample. The analysis is performed by monitoring the rate of settlement of soil particles initially suspended uniformly in distilled water. The rate of settlement, which is monitored by observing the change in fluid density with the hydrometer device, is theoretically related to the size of particles setting out of suspension.

C. Particle Density/Specific Gravity

The particle density was determined for one (1) sample in accordance with the small pycknometer method described in IS: 2720 (Part 3/Sec 1). Prior to testing, samples were ground down, if necessary, so as to pass the 2mm sieve.

D. Laboratory Tests on Rock Samples

Unit Weight & Specific Gravity of Rock specimen were determined for a total of four (4) rock samples by using saturation and buoyancy technique, in accordance with the methods of IS: 13030.

E. Point Load Index Test

The Point Load Index test is indirect test to determine the Uniaxial Compressive Strength of rock having l/d ratio less than 1.5. A total of four (4) tests were carried out in accordance with IS:8764

5.5.5 Geotechnical Results And Analysis

The sub surface conditions at the proposed locations of the various structures are investigated by drilling boreholes at respective Terminals as described in the following paragraphs.

The detailed analysis including the bore-logs, the laboratory test results and rock sample descriptions are given in the geotechnical report for the location attached separately as an Annexure D to this report. A brief summary of the methodology and the tests is given here for ready reference.

5.5.5.1 Vasai Terminal

A. Borehole Location

The area for the proposed jetty is investigated by drilling two (2) boreholes BH-02 and BH-03. These locations were identified based on the berthing Jetty location/orientation. The coordinates for the same is given in Table 5.3.

Table 5. 4: Bore Hole Locations Along Jetty

BH.NO	Grid Cooridnates		Geographical Coordinates	
	Easting (m)	Northing (m)	Latitude	Longitude
BH - 02	271 031.00	2 138 588.00	19°19'41.64"N	72°49'14.42"E
BH - 03	271 060.00	2 138 613.00	19°19'42.46"N	72°49'15.23"E

B. Surface Condition

The surface at the borehole locations is generally flat with levels varying between -9.20m CD to -9.40m CD.

C. Sub Surface Condition

The sub- surface stratigraphy is presented in Tabular form in table 5.4 below. The sub surface stratigraphy at the borehole locations is described in detail on the borehole records presented in detailed study report attached separately in Annexure F.

Table 5. 5: Description Of The Soils In The Boreholes

Sr. No.	Soil Description	Designate As	Strata Thickness Encountered (m)		
			Max	Min	Average
1.	Medium Dense SAND	Unit 1	3.00	0.50	1.75
2.	Weak BASALT	Unit 2	2.50	2.50	2.50

Table 5. 6: Generalized Sub-Soil Profile Along Jetty

BH. NO	R.L of S.B.L. w.r.t C.D	Depth Drilled Below SBL (m)	T.D. w.r.t C.D	Strata Thickness Encountered (m)	
				Unit 1	Unit 2
BH-02	-9.20	5.50	-14.70	3.00	2.50
BH-03	-9.40	3.00	-12.40	0.50	2.50

5.5.5.2 Mira Bhayander (Jasal Park) Terminal

A. Borehole Location

The borehole locations for the Mira Bhayander (Jasal Park) Terminal is given in table 5.6 below. In all three bore holes were drilled.

Table 5. 7: Bore Hole Locations Along Jetty

BH. NO	Grid coordinates		Geographical Coordinates	
	Easting (m)	Northing (m)	Latitude	Longitude
BH -01	274 897.00	2 137 390.00	19°19'4.25"N	72°51'27.16"E
BH -02	274 909.00	2 137 490.00	19°19'7.51"N	72°51'27.52"E
BH -03	274 857.00	2 137 390.00	19°19'7.72"N	72°51'25.74"E

B. Sub Surface Condition

The area for the proposed jetty is investigated by drilling three (3) boreholes BH-01 thru BH-03. The sub- surface stratigraphy is presented in Tabular form in tables given below. The sub surface stratigraphy at the borehole locations is described in detail on the borehole records presented on Annexure F.

Table 5. 8: Sub Surface Stratigraphy

Sr. No.	Soil Description	Designated As	Strata Thickness Encountered (m)		
			Max	Min	Average
1	Very Soft to Soft CLAY	Unit 1	9.00	7.50	8.00
2	Stiff CLAY	Unit 2	4.50	1.50	3.00
3	Medium Dense Silty SAND	Unit 3	1.50	1.50	1.50
4	Dense Gravels	Unit 4	6.00	1.50	3.75
5	Very Dense SAND	Unit 5	1.50	1.50	1.50
6	Stiff to Hard CLAY	Unit 6	3.00	3.00	3.00
7	Moderately Strong to Strong BASALT	Unit 7	3.00	2.00	2.50

Table 5. 9: Generalized Sub-Soil Profile Along Jetty

BH. NO	R.L of S.B.L. w.r.t C.D	Depth Drilled Below SBL (m)	T.D. w.r.t C.D	Strata Thickness Encountered (m)						
				Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
BH-01	-1.10	25.50	-26.60	9.00	1.50	1.50	6.00	1.50	3.00	3.00
BH-02	-5.20	14.00	-19.20	7.50	3.00		1.50			2.00
BH-03	-4.90	14.50	-19.40	7.50	4.50					2.50

5.5.5.3 Ghodbunder Terminal

A. Borehole Location

The borehole locations for the Ghodbunder Terminal is given in table 5.9 below. In all three bore holes were drilled.

Table 5. 10: Bore Hole Locations Along Jetty

BH. NO	Grid coordinates		Geographical Coordinates	
	Easting (m)	Northing (m)	Latitude	Longitude
BH -01	278 474.00	2 134 656.00	19°17'36.79"N	72°53' 30.79"E
BH -02	278 519.00	2 134 711.00	19°17'38.60"N	72°53' 32.31"E
BH -03	278 488.00	2 134 764.00	19°17'40.31"N	72°53' 31.23"E

B. Sub Surface Condition

The area for the proposed jetty is investigated by drilling three (3) boreholes BH-01 thru BH-03. The sub- surface stratigraphy is presented in Tabular form in table 5.9 given below. The sub surface stratigraphy at the borehole locations is described in detail on the borehole records presented on Annexure F.

Table 5. 11: Sub-Surface Stratigraphy

Sr. No.	Soil / Rock Description	Designated As	Strata Thickness Encountered (m)		
			Max.	Min	Average
1.	Very Soft to Soft CLAY	Unit 1	4.50	3.00	3.50
2.	Medium Dense to Very dense gravelly	Unit 2	3.00	1.50	2.00
3	Soft CLAY / Sandy CLAY	Unit 3	6.00	1.50	3.75
4	Stiff to Hard CLAY	Unit 4	5.20	3.00	4.10
5	Medium Dense to very gravelly dense	Unit 5	1.50	1.00	1.25
6	Very Weak BASALT	Unit 6	7.00	4.80	5.60

Table 5. 12: Generalized Sub-Soil Profile Along Jetty

BH. NO	R.L of S.B.L. w.r.t C.D	Depth Drilled Below SBL (m)	T.D. w.r.t C.D	Strata Thickness Encountered (m)					
				Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
BH-01	-6.50	18.50	-25.00	3.00	3.00	6.00		1.50	5.00
BH-02	-9.20	17.00	-26.20	4.50	1.50		3.00	1.00	7.00
BH-03	-8.90	16.00	-24.90	3.00	1.50	1.50	5.20		4.80

5.5.5.4 Nagla Bunder Terminal

A. Borehole Location

The borehole locations for the Nagla Bunder Terminal is given in table 5.12 below. In all three bore holes were drilled.

Table 5. 13: Bore Hole Locations Along Jetty

BH. NO	Grid coordinates		Geographical Coordinates	
	Easting (m)	Northing (m)	Latitude	Longitude
BH -01	284 304.00	2 134 665.00	19°17'39.36"N	72°56'50.42"E
BH -02	284 286.00	2 134 762.00	19°17'42.51"N	72°56'49.77"E
BH -03	284 333.00	2 134 811.00	19°17'44.12"N	72°56'51.36"E

B. Sub Surface Condition

The area for the proposed jetty is investigated by drilling three (3) boreholes BH-01 thru BH-03. The sub- surface stratigraphy is presented in Tabular form in table 5.13 given below. The sub surface stratigraphy at the borehole locations is described in detail on the borehole records presented on Annexure F.

Table 5. 14: Sub-Surface Stratigraphy

Sr. No.	Soil / Rock Description	Designated As	Strata Thickness Encountered		
			Max	Min	Average
1.	Local Deposit (filled up)	Unit 1	1.50	1.50	1.50
2.	Very Soft to Soft CLAY	Unit 1A	6.00	1.50	3.75
3	Loose to Medium Dense SAND with	Unit 2	3.00	3.00	3.00
4	Dense to Very Dense SAND with gravels	Unit 3	4.50	4.50	4.50
5	Stiff to Hard CLAY	Unit 4	5.50	3.00	4.25
6	Strong to Very Strong BASALT	Unit 5	2.50	2.50	2.50

Table 5. 15: Generalized Sub-Soil Profile Along Jetty

BH.NO	R.L of S.B.L. w.r.t C.D	Depth Drilled Below SBL (m)	T.D. w.r.t C.D	Strata Thickness Encountered (m)					
				Unit 1	Unit 1A	Unit 2	Unit 3	Unit 4	Unit 5
BH-01	-1.30	11.50	-12.80		6.00	3.00			2.50
BH-02	-7.40	11.50	-18.90	1.50	1.50	3.00		3.00	2.50
BH-03	-7.50	17.00	-24.50	1.50		3.00	4.50	5.50	2.50

5.5.5.5 Anjur Dive Terminal

A. Borehole Location

The borehole locations for the Anjur Dive Terminal is given in table 5.15 below. In all three bore holes were drilled.

Table 5. 16: Bore Hole Locations Along Jetty

BH. NO	Grid coordinates		Geographical Coordinates	
	Easting (m)	Northing (m)	Latitude	Longitude
BH -01	291 227.00	2 126 412.00	19°13'13.64"N	72°0'50.72"E
BH -02	291 144.00	2 126 324.00	19°13'10.74"N	73°0'47.92"E

B. Sub Surface Condition

The area for the proposed jetty is investigated by drilling two (2) boreholes BH-01 and BH-02. The sub- surface stratigraphy is presented in Tabular form in tables given below. The sub surface stratigraphy at the borehole locations is described in detail on the borehole records presented on Annexure F.

Table 5. 17: Sub-Surface Stratigraphy

Sr. No.	Soil / Rock Description	Designated As	Strata Thickness Encountered (m)		
			Max.	Min.	Average
1.	Very Dense Gravelly Sand / Gravels (filled up)	Unit 1	10.50	4.50	7.50
2.	Moderately Strong Basalt	Unit 2	2.00	2.00	2.00

Table 5. 18: Generalized Sub-Soil Profile Along Jetty

BH. NO	R.L of S.B.L. w.r.t C.D	Depth Drilled Below SBL (m)	T.D. w.r.t C.D	Strata Thickness Encountered (m)	
				Unit 1	Unit 2
BH-01	-0.50	12.50	-13.00	10.50	2.00
BH-02	-3.40	6.50	-9.90	4.50	2.00

5.5.5.6 Parsik Bunder Terminal

A. Borehole Location

The borehole locations for the Parsik Bunder Terminal is given in table 5.18 below. In all three bore holes were drilled.

Table 5. 19: Bore Hole Locations Along Jetty

BH. NO	Grid coordinates		Geographical Coordinates	
	Easting (m)	Northing (m)	Latitude	Longitude
BH -01	291 240.00	2 125 670.00	19°12'49.52"N	72°0'51.46"E
BH -02	291 313.00	2 125 762.00	19°12'52.53"N	72°0'53.92"E
BH -03	291 275.00	2 125 819.00	19°12'54.37"N	72°0'52.60"E

B. Sub Surface Condition

The area for the proposed jetty is investigated by drilling two (2) boreholes BH-01 and BH-02. The sub- surface stratigraphy is presented in Tabular form in table 5.19 given below. The sub surface stratigraphy at the borehole locations is described in detail on the borehole records presented on Annexure F.

Table 5. 20: Sub-Surface Stratigraphy

Sr. No.	Soil / Rock Description	Designated As	Strata Thickness Encountered (m)		
			Max.	Min.	Average
1.	Sand / Gravels (filled up)	Unit 1	0.50	0.50	0.50
2.	Very Weak to Weak Basalt	Unit 2	2.50	1.50	1.83
3	Moderately Strong Basalt	Unit 3	1.00	1.00	1.00

Table 5. 21: Generalized Sub-Soil Profile Along Jetty

BH. NO	R.L of S.B.L. w.r.t C.D	Depth Drilled Below SBL (m)	T.D. w.r.t C.D	Strata Thickness Encountered (m)		
				Unit 1	Unit 2	Unit 3
BH-01	-0.70	3.00	-3.70	0.50	1.50	1.00
BH-02	-1.90	2.50	-4.40		2.50	
BH-03	-2.40	2.50	-4.90		1.50	1.00

5.5.5.7 Dombivli Terminal

A. Borehole Location

The borehole locations for the Dombivli Terminal is given in table 5.21 below. In all three bore holes were drilled.

Table 5. 22: Bore Hole Locations Along Jetty

BH. NO	Grid coordinates		Geographical Coordinates	
	Easting (m)	Northing (m)	Latitude	Longitude
BH -01	296 854.00	2 127 163.00	19°13'40.12"N	72°4'3.05"E
BH -02	296 811.00	2 127 237.00	19°13'42.51"N	72°4'1.55"E
BH -03	296 811.00	2 127 175.00	19°13'40.49"N	72°4'1.54"E

B. Sub Surface Condition

The area for the proposed jetty is investigated by drilling three (3) boreholes BH-01 thru BH-03. The sub- surface stratigraphy is presented in Tabular form in table 5.22 below.

The sub surface stratigraphy at the borehole locations is described in detail on the borehole records presented on Annexure F.

Table 5. 23: Sub-Surface Stratigraphy

Sr. No.	Soil / Rock Description	Designated As	Strata Thickness Encountered (m)		
			Max.	Min.	Average
1.	Very Soft CLAY	Unit 1	3.00	3.00	3.00
2.	Gravelly Sand / Gravels	Unit 2	3.50	1.00	2.50
3	Moderately Strong to Strong Basalt	Unit 3	2.00	2.00	2.00

Table 5. 24: Generalized Sub-Soil Profile Along Jetty

BH. NO	R.L of S.B.L. w.r.t C.D	Depth Drilled Below SBL (m)	T.D. w.r.t C.D	Strata Thickness Encountered (m)		
				Unit 1	Unit 2	Unit 3
BH-01	-2.40	8.00	-10.40	3.00	3.00	2.00
BH-02	-11.30	3.00	-14.30		1.00	2.00
BH-03	-10.30	5.50	-15.80		3.50	2.00

5.5.5.8 Navigation Channel Between Kalyan And Dombivli Terminal

A. Borehole Location

The shallow area with rock outcrop in the Ulhas river between Kalyan and Dombivili was investigated by drilling one (1) borehole as given in Table 5.24.

Table 5. 25: Bore Hole Locations Along Jetty

BH. NO	Grid coordinates		Geographical Coordinates	
	Easting (m)	Northing (m)	Latitude	Longitude
BH -01	301 155.00	2 127 787.00	19°14'1.95"N	73°6'30.05"E

B. Surface Condition

The surface level at the borehole location is -1.70m CD

C. Sub Surface Condition

The sub surface stratigraphy comprises of rock (Basalt) from the top. The rock encountered was moderately string to strong with Rock Quality Designation (RQD)varying between Nil to 37%. The sub surface stratigraphy at the borehole location is described in detail on the borehole records presented on Annexure F.

D. Dredgeability

Dregeability is defined as the ease with which the material can be dredge. The channel location is investigated by drilling BH-01. The subsurface stratigraphy as revealed from the soil investigations shows that at the investigated location rock is encountered from top with TCR varying between 66% to 81% and RQD varying between Nil to 37%. The Uniaxial Compressive Strength of the rock varies between 21.0 MPa to 58.0 MPa and as per Indian Standard Code “IS4464:1985” the rock is classified as Moderately Strong to Strong and based on the geological assessment the rock is slightly weathered. Rock controlled blasting technique is to be employed to remove/dredge the said rock.

5.5.5.9 Kalyan Terminal

A. Borehole Location

The borehole locations for the Kalyan Terminal is given in table 5.25 below.

Table 5. 26: Bore Hole Locations Along Jetty

BH. NO	Grid coordinates		Geographical Coordinates	
	Easting (m)	Northing (m)	Latitude	Longitude
BH -01	302 066.00	2 128 946.00	19°14'39.95"N	73°7'0.80"E
BH -02	302 048.00	2 128 885.00	19°14'37.96"N	73°7'0.21"E
BH -03	302 085.00	2 128 912.00	19°14'38.86"N	73°7'1.47"E

B. Sub Surface Condition

The area for the proposed jetty is investigated by drilling three (3) boreholes BH-01 thru BH-03. The sub- surface stratigraphy is presented in Tabular form in table 5.26 below.

The sub surface stratigraphy at the borehole locations is described in detail on the borehole records presented on Annexure F.

Table 5. 27: Sub-Surface Stratigraphy

Sr. No.	Soil / Rock Description	Designated As	Strata Thickness Encountered (m)		
			Max.	Min.	Average
1.	Gravelly Sand / Gravels	Unit 1	7.00	1.50	4.50
2.	Moderately Strong to Strong Basalt	Unit 2	2.00	2.00	2.00

Table 5. 28: Generalized Sub-Soil Profile Along Jetty

BH. NO	R.L of S.B.L. w.r.t C.D	Depth Drilled Below SBL (m)	T.D. w.r.t C.D	Strata Thickness Encountered (m)	
				Unit 1	Unit 2
BH-01	-5.20	7.00	-12.20	5.00	2.00
BH-02	-7.90	3.50	-11.40	1.50	2.00
BH-03	-1.70	9.00	-10.70	7.00	2.00

5.6 Terminal Infrastructure Including Equipment

5.6.1 Infrastructure Requirements

The Infrastructure requirements for the terminals are required to be identified before setting on the quantification. Terminals in India are in the primitive stage and in order to enable people to have a modal shift, better facilities than that is available in the existing modes are almost certain necessity. In this context the passenger terminals over the world would be referred but the requirements for the present facility would be replicating the local need.

In this context the example of Goa would prove a point. Most of the areas of Goa, particularly the tourist spots are connected by an efficient transportation network. Apart from roads, one can also take water route to travel from one destination to another in Goa.

Boats and ferries in Goa are important means of internal transportation. Flat bottomed ferry boats form a part of Goa as her marine beauty, the ferries of Goa provide an essential means of transport connecting different regions of the state. Ferry service in Goa act as a lifeline connecting various regions where bridges are yet to be built over the coastal backwaters. These boats and ferries take in almost everyone and everything, like local fisherwomen carrying their ware to smart foreigners, motorbikes, cars, cattle and other heavy items from one place to another.

Various small villages surrounding the coast of Goa are connected by ferry. For tourists, it is a unique experience to travel by ferry, but for locals it is a day to day affair. There are places where one cannot reach without crossing the sea, for such destinations ferry is the only option. Ferries are cheap and the easiest means to reach the countryside of Goa. The ferry services in Goa are regular and affordable and thus they have become the backbone of water transport in Goa. In addition, these terminals are well connected by buses, taxis and other modes for seamless transfer.

Study of the other similar facilities elsewhere in the world indicates three categories of requirements, to be implemented based on the need and the demand. They are;

1. Basic Requirements
2. Necessary Requirements
3. Desirable Requirements

The present waterway project is rather short and confined to a less than 50 km stretch. The location of the waterway in the close proximity of the well-developed population centers also alters the general requirements. For example, an isolated terminal in the middle of 'nowhere' will have a completely different requirement than that of a terminal in a middle of a city. The current waterway passes through a semi-urban area.

In addition to the location the second aspect which determines the requirements are the vision of development for the waterway, meaning thereby that whether the waterway would be only for passenger service, or mixed with water sports and tourism. In addition, the future requirements of cargo movements if any, is also to be factored in the scalable design.
With this back ground the terminal requirements for passenger service in a semi-urban area is described in the following paragraphs.

5.6.2 Basic Requirements

The basic requirements for this passenger ferry service and tourism development is as follows.

5.6.2.1 Road Access

The last mile connectivity is often times the nemesis for the waterway transport. The success or failure of the waterway mode hinges on two vital requirements, namely, seamless connectivity to and from the terminal so that the passengers using the ferry service gets the last mile connectivity. Adequate connectivity only enhances the attraction of the mode.

The other requirement would be the regularity of the service provided. The regularity and timely service only increase the confidence of the people on the mode and would persuade them to change modes. This is only possible with regular and timely declared services. Therefore, adequate and unhindered terminal access of the passenger cars and commercial connectivity like busses is the pre-requisite for the terminal establishment and continued service.

5.6.2.2 Parking And Passenger Area

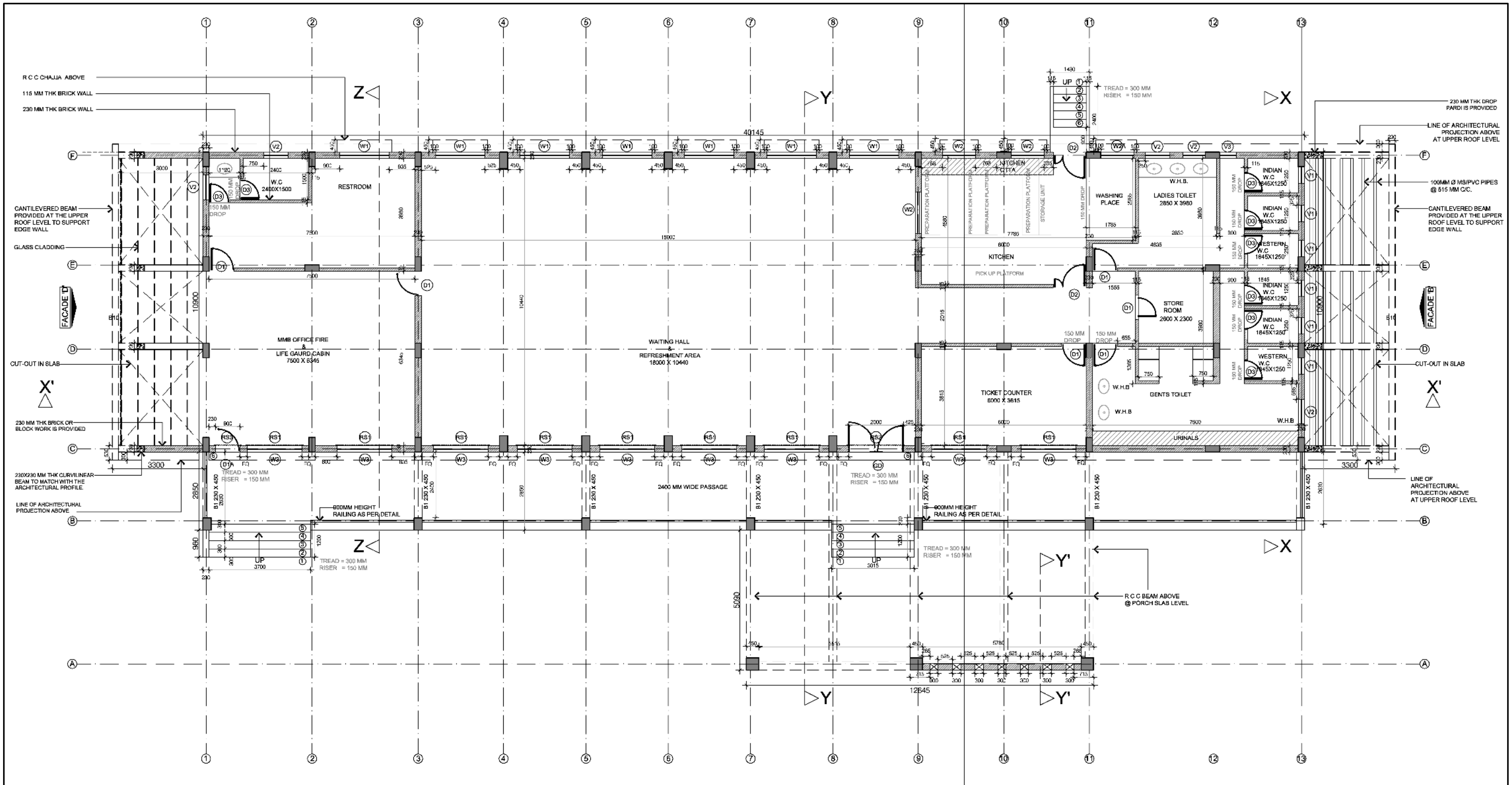
As is the norms in the other multi-modal transport systems, an assured connectivity to and from this mode is also essential. Hence, for people to avail the ferry service, their vehicles need parking facility as would the requirement of parking for the busses, taxis and other similar modes. The commercial vehicles also would need place for passenger waiting.

5.6.2.3 Terminal Building

A well-endowed terminal building with facilities as shown in Figure 5.44. The detailed plan and the facility layouts are given in Annexure E. Excerpts from the annexure E is given below for completeness and understanding. The facilities would include the following;

a. Office Facility
b. Fire/Life Guard Cabin
c. Fire Fighting Facilities
d. Waiting Area
e. Children's play area
f. Refreshment Area
g. Canteen and Kitchen area
h. Rest area
i. Wash Rooms
j. Infirmary
k. Ticketing Counter
l. Store Room

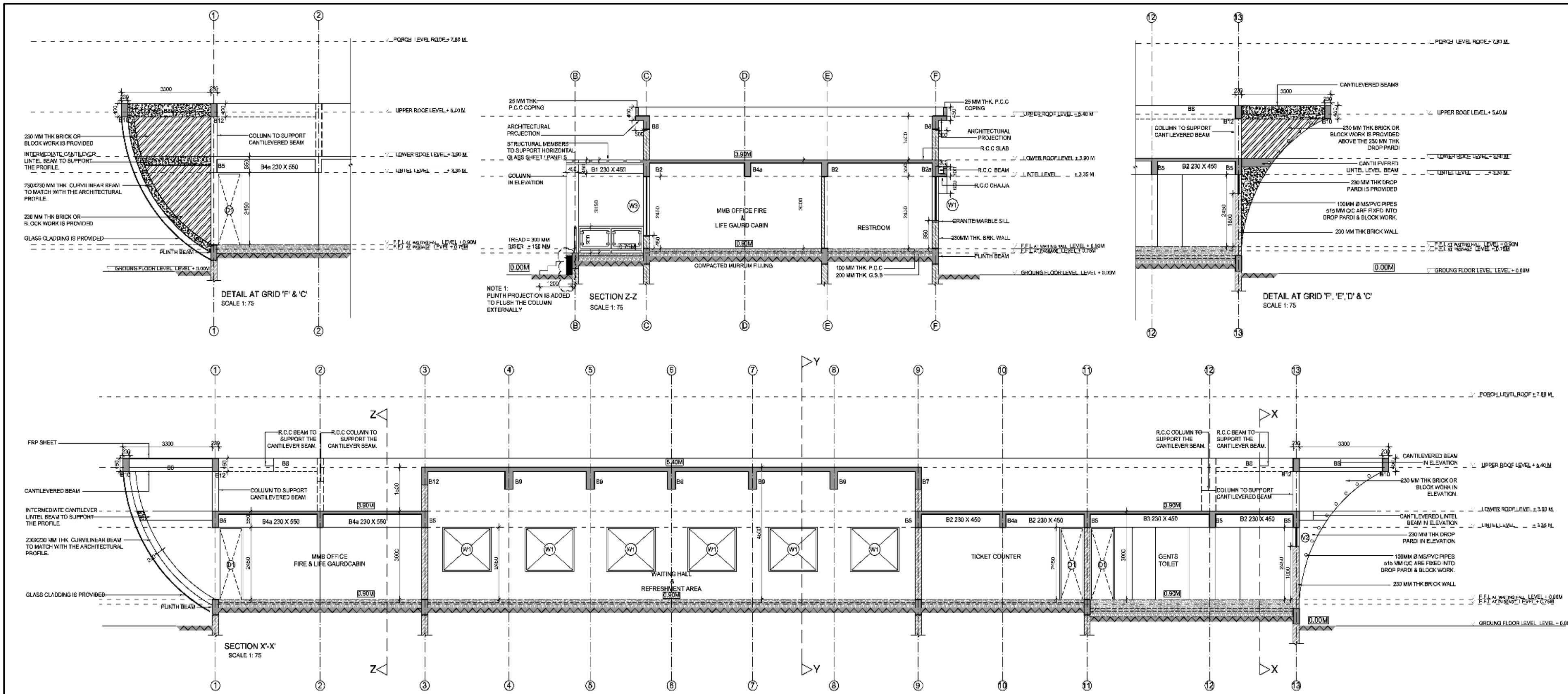
Figure 5. 44: Facilities In The Terminal Building (Plan) - Typical



Plan of the Terminal Building Facilities

The Elevation of the Terminal Building is shown in Figure 5.45.

Figure 5. 45: Facilities In The Terminal Building (Elevation) – Typical



Elevation of the Terminal Building

5.6.3 Necessery Requirements

Apart from the above facilities the other associated necessary facilities are,

1. Facilities for Fire Fighting
2. Shopping area
3. Parks and amusement centers etc.
4. Fueling Centre with facilities of
    a. Diesel/Ethanol
    b. Petrol
    c. LNG/CNG gas
    d. Electric Charging tation for Electrical Vehicles
5. Solar Power for the terminals and lighting
6. Boundary wall

5.6.4 Desirable Requirements

In the desirable requirement list the following could be added;

1. Restaurants
2. Water Park
3. Shopping Arcade
4. Hotels and Bars

Though the above is desirable in a fully developed inland water terminal, it will take a while for the proposed terminals to achieve the status. The European terminal are mostly qualifying this stage of development. All terminals must therefore plan in advance for future to acquire extra land from the beginning, so that the future expansion plans could be implemented in phases.

5.7 Berthing Structure

5.7.1 General Configuration

Berthing structures are meant for transferring goods, men and material from the water borne vessels to the land mode. Most of the time known as Jetty (when projected in to the sea) or Wharf (when along the shore and contiguous with the foreshore) these structures are designed for the following loads;

1. Berthing of Vessels
2. Dead of structures
3. Active earth pressure due to backfill soil
4. Dead load of the super imposed loads due to material and passengers
5. Load due to hydrodynamic forces and wave impact

6. Earthquake and wind forces etc.,

Broadly, these structures could be divided in to three broad categories, namely;

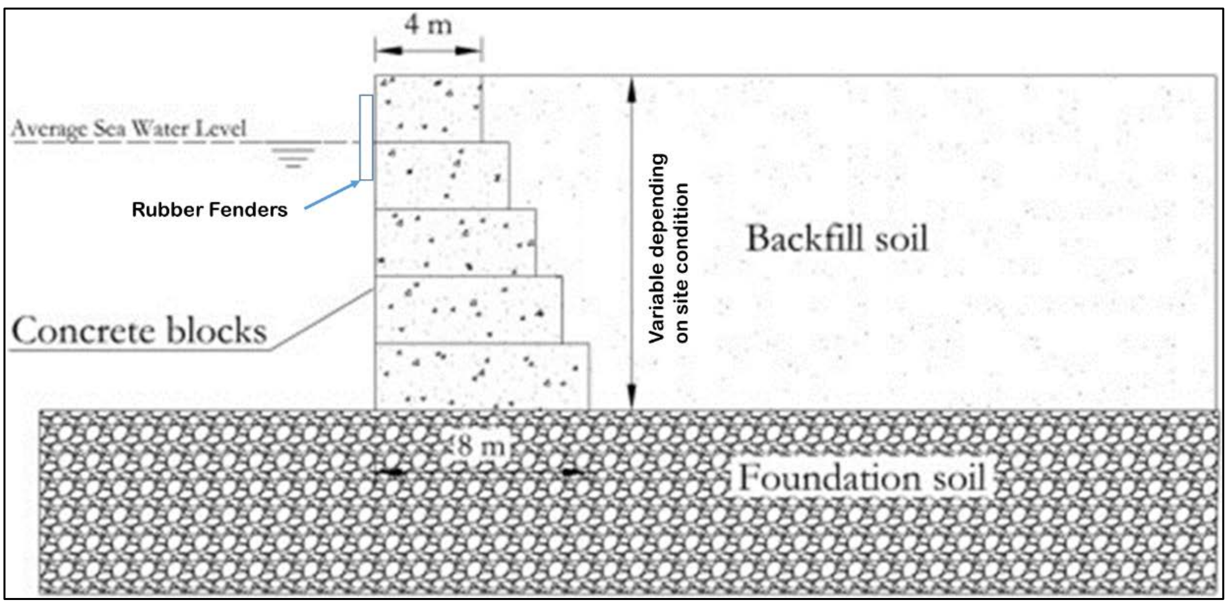
A. Wharfs
   a. Gravity Structures
   b. Sheet Piles/Diaphragm wall
B. Piled structures

A brief recount of each of them would be given in the following section, in order to Justify the type of structures adopted for this project.

5.7.1.1 Gravity Structures (Wharfs)

These structures are a type of wharf, designed to take the horizontal loads from the berthing (impact of vessels) energy of the approaching vessels by gravity, i.e. by the self-weight of the structures as indicated in the figure 5.46.

Figure 5. 46: Arrangements Of The Gravity Type Wharf - Typical



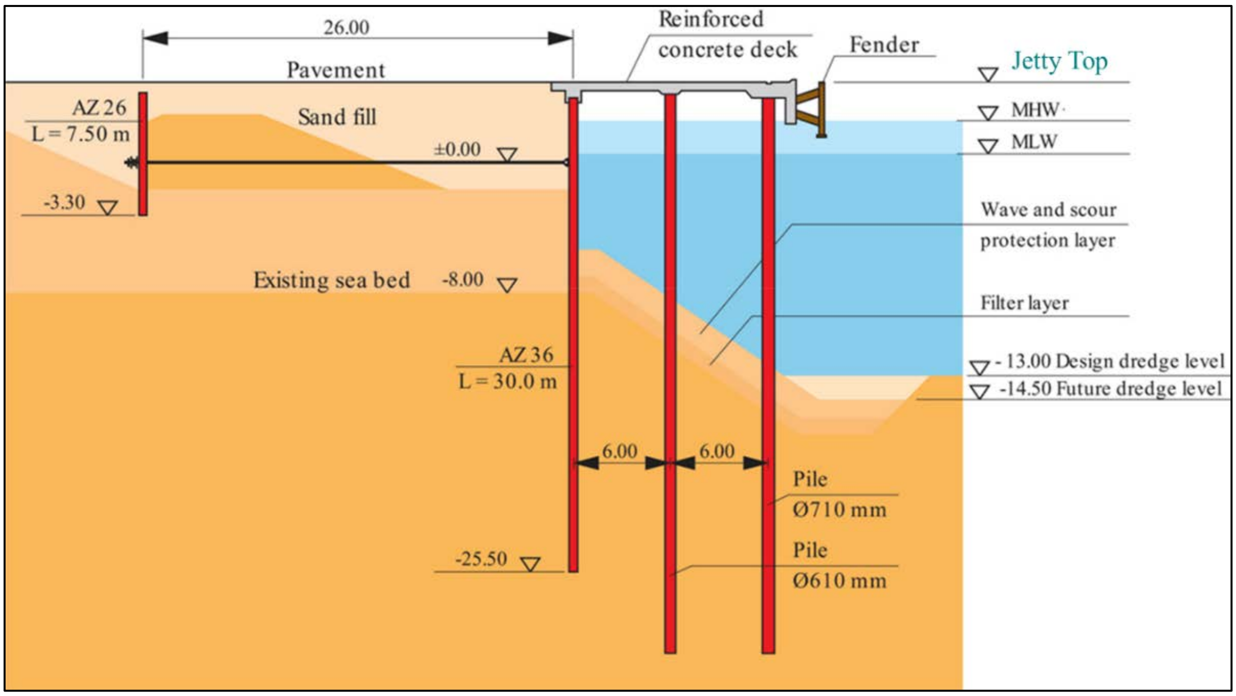
These structures equipped with rubber fenders on the face facilitates berthing of structures, the men and material can then use the continuous wharf to embark or disembark as the case may be. These wharfs are extensions of the foreshore and therefore offers the flexibility of storage just behind the loading area, thereby saving on the logistical costs.

5.7.1.2 Sheet Pile Wall / Diaphragm Wall (Wharfs)

These structures are types of wharfs which retains the back-fill soil by bending. These retaining structures form an interface between the deep water in the front of the Jetty and the back filled foreshore area. There are two types of materials which are used as interface, namely 1. Steel Piles and 2. Concrete diaphragm wall

These are thin elements driven in to the soil, so that the active earth pressure of the retained earth of the foreshore, is balanced by the passive resistance developed by the soil. Hence the length of insertion is generally dependent on the height of the Deck from the dredged level. More often than not, the depth pf penetration is reduced by adding tie rods as shown in Figure 5. 47 and 5.48 below.

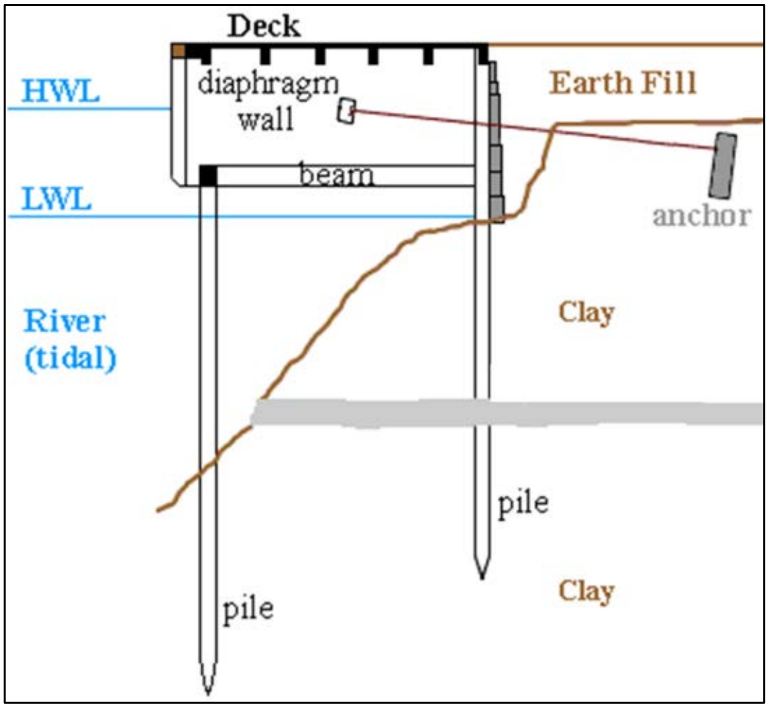
Figure 5. 47: Arrangements Of The Sheet Pile Wharf - Typical



The Sheet pile wharfs or the Diaphragm wall which are concrete walls generally installed cast-in-situ, are suitably reinforced to take the bending forces for balancing the active and the passive earth pressure.

The concrete diaphragm walls serve the same purpose as the steel sheet pile wall and behave in similar fashion. A typical Diaphragm wharf is shown in Figure 5.48.

Figure 5. 48: Arrangements Of The Diaphragm Wall Wharf - Typical



5.7.1.3 Pile Structures

The wharfs designed as an extension of the shoreline, is only possible if natural depths for the maneuvering of ships are available close to the shore. Often times it is not the case and dredging of the near shore areas are carried for creating depths artificially. Dredging is always associated with sedimentation and maintenance dredging, hence often times the jetties project in to the water so that the actual water depths without dredging is available.

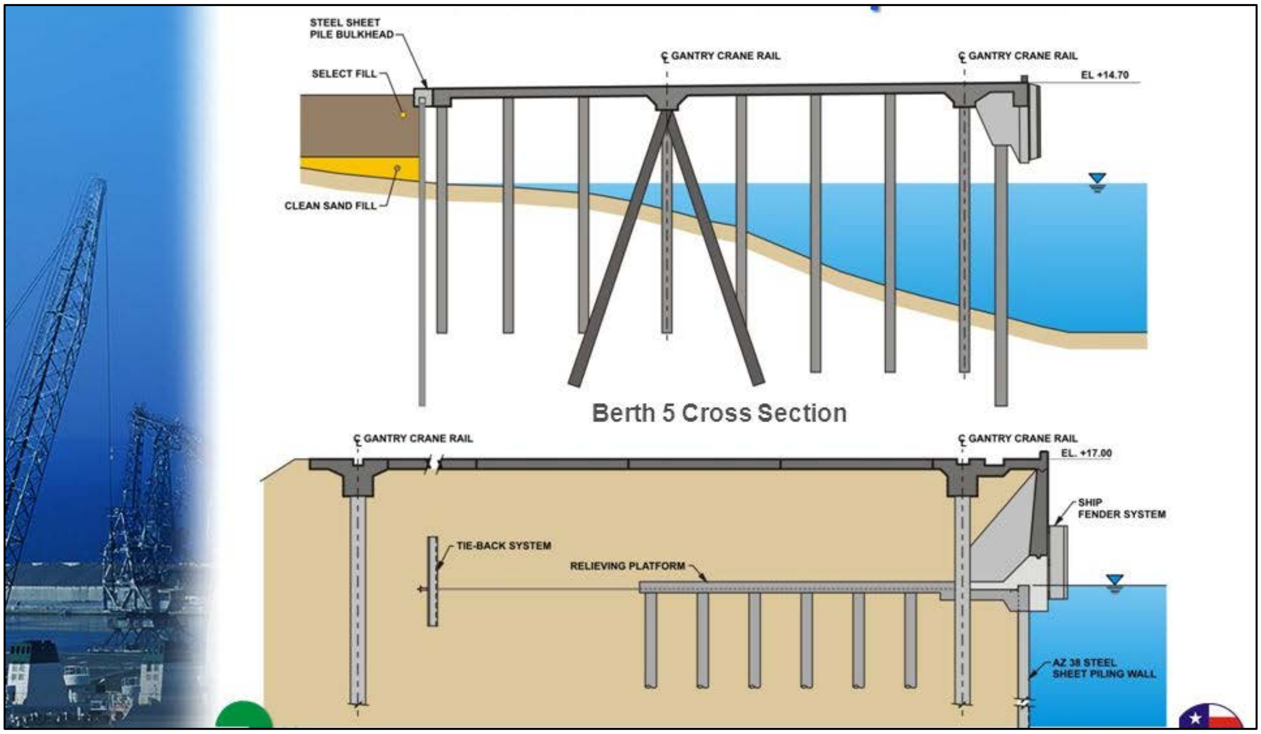
These structures are supported on piles and a concrete deck.

In the present proposal only, piles structures are considered for two main reasons,

1. Near shore depths are not adequate inside the creek
2. Being piled structures the interference with the local hydrodynamics is minimal

A typical working inland water terminal is shown in Figure 5.49 on piles.

Figure 5. 49: Arrangements Of The Piled Jetty - Typical



The detail design and drawings for the fore shore and the waterfront facilities are given in Annexure F.

5.8 Terminal Costing

5.8.1 Capital Cost

The Terminal cost for the various locations is given in Table 5.28.

Table 5. 29: Cost Estimate Of The Terminals

Sl. No.	Terminals	Structure Location		Total Cost
		Onshore	Offshore	
1	Vasai	113757831.00	237880747.05	351638578.05
2	Mira-bhayander	68288529.00	265181465.11	333469994.11
3	Ghodbunder	127205535.00	257719383.90	384924918.90
4	Nagla Bunder	60492032.00	255596869.49	316088901.49
5	Kolshet	309469405.00	314033523.81	623502928.81
6	Kalher	77667969.00	270323461.77	347991430.77
7	Parsik Bunder	80896329.00	234352952.88	315249281.88
8	Anjur Dive	53709430.00	260071925.00	313781355.00
9	Dombivili	42748919.00	239474824.98	282223743.98
10	Kalyan	117241345.00	229522477.83	346763822.83
				3615634955.83

The Estimates are inclusive of GST @12% and Contengencies @3%

5.8.2 O&M Cost

Table 5. 30: O & M Cost Of The Terminals

Sl.no	Details	Amount in Million ₹
1	Infrastructure at 1.5 %	54.23
2	Dredging	25.00
3	Erosion control	0.50
4	Navigation and Channel safety	154.00
5	Environment	21.50
6	Institutional (Terminal operations)	280.00
	Total	**535.23**

6 Preliminary Engineering Designs

6.1 Background

The waterway is proposed to develop in phases to provide an alternate mode of transportation (Inland Water Transport) bringing in reduced stress on the vehicular traffic by about 20% in the short term and effectuate fuel savings of about 33% per trip. This would entail development of a reliable and dependable transportation service. The reliability shall persuade the users to go for a modal shift and use the service with enthuse. In the terms of reference indicates the following routes and the Phases of development.

In the following sections, the design aspects of the waterway development including the river conservancy, bank protection, terminal development among other things shall be discussed.

6.2 River Training Works

The various types of river training works provided in the unidirectional as well as tidal affected rivers is described in the chapter 3. As described, there would be no requirement of high banks along the creek. The foreshore area except for certain locations like Vasai, are high enough to prevent any saltwater ingress.

The erosion areas along the river is limited and localized, hence it is recommended to have only local erosion control measures which are temporary in nature.
There are no other river training structures in the proposed waterway.

6.3 Passenger Terminals And River Ports

The Present scope of services include design of facilities for passenger and passenger ro-ro handling. There are 10 terminals as discussed in the previous chapter and each of the terminals are equipped to handle vessels of the designated size.
The facilities created would be predominantly for passengers and passenger vehicles. However, the facilities are equipped to handle ro-ro service as well, for which necessary design attributes are built in from the very beginning. The cargo services, when commences in ro-ro form could be easily handled at the facilities with virtually no alterations. For the present, the facilities would deal with passenger services alone, but are understood to be capable of cargo services as well.

The river terminals located at 10 locations would consists of following facilities,

6.3.1 Water Front Facilities

The offshore facilities consist of following elements at various terminals:

i. Mooring & Berthing Dolphins
ii. Floating Pontoon, Steel Link-span & Bank Seat.
iii. Pontoon Guide Pile & Guide Pile restraint structure.
iv. Access Jetty on Piles and Turning Platform.
v. Access Bund in Filling.
vi. Walkways connecting the dolphins

6.3.2 Onshore Facilities

The offshore facilities consist of following elements:

Buildings:

- Main Terminal
- Administration
- Roofed Area
- Pump and Underground Tank
- Security
- Substation
- Septic Tank
- STP
- Other Buildings

6.3.3 Design Data

The data used in design of offshore facilities is summarized in sections that follow.

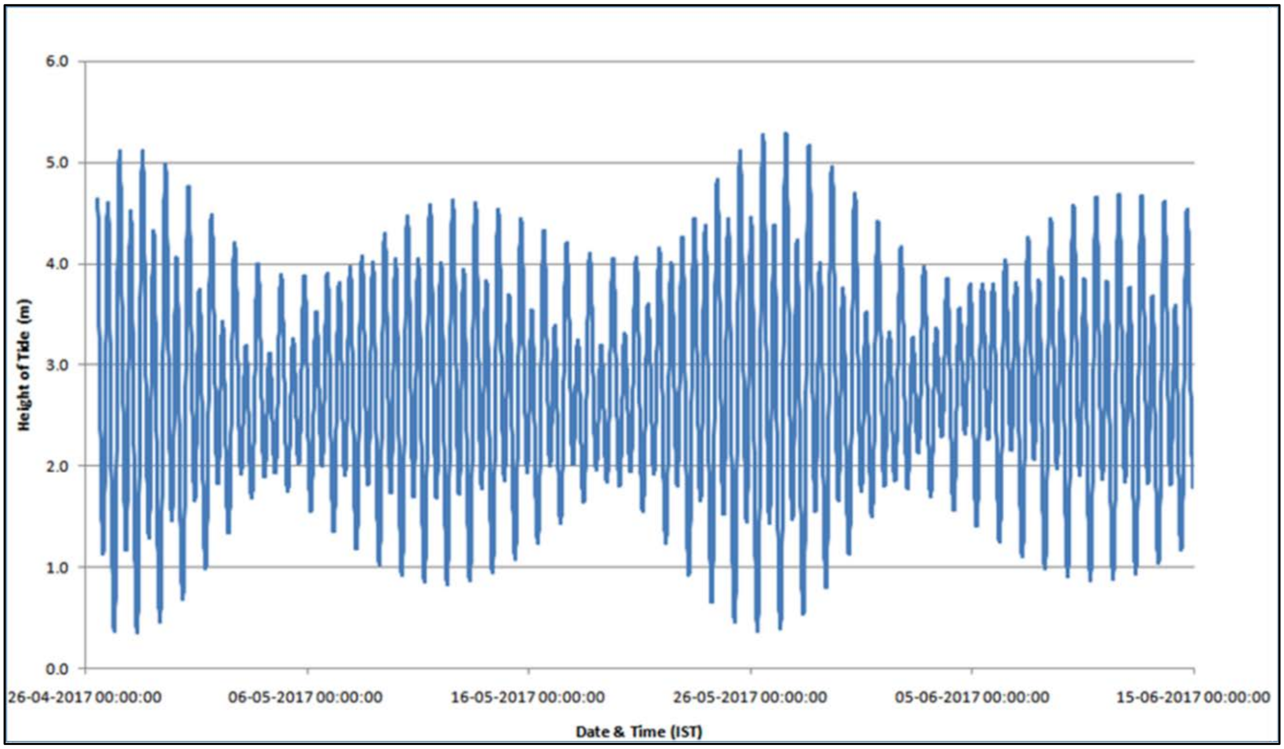
6.3.3.1 Site Specific Physical Data

A. Tidal Levels

The Tidal Level at the First Station at the Panju Island station, is given as under, the levels are derived from the Figure 6.1 below.

MHWS	5.45 m
MHWN	4.30 m
MSL	2.63 m
MLWN	1.85 m
MLWS	0.32 m

Figure 6. 1: Tidal Levels At Panju Island



The Tidal Level at the Gaimukh Station is given as under, the levels are derived from the Figure 6.2.

MHWS	5.25 m
MHWN	4.20 m
MSL	2.53 m
MLWN	2.05 m
MLWS	0.52 m

Figure 6. 2: Tidal Levels At Gaimukh

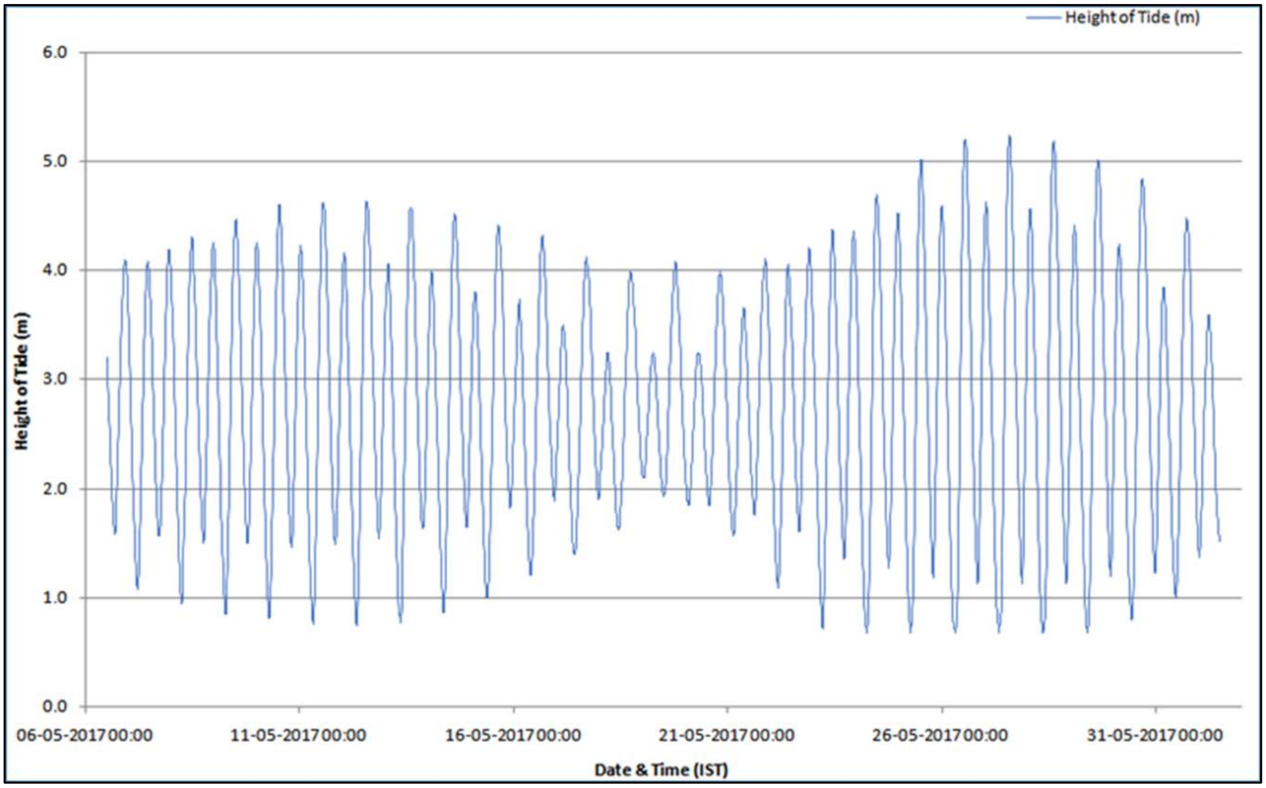


Figure 6. 3: Tidal Levels At Satpul

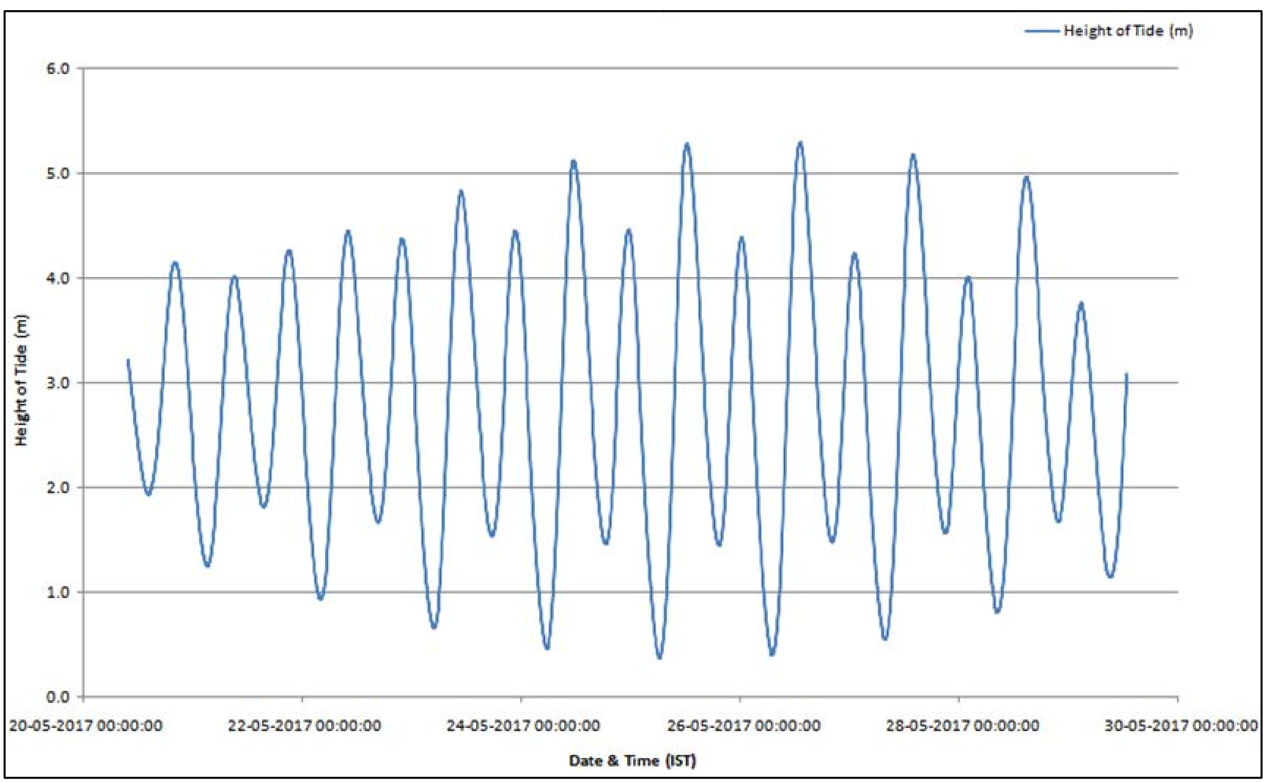
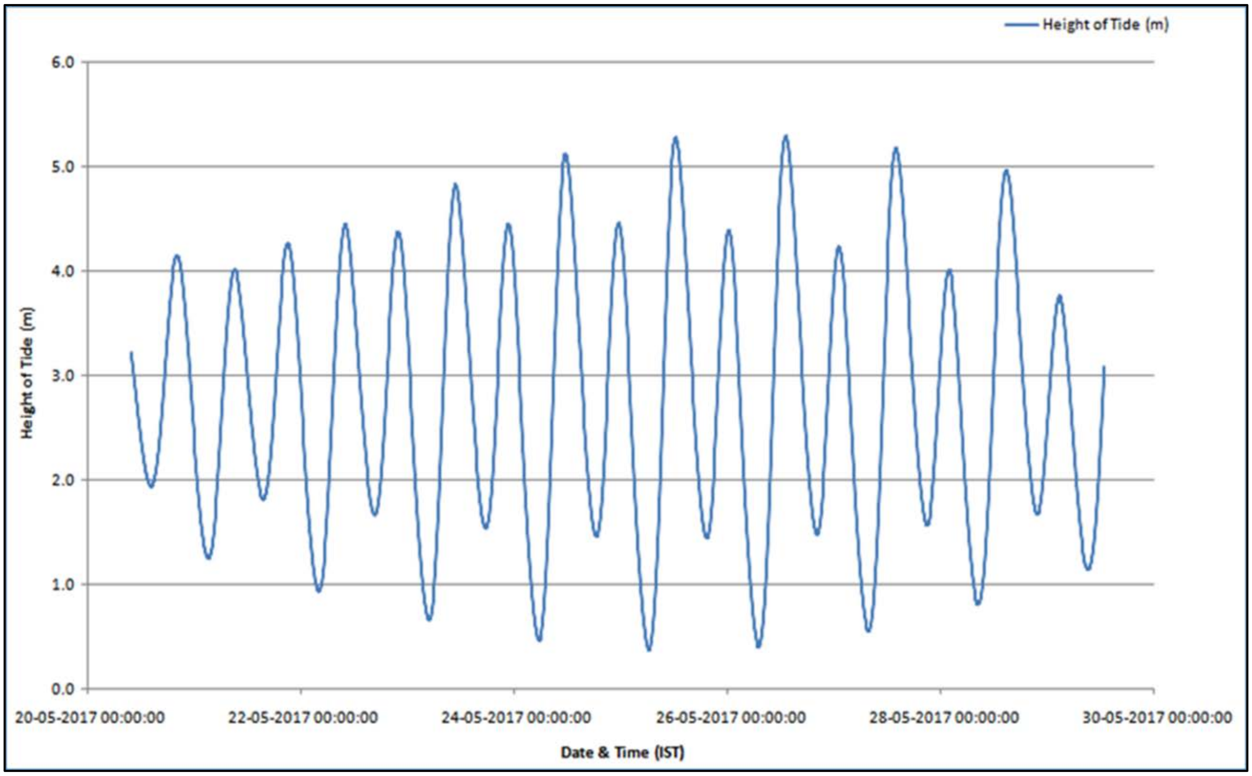


Figure 6. 4: Tidal Levels At Kalyan



B. Wind Data

The maximum wind speeds for design of the structural components like, the terminal buildings and water front structures would be designed for the survival condition wind speed as indicated in IS-875-Part 3 (2015). The floating and the other structures like marker buoys would be designed as per the data analysis carried out as part of mathematical model studies of the collected hind cast data.
Design wind speed for design of Onshore buildings will be as per IS-875-Part 3 (2015). For Thane region the design wind speed is 44 m/s. Wind forces for the approach jetty is computed as per IRC 6:2000.

C. Temperature

The effective structure temperature & loads due to temperature variation will be as per IRC 6-2000 clause 218.2. The temperature computation would be based on site data given in earlier chapter.

D. Wave

Table 6. 1: Wave Data Summary

Location	Significant Wave Height, Hs (m)			Direction corresponding to maximum Hs (deg)	Average Wave Period (s)
	Minimum	Maximum	Average		
Vasai	0.274	0.324	0.294	29.19	9.39
Panju Island	0.230	0.280	0.251	131.19	13.16
Gaimukh	0.167	0.220	0.190	28.21	16.74
Kasheli	0.145	0.198	0.169	141.71	18.97
Satpul	0.128	0.165	0.141	78.71	19.86
Kalyan	0.081	0.118	0.094	27.71	22.70

E. Currents

Table 6. 2: Current Data Summary

Location (ADCP Sl./No.)	Water Depth (m)	Observation Depths	Current Speed (m/s)			Direction of Current (max Speed) (deg.)	Average discharge (m^3/s)
			Maximum	Minimum	Average		
1. Vasai (18629)	3.6	Surface	2.026	0.003	1.092	239.1	43807.72
		Mid-Depth	1.781	0.025	0.98	232.2	
		Bottom	1.575	0.015	0.847	223.6	
2. Panju Island (18631)	3.9	Surface	1.51	0.039	0.755	143.2	9729.48
		Mid-Depth	1.47	0.013	0.801	141.8	
		Bottom	1.368	0.017	0.756	143.6	
3. Gaimukh (18629)	13.4	Surface	1.216	0.008	0.358	40.8	3008.52
		Mid-Depth	1.414	0.011	0.359	48.7	
		Bottom	1.246	0.013	0.264	43.1	
4. Kasheli (18631)	2.2	Surface	0.811	0.012	0.35	315.3	1660.2
		Mid-Depth	0.8	0.025	0.333	315.4	
		Bottom	0.713	0.012	0.314	307.8	
5. Satpul (16657)	8.5	Surface	0.781	0.012	0.465	59.4	1742.88
		Mid-Depth	0.816	0.025	0.454	59.3	
		Bottom	0.723	0.016	0.363	61.8	

Location (ADCP Sl./No.)	Water Depth (m)	Observation Depths	Current Speed (m/s)			Direction of Current (max Speed) (deg.)	Average discharge (m³/s)
			Maximum	Minimum	Average		
6. Kalyan (4852)	11.2	**Surface**	0.715	0.022	0.456	210.8	
		Mid-Depth	0.683	0.02	0.391	201.3	
		Bottom	0.726	0.006	0.312	22.2	

6.3.4 Design Loads

6.3.4.1 Dead Loads

The dead load shall consist of the weight of the structure including all permanent fixtures, surfacing, pipes, railings, fenders & fixed equipment.

The unit weight for main structural material will be as follows:
Reinforced concrete: 2500 kg/ m³
Structural steelwork: 7850 kg/m³.

The unit weight of other material will be as per relevant Indian standards and/or equipment supplier.

6.3.4.2 Live Loads

Table 6. 3: Live loads

ELEMENT	LIVE LOAD
Roads & Paved Areas	As per IS 4651-3.
Access Jetty Superstructure / Platform	As specified by IS 4651-3 or BS 5400-2 (HA Load) Or 20 kN / m² or as per IRC 6: 2000: One lane of class A occupying 2.3 m width & 500 kg/m² on remaining width of carriageway /70 R for every 2 lanes whichever governs.
Locations Accessible To Pedestrians & Light Plant	5 kN/ m².

ELEMENT	LIVE LOAD
Linkspan & Pontoon	The link-span & pontoon shall be designed for most onerous effects due to following: As specified by IS 4651-3 OR HA load as per BS 5400:2:2006. An average UDL of 20.0 kN/m^2 occupying the entire link-span is also considered as an extreme case.

6.3.4.3 Vessel Loads

The vessel loads are determined based on the maximum and minimum vessel sizes and berthing conditions. The determination of the maximum loads on the various parts of the structures would be as per IS 4651 Part III and other relevant and applicable codes pf practices like, BS and PIANC.

A. Berthing Loads

These three modes of berthing are illustrated in following figure 6.5.

As per the plan of the terminal the vessels will berth along the dolphins and butt with the pontoon (as per clause 4.7.6.1 of BS 6349-4). The condition (a) is ruled out for the present nomenclature of the berthing structure.

The berthing energy will be calculated corresponding to Navigation condition “Easy berthing, exposed.” as per clause 4.6 of BS 6349-4. for berthing mode 'b'.

Accordingly, a berthing velocity of 0.29 m/s is used for a vessel of 10000 DWT. Berthing loads using above values will be used for Dolphin structure & Fender Design for operating conditions.

For abnormal conditions, the loads will be designed as per the provisions of the British as well as the Indian Codes.

Figure 6. 5: Modes Of Berthing

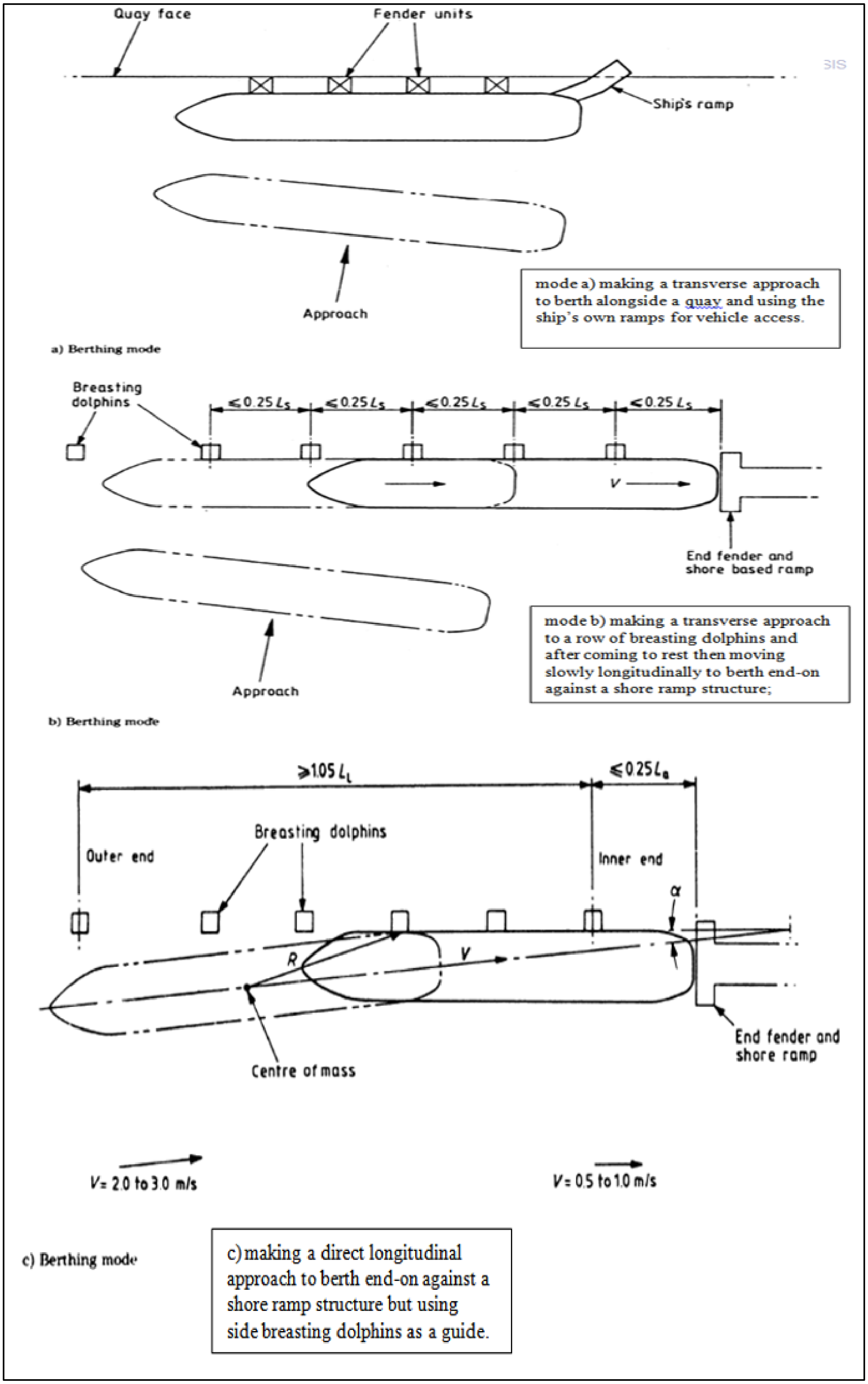


Table 6. 4: Berthing Energy Calculations

BERTHING ENERGY CALCULATIONS				
SHIP DATA				
Ship Category		Ro Ro Ferry		
Select Dimensions By		Displacement		
Deadweight	dwt	15,000	t	
Displacement	MD	10,500	t	
Overall Length	Loa	155.0	m	
Length Between Perpendiculars	LBP	144.0	m	
Beam	B	22.70	m	
Laden Draft	D	5.60	m	
Freeboard	F	3.50	m	
Block Coefficient	Cb	0.56		
BERTHING DATA				
Berthing Mode		Dolphin Berthing		
Structure Type		Open Structure		
Eccentricity Calculation Method		Simplified Calculation		
Under Keel Clearance	KD	5.00	m	
Impact from Bow	x	25.00	%	
		36.00	m	
Radius of Gyration	K	31.16	m	
Impact to Centre of Mass	R	37.75	m	
Berthing Angle	a	15.00	deg	

BERTHING ENERGY CALCULATIONS				
Velocity Vector Angle	F	90.00	deg	
Added Mass Coefficient	Cm	1.692		**Shigeru Ueda Method (1981)**
Eccentricity Coefficient	Ce	0.405		
Berth Configuration Coefficient	Cc	1.000		
Softness Coefficient	Cs	1.000		
BERTHING ENERGY				
Berthing Velocity	Vb	282	mm/s	
BS6349: Part 4: 1994: Fig 1 (Displacement v Velocity)				
	"c"	Easy berthing, exposed		
Normal Energy	EN	286	kN-m	
		29.2	t-m	
Factor of Safety	FS	1.50		
	EA	429	kN.m	
		43.7	t-m	

B. Mooring Loads

Clause no.42.2 of BS 6349-1 & clause no.10 of BS 6349-4 suggest nominal mooring loads to be used for vessels up to 20000 DWT with bollards provided at 15-30 m spacing.

Accordingly, as per table no.8 of BS 6349-1, 50 metric ton capacity bollards are specified at the rate of 2 bollards per dolphin –which is equivalent of one 50-ton capacity bollard per 15 m length.

The 50-ton bollard capacity is further validated by the breaking loads given in tables 9 & 10 of BS 6349-4 for Nylon ropes & Steel Wire Ropes. The requirement is 30 T.

Detailed mooring analysis will be performed at execution stage to confirm the mooring loads & bollard capacities.

As the berthing dolphins will be designed for much higher loads due to berthing, additional capacity bollards can be accommodated on dolphins if required.

6.3.4.4 Wave Loads

Wave load on piles is calculated using applied wave theory. Wave and Current loading are calculated by Morison equation expressed as:

$$F_T = \frac{1}{2} C_D \rho_W D V |V| + \frac{\pi D^2}{4} C_M \rho_W a$$

Where FT is the total force, ρw is the density of water, Cd and Cm are the drag and inertia coefficients respectively, D is the diameter of the member including marine growth, V is the velocity and a is the acceleration.

The first term in the equation is drag component (FD) and the second term is the inertia component (FI).

FT=FD+FI.

The separate total maximum inertia force and moment and total drag & moment on vertical cylindrical pile subjected to nonlinear waves will be estimated using equations VI-5-285 to VI-5-288 from Coastal Engineering Manual.

The inertia & Drag forces will be estimated using above equations & Nomograms based on stream function Theory.

Wave forces on Flat wall like structures is not anticipated. Where these forces are encountered, loading & response will be calculated as per section VI-5-4 of coastal engineering manual.

6.3.5 Seismic Loads

Earthquake loads are considered in accordance with IS:1893-1 (2002). Thane is located in seismic Zone - III as per seismic map of India shown in IS-1893:2002.

The earthquake Loads are calculated using following parameters:

Zone Factor: Z = 0.16

Importance Factor: I = 1.5

Response Reduction Factor: R = 3.0.

Response reduction factor R =3.0 corresponds to ordinary moment resisting frame (OMRF)

Higher base design base shear for structure designed & detailed as per IS 456 i.e. ductile detailing not required.

All onshore RC structures to be designed & detailed as per IS 456. Seismic load for approach Jetty to be as per IRC 6:2000.

100% Dead load & 50 % Live load are considered for calculating fundamental frequency & base shear due to earthquake loads.

6.3.6 Hydrodynamic Coefficients

Hydrodynamic coefficients are used in accordance with BS 6349 Part 1 guidelines as stated below. For vertical tubular members like piles, it is taken as below.

The pile diameter ranges of 0.9 m to 1.2 m is considered for the selection of hydrodynamic coefficient.

Based on the calculated particle velocity of the wave (varies from 4 to 8 m/sec),

the Reynolds Number (RN) is calculated as 5 x 106. For the value of R, the corresponding

Cd is selected from Figure 24 of BS 6349 Part 1.

Cd = 0.7 and Cm = 2.0 for clean piles (without marine growth)

Cd = 0.7 and Cm = 2.0 for covered members (with marine growth)

6.3.7 Load Combinations

All the offshore structures are designed for following load combinations as per IS:4651-4 (1989):

Table 6. 5: Load Combinations

Sl .No	Load Description	LIMIT STATE OF SERVICEABILITY			LIMIT STATE OF COLLAPSE						
					NORMAL			EXTREME			
		I	II	III	IV	V	VI	VII	VIII	IX	X
1	Dead Load	1.0	1.0	1.0	1.5	1.5	1.2	1.2	0.9	1.2	0.9
2	Live Load	1.0	1.0	1.0	1.5	1.5	1.2	1.2	0.9	1.2	0.9
3	Wave & Current	1.0	1.0	1.0	1.0	1.0	1.2	1.2	1.0	1.0	1.0
4	Berthing Force		1.0		1.5						
5	Mooring Force			1.0		1.5					
6	Temperature	1.0									
7	Wind Load (Operational)	1.0	1.0	1.0						1.0	1.0
8	Wind Load (Extreme)							1.5	1.5		
9	Seismic Load	1.0	1.0	1.0						1.5	1.5

Allowable stress values will be modified as per relevant codes where wind load acts simultaneously with seismic load or any other horizontal loads.

6.3.8 Crack Width / Material Properties & Concrete Covers

6.3.8.1 Crack Width

Crack width is checked under serviceability load conditions and will be limited to of 0.004 times cover to main reinforcement or 0.3 mm whichever is lower (Cl.8.3.4,IS 4651 -4) 2014.

6.3.8.2 Material Properties

Concrete Used in Marine Structures: Design Mix Grade M40 or Higher with minimum cement quantity of 400 kg/m³ & maximum free water cement ratio of 0.45.

The cement used for concrete in marine works will be Ordinary Portland cement or cement blended with ground granulated blast furnace slag.

M30/M25 Grade concrete shall be used for onshore works with appropriate mix design & cement content, concrete cover to provide required protection to reinforcement against corrosion.

Reinforcement Steel: Fe-415 and/or Fe500 confirming to IS: 1786:2008.

Structural Steel for Link-span, pontoon & guide Piles: Grade S355JO and S355J2G3 conforming to BS-EN-10-025. 1993(Or equivalent approved IS grade-as per cl:5.5 with min yield stress= 350Mpa).

6.3.9 Concrete Cover

The clear cover provided to reinforcement in various concrete elements is as listed below:
Bored cast in-situ piles: 75 mm
Beams :50 mm all sides.
Slabs: 25 mm all sides
Open foundations: 50 mm all sides.
Water retaining structures: 40 mm all sides.

6.3.10 Design Standards

Following principal design standards are used for different elements as listed below:

i. Concrete Structures: IS456:2000, 4651 (all parts), IRC 6: 2000., IRC 21 - 2000.
ii. Steel Link span & Pontoon: BS 6349-8, BS 5400 (all parts), CIRIA 518, Lloyd's Register's "Classification of Link spans: Rules & Regulations"
iii. Water retaining structures: IS 3370 (part 1&2 :2009, Part 3 & 4 1967)., BS 8007:1987.
iv. Roads & Paved areas: IRC: SP63-2004, IRC58:2002, IRC15:2002.
v. Access Bunds & Revetments: Shore Protection manual (1984 Edition) & Coastal Engineering Manual (All parts- 2002 Edition with July 2003 & April 2008 Amendments) by US army CORPS of Engineers. CIRIA C683 –The Rock Manual 2nd Edition (2007).

6.3.11 Foundation Design

Foundation design will be based on output of geotechnical investigations to be performed at each site as per specifications listed.

Bored RC piles are designed as per IS 2911 (all parts).

- Structural design of RC piles will be carried out in accordance with IS 456.
- Piles shall be spaced at a minimum distance of 3.0 times the diameter to avoid group effect.
- Factor safety for axial compressive loads shall be 2.5 for normal loads 2.0 for extreme loads.

- Factor of safety for axial tension and lateral loading shall be 3.0 and 2.0 for normal and extreme load cases respectively.
- Axial Capacity for compression is calculated as combination of Skin friction & end bearing. Axial capacity for tension is calculated as a combination of skin friction & dead weight.
- Lateral capacity of piles is calculated as per CIRIA "Report 103 – Design of Laterally Loaded Piles.

6.3.12 Allowance For Scour And Over Dredging

While determining pile lengths an overall river bed scour of 1.0 m is allowed. In addition, a local scour of 1.5 m around piles is also allowed for.

At detailed design stage the scour allowance will be reviewed by detailed analysis. If required, the pile lengths will be increased or scour protection measures provided around individual piles as per Shore protection manual /any other appropriate standard. For piles at berthing dolphins & pontoon restraint structure an additional allowance for 2 m of over dredging is also made.

6.3.13 Design Provisions For Waterfront Facilities

6.3.13.1 Linkspan - Pontoons

A. Design Loadings

- The pontoon is sized to carry one full lane of HA/IS:4651: Part III loading along the full length of the link span/pontoon with an 8m ship ramp not deviating more than +/- 1º from the median position between the unloaded and loaded position. Variable water ballasting is used to adjust the freeboard at the interface limit between 1.5 m and 1.75 m above still water level.
- The deck will be designed to be structurally capable of supporting 20 kN/m2 general loading over its entire surface. However, we assume it will not be an operational that the whole deck is loaded simultaneously with 20 kN/m². The sinkage of the pontoon will exceed operational limits if applied to the entire surface.
- In the ship ramp landing area, and pontoon and shore flaps, rubbing strips are welded to the deck or embedded into concrete ramps to prevent damage to the running surface from the ship ramps or flaps.
- In areas where ferries or launches berth, fender panels designed to absorb the full berthing energy are provided. In other areas the 500 kN boat collision load applied over 1m2 is treated as an accidental loading rather than a normal loading.

B. Basis of Modelling of Structures

Global analysis

- The global analysis will be carried out using Staad Pro. The pontoon will be modelled as a grillage comprising beam elements All joints will be modelled as rigid. At the bank seat pinned supports will be used.
- At the pontoon end spring supports having a stiffness equal to the buoyancy provided will be used. Gross section properties will be used for the analysis at ULS. Net section properties will be used for analysis at SLS taking into account shear lag as required.
- Derivation of the horizontal natural frequency of the structure for obtaining the seismic loads, it is necessary to calculate the natural frequency of the bridge. STAAD PRO software used in the design incorporates two analysis engines for the calculation of natural frequencies
    i. An approximation of the natural frequency using the Rayleigh iteration method
    ii. Modal analysis which uses a full scale Eigen solution to obtain the relevant frequencies and mode shapes. For the global analysis the latter method will be used. The appropriate model for obtaining the horizontal natural frequency would be to incorporate the spring stiffness of the bank seat piles, the spring stiffness of the pontoon guide piles and clearances. However, a simpler model assuming rigid supports for the pontoon will be used.

Design Codes:

- For loading conditions loadings from the following codes has been used
- BS 6349 pt. 8 HR Type 1 Loading
- BS 5400 PT 2
- IRC 6:2014 for seismic loading and site wind speed
- BD37/01 for wind loading parameters
- Design of the Pontoon/Link span will be carried using the following codes and publications
- BS5400 Part 3. for the design of the steelwork elements
- BS5400 part 10 Fatigue and EN 1993-1-9 for the fatigue check of the trapezoidal deck

The General layout and section of the Link Span is given in the Figure 6.6 and 6.7.

Figure 6. 6: Link Span In Plan

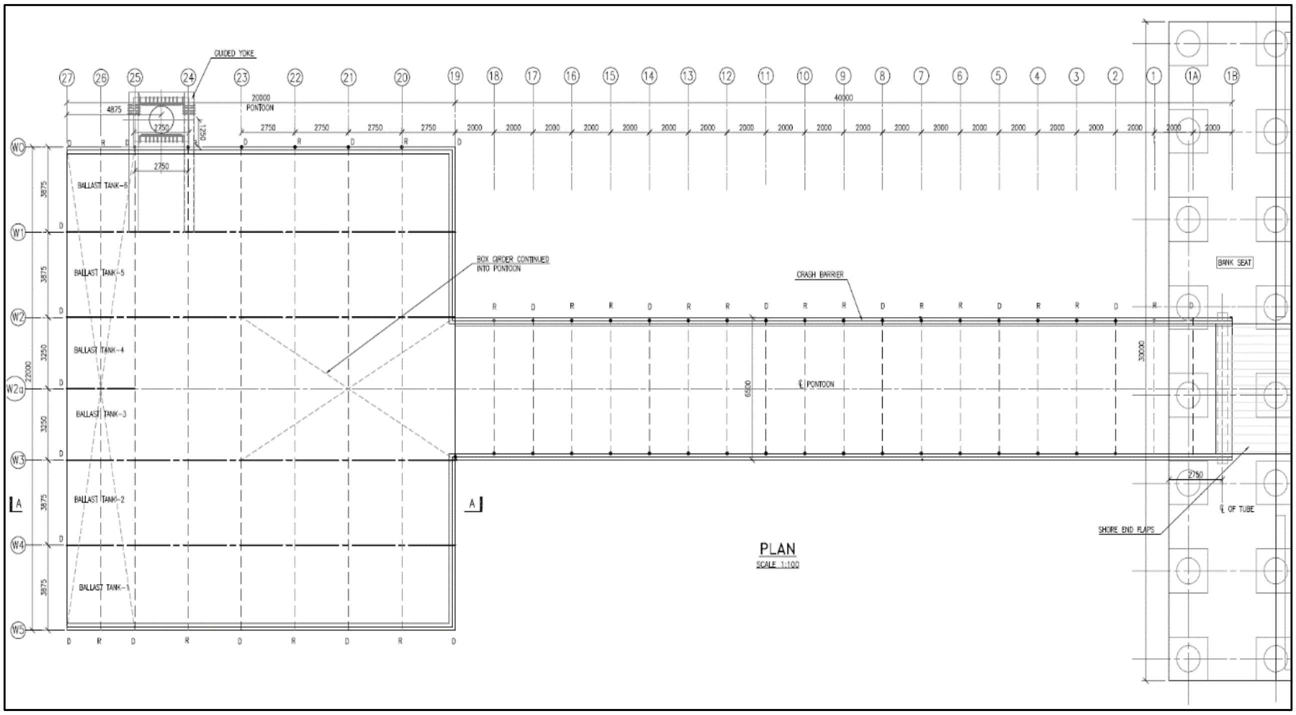
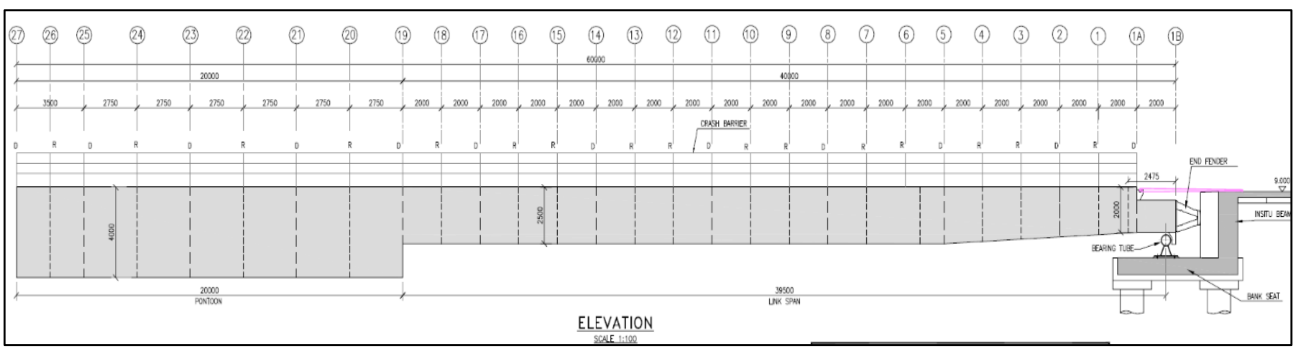


Figure 6. 7: Link Span In Section



6.3.14 Approach Jetty

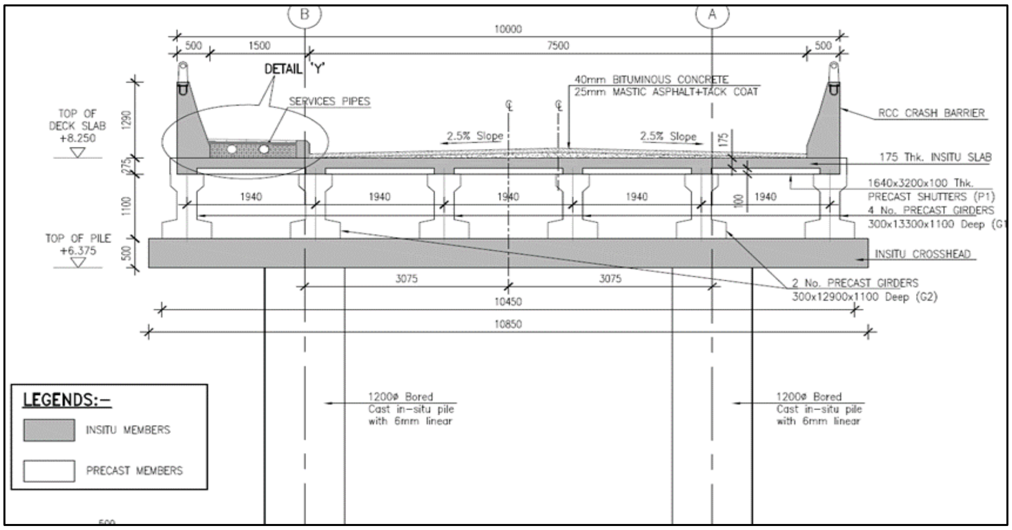
Approach jetty servers as link between the access bund at one end and the steel link span at the other end.

The Approach jetty is designed for all the loads and combinations listed earlier in this section. The design features of approach jetty are summarized below:

- Total Length of the jetty depends on the distance shore to adequate depth of water to launch the floating pontoon in position.
- Total width 10.00 m

- 7.5 m clear carriageway, 2 lane road way as per IRC. 1.5 m wide footpath/walkway on one side with utility pipes for water supply, wastewater, electrical & communication lines etc. Kerbs on either side 2 x 0.5 m = 1.0 m. Refer Figure 6.8.

Figure 6. 8: Section Of The Approach



- Each span supported on cross heads consisting of 2 Nos of 1000/1200 mm diameter piles spaced at 10.4 m apart.
- Deck consisting of RC slab supported on 1100 mm deep, pre-cast beams spaced at 1.94m c/c. Deck Slab is composed 175 mm thick. In situ slab which rests over Precast planks 1.64 w x 3.2 l x 0.1 m thick. which rests on these beams. There RC Anti crash barrier present of height 1290 mm on both sides.
- Expansion Joints composed of precast planks 1.5 m wide and 5.2 m in length and in situ deck spanning 6 m approx. bearing on 25 mm thick rubber bearing strip and dowel bars at either side with compressible filler board. Expansion Joints are provided after every 5 continuous spans.
- Piles embedment is done in weathered rock with socketing at least 2.5 times diameter of piles
- Piles are designed for a combination of Axial Load from Deck & Lateral Load due to Waves/Current, Earthquake & Traction due to Vehicle braking & acceleration, Temperature etc.

6.3.15 Turning Platform

Turning platform 30 m x 30 m approx. serves as a platform for vehicles to turn and also provides a seat for links pan to rest.

- Link Span seat: Designed for vertical & lateral Loads from Link span & Pontoon
- Horizontal loads from Pontoon transferred to Link span seat by end fenders.
- Deck consisting of RC slab supported on cross head beams 1000 mm deep, cast in situ beams spaced at 7 m c/c. Deck Slab is 250 mm thick cast in situ slab, rests over the precast planks of

1.5 m x 5.6 m x 0.25 m thick resting over the cross head beams. There are RC Anti crash barrier of 1290 mm height on the periphery.

- The cross beams are supported by piles spaced at 7 m c/c. Piles embedment is done in weathered rock with rock socketing of at least 2.5 times diameter of piles
- Piles are designed for a combination of axial load from deck & lateral load due to waves/current, Earthquake & traction due to vehicle braking & acceleration, temperature etc.

The plan and the section of the turning platform is shown as Figure 6.9 and 6.10.

Figure 6. 9: Plan Of Turning Platform

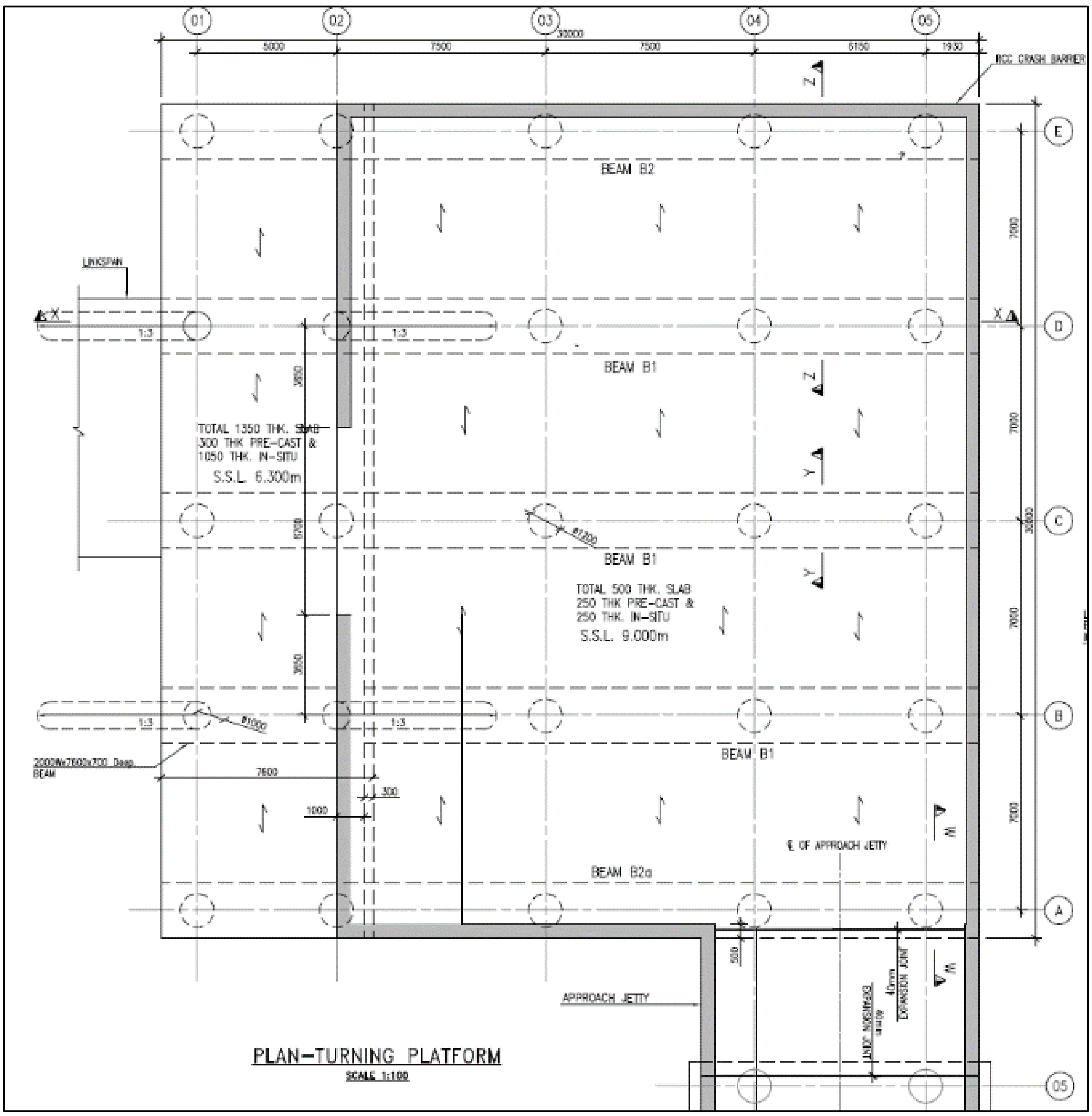
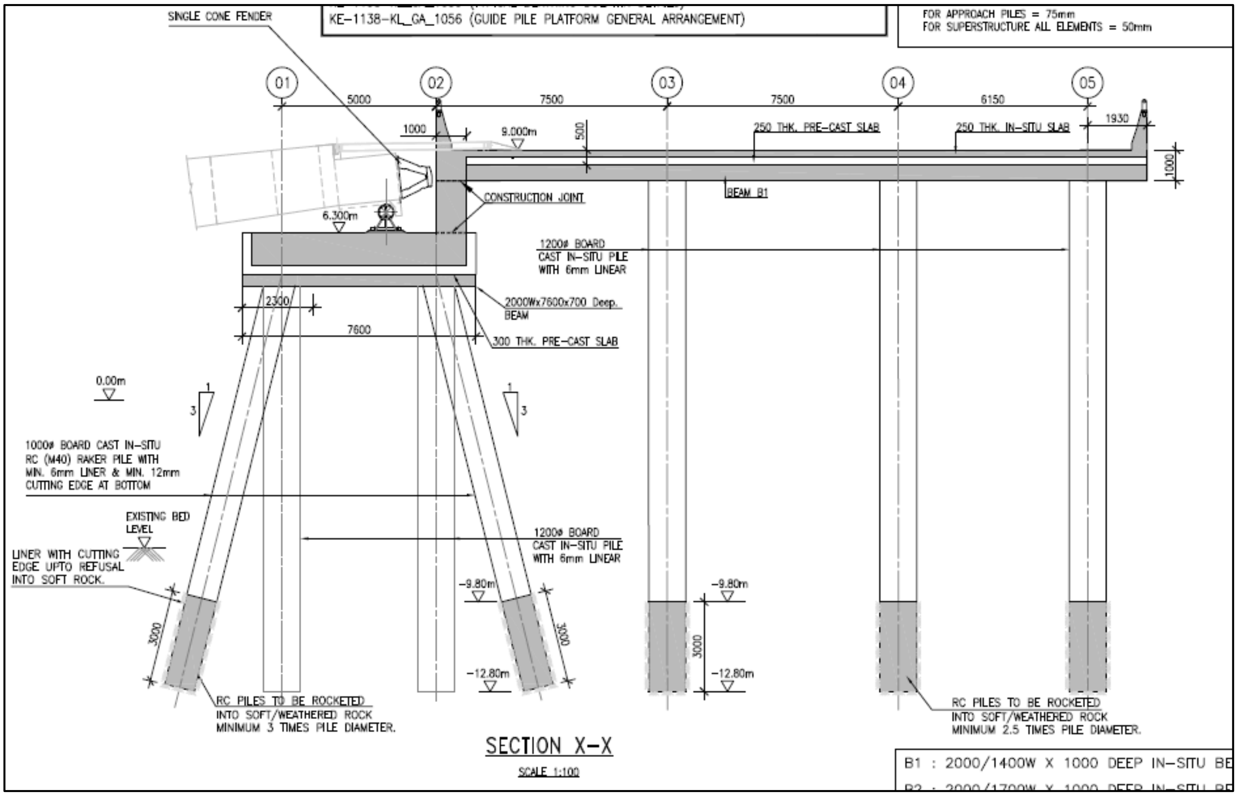


Figure 6. 10: Section Of The Turning Platform



6.3.16 Mooring And Berthing Dolphins

For the main terminals 5 Nos. of Berthing-Mooring Dolphins spaced at 15 m c/c are provided. For the secondary terminals these are reduced to three. The dolphins are designed to absorb berthing energies from Vessels up to 10500 Displacement. The Berthing load on dolphins is calculated assuming berthing Mode (b) given in clause 4.7.6 of BS6349-4.

Design Features of Dolphins are summarized below:

- Each Dolphin consists of 4 Nos of 1200 mm diameter Bored cast in-situ Piles & 6 m x 7 m x 1.5 m deep pile cap.
- Dolphins & Fender System on Dolphins are designed for Operating berthing velocity up to 0.29 m/s.
- The maximum berthing energy of 430 kN-m is arrived at using a berthing velocity of 0.29 m/s.
- To allow berthing along entire tidal range, 2 Nos of SCN Cone fenders along with UHMW – PE pads & Restraining chains are provided on each dolphin.
- Two Nos of 50 Ton capacity Mooring Bollards are provided per dolphin.
- 1.5 m wide steel walkways are provided connecting all dolphins & Main Pontoon.
- Loads for Accidental berthing are considered as twice of operating condition & designed for ultimate limit state only.

Figure 6. 11: Plan Of The Mooring As Well As Berthing Dolphins

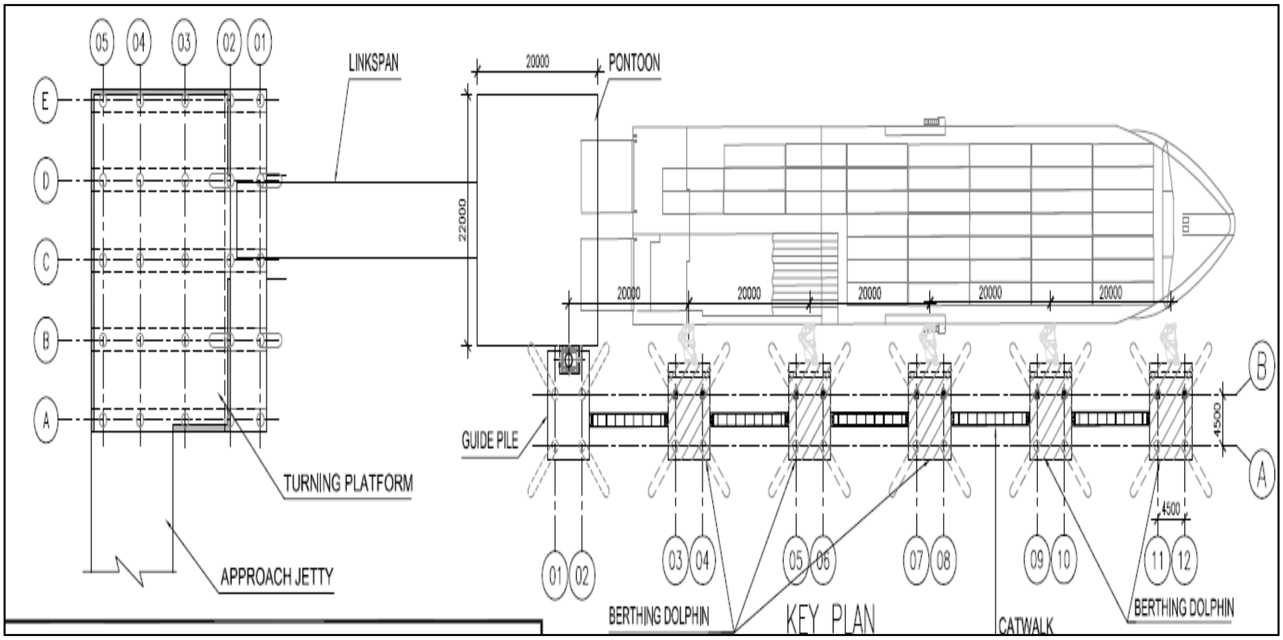
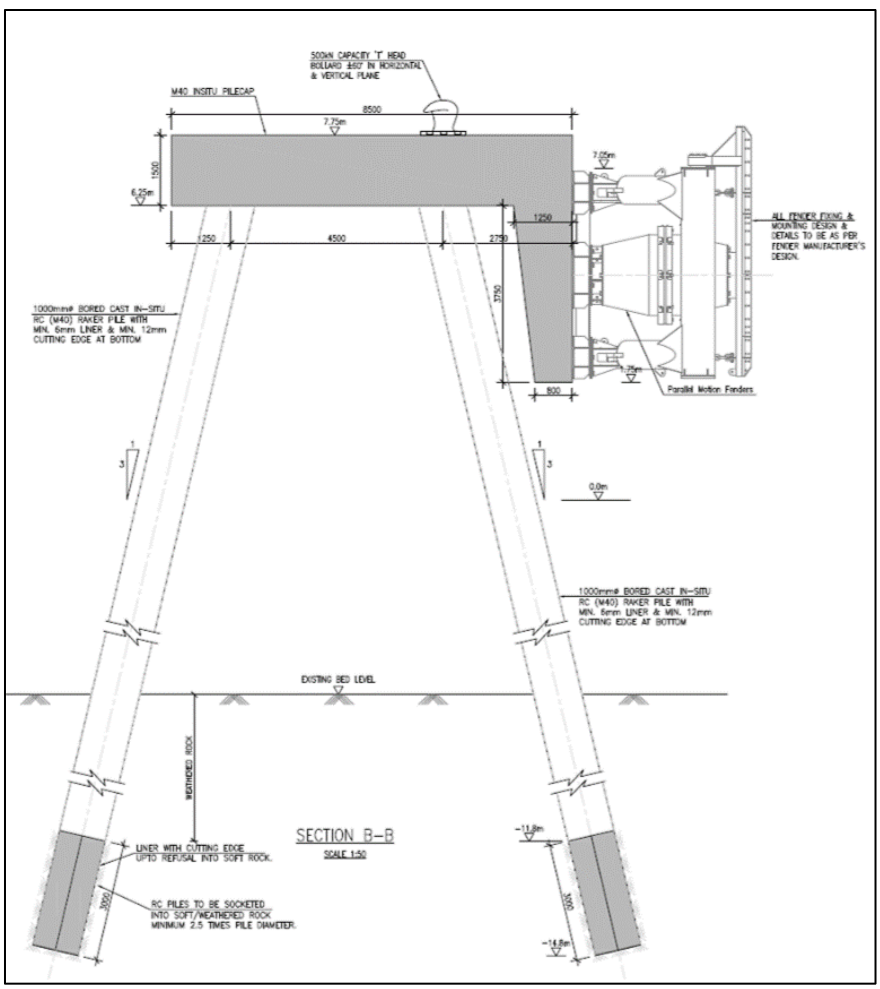


Figure 6. 12: Section Of The Mooring As Well As Berthing Dolphins



6.3.17 Corrosion Protection

- All Marine Structures excluding link span & pontoons to be provided with Corrosion Resistant Paint System to Provide 12 years' life to first maintenance.
- Link span & Pontoon to be provided with Paint system to provide 15 years life to first maintenance.
- All steel structures will be shot blasted to bright metal finish to Surface grade Sa 2.5 as per Swedish standard SIS 055900.
- Paint system consisting of Coal Tar epoxy – 3 coats of minimum 150 micron DFT, totaling to 450 micron DFT is proposed.
- Corrosion resistant paint system to be as per BS:3900-F1:1985, BS EN 13173:2001, CIRIA Report 93: Painting of Steel Work.
- Beyond Planned First Maintenance corrosion protection will be provided using combination of Sacrificial Cathodic Protection and/or Provision of additional metal thickness.
- Final Corrosion protection system to be based on additional tests & survey of existing structures adjacent to proposed sites.
- For Concrete Structures, Corrosion protection is provided by specifying increased concrete cover to reinforcement, minimum cement content & type (GGBS /OPC).RC Piles will also derive additional protection from steel liners. Access trestle deck slab will have additional protection from pre-cast permanent formwork.
- All other secondary steel work like railings, signage boards, chains, fixtures etc. will be provided corrosion protection as per tender conditions.

6.3.18 Anti-Skid Surfacing

- Anti-skid surfacing with min. 15 years design life is provided to all areas of Pontoon & Link span accessible by Pedestrians or Vehicles.
- Anti-Skid Surfacing by ROCOL UK – Cicol NT which has a proven record of min 15 years' design life is proposed.
- 3 mm thick Anti-skid surfacing is proposed for areas accessible to pedestrians only.
- 5 mm thick Anti-skid surfacing is proposed for areas with vehicle traffic.

6.3.19 Design Life And Maintenance Schedules

6.3.19.1 Design Life

The Various facilities provided under the contract will be designed for service life as listed below:

- Link Span & Pontoon: 25 Years.
- Concrete Structures: 50 Years.
- Mechanical Plants: 20 Years.

- Electrical Plants: 20 Years.
- Buried earth electrical system: 50 Years.
- Control Panels: 25 Years.
- External Instrumentation Systems: 15 Years.
- Transmission Main: 30 Years.

6.3.20 Maintenance Schedule

All the facilities provided under contract should perform satisfactorily for their intended design life as mentioned above. However, to ensure required performance the facilities should be inspected regularly for damage due to abuse & accidents.

The inspection & Maintenance (If required) schedule for various elements shall be as follows:

1. Pontoon, Link span, Dolphins, Access Jetty & Bund. Inspection for these facilities should be carried out as per UK Highways agency DMRB document “BD 63/07 inspection of Highway structures”. This involves following inspections.
   i) Safety inspections: These inspections are not specific to just above structures and generally cover all fixed assets including carriageways, footways, structures, drainage, verges & lighting. Safety inspections should be carried at frequencies which ensure the timely identification of safety related defects & reflect the importance of a particular asset. Safety inspections may also be as a result of notification of a defect by third party e.g. police or public.
   ii) General Inspections: These should be carried out at every two years. Where general inspection coincides with Principal inspection, only latter should be performed.
   iii) Principal Inspections: These should be carried out every 6 years.
   iv) Maintenance Painting of steel structures should be done at the end of paint system design life, i.e. 15 years for link span & pontoon & 12 years for all other steel structures.

6.3.21 For Onshore Structures

i) Safety Inspections as determined by client/operator.
ii) General Inspection every 2 years.

6.3.22 Electrical / Mechanical Equipment

Maintenance of above facilities /equipment should be carried out as per the equipment manufacturer’s specifications & schedules.

Detailed schedules & specifications for Inspection & maintenance of all facilities will be provided at completion of works as part of O&M manual.

6.3.23 Reference Codes, Standards And Guides

The Principal codes & standards used in design are listed below. In addition, the design confirms to all the standards listed in the tender documents. Latest version of all the codes will be used.

- BS 6349 – Part 1 to 8. Code of Practice for Design of Maritime Structures.
- IS 4651 – Part 1 to 5. Code of Practice for Planning & Design of Ports & Harbours
- Lloyd's Register "Classification of Link spans: Rules & Regulations".
- CIRIA 518.
- BS5400 – All parts.
- IS 456:2000.
- IRC 5 : 1998 ,IRC 6 : 2000
- IRC : 21 ,IRC 78:2000
- API RP 2A
- IS 800:2007.
- IS 3370 – All parts.
- BS 8007.
- IS 875 - All Parts.
- IRC SP 63-2004, IRC 58: 2002, IRC 15:2002.
- CIRIA C683 – The Rock Manual.
- CIRIA 103 – Design of Laterally Loaded Piles.
- IS 2911 – All Parts.
- Shore Protection Manual (Volume 1-3) By US Army Corps of Engineers.
- Coastal Engineering Manual: Volume 1-5. By US Army Corps of Engineers.
- IS 1893 -1: 2002 Criteria for Earthquake Resistant Design of Structures.

6.4 Navigation Aids

6.4.1 General

Aid to navigation was described in detail in the Chapter 3. The various signage for leading a ship from high seas to the Inland water and vice versa are also described. The main navigational aids for the present context are;

1. Channel marker Buoys
2. Leading lights for night navigation
3. Terminal location lights
4. Marking on the Cross structures
5. Shore beacons and radar reflectors
6. Marking of the permanent structures such as electric towers

7. Marking along the curves
8. No navigation/Shallow area markings

6.4.2 Aids To Navigation

In SOLAS-V/13 ("Safety of navigation" IMO, 1974), IMO established that each state shall provide the aids to navigation appropriate to the level of traffic and the degree of risk. This requires that contracting States apply uniformly standardised aids to navigation. To achieve this, the International Association of Lighthouse Authorities (IALA) was created in 1957. IALA defines aids to navigation as systems external to the ship capable of helping determine its position and course, warning about dangers and obstacles and indicating the best route to follow. In appendices 2 and 3 of Resolution A.915 (22), the IMO indicates that the absolute horizontal accuracy of aids to navigation regarding vessel posit ion on inland waterways should be 10 m, with a probability of 95%. The accuracy of nautical charts is also very important. The national authority responsible for their publication must work in coordination with the body responsible for aids to navigation. In the particular case of restricted waters, the nautical chart scale is 1:10 000, requiring an accuracy of 10 m (IALA-AISM, 2014). Aids to navigation include visual aids (lighthouses, beacons, buoys and leading lines), electronic navigation, a pilotage service and traffic organisation boats (Figures 6.13 and 6.14).

Figure 6. 13: Channel Marker Buoys Marking The Edge Of Dredge Channels

Figure 6. 14: Led Sector Lights Marking The Central Line Of The Channel In A River (Extreme Precision)

These are ready made systems and needs to be installed as per requirements. The only element to be introduced is the concrete elements or pedestal used for installing these gadgets.

7 Vessel Design

7.1 General Review

Vessel Design is very specific and is intended for a particular operation. There are many specific use vessels intended for a particular use only. There are many types of vessel each suited for a specific purpose. The main categories of the vessels for inland waterway context are;

i. Passenger Ferry
ii. Catamarans
iii. Ro-Ro Passenger ferry
iv. Ro-pax Vessel
v. Car Passenger Ferry
vi. Ro-Ro Vessel
vii. Search and Rescue Boat
viii. Ro-Ro Car Container Carrier
ix. Passenger Cruise Ship
x. Motor Yatch
xi. Expedition Cruise Ship
xii. Ro-Ro Cargo Vessel
xiii. Car Truck Carrier
xiv. Wagon Carrier

For the present purpose, Passenger and passenger car ro-ro vessels are relevant. In addition, since the waterway operation are nascent in the area, cost factor also need to be considered. In this context the recent ro-ro vessel designed and constructed by the Cochin Ship Yard is a fine example.

The Cochin Shipyard Limited (CSL) has launched the first of the two double-ended Roll on, Roll off (Ro-Ro) ferry vessels, it is building for the Corporation of Kochi. The ferry will ply between Vypin and Fort Kochi carrying 12 cars and three trucks or 18 cars besides 50 passengers, enabling movement of lorry/passenger vehicles without entering the city.

Figure 7. 1: Cochin Passenger Ro-Ro Vessel Ideally Suited For The Present Waterway

The vessels work like a floating bridge, with ramps at either end. The most important feature of the vessel is that the vehicles drive in and drive out on a "first-in, first-out" basis, without the need to reverse the vehicles during loading on the vessel which drastically reduces loading/ unloading time. Hence, special driving skills are not required for vehicle drivers to load the vehicles onto the vessels.

Another special feature of the vessel, it said, was an air-conditioned wheel house for comfort of the operator.

The vessel was also designed to withstand deck loading for trucks and heavy vehicles, with heavy duty ramp and hinged flaps to ensure safe loading and unloading.

The ferry was designed in-house at CSL and was built according to the rules of the Indian Register of Shipping (IRS), a ship classification society.

The vessel is equipped with azimuth propulsion systems on both ends for easy manoeuvring, allowing it to be operated without the need for turning around at the jetty during cast-off, thereby reducing trip times.

They also have a number of inbuilt safety features.

The structural tanks are designed to withstand flooding of engine/thruster compartments ensuring the safety of the vessel in case of structural damage in the event of a collision.

Bilge safety alarms in all compartments are provided to detect flooding even in closed compartments. Fire alarm systems are provided for engine rooms.

Apart from this, safety tips and alarms of the engine and thruster are displayed in the wheel house and an echo sounder is also provided to know the depth of the water. The Ferry has an overall length of 27 m and is 8.25 m wide. It has the capacity to attain a speed of about 6 knots (about 3.06 m/s)

7.2 Design Basis

The general requirements of vessel design are as follows;
Vessels shall be built in accordance with good shipbuilding practice.

7.2.1 Strength And Stability

1. The hull shall be sufficiently strong to withstand all of the stresses to which it is normally subjected.
   a. In the case of newly built vessels or major conversions affecting vessel strength, adequate strength shall be demonstrated by presenting the design calculation proof. That proof is not required where a classification certificate or an attestation from a recognized classification society is submitted.
   b. In the event of periodical inspection, the minimum thickness of the bottom, bilge and side plates of vessels made from steel shall be no less than the higher of the values resulting from the following formulae:
   c. In longitudinally framed vessels with double bottom and wing voids, the minimum value calculated for the plate thickness in accordance with the formulae in (b) may be reduced to a calculated value certified by a recognised classification society for sufficient hull strength (longitudinal, lateral and local strength).

   Plates shall be renewed if bottom, bilge or side plates are below the permissible value laid down in this way. The minimum values calculated in accordance with the method are limit values taking account of normal, uniform wear, and provided that shipbuilding steel is used and that the internal structural components such as frames, frame floor, main longitudinal and transverse structural members are in a good state and that the hull shows no indication of any overloading of the longitudinal strength.

   As soon as these values are no longer achieved, the plates in question shall be repaired or replaced. However, lesser thicknesses, of not more than 10 % reduction from calculated values, are acceptable locally for small areas.
2. Where a material other than steel is used for the construction of the hull, it shall be proved by calculation that the hull strength (longitudinal, lateral and local strength) equals at least the strength that would result from the use of steel under the assumption of minimum thickness in

accordance with (1). If a certificate of class or a declaration issued by a recognised classification society is presented, a proof by calculation may be dispensed with.

3. The stability of vessels shall correspond to their intended use.

7.2.2 Hull

1. Bulkheads rising up to the deck or, where there is no deck, up to the gunwale, shall be installed at the following points:
   a. A collision bulkhead at a suitable distance from the bow in such a way that the buoyancy of the laden vessel is ensured, with a residual safety clearance of 100 mm if water enters the watertight compartment ahead of the collision bulkhead.
      As a general rule, the requirement referred to in (1) shall be considered to have been met if the collision bulkhead has been installed at a distance of between 0,04 L and 0,04 L + 2 m measured from the forward perpendicular in the plane of maximum draught.
      If this distance exceeds 0,04 L + 2 m, the requirement set out in (1) shall be proved by calculation.
      The distance may be reduced to 0,03 L. In that case the requirement referred to in (1) shall be proved by calculation on the assumption that the compartment ahead of the collision bulkhead and those adjacent have all been filled with water
   b. An aft-peak bulkhead at a suitable distance from the stern where the vessel length L exceeds 25 m in such a way that the buoyancy of the laden vessel is ensured, with a residual safety clearance of 100 mm if water enters the watertight compartment aft of the aft peak bulkhead.
      As a general rule, the requirement referred to in the first subparagraph shall be considered to have been met if the aft peak bulkhead has been installed at a distance of between 1,4 m and 0,04 L + 2 m measured from the aft point of the intersection of the hull with the maximum draught line.
      If this distance is greater than 0,04 L + 2 m, the requirement referred to in the first subparagraph must be proved by calculation.
      The distance may be decreased to 1 m. In this case, the requirement referred to in the first subparagraph must be substantiated by calculation on the assumption that the compartment aft of the aft peak bulkhead and the immediately adjacent compartments have been filled with water.
2. No accommodation or installations needed for vessel safety or operation may be located ahead of the plane of the collision bulkhead or aft of the aft-peak bulkhead. This requirement shall not apply to anchor gear or steering apparatus.

3. The accommodation, engine rooms and boiler rooms, and the workspaces forming part of these shall be separated from the holds by watertight transverse bulkheads that extend up to the deck.
4. The accommodation shall be separated from engine rooms, boiler rooms and holds in a gastight manner and shall be directly accessible from the deck. If no such access has been provided an emergency exit shall also lead directly to the deck.
5. The bulkheads specified in (1) and (3) and the separation of areas specified in (4) shall not contain any openings.
6. However, doors in the aft-peak bulkhead and penetrations, in particular for shafts and pipework, shall be permitted where they are so designed that the effectiveness of those bulkheads and of the separation of areas is not impaired. Doors in the aft-peak bulkhead shall be permitted only if it can be determined by remote monitoring in the wheelhouse whether they are open or closed and shall bear the following readily legible instruction on both sides:
   'Door to be closed immediately after use'.
7. The water inlets and discharges, and the pipework connected to these, shall be such that no unintentional ingress of water into the vessel is possible.
8. The fore-sections of vessels shall be built in such a way that the anchors neither wholly nor partly protrude beyond the side plating

7.2.3 Engine, Boiler Room And Bunker

1. Engine or boiler rooms shall be arranged in such a way that the equipment therein can be operated, serviced and maintained easily and safely.
2. The liquid-fuel or lubricant bunkers and passenger rooms and accommodation may not have any common surfaces which are under the static pressure of the liquid when in normal service.
3. Walls, ceilings and doors of engine rooms, boiler rooms and bunkers shall be made of steel or another equivalent non-combustible material.

Insulation material used in engine rooms shall be protected against the intrusion of fuel and fuel vapours.

All openings in walls, ceilings, and doors of engine rooms, boiler rooms, and bunker rooms shall be such that they can be closed from outside the room. The locking devices shall be made from steel or an equivalent non-combustible material.

1. Engine and boiler rooms and other premises in which flammable or toxic gases can escape shall be capable of being adequately ventilated.
2. Companionways and ladders providing access to engine and boiler rooms and bunkers shall be firmly attached and be made of steel or another shock-resistant and non-combustible material.

3. Engine and boiler rooms shall have two exits of which one may be an emergency exit. The second exit may be dispensed with if:
    a. The total floor area (average length × average width at the level of the floor plating) of the engine or boiler room does not exceed 35 m^3
    b. the path between each point where servicing or maintenance operations are to be carried out and the exit, or foot of the companionway near the exit providing access to the outside, is not longer than 5 m
    c. a fire extinguisher is located at the servicing point that is furthest removed from the exit door and also, by way of derogation from Article 13.03(1)(e), where the installed power of the engines does not exceed 100 kW.
4. The permissible sound pressure level in the engine rooms shall not exceed 110 dB(A). The measuring points shall be selected as a function of the maintenance work needed during normal operation of the plant located therein

7.2.4 Safety Clearance, Freeboard And Draught Marks

7.2.4.1 Safety Clearance

1. The safety clearance shall be at least 300 mm.
2. The safety clearance in the case of vessels whose openings cannot be closed by spray-proof and weather tight devices, and for vessels sailing with their holds uncovered, shall be increased in such a way that each of those openings shall be at least 500 mm from the plane of maximum draught.

7.2.4.2 Freeboard

1. The freeboard of vessels with a continuous deck, without sheer and superstructures, shall be 150 mm.
2. The freeboard of vessels with sheer and superstructures shall be calculated using the following formula:

$$\mathrm{F} = 150(1-\alpha) - \frac{\beta_v . Se_v + \beta_a . Se_a}{15}\ mm$$

where:

α is a correction coefficient that takes account of all of the superstructures involved;

β_v is a coefficient for correcting the effect of the forward sheer resulting from the presence of superstructures in the forward quarter of length L of the vessel;

β_a is a coefficient correcting the effect of the aft sheer resulting from the presence of superstructures in the aft quarter of length L of the vessel;

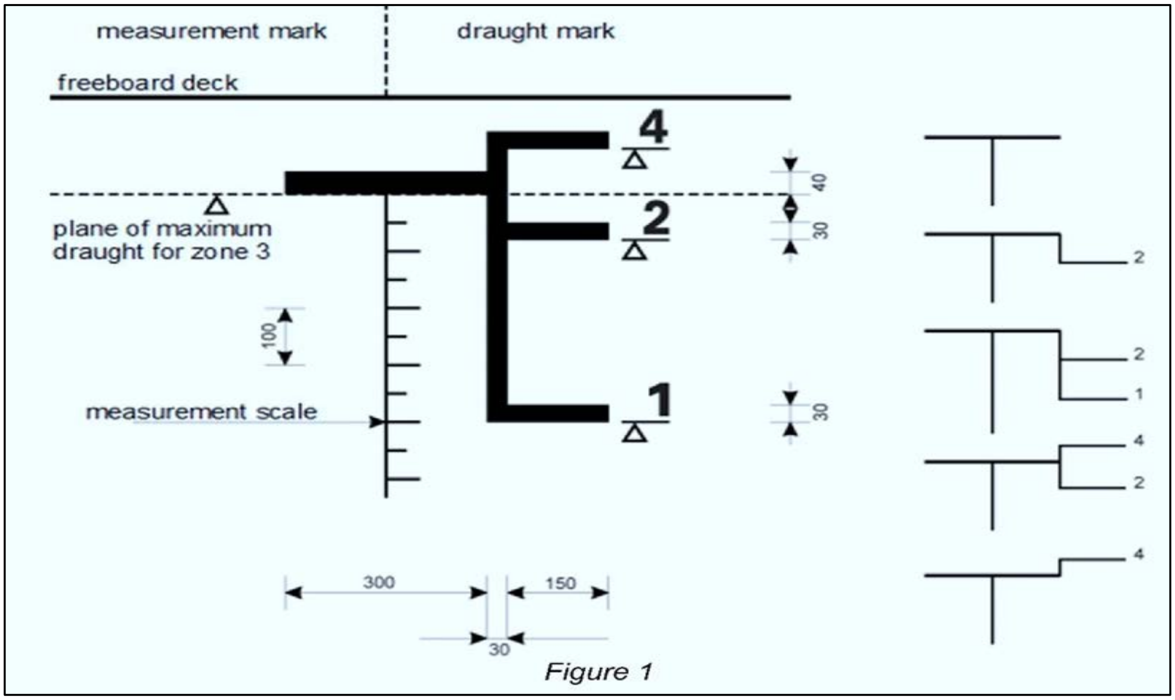
Se_v is the effective forward sheer in mm;

Se_a is the effective aft sheer in mm.

7.2.4.3 Draught Marks

1. The plane of maximum draught shall be determined in such a way that the specifications concerning minimum freeboard and minimum safety clearance are both met. However, for safety reasons, the inspection body may lay down a greater value for the safety clearance or freeboard.
2. The plane of maximum draught shall be indicated by means of highly visible, indelible draught marks.
3. The draught marks for Zone 3 shall consist of a rectangle 300 mm long and 40 mm deep, the base of which is horizontal and coincides with the plane of the maximum authorized draught. Any differing draught marks shall include such a rectangle.
4. Vessels shall have at least three pairs of draught marks, of which one pair shall be at 1/2 of the length L and the two others located, respectively, at a distance from the bow and stern that is equal to roughly 1/6 of the length L.
   However,
   a) where a vessel is less than 40 m in length *L* it will suffice to affix two pairs of marks at a distance from the bow and stern, respectively, that is equal to a quarter of the length *L*;
   b) where vessels are not intended for the carriage of goods, a pair of marks located roughly halfway along the vessel will suffice.
5. Marks or indications which cease to be valid following a further inspection shall be deleted or marked as being no longer valid under the supervision of the inspection body. If a draught mark should disappear, it may only be replaced under the supervision of an inspection body.
6. Where a vessel has been measured in implementation of the 1966 Convention on the Measurement of inland navigation vessels and the plane of the measurement marks meet the requirements of this Standard, the measurement marks shall take the marks; this shall be mentioned in the inland navigation vessel certificate.
7. For vessels operating on zones of inland waterways other than Zone 3 (i.e. Zones 1, 2 or 4), the bow and stern pairs of draught marks relevant to this zone referred to in (4) shall be supplemented by adding a vertical line to this line or, in the case of several zones, several additional lines shall be affixed towards the Bow.
8. This vertical line and the horizontal line shall be 30 mm thick. In addition to the draught mark towards the bow of the vessel, the relevant zone numbers shall be indicated in lettering 60 mm high × 40 mm deep (see Figure below).

Figure 7. 2: Draught Marks



7.2.5 Manoeuvrability

7.2.5.1 General

1 Vessels and convoys shall display adequate navigability and maneuverability.

2 Unpowered vessels intended to be towed shall meet the specific requirements laid down by the inspection body.

3 Powered vessels and convoys shall meet the requirements set out in the next sections.

7.2.5.2 Navigation Tests

1. Navigability and maneuverability shall be checked by means of navigation tests. Compliance with the requirements of Articles 7.2.5.6 to 7.2.5.10 shall, in particular, be examined.
2. The inspection body may dispense with all or part of the tests where compliance with the navigability and maneuverability requirements is proven in another manner.

7.2.5.3 Test Area

1. The navigation tests referred to in Article 7.2.5.2 shall be carried out on areas of inland waterways that have been designated by the competent authorities.
2. Those test areas shall be situated on a stretch of flowing or standing water that is if possible straight, at least 2 km long and sufficiently wide and is equipped with highly-distinctive

marks for determining the position of the vessel.

3. It shall be possible for the inspection body to plot the hydrological data such as depth of water, width of navigable channel and average speed of the current in the navigation area as a function of the various water levels.

7.2.5.4 Degree Of Loading Of Vessels And Convoys During Navigation Tests

During navigation tests, vessels and convoys intended to carry goods shall be loaded to at least 70 % of their tonnage and loading, distributed in such a way as to ensure a horizontal attitude as far as possible. If the tests are carried out with a lesser load the approval for downstream navigation shall be restricted to that loading.

7.2.5.5 Use Of On-Board Facilities For Navigation Test

1. During the navigation test, all of the equipment referred to in items 34 and 52 of the inland navigation vessel certificate which may be actuated from the wheelhouse may be used, apart from anchors.
2. However, during the test involving turning into the current referred to in Article 7.2.5.10, bow anchors may be used.

7.2.5.6 Prescribed (Forward) Speed

1. Vessels and convoys shall achieve a speed in relation to the water of at least 13 km/h. That condition is not mandatory where pushers are operating solo.
2. The inspection body may allow derogations to vessels and convoys operating solely in estuaries and ports.
3. The inspection body shall check if the unladen vessel is capable of exceeding a speed of 40 km/h in relation to water. If this can be confirmed, the following entry shall be entered in item 52 of the inland navigation vessel certificate.

‘The vessel is capable of exceeding a speed of 40 km/h in relation to water.’

7.2.5.7 Stopping Capacity

1. Vessels and convoys shall be able to stop facing downstream in good time while remaining adequately maneuverable.
2. Where vessels and convoys with a length L of not more than 86 m and with a breadth B of not more than 22.90 m the stopping capacity mentioned above may be replaced by turning capacity.
3. The stopping capacity shall be proved by means of stopping maneuvers carried out within a test area as referred to in Article 5.03 and the turning capacity by turning maneuvers in

accordance with Article 7.2.5.10.

7.2.5.8 Capacity For Going Astern

Where the stopping maneuver required by Article 7.2.5.7 is carried out in standing water it shall be followed by a navigation test while going astern

7.2.5.9 Capacity For Taking Evasive Action

Vessels and convoys shall be able to take evasive action in good time. That capacity shall be proven by means of evasive maneuvers carried out within a test area as referred to in Article 7.2.5.3.

7.2.5.10 Turning Capacity

Vessels and convoys with a length L of not more than 86 m or with a breadth B of not more than 22.90 m shall be able to turn in good time.

That turning capacity may be replaced by the stopping capacity referred to in Article 7.2.5.7. The turning capacity shall be proven by means of turning maneuvers against the current

7.2.6 Steering System

7.2.6.1 General Requirements

1. Vessels shall be fitted with a reliable steering system which provides at least the maneuverability required by section 7.2.5.
2. Powered steering systems shall be designed in such a way that the rudder cannot change position unintentionally.
3. The steering system as a whole shall be designed for permanent lists of up to 15° and ambient temperatures from - 20 °C to + 50 °C.
4. The component parts of the steering system shall be rugged enough to always be able to withstand the stresses to which they may be subjected during normal operation. No external forces applied to the rudder shall impair the operating capacity of the steering apparatus and its drive unit.
5. The steering system shall incorporate a powered drive unit if so required by the forces needed to actuate the rudder.
6. A steering apparatus with powered drive unit shall be protected against overloads by means of a system that restricts the torque applied by the drive unit.
7. The penetrations for the rudder stocks shall be so designed as to prevent the spread of water-polluting lubricants.

7.2.6.2 Steering Apparatus Drive Unit

1. If the steering apparatus has a powered drive unit, a second independent drive unit or an additional manual drive shall be present. In case of failure or malfunction of the drive unit of the rudder system, the second independent drive unit or the manual drive has to be in operation within 5 seconds.
2. If the second drive unit or manual drive is not placed in service automatically, it shall be possible to do so immediately by means of a single operation by the helmsman that is both simple and quick.

The second drive unit or manual drive shall ensure the maneuverability required by Chapter 7.2.5 as well

7.2.6.3 Hydraulic Steering Apparatus Drive Unit

1. No other power consumers may be connected to the hydraulic steering apparatus drive unit.
2. Hydraulic tanks shall be equipped with a warning system that monitors a dropping of the oil level below the lowest content level needed for safe operation.
3. The dimensions, design and arrangement of the pipework shall as far as possible exclude mechanical damage or damage resulting from fire.
   a. Hydraulic hoses are only permissible, if vibration absorption or freedom of movement of components makes their use inevitable
   b. to be designed for at least the maximum service pressure
   c. to be renewed at the latest every eight years
4. Hydraulic cylinders, hydraulic pumps and hydraulic motors as well as electric motors shall be examined at the latest every eight years by a specialised firm and repaired if required.

7.2.6.4 Power Source

1. Steering systems fitted with two powered drive units shall have at least two power sources.
2. If the second power source for the powered steering apparatus is not constantly available while the vessel is under way, a buffer device carrying adequate capacity shall provide back-up during the period needed for start-up.
3. In the case of electrical power sources, no other power consumers may be supplied by the main power source for the steering system.

7.2.6.5 Manual Drive

1. The manual wheel shall not be driven by a powered drive unit.

Regardless of rudder position, a kick-back of the wheel shall be prevented when the manual drive is engaged automatically.

7.2.6.6 Rudder-Propeller, Water-Jet, Cycloidal-Propeller And Bow-Thruster Systems

1. Where the thrust vectoring of rudder-propeller, water-jet, cycloidal-propeller or bow thruster installations is remotely actuated by electric, hydraulic or pneumatic means, there shall be two steering controls, each independent of the other, between the wheelhouse and the propeller- or thruster-installation which, mutatis mutandis, meet the requirements of Articles 7.2.6.1 to 7.2.6.5.
2. Such systems are not subject to this paragraph if they are not needed in order to achieve the maneuverability required by Chapter 5 or if they are only needed for the stopping test.
3. Where there are two or more rudder-propeller, water-jet or cycloidal-propeller installations that are independent of each other the second actuation system is not necessary if the vessel retains the maneuverability required by Chapter 5 if one of the systems fails.

7.2.6.7 Indicators And Monitoring Devices

1. The rudder position shall be clearly displayed at the steering position. If the rudder-position indicator is electric it shall have its own power supply.
2. An optical and acoustic alarm shall be present at the steering position to signal the following:
   a) oil level of the hydraulic tanks falling under the lowest content level in accordance with Article 6.03(2) and decrease of service pressure of the hydraulic system.
   b) failure of the electrical supply for the steering control.
   c) failure of the electrical supply for the drive units.
   d) failure of the rate-of-turn regulator.
   e) failure of the required buffer devices.

7.2.6.8 Rate-Of-Turn Regulators

1. Rate-of-turn regulators and their components shall meet the requirements laid down in Article 10.20.
2. The proper functioning of the rate-of-turn regulator shall be displayed at the steering position by means of a green indicating light.

   Any lack of or unacceptable variations in the supply voltage and an unacceptable decrease in the speed of rotation of the gyroscope shall be monitored
3. Where, in addition to the rate-of-turn regulator, there are other steering systems, it shall be possible to clearly distinguish at the steering position which of these systems has been activated. It shall be possible to shift from one system to another immediately. The rate-of-turn regulator shall not have any influence on the steering systems.

4. The electricity supply to the rate-of-turn regulator shall be independent of other power consumers.
5. The gyroscopes, detectors and rate-of-turn indicators used in the rate-of-turn regulators shall meet the minimum requirements of the minimum specifications and test conditions concerning rate-of-turn displays for inland waterways, as laid down by authorities.

7.2.6.9 Testing

1. The correct installation of the steering system shall be inspected by an inspection body. For this purpose, the inspection body can require the following documents:
   a) description of the steering system.
   b) drawings of and information on the steering apparatus drive units and the steering control.
   c) information concerning the steering apparatus.
   d) electrical wiring diagram.
   e) description of the rate-of-turn regulator.
   f) operating and maintenance instructions for the steering system.
2. Operation of the entire steering system shall be checked by means of a navigation test. If a rate-of-turn regulator is installed it shall be checked that a predetermined course can be reliably maintained and that bends can be negotiated safely.
3. Power-driven steering systems shall be inspected by a competent person:
   a) before being put into service.
   b) after a failure.
   c) after any modification or repair.
   d) regularly at least every three years.
4. The inspection has to cover at least:
   a) a check of conformity with the approved drawings and at periodical inspections whether alterations in the steering system were made.
   b) a functional test of the steering system for all operational possibilities.
   c) a visual check and a tightness check of the hydraulic components, in particular valves, pipelines, hydraulic hoses, hydraulic cylinders, hydraulic pumps, and hydraulic strainers.
   d) a visual check of the electrical components, in particular relays, electric motors and safety devices.
   e) a check of the optical and acoustic control devices.

An inspection attestation, signed by the competent person, shall be issued, showing the date of inspection

7.2.7 Wheel House

7.2.7.1 General

1. Wheelhouses shall be arranged in such a way that the helmsman may at all times perform his task while the vessel is under way.
2. Under normal operating conditions, sound pressure generated by the vessel and measured at the level of the helmsman's head at the steering position shall not exceed 70 dB(A).
3. Where a wheelhouse has been designed for radar navigation by one person, the helmsman shall be able to accomplish his task while seated and all of the display or monitoring instruments and all of the controls needed for operation of the vessel shall be arranged in such a way that the helmsman may use them comfortably while the vessel is under way without leaving his position or losing sight of the radar screen.

7.2.7.2 Unobstructed View

1. There shall be an adequately unobstructed view in all directions from the steering position.
2. The area of obstructed vision for the helmsman ahead of the vessel in an unladen state with half of its supplies but without ballast shall not exceed 250 m.
3. To further reduce any area of obstructed vision, only appropriate auxiliary means shall be used.
4. Auxiliary means for reducing the area of obstructed vision may not be taken into account during the inspection.
5. The helmsman's field of unobstructed vision at his normal position shall be at least 240° of the horizon and at least 140° within the forward semicircle.

No window frame, post or superstructure shall lie within the helmsman's usual axis of vision.
Even in the case where a field of unobstructed vision of at least 240° of the horizon is provided, the inspection body may require other measures and in particular the installation of appropriate auxiliary means if no sufficiently unobstructed view is provided towards the rear.

The lower edge of the side windows must be located as low as possible and the upper edge of the side and rear windows must be located as high as possible.

In determining whether the requirements in this Article for visibility from the wheelhouse are met, the helmsman shall be assumed to have a height of eye of 1,65 m above the wheelhouse floor at the steering position

1. The upper edge of the forward facing windows of the wheelhouse shall be high enough to allow a person at the steering position a clear forward view.
2. This requirement shall have been fulfilled when a person at the steering position with height of

eye of 1,80 m have a clear forward view to at least 10° above the horizontal at eye-level height.

3. There shall in all weathers be appropriate means of providing a clear view through the front windows.
4. The glazing used in wheelhouses shall be made of safety glass and have a light transmission of at least 75 %.

To avoid reflections, the wheelhouse front windows must be glare-free or fitted so as to exclude reflections effectively.

The requirement of the second sentence shall have been fulfilled when the windows are inclined from the vertical plane at an angle of not less than 10° and not more than 25°.

7.2.7.3 General Requirements Concerning Control, Indicating and Monitoring Equipment

1. Control equipment needed to operate the vessel shall be brought into its operating position easily. That position shall be unambiguously clear.
2. Monitoring instruments shall be easily legible. It shall be possible to dim their lighting down to their extinction. Light sources shall be neither intrusive nor impair the legibility of the monitoring instruments.
3. There shall be a system for testing the warning and indicating lights.
4. It shall be possible to clearly establish whether a system is in operation. If its functioning is indicated by means of an indicating light, this shall be green.
5. Any malfunctioning or failure of systems that require monitoring shall be indicated by means of red warning lights.
6. An audible warning shall sound at the same time that a red warning light lights up. Audible warnings may be given by a single, collective signal. The sound pressure level of that signal shall exceed the maximum sound pressure level of the ambient noise at the steering position by at least 3 dB(A).
7. The audible warning shall be capable of being switched off after a malfunction or failure has been acknowledged. Such shutdown shall not prevent the alarm signal from being triggered by other malfunctions. The red warning lights shall only go out when the malfunction has been corrected.

The monitoring and indicating devices shall be automatically switched to an alternative power supply if their own power supply fails.

7.2.7.4 Specific Requirements Concerning Control, Indicating And Monitoring Equipment Of Main Engines And Steering System

1. It shall be possible to control and monitor the main engines and steering systems from the steering position. Main engines fitted with a clutch which can be actuated from the steering position, or driving a controllable pitch propeller which can be controlled from the steering position, need only to be capable of being started up and shut down from the engine room.
2. The control for each main engine shall take the form of a single lever which prescribes an arc within a vertical plane that is approximately parallel to the longitudinal axis of the vessel. Movement of that lever towards the bow of the vessel shall cause forward motion, whereas movement of the lever towards the stern shall cause the vessel to go astern. Clutch engagement and reversal of the direction of motion shall take place about the neutral position of that lever. The lever shall catch in the neutral position.
3. The direction of the propulsion thrust imparted to the vessel and the rotational speed of the propeller or main engines shall be displayed.
4. The indicating and monitoring devices required by Article 6.07(2), Article 8.03(2), and Article 8.05(13), shall be located at the steering position.
5. Vessels with wheelhouses designed for radar navigation by one person shall be steered by means of a lever. It shall be possible to move that lever easily by hand. The position of the lever in relation to the longitudinal axis of the vessel shall correspond precisely to the position of the rudder blades. It shall be possible to release hold of the lever in any given position without that of the rudder blades changing. The neutral position of the lever shall be clearly perceptible.
6. Where the vessel is fitted with bow rudders or special rudders, particularly for going astern, these shall be actuated in wheelhouses designed for radar navigation by one person by special levers which, mutatis mutandis, meet the requirements set out in (5).
7. That requirement shall also apply where, in convoys, the steering system fitted to craft other than those powering the convoy is used.
8. Where rate-of-turn regulators are used, it shall be possible for the rate-of-turn control to be released in any given position without altering the speed selected.
9. The control shall turn through a wide enough arc to guarantee adequately precise positioning. The neutral position shall be clearly perceptible from the other positions. It shall be possible to increase or decrease the level of illumination.
10. The remote-control equipment for the entire steering system shall be installed in a permanent manner and be arranged in such a way that the course selected is clearly visible. If the remote control equipment can be disengaged, it shall be equipped with an indicating device

displaying the respective operational conditions ‘in service’ or ‘out of service’. The disposition and manipulation of the controls shall be functional.

11. For systems that are subsidiary to the steering system, such as active bow thrusters, remote-control equipment not permanently installed shall be acceptable provided that such a subsidiary installation can be activated by means of an override at any time within the wheelhouse.
12. In the case of rudder-propeller, water-jet, cycloidal-propeller and bow-thruster systems, equivalent devices shall be acceptable as control, indicating and monitoring devices.
13. The requirements set out in (1) to (8) shall apply, mutatis mutandis, in view of the specific characteristics and arrangements selected for the abovementioned active steering and propulsion units. In analogy to (2), each unit shall be controlled by a lever which moves in the form of an arc within a vertical plane that is approximately parallel to the direction of the thrust of the unit. From the position of the lever the direction of the thrust acting on the vessel shall be clear
14. If rudder propeller or cycloidal-propeller systems are not controlled by means of levers, the inspection body may allow derogations from (2). These derogations shall be entered in item 52 of the inland navigation vessel certificate.

7.2.7.5 Navigation Lights, Light Signals And Sound Signals

1. Navigation lights, their casings and accessories shall bear the approval mark as prescribed.
2. Current indicating lights or other equivalent devices, such as repeater lights, for monitoring the navigation lights shall be installed in the wheelhouse unless that monitoring can be performed direct from the wheelhouse.
3. In wheelhouses designed for radar navigation by one person, repeater lights shall be installed on the control panel in order to monitor the navigation lights and the light signals. Switches of navigation lights shall be included in the repeater lights or be adjacent to these and shall be clearly assigned to them.

   The arrangement and colour of the repeater lights for the navigation lights and light signals shall correspond to the actual position and colour of those lights and signals.

   The failure of a navigation light or light signal to function shall cause the corresponding repeater light either to go out or to provide a signal in another manner.
4. In wheelhouses designed for radar navigation by one person it shall be possible to activate the sound signals by a foot operated switch. That requirement shall not apply to the ‘do not approach’ signal in accordance with the applicable navigational authority regulations of the Member States.

7.2.7.6 Navigation And Information Equipment

1. Navigational radar installation and rate-of-turn indicators shall fulfil the requirements as laid down. Compliance with these requirements shall be determined by a type-approval issued by the competent authority.
2. Inland ECDIS equipment which can be operated in navigation mode shall be regarded as navigational radar installation.
3. The requirements of the current Inland ECDIS Standard shall be met. The requirements of Annex 5 must be complied with.
4. Inland AIS equipment shall meet the requirements of the current "Vessel Tracking and Tracing Standard for Inland Navigation".
5. The rate-of-turn indicator shall be located ahead of the helmsman and within his field of vision.
6. In wheelhouses designed for radar navigation by one person:
   a) the radar screen shall not be shifted significantly out of the helmsman's axis of view in its normal position;
   b) the radar image shall continue to be perfectly visible, without a mask or screen, whatever the lighting conditions outside the wheelhouse;
   c) the rate-of-turn indicator shall be installed directly above or below the radar image or be incorporated into this.

7.2.7.7 Radio Telephony Systems For Vessels With Wheelhouses Designed For Radar Navigation By One Person

1. Where vessel wheelhouses have been designed for radar navigation by one person, reception from the vessel to vessel networks and that of nautical information shall be via a loudspeaker, and outgoing communications via a fixed microphone. Send/receive shall be selected by means of a push-button.
   It shall not be possible to use the microphones of those networks for the public correspondence network.
2. Where vessel wheelhouses designed for radar navigation by one person are equipped with a radio telephone system for the public correspondence network, reception shall be possible from the helmsman's seat.

7.2.7.8 Internal Communication Facilities On Board

There shall be internal communication facilities on board vessels with a wheelhouse designed for radar navigation by one person.

It shall be possible to establish communication links from the steering position:

a) with the bow of the vessel or convoy;
b) with the stern of the vessel or convoy if no direct communication is possible from the steering position;
c) with the crew accommodation;
d) with the boat master's cabin.

Reception at all positions of these internal communication links shall be via loudspeaker, and transmission shall be via a fixed microphone. The link with the bow and stern of the vessel or convoy may be of the radio-telephone type.

7.2.7.9 Alarm System

1. There shall be an independent alarm system enabling the accommodation, engine rooms and, where appropriate, the separate pump rooms to be reached.
2. The helmsman shall have within reach an on/off switch controlling the alarm signal; switches which automatically return to the off position when released are not acceptable.
3. The sound pressure level for the alarm signal shall be at least 75 dB(A) within the accommodation area.

In engine rooms and pump rooms the alarm signal shall take the form of a flashing light that is visible on all sides and clearly perceptible at all points.

7.2.7.10 Heating And Ventilation

Wheelhouses shall be equipped with an effective heating and ventilation system that can be regulated.

7.2.7.11 Stern-anchor Operating Equipment

On board vessels and convoys whose wheelhouse has been designed for radar navigation by one person and exceeding 86 m in length or 22.90 m in breadth it shall be possible for the helmsman to drop the stern anchors from his position

7.2.7.12 Retractable Wheelhouses

Retractable wheelhouses shall be fitted with an emergency lowering system.

All lowering operations shall automatically trigger a clearly audible acoustic warning signal. That requirement shall not apply if the risk of injury which may result from the lowering is prevented by appropriate design features.

It shall be possible to leave the wheelhouse safely whatever its position.

7.2.7.13 Entry In The Inland Navigation Vessel Certificate For Vessels With Wheelhouses Designed For Radar Navigation By One Person

Where a vessel complies with the special provisions for wheelhouses designed for radar navigation by one person as set out in Articles 7.2.7.1(3), 7.2.7.4(5) and (6), 7.2.5.7(3), 7.2.7.6(2), 7.2.2(7), 7.2.7.8 and 7.2.7.11, the following entry shall be made in the inland navigation vessel certificate.

'The vessel has a wheelhouse designed for radar navigation by one person'

7.2.8 Engine Design

7.2.8.1 General

1. Engines and their ancillaries shall be designed, built and installed in accordance with best practice.
2. Pressure vessels dedicated for the operation of the vessel shall be checked by an expert to verify that they are safe for operation:
    a) before being put into service for the first time;
    b) before being put back into service after any modification or repair; and
    c) regularly, at least every five years.
3. The inspection shall involve an internal and an external inspection. Compressed-air vessels the interior of which cannot be properly inspected, or the condition of which cannot be clearly established during the internal inspection, are required to undergo additional non-destructive testing or a hydraulic pressure test.
4. An inspection attestation shall be issued, signed by the expert and showing the date of the inspection.
5. Other installations requiring regular inspection, particularly steam boilers, other pressure vessels and their accessories, and lifts, shall meet the regulations applying in one of the Member States.
6. Only internal-combustion engines burning fuels having a flashpoint of more than 55 °C may be installed.

7.2.8.2 Safety Equipment

1. Engines shall be installed and fitted in such a way as to be adequately accessible for operation and maintenance and shall not endanger the persons assigned to those tasks. It shall be possible to make them secure against unintentional starting.
2. Main engines, auxiliaries, boilers and pressure vessels, and their accessories, shall be fitted

with safety devices.

3. In case of emergency, it shall also be possible to shut down the motors driving the blower and suction fans from outside the space in which they are located, and from outside the engine room.

Where necessary, connections of pipes which carry fuel oil, lubricating oil, and oils used in power transmission systems, control and activating systems and heating systems shall be screened or otherwise suitably protected to avoid oil spray or leakages onto hot surfaces, into machinery air intakes, or other sources of ignition. The number of connections in such piping systems shall be kept to a minimum.

1. External high pressure fuel delivery pipes of diesel engines, between the high pressure fuel pumps and fuel injectors, shall be protected with a jacketed piping system capable of containing fuel from a high pressure pipe failure. The jacketed piping system shall include a means for collection of leakages and arrangements shall be provided for an alarm to be given of a fuel pipe failure, except that an alarm is not required for engines with no more than two cylinders. Jacketed piping systems need not be applied to engines on open decks operating windlasses and capstans.
2. Insulation of engine parts shall meet the requirements of Article 3.04(3), second subparagraph.

7.2.8.3 Propulsion Systems

1. It shall be possible to start, stop or reverse the ship's propulsion reliably and quickly.
2. The following areas shall be monitored by suitable devices which trigger an alarm once a critical level has been reached:
    a) Temperature of the cooling water of the main engines.
    b) Lubricating-oil pressure for the main engines and transmissions.
    c) The oil and air pressure of the reversing units of the main engines, reversible transmissions or propellers.
3. Where vessels have only one propulsion engine, that engine shall not be shut down automatically except in order to protect against over speed.
4. Where vessels have only one propulsion engine, that engine may be equipped with an automatic device for the reduction of the engine speed only if an automatic reduction of the engine speed is indicated both optically and acoustically in the wheelhouse and the device for the reduction of the engine speed can be switched off from the helmsman's position.
5. Shaft bushings shall be designed in such a way as to prevent the spread of water-polluting lubricants.

7.2.8.4 Engine Exhaust System

1. The exhaust gases shall be completely ducted out of the vessel.
2. All suitable measures shall be taken to avoid ingress of the exhaust gases into the various compartments. Exhaust pipes passing through accommodation or the wheelhouse shall, within these, be covered by protective gas-tight sheathing. The gap between the exhaust pipe and this sheathing shall be open to the outside air.
3. The exhaust pipes shall be arranged and protected in such a way that they cannot cause a fire.

The exhaust pipes shall be suitably insulated or cooled in the engine rooms. Protection against physical contact may suffice outside the engine rooms.

7.2.8.5 Fuel tanks, Pipes And Accessories

1. Liquid fuels shall be stored in steel tanks which are either an integral part of the hull or which are firmly attached to the hull. If so required by the design of the vessel, an equivalent material in terms of fire-resistance may be used. These requirements shall not apply to tanks having a capacity of no more than 12 liters that have been incorporated in auxiliaries during their manufacture. Fuel tanks shall not have common partitions with drinking-water tanks.
2. Fuel tanks and their pipework and other accessories shall be laid out and arranged in such a way that neither fuel nor fuel vapours may accidentally reach the inside of the vessel. Tank valves intended for fuel sampling or water drainage shall close automatically.
3. No fuel tanks may be located forward of the collision bulkhead or aft of the aft-peak bulkhead.
4. Fuel tanks and their fittings shall not be located directly above engines or exhaust pipes.
5. The filler orifices for fuel tanks shall be marked distinctly.
6. The orifice for the fuel tank filler necks shall be on the deck, except for the daily-supply tanks. The filler neck shall be fitted with a connection piece in accordance with European Standard EN 12827: 1999.
7. Such tanks shall be fitted with a breather pipe terminating in the open air above the deck and arranged in such a way that no water ingress is possible. The cross-section of the breather pipe shall be at least 1,25 times the cross-section of the filler neck.
8. If tanks are interconnected, the cross-section of the connecting pipe shall be at least 1,25 times the cross-section of the filler neck.
9. Directly at tank outlets the pipework for the distribution of fuels shall be fitted with a quick-closing valve that can be operated from the deck, even when the rooms in question are closed.
10. If the operating device is concealed, the lid or cover shall not be lockable.
11. The operating device shall be marked in red. If the device is concealed it shall be marked with a symbol for the 'quick-closing valve on the tank' with a side length of at least 10 cm.

12. The first subparagraph shall not apply to fuel tanks mounted directly on the engine. Fuel pipes, their connections, seals and fittings shall be made of materials that are able to withstand the mechanical, chemical and thermal stresses to which they are likely to be subjected. The fuel pipes shall not be subjected to any adverse influence of heat and it shall be possible to inspect them throughout their length.
13. Fuel tanks shall be provided with a suitable capacity-gauging device. Capacity-gauging devices shall be legible right up to the maximum filling level. Glass gauges shall be effectively protected against impacts, shall be fitted with an automatic closing device at their base and their upper end shall be connected to the tanks above their maximum filling level. The material used for glass gauges shall not deform under normal ambient temperatures. Sounding pipes shall not terminate in accommodation spaces. Sounding pipes terminating in an engine or boiler room shall be fitted with suitable self-closing devices.
14. a) Fuel tanks shall be safeguarded against fuel spills during bunkering by means of appropriate onboard technical devices which shall be entered in item 52 of the inland navigation vessel certificate.
15. b) If fuel is taken on from bunkering stations with their own technical devices to prevent fuel spills on board during bunkering, the equipment requirements in (a) and (11) shall no longer apply.
16. If fuel tanks are fitted with an automatic shut-off device, the sensors shall stop fueling when the tank is 97 % full; this equipment shall meet the 'failsafe' requirements.
17. If the sensor activates an electrical contact, which can break the circuit provided by the bunkering station by a binary signal, it shall be possible to transmit the signal to the bunkering station by means of a watertight connection plug meeting the requirements of International Standard IEC 60309-1: 1999 for 40 to 50 V DC, housing colour white, earthing contact position ten o'clock.
18. Fuel tanks shall be provided with openings having leak-proof closures that are intended to permit cleaning and inspection.
19. Fuel tanks directly supplying the main engines and engines needed for safe operation of the vessel shall be fitted with a device emitting both visual and audible signals in the wheelhouse if their level of filling is not sufficient to ensure further safe operation.

7.2.8.6 Storage Of Lubricating Oil, Pipes And Accessories

1. Lubricating oil shall be stored in steel tanks which are either an integral part of the hull or which are firmly attached to the hull. If so required by the design of the vessel, an equivalent material in terms of fire-resistance may be used. These requirements shall not apply to tanks having a capacity of no more than 25 liters. Lubricating oil tanks shall not have

common partitions with drinking-water tanks.

2. Lubricating oil tanks and their pipework and other accessories shall be laid out and arranged in such a way that neither lubricating oil nor lubricating oil vapour may accidentally reach the inside of the vessel.

   No lubricating oil tanks may be located forward of the collision bulkhead

3. Lubricating oil tanks and their fittings shall not be located directly above engines or exhaust pipes.

4. The filler orifices for lubricating oil tanks shall be marked distinctly.

5. Lubricating oil pipes, their connections, seals and fittings shall be made of materials that are able to withstand the mechanical, chemical and thermal stresses to which they are likely to be subjected. The pipes shall not be subjected to any adverse influence of heat and it shall be possible to inspect them throughout their length.

6. Lubricating oil tanks shall be provided with a suitable capacity-gauging device. Capacity-gauging devices shall be legible right up to the maximum filling level. Glass gauges shall be effectively protected against impacts, shall be fitted with an automatic closing device at their base and their upper end shall be connected to the tanks above their maximum filling level. The material used for glass gauges shall not deform under normal ambient temperatures. Sounding pipes shall not terminate in accommodation spaces. Sounding pipes terminating in an engine or boiler room shall be fitted with suitable self-closing devices.

7.2.8.7 Storage Of Oils Used In Power Transmission Systems, Control And Activating Systems And Heating Systems, Pipes And Accessories

1. Oils used in power transmission systems, control and activating systems and heating systems shall be stored in steel tanks which are either an integral part of the hull or which are firmly attached to the hull. If so required by the design of the vessel, an equivalent material in terms of fire-resistance may be used. These requirements shall not apply to tanks having a capacity of no more than 25 litres. Oil tanks according to sentence (1) shall not have common partitions with drinking-water tanks.

2. Oil tanks according to (1) and their pipework and other accessories shall be laid out and arranged in such a way that neither such oil nor such oil vapour may accidentally reach the inside of the vessel.

3. No oil tanks according to (1) may be located forward of the collision bulkhead.

4. Oil tanks according to (1) and their fittings shall not be located directly above engines or exhaust pipes.

5. The filler orifices for oil tanks according to (1) shall be marked distinctly.

Oil pipes according to (1), their connections, seals and fittings shall be made of materials that are able to withstand the mechanical, chemical and thermal stresses to which they are likely to be subjected. The pipes shall not be subjected to any adverse influence of heat and it shall be possible to inspect them throughout their length

6. Oil tanks according to (1) shall be provided with a suitable capacity-gauging device. Capacity-gauging devices shall be legible right up to the maximum filling level. Glass gauges shall be effectively protected against impacts, shall be fitted with an automatic closing device at their base and their upper end shall be connected to the tanks above their maximum filling level. The material used for glass gauges shall not deform under normal ambient temperatures. Sounding pipes shall not terminate in accommodation spaces. Sounding pipes terminating in an engine or boiler room shall be fitted with suitable self-closing devices.

7.2.8.8 Bilge Pumping And Drainage Systems

1. It shall be possible to pump out each watertight compartment separately. However, that requirement shall not apply to watertight compartments that are normally sealed hermetically during operation.
2. Vessels requiring a crew shall be equipped with two independent bilge pumps which shall not be installed within the same space. At least one of these shall be motor driven. However, for vessels with a power of less than 225 kW or with a deadweight of less than 350 t, or where vessels not intended for the carriage of goods have a displacement of less than 250 m³, one pump will suffice which can be either manually-operated or motor-driven.
3. Each of the required pumps shall be capable of use in each watertight compartment.
4. The minimum pumping capacity Q1 of the first bilge pump shall be calculated using the following formula:

   $Q_1 = 0.1 \cdot d_1^2$ [l/min]

   d_1 is calculated via the formula:

   d1 = 1.5 • JL (B + H) + 25 [mm]

   The minimum pumping capacity Q_2 of the second bilge pump shall be calculated using the following formula
5. Where the bilge pumps are connected to a drainage system the drainage pipes shall have an internal diameter of at least d_1, in mm, and the branch pipes an internal diameter of at least d_2, in mm.

   Where the vessels length L is less than 25 m the values d_1 and d_2 may be reduced to 35 mm.
6. Only self-priming bilge pumps are permitted.
7. There shall be at least one suction on both the starboard and port sides of all flat-bottomed,

drainable compartments that are wider than 5 m.

8. It may be possible to drain the aft peak via the main engine room by means of an easily accessible, automatically closable fitting.
9. Branch pipes of single compartments shall be connected to the main drainage pipe by means of a lockable non-return valve.

   Compartments or other spaces that are capable of carrying ballast need to be connected to the drainage system only by means of a simple closing device. That requirement shall not apply to holds that are capable of carrying ballast. Such holds shall be filled with ballast water by means of ballast piping that is permanently installed and independent of the drainage pipes, or by means of branch pipes that can be connected to the main drainage pipe by flexible pipes or flexible adaptors. Water intake valves located in the bottom of the hold shall not be permitted for this purpose.
10. Hold bilges shall be fitted with gauging devices.
11. Where a drainage system incorporates permanently installed pipework the bilge-bottom drainage pipes intended to extract oily water shall be equipped with closures that have been sealed in position by an inspection body. The number and position of those closures shall be entered on the inland navigation vessel certificate.
12. Locking the closures in position shall be regarded as equivalent to sealing in accordance with (10). The key or keys for the locking of the closures shall be indicated accordingly and kept in a marked and easily accessible location in the engine room.

7.2.8.9 Oily Water And Used Oil Stores

1. It shall be possible to store, on board, oily water accumulated during operation. The engine- room bilge is considered to be a store for this purpose.
2. In order to store used oils there shall, in the engine room, be one or several specific receptacles whose capacity corresponds to at least 1.5 times the quantity of the used oils from the sumps of all of the internal combustion engines and transmissions installed, together with the hydraulic fluids from the hydraulic-fluid tanks.
3. The connections used in order to empty the receptacles referred to above shall comply with European Standard EN 1305: 1996.
4. Where vessels are only used on short-haul operation the inspection body may grant exceptions from the requirements of (2).
5. The noise produced by a vessel under way, and in particular the engine air intake and exhaust noises, shall be damped by using appropriate means.
6. The noise generated by a vessel under way shall not exceed 75 dB(A) at a lateral distance of 25 m from the ship's side.

Apart from transshipment operations the noise generated by a stationary vessel shall not exceed 65 dB(A) at a lateral distance of 25 m from the ship's side.

7.3 Type of proposed Vessels

7.3.1 General

Inland vessels are typically divided in to six types, namely:

1. Passenger ships
2. Ro-Ro
3. Dry-cargo carriers
4. Well barges
5. Tank vessels
6. Push/tugboats

The above could be further subdivided in to various classes depending on the medium in which they operate. For example, the River vessels are classified separately from the River-Sea vessels. In this chapter a short recount of each of the type shall precede the actual choice of vessels.

It must be remembered that though cargo handling is not in the present scope of services of the report, a discussion on the cargo carrying vessel is included for providing necessary completeness.

In addition to the different carriers mentioned in Figure 7.3 below, the existing vessels plying locally could also be improvised, modified and made to ply in the creek in the spirit of Make in India. This aspect would be further elaborated later in the chapter.

7.3.2 Different Types Carriers

A list of classified vessels for cargo carriage is given in the following Figures.

Figure 7. 3: Types Of Cargo Barges

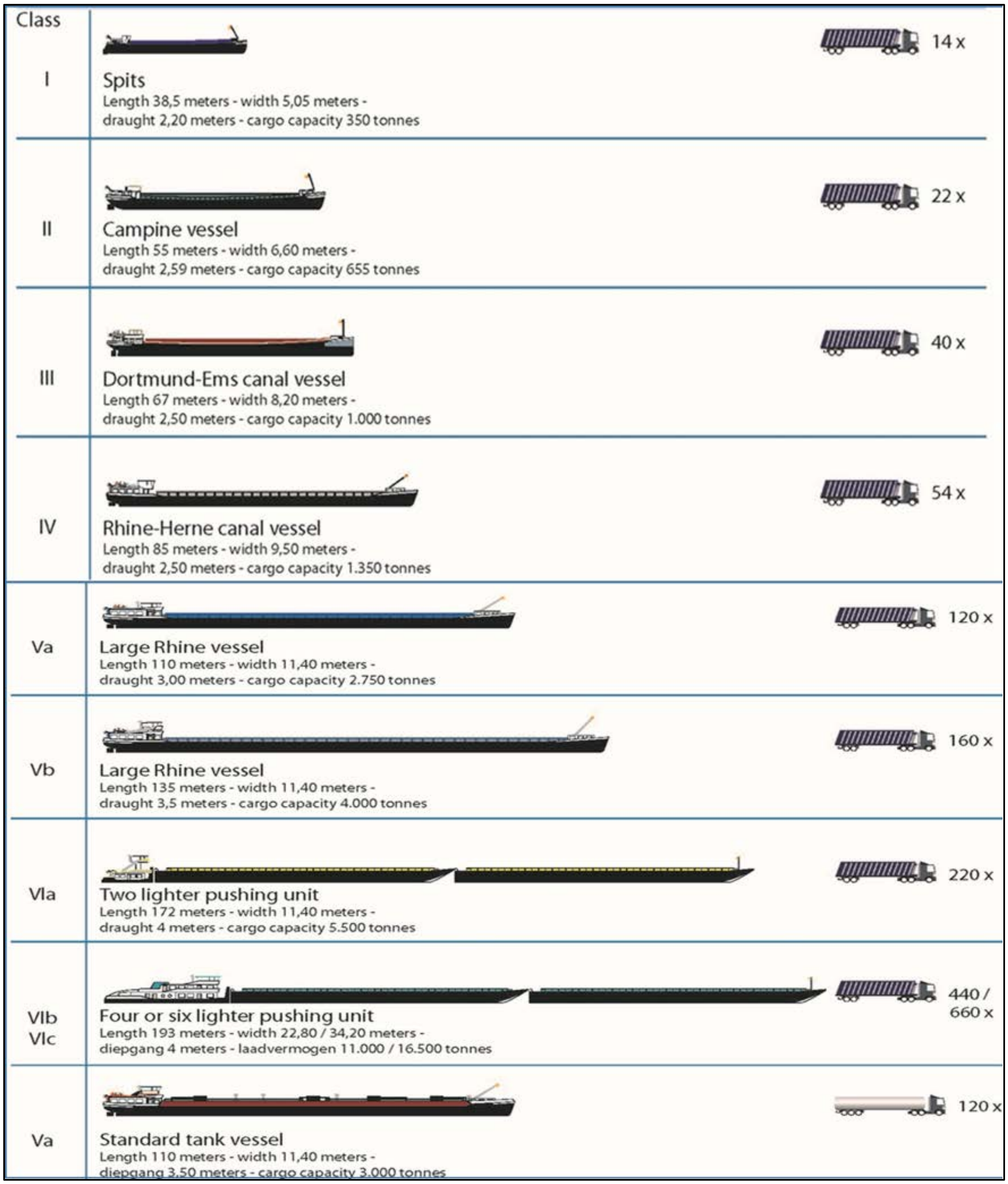
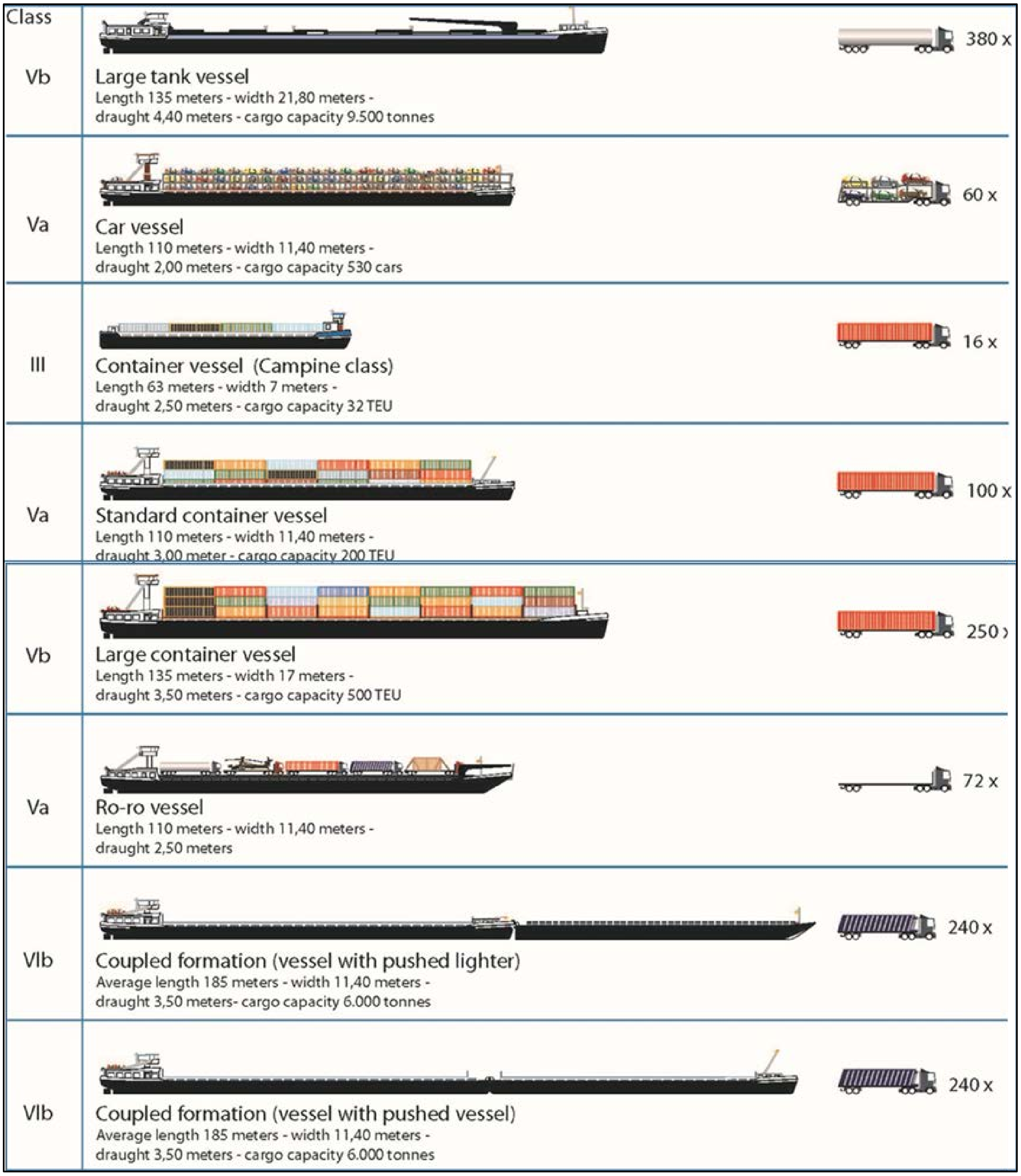


Figure 7. 4: Types Of Cargo Barges – Continued



7.3.3 Passenger Vessels

There are many types of Passenger vessels that adorns the ocean and the Inland waterways around the world. The latest and the fast-moving ones are designed as multi hull boats to reduce resistances of their glide on the water. They are also Low wash and least wake producing than the conventional ones. These boats are compact and has relatively large capacity for their sizes. A detailed discussion on the various types of passenger vessels around the world is necessary to select the suitable vessel for the proposed waterway.

A. Catamarans

A catamaran(informally, a "cat") is a multi-hulled watercraft featuring two parallel hulls of equal size. It is a geometry-stabilized craft, deriving its stability from its wide beam, rather than from a ballasted keel as with a monohull sailboat. Catamaran is from a Tamil word "Kattumaram" which means logs tied together.

Catamarans typically have less hull volume, higher displacement, and shallower draft (draught) than monohulls of comparable length. The two hulls combined also often have a smaller hydrodynamic resistance than comparable monohulls, requiring less propulsive power from either sails or motors. The catamaran's wider stance on the water can reduce both heeling and wave-induced motion, as compared with a monohull, and can give reduced wakes.

Catamarans range in size from small (sailing or rowing vessels) to large (naval ships and car ferries). The structure connecting a catamaran's two hulls ranges from a simple frame strung with webbing to support the crew to a bridging superstructure incorporating extensive cabin and/or cargo space.

Performance

Catamarans have two distinct primary performance characteristics that distinguish them from displacement monohull vessels: lower resistance to passage through the water and greater stability (initial resistance to capsize). Choosing between a monohull and catamaran configuration includes considerations of carrying capacity, speed, and efficiency.

Resistance

At low to moderate speeds, a lightweight catamaran hull experiences resistance to passage through water that is approximately proportional to the square of its speed. A displacement monohull, by comparison, experiences resistance that is at least the cube of its speed. This means that a catamaran would require four times the power in order to double its speed, whereas a monohull would require eight times the power to double its speed, starting at a slow speed. For powered catamarans, this implies smaller power plants (although two are typically required). For sailing catamarans, low allows the sails to derive power from attached flow, their most efficient mode—analogous to a wing—leading to the use of wing sails in racing craft.

Stability

Catamarans rely primarily on form stability to resist heeling and capsize. Comparison of heeling stability of a rectangular-cross section monohull of beam, B, compared with two catamaran hulls of width B/2, separated by a distance, 2×B, determines that the catamaran has an initial resistance to heeling that is seven times that of the monohull. Compared with a monohull, a cruising catamaran sailboat has a high initial resistance to heeling and capsize—a fifty-footer requires four times the force to initiate a capsize than an equivalent monohull.

Tradeoffs

One measure of the trade-off between speed and carrying capacity is the displacement Froude number (FnV), compared with calm water transportation efficiency. FnV applies when the waterline length is too speed-dependent to be meaningful—as with a planning hull. It uses a reference length, the cubic root of the volumetric displacement of the hull, V, where, u, is the relative flow velocity between the sea and ship, and g is acceleration due to gravity:

Calm water transportation efficiency of a vessel is proportional to the full-load displacement and the maximum calm-water speed, divided by the corresponding power required.

$$Fn_{\mathrm{v}} = \frac{u}{\sqrt{gV^{1/3}}}$$

Large merchant vessels have a FnV between one and zero, whereas higher-performance powered catamarans may approach 2.5 - denoting a higher speed per unit volume for catamarans. Each type of vessel has a corresponding calm water transportation efficiency, with large transport ships being in the range of 100-1,000, compared with 11-18 for transport catamarans, denoting a higher efficiency per unit of payload for monohulls.

B. Monohull Vessels

Monohull Vessels are single hull constructions which is used in conventional vessel building. In India mostly monohull vessels are used for passenger transport. In this regard it could be generally said that monohull vessels are of lower speed as they perceived to be less efficient than the multihull vessels.

C. Variety of Passenger Vessels

Mostly the passenger vessels can be broadly divided in to four types,

1. Fast Ropax Ferry
2. Ropax Ferry
3. Modular Ferry
4. Road Ferry

Some of the examples of the above vessels are given as form of illustrations so that ease of selection is facilitated. These are typical vessels and similar vessels could be constructed in any ship yards of the Government's choice.

Fast Ropax Ferry

These are fast ro-ro and passenger vessels often times attaining speeds of 35 to 40 knots.

Figure 7. 5: Fast Ropax Ferry – Typical

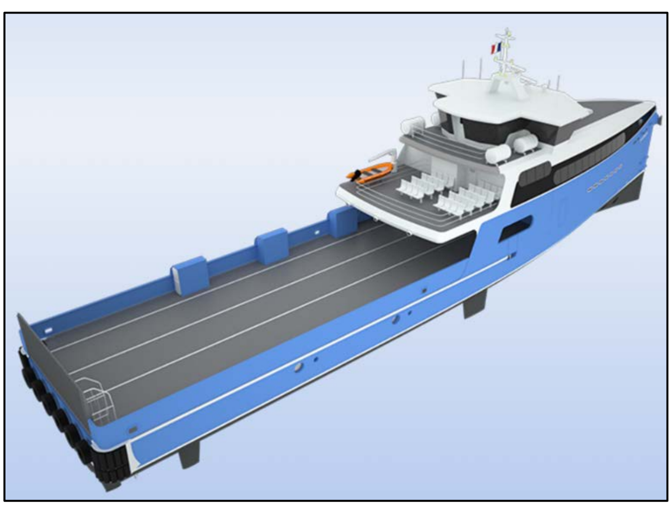
Typical Dimensional details are;

Length (meter)	62
Beam (m)	18
Passengers	740
Speed max (knots)	35
Number of cars	60

There is another variety as shown in Figure 7.8 has the following dimensions;

Length (meter)	55.9
Beam (m)	10.8
Passengers	199
Speed max (knots)	20
Number of cars	18

Figure 7. 6: Fast Ropax Ferry – Typical



Ropax Ferry

Figure 7.9 shows a Ropax Ferry with its dimensions. RoPax ferries are an excellent means of waterborne public transport. They ensure safe and efficient journeys for cars, trucks and passengers

Figure 7. 7: Ropax Ferry – Typical

Length (meter)	65.6
Beam (m)	16.6
Passengers	600
Speed max (knots)	14
Number of cars	60

Modular Ferry

An entire Ferry is configured out of container sized units. The units are called Modular Barges and can be coupled together in the water with the specially designed coupling system, called the Link. Also machinery, superstructure and deck equipment are mounted as modular units to the hull construction. All selected machinery and equipment is based on robust and proven technology. Easy access allows good and safe maintenance, resulting in reliable and predictable operations. The modular system allows efficient modification of the design, now and for future operations. Modular Barges can easily be transported to remote areas and allow assembly on site. The fit for purpose design allows safe and sustainable crossings, forging local connections and developing infrastructure. Typical dimensions of a Modular ferry is given below.

Figure 7. 8: Modular Ferry – Typical

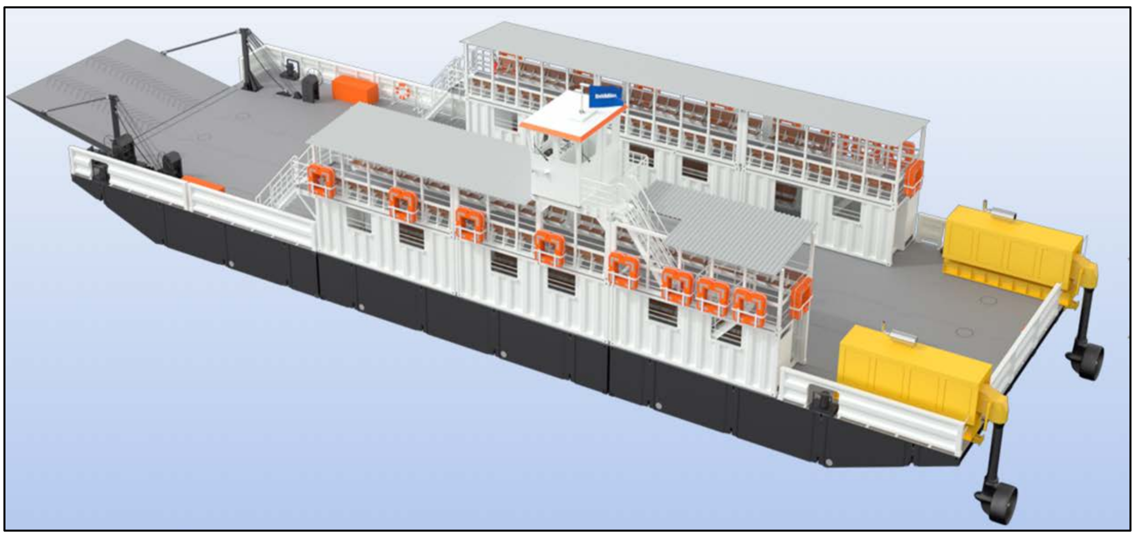
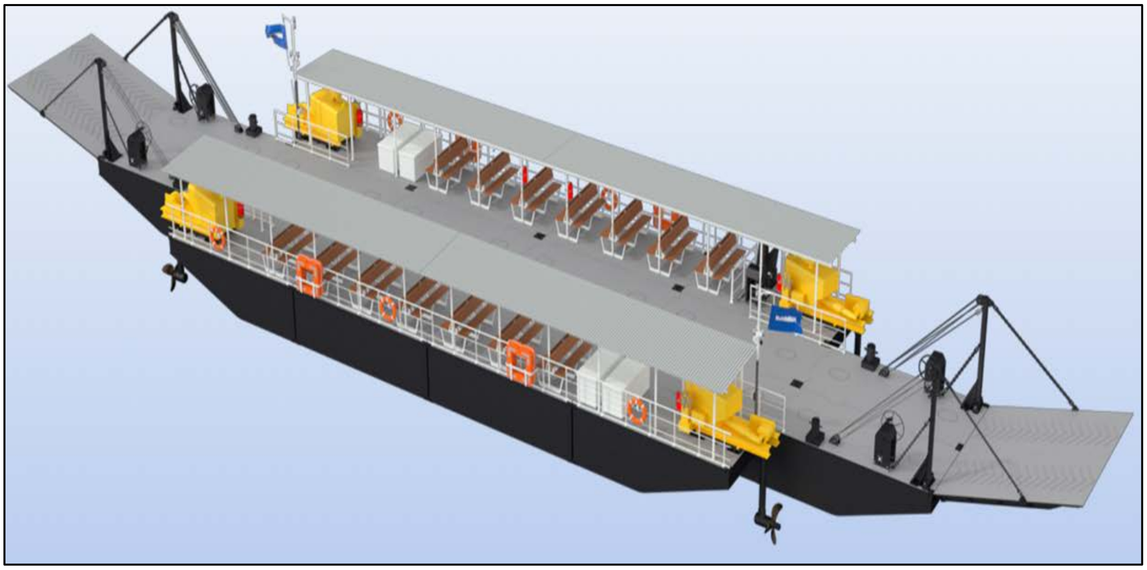


Figure 7. 9: Modular Ferry – Type 2 - Typical



Length (m)	36.3
Beam (m)	9.8
Passengers	150
Speed max (knots)	7.4
Number of cars	14

Road Ferry

Road ferry is high volume vessels connecting coasts, highways or rail heads. These are comfortable in ferrying at all weather conditions with low fuel consumption. However, the fuel efficiency apart, the volume of passenger movement and the comfort it offers is unparalleled.

Typical sizes and the capacity of a road ferry is given below for ready reference;

Length (meter)	85
Beam (m)	21
Passengers	600
Speed max (knots)	22
Number of cars	112

Figure 7. 10: Road Ferry – Typical

D. Water Bus

Water buses are available in the European market for both communication and transfer of passengers. This is very convenient for intra-waterway transfer of men. Often times these vessels carry people for pleasure transport as well. A typical dimension and the illustration of the water bus is given below.

Figure 7. 11: Water Bus – Typical

Length (meter)	30
Beam (m)	7.6
Passengers	80
Speed max (knots)	22
Capacity	80

E. Water Taxi

In advanced waterways, often times water taxis are very popular. These taxis are quick and have limited passenger capacity. Used for transfer and recreation of the Passengers. A typical water taxi and its size is given below.

Figure 7. 12: Water Taxi – Typical

Length (meter)	11.9
Beam (m)	3.8
Passengers	12
Speed max (knots)	25
Fuel capacity	0.8

F. Ferries

Though there are many other types of vessels, for the purpose of this report this is the last type of the vessel that would fit in to the scheme of things. These ferries are robust and carefully selected heavy duty equipment makes this ferry outstanding for a reliable operation. Furthermore, all essential machinery is double constructed. This design, with its functional purity is perfect for inland water navigation. The fuel-efficient propulsion, large capacity and minimal maintenance requirements make this a valuable investment.

The layout and personal lifesaving equipment guarantee a safe escape. The multiple compartment arrangement provides a stable vessel for damage conditions. The risk of fire is minimized by using mainly nonflammable materials and an ample amount of firefighting equipment. The essential functions of this vessel are provided with an emergency backup system.

Figure 7. 13: Ferries – From Different Angles – Typical

A typical dimension is;

Length (m)	28
Passengers	200
Beam (m)	6
Depth (m)	2
Speed max (knots)	13.5

7.3.4 Selection Of Proposed Vessels For The Waterway

Development of a modern waterway is a concept which is in a nascent stage at present in the Indian context. Though, States of Maharashtra, Goa, Kerala, and West Bengal have been using this mode for a long period of time, a scientific approach has been lacking. Many inland water infrastructures once busy and happening, is dormant, silted and stopped due to continuous non-use. Hence, a pragmatic approach to the development of the water transport is the need of the hour. Though, NW I have been using passenger ferry service, this waterway would be the first and foremost waterway pioneering the passenger movement through waterway in a competitive manner.

With out a precedence of scientific waterway development model, the job of a planner is difficult, as well as easy. Difficult because the planning and the investments would have to go hand in hand, so as to have a sustainable model, and easy because there is no model to follow and creativity can have a field day.

In this context, the preceding description on the availability of the vessels used in the waterway of similar nature in the western countries, where the waterway transport is widely practiced. Those waterways in Europe and America are an integral part of the transport system and carries proportionate burden. Hence, investments in the waterway is forth coming and encouraged even by the financial Institutions.

On the contrary, India has a fledgling waterway system being planned at this scale, therefore due care must be excercised in the process. It is proposed to adapt the technology, use the local facilities and develop special crafts to suit the requirements of the present waterway. Hence, the recommended vessels must have the following minimum criteria;

1. Must be elegant and efficient
2. Easy to handle
3. Safe
4. Capable of using multiple fuels
5. Possible to build and repair in India preferably locally

In addition, it must be recognised that the proposed water way is of limited length of around 50 km. The distance is further limited in the cross travel where in the most part of the waterway is limited to less than a kilometer. Therefore, high speed vessels may not be required for this water way. Therefore, a top speed of 12 knots was considered adequate, for the long-haul journeys. For cross journeys the speed would be further reduced to 6 knots or there about. Slowest movement would be around the bends where the speed would be further reduced to about 3 knots or so. Intermediate speeds of 8 knots, 10 knots also could be adopted depending on the number of stoppages and the length of the travel.

It is also proposed on the behest of IWAI and rightly so, to manufacture these vessels locally, preferably through one of the Public Sector Shipyards, who has the necessary expertise. But if the process is desired to be expedited, a separate Shipyard in a green field location (Kolshet suggested) or through brown field acquisition. In both the cases, in house expertise for the future builds and repairs would be developed in house.

Accordingly, a judicious mix of the Public Sector Ship yards, new/acquired shipyard for the waterway operation and up keep would be able to provide the requisite number of vessels in a gradual manner keeping pace with the demand.

Since the ship building is a long and cumbersome process in addition to the Government Process of tendering, it is expected that the first vessels would not be expected in less than 3 years of starting the process. Since the civil works along the creek would be finished in a matter of 12 to 18 months, the operation could start with used second hand vessels from the International market.

It is also proposed that the vessels, atleast the first 10, should be owned by the SPV company running the waterway. At a later stage when the operation stabilizes, the process could be out sourced through Private Public Partnership (PPP).

7.4 Proposed Vessel Size And Specifications

7.4.1 General Consideration

The foregoing narration suggests that with in the ambit of the discussions in paragraph 7.3, new concept vessels would have to be innovated for use of the passengers and passenger cars. Therefore, it is suggested that passenger ro-ro vessels will have capabilities for the following;

1. Carry large number of passengers comfortably
2. Carry passenger cars
3. Carry occasional trucks
4. Facilities for eateries and drinking fountains

It will not make sense to adopt the most advanced equipment with a high speed and state of art facility if the waterway does not deserve one. Hence, in the following paragraphs, some suggestions with regard to vessel type, speed and engine capacity shall be described.

7.4.2 Requirements For The Design Vessel

7.4.2.1 Partial Starting Of Services Without Any Infrastructure

The immediate starting of services would entail commencement of water transport with minimum or no infrastructure. Before describing the same, it would be worth while to examine whether immediate service could be started without any real infrastructure. A reference to the Table 3.11 and 3.12 shows that except for a small stretch involving about 10,470.00 cu.mt soft-material between Chainage Km 35 and Km 36, uninterrupted depths of 2.0 m below chart datum is available between the start of the channel up to chainage 46 Km. Rest of the channel is shallow and could be excluded out of the ambit of the waterway for initial start. Hence, vessels suitable for channels with a dredged depth of about 2.0 m below chart datum, could be deployed in this stretch of the waterway.

The second impediment to the navigation in the waterway is the vertical clearance under the Old railway bridge at Bhayander. This abandoned bridge located at chainage 9.344 Km, needs to be dismantled, which can only precede permission from the relevant departments.

Therefore, between the chainage 9.344 Km and chainage 46.00 Km the operation with a 2.0 m draft can immediately commence with locally available low draught vessels. This would entail obtaining vessels with ramp in the aft of the ship for the passengers and the vehicles, akin to the ones in present use. The shore infrastructure would involve low cost slopping jetties, made of stone masonry or concrete. These infrastructures could be assembled with in a very short period and at very low cost. Navigation between some O-D paired terminals could be taken up through this, which can help assuaging the traffic on the road/bridge crossings across the creek. This operation could commence within 6 months of the Zero date.

7.4.2.2 Regular Services With Limited Infrastructure And Leased Crafts

Regular service could commence when the entire waterway would be available for navigation. This would entail the following;

1. Dredging of the entire waterway
2. Dismantling of the bridge (Old Bhayander Bridge)
3. Creation of the fore shore infrastructure in the main terminals
4. Leased vessels of decent size

The dredging is expected to be completed in 8 months through the presently adopted assured depth contract by IWAI. The main terminals if concurrently built allowing a 4 months' time for tendering and evaluation, could be completed in about 12 months. Hence, this phase of operation could commence within a period of 18 months from the Zero date. During this period, adequate number of vessels based on the demand generated through the one year of operation prior to start of this operation. It must be recognised that the partial operation described above would have run for a full one-year service by the time this operation commences albeit using leased vessels. This period could be used to evince interest of the public in the waterway, through good and quality service and assuring people of the better infrastructure that the waterway is proposing for its users.

The number of vessels and locations would be decided by the time the operation commences, gauging from the response of the public to the partial operation. In this phase only the 4 main terminals and Kalher or Anjur Dive terminal is required to be built. The infrastructure facility would include, dredging of the channel, dismantling of the old railway bridge, creation of the waterfront facility at main terminals and Kalher/Anjur Dive Terminal and development of basic foreshore facilities. This is an assumption subjected to the experience gained during the partial operation. Based on the current estimates, about 6 to 7 vessels at this stage of operation would be meeting the desired result.

7.4.2.3 Full Service With Full Infrastructure

Regular services are expected to commence after 30 months from the Zero date, as per the construction programme described later in the document. Since the investments in the vessel procurement is probably the highest, some handholding in the beginning may be desirable. Although, the partial operations of almost two years, by this time would have given enough insights to the investors about the likely viability, it is suggested that the capital cost of the first 10 vessels and the leased cost of the partial operation must be financed by the waterway authorities.

The first 10 vessels proposed to be owned by the waterway authorities would be constructed by an eligible Indian Ship yard. The specifications and the design of the vessels including the engine, fuel on which they would run, would be prepared by IRF approved competent consultant appointed for the purpose. In this chapter only, the outline design of the vessel types would be suggested.

The main criterias to be followed for the vessel design are,

1. Loaded draught: 1.5 to 2.0 m (maximum)
2. Length about 32 - 34 m
3. Draught 1.5 to 2.0 m
4. Width 9 - 10 m
5. Dual Fuel Engines

Standard designs available in the market indicate that a 32 m length and 10 m wide modular vessel can carry 150 passengers and 14 cars. These kind of vessels with the engine capable of running on MDO and/or LNG/CNG, could be adopted in the beginning for their low draft and engine efficiency. If required, the technology could be imported and manufactured in India. In general, the vessel engines are the longest lead items, hence the engine size for the first phase vessel shall be standardised.

The initial vessels would be judicious mix of passenger carrying capacity and passenger cars. Some of the vessels may have an air-conditioned section to provide the necessary comfort for the passengers using the mode.

The suggested vessels for the first phase full waterway operation is as follows;

1. Modular vessels: 2 numbers
   a. Length (m) 32
   b. Beam (m) 10
   c. Passengers 150
   d. Speed max (knots) 12
   e. Number of cars 14
   f. Engine size 250 HP x 2
   g. First in and First Out System
2. Passenger Ferry: 2 numbers
   a. Length (m) 34
   b. Beam (m) 10
   c. Passengers 160
   d. Speed max (knots) 12.0
   e. Number of cars 0
   f. Engine size 250 HP x 2
3. Water Buses: 2 numbers
   a. Length (meter) 32
   b. Beam (m) 8.1
   c. Passengers 86
   d. Speed max (knots) 12
   e. Engine 250 HP x 2
4. Ferry : 2 numbers
   a. Length (meter) 36
   b. Beam (m) 12
   c. Passengers 400
   d. Speed max (knots) 10
   e. Number of cars 40
   f. Engine 250 HP x 2

5. Cross Ferries: 2 numbers
   a. Length (meter) 34
   b. Beam (m) 12
   c. Passengers 150
   d. Speed max (knots) 8
   e. Number of cars 25
   f. Engine 250 HP x 2

It is imperative to note that the maximum cruising speed of the vessels would be restricted to about 12 knots, due to the limited length of the waterway. For the cross ferries the speeds would be further reduced to about 6 knots because of the narrow width that they have to cover.

At the later stage, the vessel could be out sourced through own operate and maintained model, with some hand holding with regard to technology, fuel uniformity and the classification of the vessels to keep the waterway safe. The vessel type and the standards need to be kept uniform so that, maintenance and repair could be handled at the ship yard being set up for the waterway. In addition, all vessel must have latest communication system for vessel positioning and tracking.

7.5 Turnaround Time

A half hour time delay slot has been scheduled at the end of each ferry crossing to allow for deceleration, maneuvering, berthing, discharging vehicles and passengers, boarding, loading extra cargo, fuel and crew changes. This time has been selected from typical operations of a similar type elsewhere although it is expected that a slightly greater turnaround time would be required until experience is gained in operating vessels on these routes. However, in each 6 hours there will be time for refueling of the vessels.

In practice the time that each ferry would actually spend at the berth would vary slightly because of the desire to maintain a regular schedule despite the changing conditions, particularly tidal velocities which follow a lunar rather than solar calendar and would be out of phase with the ferry time scale. However, turnaround time is not critical to minor variations.

The creek at the widest expanse is about 2.5 km and length wise the waterway expands about 45 km. Hence, without examining and experiencing the growth pattern of the passenger traffic, it will be futile to predict a system functioning. But the limited passenger behavior and the modal shift studies indicate that about 60% of the passengers will have crossing river/creek requirements and the rest would be across the length expanses. With an average 8 knot speed the vessel could turn around across the river in roughly 11 - 12 minutes depending on the location of the terminal on the creek. Hence; one vessel per terminal would be enough to start the operations.

7.6 Number Of Vessel Required

In total 10 vessels, one assigned to each of the 10 terminals along the creek would be enough to start the operation. There can be 5 different types of vessels, and based on the need the vessel numbers and types could be altered. Though it may be ideal to have a versatile vessel like modular vessel deployed in all the terminals, it was considered prudent to have a judicial mix with passenger only vessels for amusement and pleasure. The details of the facility to be provided in the waterway vessels would depend on the investment potential and the resulting viability.

Naturally part of the cost would have to be taken out from the system and borne by the Government to make the system viable as subsidy/grant.

7.7 Vessel Costing

7.7.1 Capital Cost

7.7.1.1 General

The Capital Cost of the vessel is often times kept out of the fairway development cost due to the following reasons;

1. Fairway in general is developed by the State, because the investments in fairway development may not have immediate and desired returns: viz. Waterways in USA
2. Fairway operation needs supports of the state statute for conservancy
3. Control of the navigation requires implementation of the Global Information system for integration, which is not possible by individual private operators
4. Safety and security of the channel is in the preview of the state.

Due to high cost of the vessels, especially the ones being proposed for the waterway, it may not be an ideal business proposition for any private entrepreneurs to invest under a cloud of uncertainty. Uncertainty is due to the likely patronization or lack of it of the passengers who are supposed to use the mode. Under such a scenario, it is only imperative to imagine that in order the State must put forward the incentives in the beginning so that the business model stabilizes for people who want to invest in it. Therefore, it is suggested that the State or the Thane Municipal Corporation (TMC) should own the first vessels. It is presumed that at least 10 vessels in the beginning, assigned one each to the 10 terminals being developed would solve the initial demand in the waterway. But since the partial operation is starting in the interim, for a period of almost two years, the demand and the patronage would be visible by the time the full-service operation commences, and may be by then private entrepreneurs would be willing to invest. In the following paragraph, the capital cost of the vessels is indicated based on the industry benchmarks. The prices may be brought down substantially with bulk orders and developing own capabilities along the waterway.

It is presumed that the vessels beyond the initial 10 vessels shall be in the PPP mode and is likely to be fabricated at the Kolshet Ship Yard or any other Indian shipyard.

7.7.1.2 Capital Cost Estimates for the vessels

The cost to purchase the vessels, whether they are new or second-hand, represents a significant commitment for the ferry operating company. There are 5 types of vessels proposed for the waterway of different capacity and dimensions. The new vessels would be either purchased by a Special Purpose Vehicle (SPV) or equity financed by the TMC. For flexibility of service it has been assumed that ten ferries capable of making the longest journey on the network will be used one assigned to each terminal.

The approximate cost of the different types of vessels are indicated below;

A. Modular Vessels – 2 numbers

Capital cost per vessel: $ 1.75 Million = ₹120 million

B. Passenger Ferry – 2 numbers

Based on approximate market price for the similar vessels = $ 2.0 Million = ₹140 million

C. Water Buses – 2 numbers

Based on approximate market price for the similar vessels = $ 2.15 Million = ₹150 million

D. Ferries – 2 numbers

Based on approximate market price for the similar vessels = $ 2.6 Million = ₹180 million

E. Cross Ferries – 2 numbers

Based on approximate market price for the similar vessels = $ 2.4 Million = ₹160 million

It should be noted that the second-hand ferry market is could also be explored for finding similar vessels. But the second-hand market is dependent on many specific factors and the prices will obviously be different for different vessel specifications and ages. All prices are liable to change depending on market conditions.

Total Capital cost from above is =120 x 2 + ₹140 x 2 + ₹150 x 2 + ₹180 x 2 + ₹160 x 2 = ₹1500 Million

It is however clear that the second-hand vessels would be significantly cheaper and could be explored at the later stage. They may cost depending on the quality of the vessel and the year of service. Similar vessels are available in the International market.

7.7.2 O&M Cost

7.7.2.1 Operation And Maintenance Philosphy

The vessels would be owned by the waterway but the operation and the maintenance of the same is proposed to be out sourced to a professional agency. The waterway however shall retain the control on the scheduling, routing and the operational aspects and the outsourced contractor would be responsible for the running, up keep and maintenance of the vessels at a fixed cost for a fixed period.

7.7.2.2 Cost Of Operation

The cost of operating a ferry is made up from a number of component parts. An assessment of these costs considering fixed costs charged on a time basis and running costs charged on a distance basis is made.

7.7.2.3 Charge Against Equity

It has been assumed that the vessels leased or bought shall be financed or arranged by the TMC. Beyond the initial investment, additional vessel could be outsourced in future, with a control on the quality, fuel uniformity and efficiency.

7.7.2.4 Crew Costs

Manning levels have been taken for similar vessels operating elsewhere and related to costs in India. Two crews have been allocated for each vessel to enable round the clock operation. A total of twenty crews of 20 have therefore been taken for costing purposes to give a total cost of USD 750,000 per month which relates to ₹ 1.7 million per day. There are a number of factors that can affect the cost of crewing the vessels. These include the flag under which the vessel sails, nationality of the crew and whether the officers are licensed for home or foreign trade.

7.7.2.5 Consumables And Maintenance

Consumables such as oil and lubricants are generally used at a predictable rate.

7.7.2.6 Fuel

The utilisation of fuel by the vessels has been worked out as a cost for the distance travelled. This has been related to the quantity of fuel and its current price. As vessels consume considerably more fuel when sailing between ports than at the berth, different consumption rates of 24 and 2 tons per day have been derived for respective activities. The proportion of time at sea during a weekly schedule has been calculated for each network of routes and this has been used to calculate the total fuel consumption.

A cost of ₹35,000 per ton has been taken as the current (2018) duty paid price for marine diesel oil. This price is liable to significant fluctuation depending on where and when it is purchased. Other factors affecting the total fuel costs are the actual fuel consumption and type of fuel used, both of which are specifically dependent on the type of vessel used and its mechanical condition. Total fuel cost of about ₹ 4.5 million per day. Total Operation cost is given in Table 7.1.

Table 7. 1: Operation And Maintennace Cost Of Vessels

Item	Operation Cost /Day ₹	Operation Days	Total Cost Million ₹
Crew	1,700,000	330	561
Fuel	4,500,000	330	785
Oil and Other Consumable	300,000	330	99
TOTAL			**1045**

7.7.2.7 Maintenance

To ensure that the ro-ro terminals are kept in an efficient and safe condition, it will be necessary to ensure that money is set aside for manual maintenance. In the first four years of operation, maintenance costs are comparatively low but would then build up as structures and equipment begin to be affected by wear and tear.

In the first four years, the maintenance staff might consist only of fitters, electricians and plumbers together with their mates all under the control of a general trades foreman. Their duties would be to deal with breakdowns in the mechanical and electrical equipment as well as the water supply system. In the fourth year, it would be advisable to provide a fully equipped workshop where equipment can be repaired and serviced. The workshops would provide storage space for spare parts and would provide a base for all maintenance staff.

The annual cost of maintaining port structures is about 1% of the capital cost, whilst the annual cost of maintaining link span and associated equipment, is about 3% of the purchase price. On this basis, the full annual maintenance cost from the fifth year onwards as indicated in Table 7.2.

Table 7. 2: Operation And Maintenance Port Structures

Item	Capital/Purchase Price In million ₹	ANNUAL COST %	In ₹ million
Port Structures	2940	1	29.50
Link Spans etc.	825	3	24.80
Street Lighting	10	25	2.50
T O T A L			56.80

7.8 Concluding Comments

To summerise the above the following could be deduced;

1. Only Passenger and Passenger Ro-Ro service shall be provided in this phase of development
2. All the Vessel would be self propelled and twin engine multi fuel compliant
3. The maximum size of the vessels is: L = 36 m, B=12 m, Loaded Draught = 2.0 m
4. All the vessels would be capable of handling passenger cars and passengers together, along with occasional cargo vehicles
5. The vessels as far as practicable would be modular types, with access on either side.
6. The maximum cruising speed in the waterway, on account of its short expanse, would be 12 knots. The vehicles would be capable of this speed but follow the speed regimen implemented by the waterway authority from time to time in different zones.
7. All cross movement (between left and right bank) between OD pair terminals would have a maximum speed of 6 knots or there about
8. This phase of waterway development would have sub-phases for starting of immediate operation with no or minimum infrastructure while the waterway is getting ready for the full service.
9. The first sub-phase starting after the zero date, would consist of slopping jetties and/or floating jetties, for immediate starting of the operation using locally available improvised Ro-Ro vessels, for cars and passengers at Parsik Bunder, Kolshet, Kalher and Anjur Dive.
10. In the second sub-phase 6 terminals would be readied (Vasai, Mira Bhayander, Parsik Bunder, Anjur Dive, Kolshet, Kalher and and Kalher terminal) and the better-quality services would be provided through leased vessels. This service would commence after about 18 months from the zero date.
11. The full service would start after 30 months from the zero date with the waterway owning 10 brand new vessels and operated through an outsourced company.
12. All subsequent vessels would be financed by the private entrepreneurs through PPP route.
13. About ₹1500 Million is earmarked for the Capital cost of the Vessels.
14. The operation and maintenance of the vessel would be outsourced.

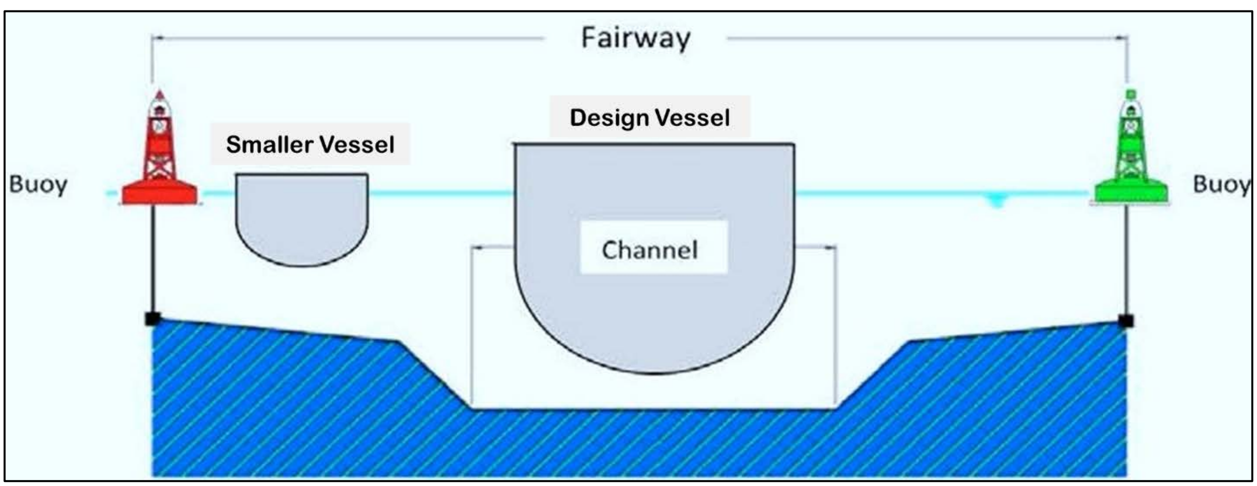
8 Navigation And Communication System

8.1 General Requirements

8.1.1 Need & Extent Of Navigation And Communication System

In the past decades considerable changes has undergone in the maritime transport safety control. A navigable inland waterway is defined as any stretch of water, canal or lake, which due to natural or artificial features, is suitable for navigation, especially for inland boats (Directive 80/1119/EEC). The Permanent International Association of Navigation Congresses (PIANC) defines several concepts related to the configuration of maritime ports in its report N.121-2014. First, the approach channel is defined as a stretch of waterway connecting the port docks with the open sea, and can be of two types: an outer channel in open sea, exposed to the waves and therefore capable of producing rolling and pitching motions on vessels; and an inner channel which is protected from the action of the waves. A distinction is made between channel and waterway. The channel is the deepest area, whether natural or dredged, with sufficient width and depth to allow the safe passage of deeper draught vessels. Some countries, however, define the waterway as suitable for all types of ship, across its entire width, including the channel and shallower areas for the transit of smaller ships. In both cases, the boundaries are marked with buoys, as shown in Figure 8.1 below.

Figure 8. 1: Channel And Waterway



The main aspects of the physical environment to consider are: tides, which affect the depth of the channel and may oblige larger vessels to navigate at high tide; visibility, which tends to be reduced by fog; currents; wind; and even ice formation. Ships initiate transit during the “tidal window”, which is the period of time between high tide in the landfall area at open sea and high tide in the inner harbour docks. This is when the channel offers maximum depth and thus ensures under keel clearance. They generally set sail an hour before high tide in order to leverage the tidal wave (IALAAISM, 2014).

8.1.1.1 Under Keel Clearance (UKC)

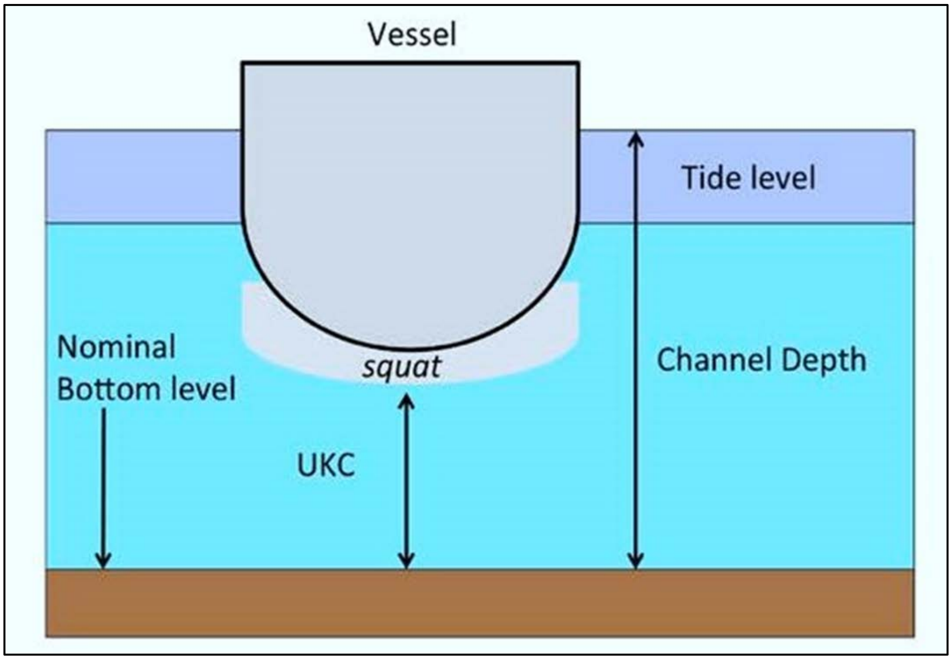
The PIANC defines UKC, as the distance between the ship's keel and the bottom of the channel. The factors used to calculate this distance are the reference level of the water, which depends on the height of the tide at the time, and the nominal level of the bottom of the channel, which is the level above which no obstacles to navigation should be found (PIANC, 1985). There are two concepts of UKC:

- Gross UKC: this is the theoretical value of the margin between the ship's keel and the nominal level of the channel bottom, measured in calm waters. It allows for an increase in draught due to uneven loading, changes in salinity along the estuary, squat (the effect of speed on draught: the higher the speed, the lower a ship sits in the water), response to the wind and waves, and a safety margin.
- Net UKC: this can be calculated using a deterministic approach, which is the minimum margin between the nominal level of the bottom and the ship's keel in the most unfavorable position.

If all the elements included in the gross UKC are assigned maximum values, then the net UKC can be considered an additional safety measure. The UKC can also be calculated using a probabilistic approach, taking into account errors, uncertainties and variations in values. It is also important to highlight the effect of the current: this is significantly greater when the UKC is small, and affects ship maneuverability, which is considerably better when sailing into the current (Figure 8.2)

The minimum safe UKC value that also guarantees ship maneuverability is 1 m (PI A NC, 1985). With a deterministic approach, the safety criterion established for the minimum net UKC is that applied in the ICORELS report (PIANC, 1985), which recommends a minimum value of 0.5 m, allowing a value of 1 m when the chances of touching the bottom are high (PIANC 1985). Alternatively, the IMO Helsinki Committee has indicated that the UKC should be 10% - 20% of the ship's draught.

Figure 8. 2: Under Keel Clearance (UKC)



8.1.1.2 Under Keel Clearance Management System

Currently, inland ports employ UKC management systems based on software applications that calculate probabilistic tidal windows and incorporate real-time monitoring systems during transit (IALAAISM, 2014). These systems employ dynamic data, including water level and density, the current, the wind and wave height and direction, which are measured by devices installed along the waterway, such as tide gauges, current meters or wave-measuring buoys. Static data are also used, such as the ship's characteristics (wave response, draught at bow, mid-length and stern), squat and actual depth (IALA-AISM, 2014). When the authorities responsible decide to implement UKC management systems, the maximum draught of vessels admitted in the channel is increased, although the use of a probabilistic tidal window implies that the greater the ship's draught, the greater the likelihood that it will have to wait one or more tides (IALA-AISM, 2014).

When the authorities responsible decide to implement UKC management systems, the maximum draught of vessels admitted in the channel is increased, although the use of a probabilistic tidal window implies that the greater the ship's draught, the greater the likelihood that it will have to wait one or more tides (IALA-AISM, 2014).

8.1.1.3 E-Navigation

The first decade of the 21st century has witnessed the development of e-navigation for traffic and transport management support. Aids to Navigation Systems on Inland Waterways as an Element of

Competitiveness in Traffic services. The river information services (RIS) system is of particular importance for inland waterways and will be discussed later in the state-of-the-art section. However, other systems are also increasingly being used to improve safety, surveillance, reliability and efficiency of maritime and river transport, although this requires a more integrated and coordinated approach to ensure that these technologies represent added value rather than posing an obstacle. Thus, as new systems are developed, there is a growing need for standardization and efficient, simplified, interoperable solutions that reduce the burden for users and are integrated with systems throughout the transport chain (IALA-AISM, 2014), highlighting the S-Mode who arranges all the on-board electronic systems by pressing one single button (Patraiko, 2007). In 2008, the I MO Maritime Safety Committee defined e-navigation as the harmonized collection, integration, exchange, presentation and analysis of marine information on board and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment (IMO. E-navigation).

The objectives of e-navigation are:

1. To facilitate the safe navigation of vessels with regard to hydrographical, meteorological and navigation information, facilitate maritime traffic management, facilitate communication and provide opportunities to improve the efficiency of transport and logistics.
2. E-navigation is a concept that incorporates systems and services (Patraiko, 2 0 07). Some of the most important e-navigation systems are:
   i. **The Automatic Identification System (AIS):** It is used in traffic coordination centers, tracking vessels in real-time on digital maps. In 2000, the IMO adopted the AIS as part of Regulation 19 of Chapter V of the SOLAS (Safety of Life at Sea) Convention (IMO. AIS Transponders). Furthermore, virtual Aids to Navigation don't physically exist and they are provided by AIS stations and they are showed on ENC. There are a lot of applications, for example, they can mark new risks at the time they are known or they can mark the deepest areas in a fairway (IALA-AISM, 2010).
   ii. **The Differential Global Positioning System (DGPS):** an enhancement to GPS that improves accuracy to under 3 meters, by means of a ground-based network of reference stations.
   iii. **Radar, racons (Radar and Beacons) and radar Reflectors:** radar allows a ship to identify targets such as racons and reflectors installed on buoys and beacons. It also allows traffic coordination centers to identify ships.
   iv. **Vessel Traffic Services (VTS) systems:** they are usually equipped with radar sensors, closed circuit television (CCTV), AIS, VHF and meteorological and hydrological stations.
   v. **Vessel Traffic Management (VTM) system:** a new, more comprehensive concept of VTS composed of harmonised media and services to improve safety, surveillance, navigation

efficiency and protection of the marine environment in all navigable waters (IALA-AISM 2014).

vi. **Electronic Chart Display and Information System (ECDIS):** the new generation of electronic nautical charts (ENC) on electronic media, which also provides additional information such as bathymetry or hydrological data. 9 International Journal for Traffic and Transport Engineering, 2017, 7(1): 1 - 18

Among the above services in the e-navigation provides comprehensive data in standard format, and infrastructure to transfer the data (Patraiko, 2007). Another recent concept is that of e-Maritime, through which the European Commission, in its communication COM92009 8, "Strategic goals and recommendations for the EU's maritime transport policy until 2018", aims to improve the efficiency of maritime transport in Europe and to ensure its long-term competitiveness. This consists of a series of policies, strategies and capabilities to facilitate online or electronic interaction between the different agents involved in the development of a sustainable and efficient maritime transport system throughout Europe that is fully integrated with logistic transport chains. It must be aspired for the waterway a system, that is vibrant and adaptive to the environment and collect and collate as much data as possible to aid the vessel and the vessel master with the best possible knowledge to encounter any exigencies. A detailed discussion on the components of the E-Navigation is discussed in the following paragraphs.

8.1.2 Communication Systems

8.1.2.1 Background

The inland waterways are becoming busier with increased commercial traffic and new pleasure craft. Many new boaters may not be fully familiar with the waterway or with traditional means of communication such as sound signals or flags. Both these factors have produced a situation where marine VHF radio on pleasure craft is becoming an essential piece of equipment leading to an improvement in safety. As a result, most commercial users and now consumers are being advised to use marine VHF radio as a primary safety tool to aid communication and navigation.

A marine VHF radio allows a boat owner to listen to broadcast messages, to call other ship or shore stations or groups of ship stations and to broadcast distress, urgency and safety messages. Gaining an operator's certificate is straightforward and should present no problem to the average inland waterways leisure craft user.

8.1.2.2 Communication Frequencies

Very high frequency (VHF) is the International Telecommunication Union (ITU) designation for the range of radio frequency electromagnetic waves (radio waves) from 30 to 300 megahertz (MHz), with corresponding wavelengths of ten to one meters. Frequencies immediately below VHF are denoted high frequency (HF), and the next higher frequencies are known as ultrahigh frequency (UHF).

Common uses for VHF are FM radio broadcasting, television broadcasting, two way land mobile radio systems (emergency, business, private use and military), long range data communication up to several tens of kilometers with radio modems, amateur radio, and marine communications. Air traffic control communications and air navigation systems (e.g. VOR & ILS) work at distances of 100 kilometers or more to aircraft at cruising altitude.

8.1.2.3 About VHF / HF

Radio waves in the VHF band propagate mainly by line-of-sight and ground-bounce paths; unlike in the HF band there is only some reflection at lower frequencies from the ionosphere (sky wave propagation). They do not follow the contour of the Earth as ground waves and so are blocked by hills and mountains, although because they are weakly refracted (bent) by the atmosphere they can travel somewhat beyond the visual horizon out to about 160 km (100 miles).

These characteristics allow the same VHF frequencies to be used by different users in neighboring geographical areas without interference (frequency reuse). They can penetrate building walls and be received indoors, although in urban areas reflections from buildings cause multipath propagation, which can interfere with television reception. Atmospheric noise and interference (RFI) from electrical equipment is less of a problem in the band than at lower frequencies. The VHF band is the first band at which efficient transmitting antennas are small enough that they can be mounted on vehicles and portable devices, so the band is used for two-way land mobile radio systems, such as walkie-talkies. Occasionally, when conditions are right, VHF waves can travel long distances by tropospheric ducting due to refraction by temperature gradients in the atmosphere.

8.1.2.4 Need Of Marine VHF

It is a matter of safety. Marine VHF radio provides a means to communicate with other vessels and shore stations (e.g. ports, locks, bridges and marinas) on operational, navigation and safety matters. Because the VHF radio is now common among vessels on waterways, there is a tendency to rely on it as a means of ascertaining the locations of other vessels and communicate with each other. It is also commonly used on larger waterways, replacing flag signals and to some extent sound signals, without a VHF radio, you may be exposing yourself to unnecessary risks.

8.1.2.5 Safer Navigation On Inland Waterway Networks

Marine VHF provides a means for calling for locks to be prepared or moveable bridges to be swung or raised in advance of your arrival.

8.1.2.6 Requirements Of VHF

Marine VHF radio is obligatory on vessels navigating many tidal waterways, including parts of the Humber, Trent, Witham and Thames. The ship portable radio license is given at site including training for a day. It keeps the vessel in touch with other vessels in the systems and the terminals.
For these reasons, the Inland Waterways Association strongly recommends that all pleasure craft using larger waterways in active use by freight carrying vessels, or any tidal waterway, should carry a marine VHF radio. Every vessel of this waterway shall be mandated to carry and operate within the integrated VHF system of the waterway.

8.1.3 DGPS

Differential Global Positioning System (DGPS) is an enhancement to Global Positioning System which provides improved location accuracy, from the 15-meter nominal GPS accuracy to about 10 cm in case of the best implementations. The general accuracy is around 1 m for a moving craft.

DGPS uses a network of fixed ground-based reference stations to broadcast the difference between the positions indicated by the GPS satellite systems and the known fixed positions. These stations broadcast the difference between the measured satellite pseudoranges and actual (internally computed) pseudoranges, and receiver stations may correct their pseudoranges by the same amount. The digital correction signal is typically broadcast locally over ground-based transmitters of shorter range. These systems on board the vessels help identify the Global position of the vessels in the system so that the traffic control and management systems is enforced in a comprehensive way from the control tower.

Figure 8. 3: DGPS Reference Stations (With Regular Antenna And Other With A Choke Ring Antenna)

8.1.4 Radar / AIS / VTMS / RIS

8.1.4.1 Radar

Radar is an object-detection system that uses radio waves to determine the range, angle, or velocity of objects. It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain. A radar system consists of a transmitter producing electromagnetic waves in the radio or microwaves domain, a transmitting antenna, a receiving antenna (often the same antenna is used for transmitting and receiving) and a receiver and processor to determine properties of the object(s). Radio waves (pulsed or continuous) from the transmitter reflect off the object and return to the receiver, giving information about the object's location and speed.

The information provided by radar includes the bearing and range (and therefore position) of the object from the radar scanner. It is thus used in many different fields where the need for such positioning is crucial. The first use of radar was for military purposes: to locate air, ground and sea targets. This evolved in the civilian field into applications for aircraft, ships, and roads.

A radar system has a transmitter that emits radio waves called radar signals in predetermined directions. When these come into contact with an object they are usually reflected or scattered in many directions. But some of them absorb and penetrate into the target to some degree. Radar signals are reflected especially well by materials of considerable electrical conductivity—especially by most metals, by seawater and by wet ground. Some of these make the use of radar altimeters possible. The radar signals that are reflected back towards the transmitter are the desirable ones that make radar work. If the object is moving either toward or away from the transmitter, there is a slight equivalent change in the frequency of the radio waves, caused by the Doppler effect.

Radar receivers are usually, but not always, in the same location as the transmitter. Although the reflected radar signals captured by the receiving antenna are usually very weak, they can be strengthened by electronic amplifiers. More sophisticated methods of signal processing are also used in order to recover useful radar signals

Marine radars are used to measure the bearing and distance of ships to prevent collision with other ships, to navigate, and to fix their position at sea when within range of shore or other fixed references such as islands, buoys, and lightships. In port or in harbour, vessel traffic service radar systems are used to monitor and regulate ship movements in busy waters.

8.1.4.2 Automatic Identification System (AIS)

The automatic identification system (AIS) is an automatic tracking system used on ships and by vessel traffic services (VTS). When satellites are used to detect AIS signatures, the term Satellite-AIS (S-AIS) is used. AIS information supplements marine radar, which continues to be the primary method of collision avoidance for water transport.[citation needed]

Information provided by AIS equipment, such as unique identification, position, course, and speed, can be displayed on a screen or an ECDIS. AIS is intended to assist a vessel's watchstanding officers and allow maritime authorities to track and monitor vessel movements. AIS integrates a standardized VHF transceiver with a positioning system such as a GPS receiver, with other electronic navigation sensors, such as a gyrocompass or rate of turn indicator. Vessels fitted with AIS transceivers can be tracked by AIS base stations located along coast lines or, when out of range of terrestrial networks, through a growing number of satellites that are fitted with special AIS receivers which are capable of de-conflicting a large number of signatures.

The International Maritime Organization's International Convention for the Safety of Life at Sea (SOLAS) requires AIS to be fitted aboard international voyaging ships with 300 or more gross tonnage (GT), and all passenger ships regardless of size.

8.1.4.3 VTMS

A. General

Vessel Traffic Management System is a marine traffic monitoring system, similar to Air Traffic Control for aircraft. Typical VTMS use Radar, Closed-Circuit Television (CCTV), VHF radio and Automatic Identification System (AIS) to keep track of vessel movements and provide navigational safety in a limited geographical area. VTMS is designed to improve the safety and efficiency of navigation, safety of life at sea and the protection of the marine environment. VTS is governed by SOLAS Chapter V Regulation 12 together with the Guidelines for Vessel Traffic Services [IMO Resolution A.857(20)] adopted by the International Maritime Organization on 27 November 1997.

Vessel Traffic Management System improves port and waterway efficiency and reduces the risk of marine accidents by providing timely, accurate, and relevant information to mariners and allied services. VTMS system is also being recognized as a significant contributor to enhanced port and waterway security.

B. Working of VTMS

The task of managing vessel traffic in ports, harbours and coastal areas places significant demands on those responsible for safety, security and protection of the environment.

VTMS offers a range of flexible, scalable and configurable solutions optimised for use in everything: from small ports and harbors to major ports, and regional or national scale coastal areas.

Main Objectives:

- Provides enhanced Situational Awareness
- Information exchange with AIS equipped vessels
- Provision of information about AIS equipped vessels
- Traffic analysis

Functionality:

- Single and Multiple AIS sensor support
- Multi-AIS data filtering and integration
- Automatic AIS targets identification
- AIS dynamic and static data presentation
- Reception and Transmission of AIS text telegrams (Transmits requires base station)
- Record and Playback
- Extensive Chart functionality

C. VTMS Functionality

VTMS helps vessel traffic management and safety provision in large-scale high- density ports and efficient utilisation of port infrastructure (supports ISPS code compliance) to improve the quality of port services. It improves economic performance by operational cost savings and increased efficiency of port operations by large scale planning and traffic coordination in regional or national areas. Helps detecting illegal activity and carries out the following functionality.

- Radar, AIS, CCTV, RDF, Metro-Hydro sensors support and control
- Multi-radar tracking integration
- Multi-sensor (Radar and AIS) tracking integration
- Manual or automatic target acquisition and drop
- Manual or automatic target identification
- Radar video presentation
- AIS dynamic and static data presentation
- Transmission and reception of AIS text telegrams
- Target simulation (creation, modification, tracking)

- Route management (creation of route lines, routes, route targets mode – associated alarms generation, route point ETA calculation, Route Profile tool)

Central server collects and process all the information from the system sensors and distributes and displays of this information among various operator workstations.

VHF Communication System Provides shore to ship VHF communications scanning the marine VHF channels. The directions and the bearings on the chart system is marked and the meteorological and hydraulic data presented in to the system.

Port Management Information System (PMIS) is an advanced information system providing extensive functionality for managing and storing different types of data related to ships, ship visits and port activities. PMIS interfaces to VTM software (to receive real-time information and for data exchange with external agencies (for example, ship agents) via the Internet.

8.1.4.4 River Information System (RIS)

River Information Services (RIS), also called River Information Services, is a package of harmonized information services to support traffic and inland transport has been discussed in detail earlier chapters. It is mainly used in inland navigation to create a fast electronic data transfer between water and land. The field of application is very wide, so RIS therefore forms a platform by means of safety and efficiency in terms of both traffic and transport processes.

The RIS directive was published on 30 September 2005. In the years that followed, more and more RIS standards were adopted by the Central Commission for Navigation on the Rhine, such as the standard for electronic navigation charts (Inland ECDIS) and a standard for the exchange of shipping notices and notifications (Notices to Skippers and Electronic Reporting).

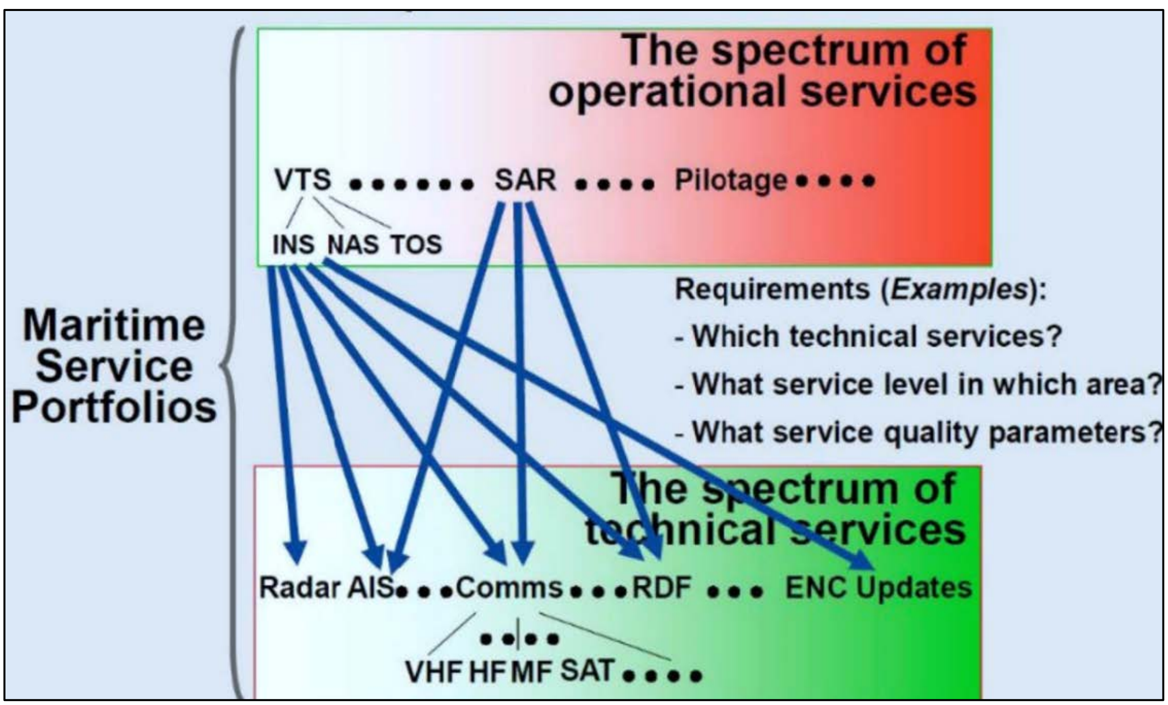
Globally, therefore, RIS covers cartography and message exchanges to and from ships. In the context of RIS, it is stipulated that in due course all major waterways must be covered by sufficient navigation maps (ENCs) for the Inland ECDIS standard. RIS has been launched in India and part of National Waterway No. 1 is now under the RIS and is being tested in prototype. Soon the RIS would cover the operations of the Inland waterways of the entire country akin to the Air Traffic Controller (ATC) in aviation.

8.1.4.5 System Applicability To The Present Waterway

The system applicability is measured through the various implemented protocols known as Maritime Service Protocol. They are;

1. (MSP 1) VTS Information Service (INS)
2. (MSP 2) VTS Navigation Assistance Service (NAS)
3. (MSP 3) VTS Traffic Organisation Service (TOS)
4. (MSP 4) Local Port Service (LPS)
5. (MSP 5) Maritime Safety Information (MSI) service
6. (MSP 6) Pilotage service
7. (MSP 7) Tugs service
8. (MSP 8) Vessel shore reporting
9. (MSP 9) Remote monitoring of ships systems
10. (MSP 10) Telemedical Maritime Assistance Service (TMAS)
11. (MSP 11) Maritime Assistance Service (MAS)
12. (MSP 12) Nautical chart service
13. (MSP 13) Nautical publications service
14. (MSP 14) Ice navigation service
15. (MSP 15) Meteorological information service
16. (MSP 16) Real-time hydrographic and environmental information services
17. (MSP 17) Search and Rescue (SAR) Service

Figure 8. 4: Maritime Service Portfolios For Integrated Service Protocol



The main aim of the RIS: “the harmonised information services to support traffic and transport management in inland navigation, including interfaces to other transport modes. RIS aims at contributing to a safe and efficient transport process and utilizing the inland waterways to its fullest extent.”

a. **Fairway information services**
- IENCs
- Notices to Skippers

b. **Vessel Traffic Information Services**
- Traffic monitoring

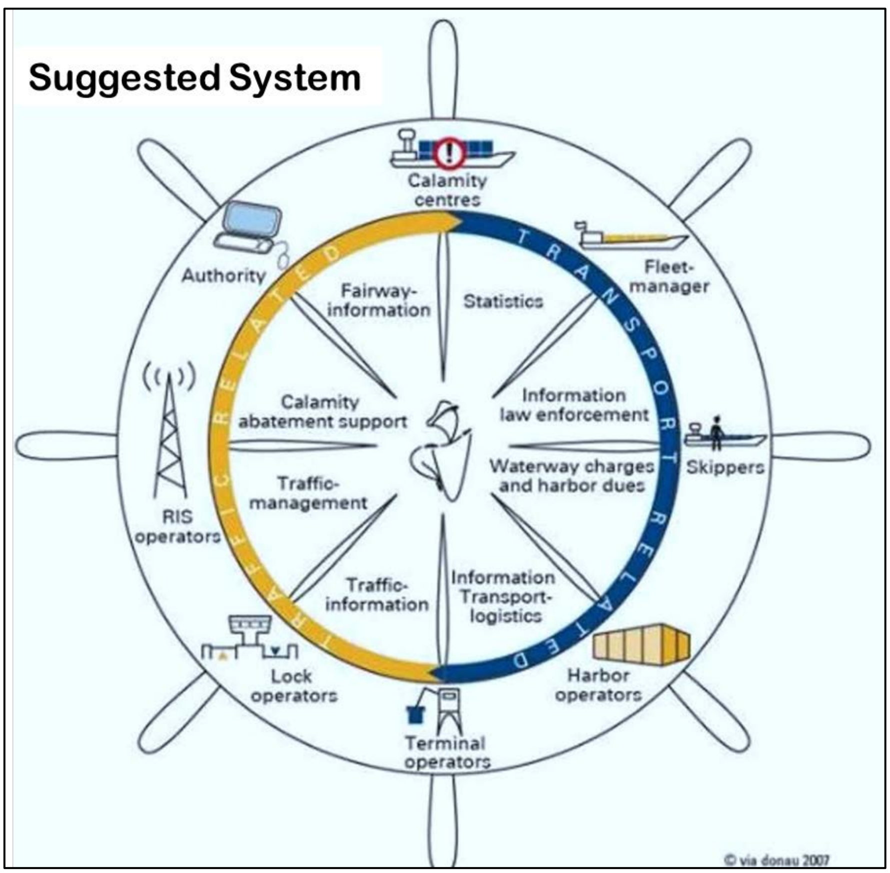
c. **Traffic management**
- Lock management

d. **Calamity abatement support**
- Support for responders

e. **Calamity abatement support**
- Voyage information
- Electronic cargo reporting
- Voyage planning

The Maritime services controlled through the RIS is shown in Figure 8.5 below.

Figure 8. 5: Maritime Service Portfolios Integrated In To RIS Protocol

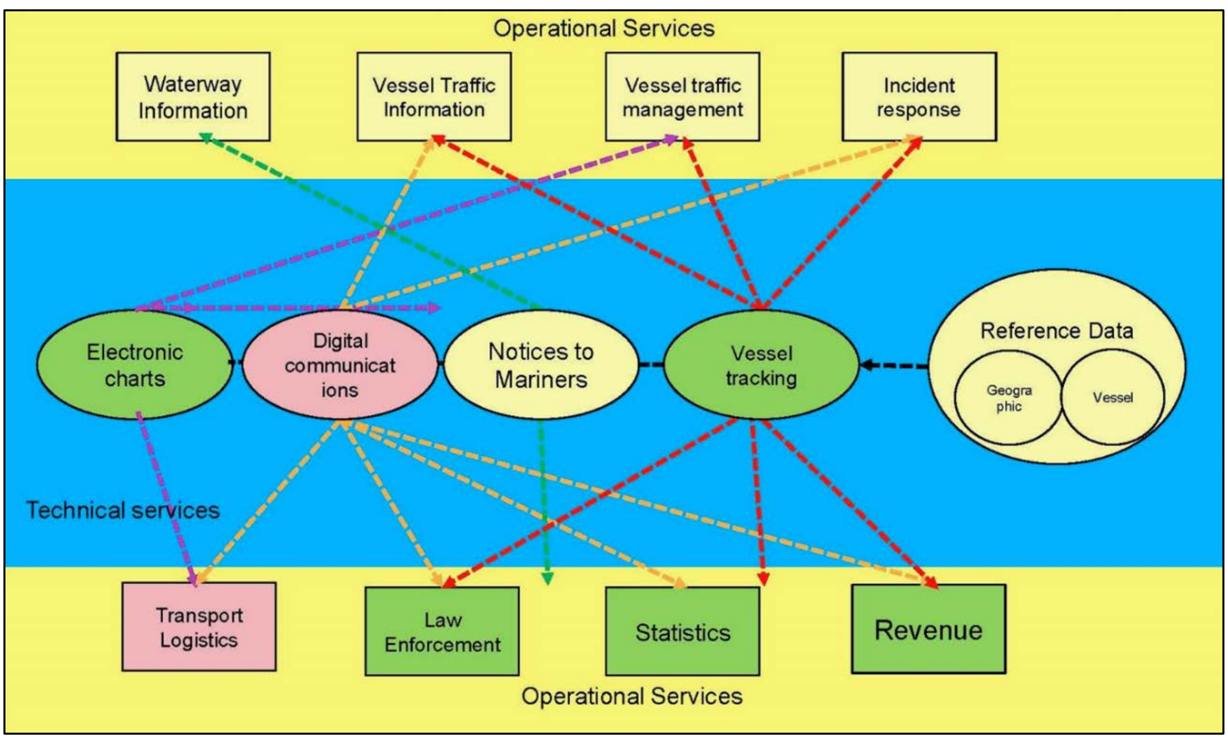


The key technologies involved in the RIS system are;

- Inland ECDIS
  - ► Inland Electronic Navigation Charts (IENC)
- Notices to Skippers
- Electronic Reporting
  - ► Industry, interagency
- Reference data
  - ► Geographic locations, hull data
- Inland AIS
  - ► Vessel tracking and communications

And finally, the RIS key Technologies and the services are related as shown in Figure 8.6.

Figure 8. 6: Relation Of The RIS Key Technologies And Services



8.1.5 Survey Equipment

The survey data with respect to the current and tidal data at various places of the river is required if the stretch is long and there are multiple mean sea level situations. In such a case, multiple tidal and current data collection centers would be erected along the waterway. The RIS requires complete and correct data system updated almost on an hourly basis with regard to various parameters such as;

1. Depth in the Channel
2. Current Speed and direction

3. Tidal heights at different stretches of the river/creek
4. Wave heights especially in the monsoon conditions

In order to achieve this the following logistics are planned;

1. Survey boats armed with:
   a. Multi-beam/single beam Eco-sounder
   b. Side scan Sonar
   c. Movable current recorder
2. At least 4 permanent tidal stations equipped with sensors to record current and wave heights
3. Weather stations for collecting data with regard to wind, rainfall and other data and feed to the command center.

8.2 Existing System

Currently there is no aids to navigation in the river and so there is no structure that can support the navigation. The existing navigation are limited and does not follow a code or protocol. Hence, entire infrastructure needs to be created.

8.3 Additional Requirement

The entire navigation system in the waterway (NW 53) would be created and no reinforcement of the existing facility would help.

8.4 Costing

8.4.1 Capital Cost

The capital cost of the Navigation and communication system would be detailed below;

1.	Channel Marker Buoys for 47.5 km waterway:	₹ 30 million
2.	River Information system and hooking up the network:	₹ 30 million
3.	Terminal Control systems and navigation aid:	₹ 75 million
4.	Survey boat and Equipment:	₹ 25 million
	Total	₹ 160 million

8.4.2 O&M Cost

The operation and maintenance cost would involve the manning of the systems and the processing and in putting the same back in to system.

8.4.2.1 Operation And Maintenance Cost

The following staffing is considered for the Operation and maintenance of the waterway;

AIS:

Total number of operators/officers:		10.0
No. of Shifts:		3.0
Number of months:		12.0
Staffing of the RIS in three shifts:	10 x 3 x 12 x ₹ 75000	= ₹ 27 million

Terminal

Number of Terminals:		10.0
Number of Persons/Officers per terminal:		4.0 working in 3 shifts
Number of months:		12.0
Terminal Communication:	10 x 4 x 3 x 12 x ₹ 50000	= ₹ 72 million

Survey and Channel Safety

Number of Boats:		2.0
Staffing on the Boat for survey/boat:		2.0
Staffing on the Boat for Safety/boat:		6.0
Survey and channel safety:	2 x 8 x 12 x ₹ 70000	= ₹ 13.50 million
Consumables and Fuel:		= ₹ 41.50 million
Total		**= ₹ 154 million**

9 Environmental And Social Aspects

9.1 Objective of Environmental And Social Studies

9.1.1 General

The waterway transport is an environmentally friendly mode of movement of passengers and goods over large distances with less energy and effort. The waterways are ready made highways in water which needs a little care and much less cost to maintain than the surface counterpart. Waterways have a great social appeal in the Indian context and people adapt it quickly and gleefully if the impediments in the waterways are removed and the connectivity to the demand areas established. However environmental friendly the mode, it is imperative to evaluate the likely impact of the development on the environment and the society in a dispassionate manner. The creek and river navigation has been a long-standing practice in the context of the MMR region. The Vasai Creek/Ulhas River has always been in existence and therefore unlike new highways, the land acquisition and consequential displacements leading to resettlement and rehabilitation issues are not there. This chapter summarizes the Environmental, Social and Risk Assessment studies, for detailed information on the same kindly refer to the Environmental Impact Assessment (EIA) Report

9.1.2 Environmental Studies

The environmental studies in general include finding the baseline status of the environmental settings consisting of various parameters listed below.

1. Terrestrial Ecology
2. Marine Ecology (in the present case, it is a creek)
3. Water Environment
4. Air Environment
5. Noise Environment

The next step is to understand the developmental works to be carried out and the likely effects it will have on the environment and suggest suitable effective mechanisms to manage the environment and take mitigative actions on the potential risks that might confront the development during construction as well the operation stage. Hence, the study would involve;

1. Baseline Data collection
2. Analysis of Data
3. Study the stages of development and extent of construction involved

4. Likely impact during the construction and the operation phase
5. Prepare a Management Plan for both the phases
6. Identify the likely risks and devise a mitigation plan
7. Establish an Environmental Monitoring Program for close watch on the day to day environmental impact

9.1.3 Socio Economic Studies

Social environmental studies include the demographic profile in the study area. This would entail quantifying and categorising various demographic groups, viz. men, women, educated, uneducated, graduates, etc. This profile also shall focus on the profession, working profile, social standings and financial status. In addition, the living pattern and the availability of water, electricity, road, sewerage, etc.

The second step is to evaluate the likely effect of the development on the social fabric of the area, including economic, social and financial.

The waterway project no doubt will bring in greater and smoother mobility of men and material and is likely to affect the lives of people in a positive way.

9.1.4 Objectives of Environmental Management

- Establish systems and procedures
- Ensure that the mitigation measures are implemented
- Monitor the effectiveness of mitigation measures
- Protect environmental resources where possible
- Enhance the value of environmental components

9.2 Legislation Applicable For This Project

9.2.1 Environmental Legislation

- Environmental Impact Assessment Notification, 2006 and amendments
- Coastal Regulation Zone Notification, 2011 and subsequent amendments
- Air (Prevention and Control of Pollution) Act, 1981, 1987
- Water (Prevention and Control of Pollution) Act, 1974, 1988
- Noise Pollution (Regulation and Control Act) 2000 and amendment till date
- Hazardous Wastes (Management Handling and Trans boundary) Rules, 2008
- MSIHC Rules, 1989
- Biological Diversity Act, 2002

- Wild Life Protection Act, 1972, 1993
- Disaster Management Act, 2005
- The Wetland rules, 2010
- Inland Vessels (Prevention and control of pollution and Protection of Inland water) Rules 2016
- The Archaeological Sites and Remains Act, 1958

9.2.2 Social Legislations

- The RFCTLAR&R Land Acquisition, Rehabilitation and Resettlement Act, 2013
- Legal Provision related to Sexual Harassments of Women at workplace (Prevention, Prohibition and Redress) Act, 2013 etc.
- Payment of Wages Act, 1936
- Equal Remuneration Act, 1979
- Child Labour (Prohibition and Regulation) Act, 1986,
- Minimum Wages Act, 1948
- The Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996 and the Cess Act of 1996
- Workmen's Compensation Act 1923
- Contract Labour (Regulation and Abolition) Act, 1970
- Inter-State Migrant Workmen's (Regulation of Employment and Conditions of Service) Act, 1979 and Rules, 1996
- The Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act, 1995 and Rules, 1996
- Public Liability Insurance Act, 1991.

9.2.3 Generic Structure of the EIA Report

The following chapters have been included in this EIA report, which is in line with the Generic Structure of Environmental Impact Assessment and as per the EIA Notification 2006:

1. Introduction

This chapter contains the scope of the study, purpose of the report, identification of project proponent and details of the environmental and CRZ clearance processes.

2. Project description

This chapter covers the description of the project, such as the type of project, need for the project, project location, project layout, the project implementation schedule, estimated cost of development etc.

3. Description of the Environment

This chapter contains the one season baseline environmental data of the project area as well as in the surrounding area that is likely to be affected by the proposed activity. The chapter also includes social impacts and social reporting process.

4. Anticipated Environmental Impacts and Mitigation Measures

This chapter covers the anticipated impact on the environment and mitigation measures. It consists of the details of the impact on the baseline parameters, both during the construction and operational phases and the mitigation measures to be implemented by the proponent.

5. Analysis of Alternatives (Technology & Site)

This chapter covers the details of various alternatives both in respect of location of site and technologies to be deployed in case the initial scoping exercise considers such a need.

6. Environmental Monitoring Program

This chapter covers the planned Environmental Monitoring Program. It includes the technical aspects of monitoring the effectiveness of mitigation measures.

7. Additional Studies

This chapter covers the details of the additional studies such as risk assessment, R and R, if any, required in addition to those specified in the standard ToR.

8. Project Benefits

This chapter covers the benefits accruing to the locality, neighborhood, region and nation as a whole. It brings out details of benefits by way of improvements in the physical infrastructure, social infrastructure, employment potential and other tangible benefits.

9. Environmental Cost Benefit Analysis

This chapter presents detailed project development cost, Operation and Maintenance expenditure, and cost for Area Development Activities and Environmental Management Plan.

10. Environmental Management Plan (EMP)

This chapter comprehensively presents the Environmental Management Plan (EMP), which includes the administrative and technical setup, summary matrix of EMP, the cost involved to implement the EMP, both during the construction and operational phases.

11. Summary and Conclusion

This chapter makes the summary of the full EIA report duly condensed. It provides the overall justification for implementation of the project and also explains how the adverse effects are proposed to be mitigated.

12. Disclosure of Consultants engaged

This chapter includes the names of the consultants engaged with their brief resume and nature of consultancy rendered.

9.3 Environmental Setting In The Project Area

9.3.1 Background

In order to assess the baseline environmental setting of the area a core area with in the 10 km radius of the project is considered as is the norm. The location of the data collection stations and the eco sensitive area vis-à-vis the project area is also examined. The following paragraphs would detail the findings and the methodology.

9.3.2 Eco-Sensitive Area

The project area falls in the vicinity of the following eco-sensitive zones.

1. Tungareshwar Wild life Sanctuary
2. Sanjay Gandhi National Park
3. Thane Flamingo Wild Life Sanctuary
4. Dombivli Critically polluted area

These sensitive areas are shown pictorially in Figure 9.1 and 9.2 below. The distances of the proposed IWT terminals from eco-sensitive zones are given in table 9.1.

Figure 9. 1: Eco-Sensitive Zones Near The Project Area (Showing Overlaps)

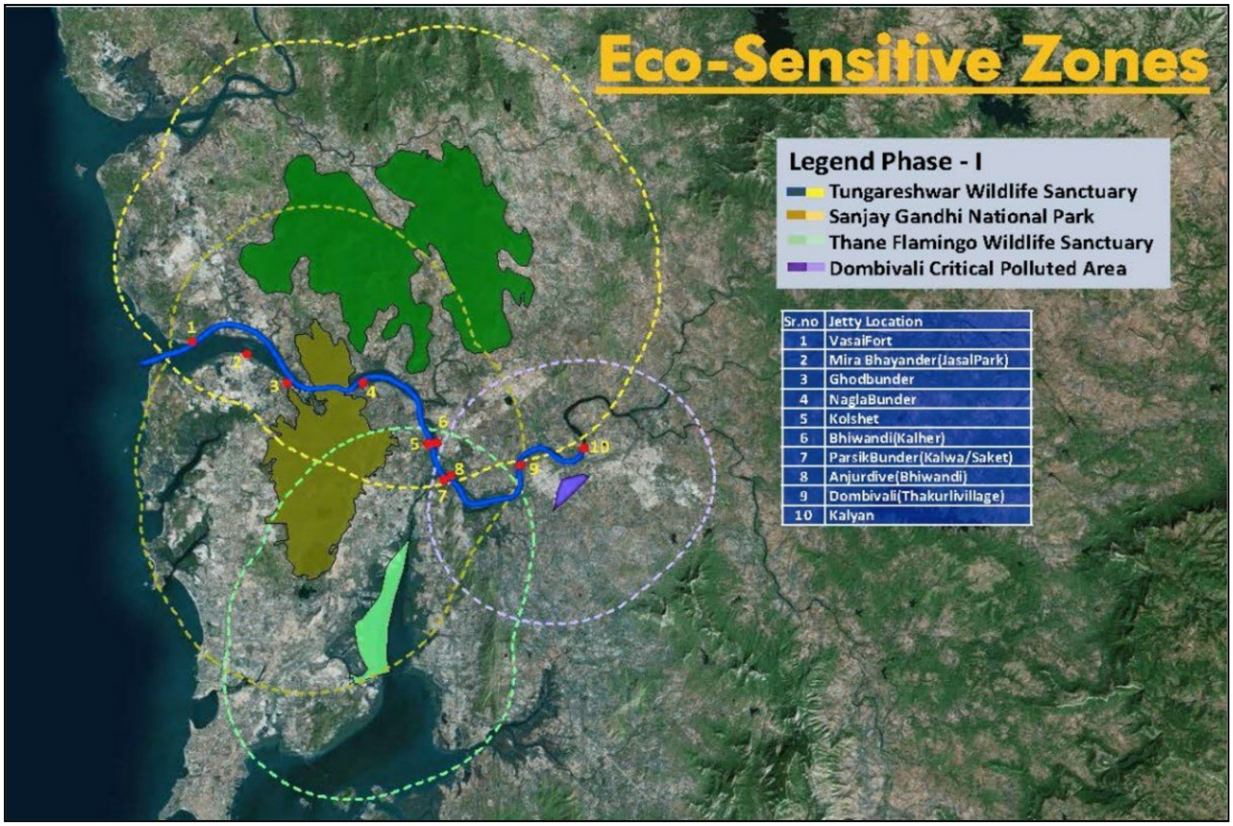


Figure 9. 2: Eco-Sensitive Zones Near The Project Area (Resultant Affected Area)

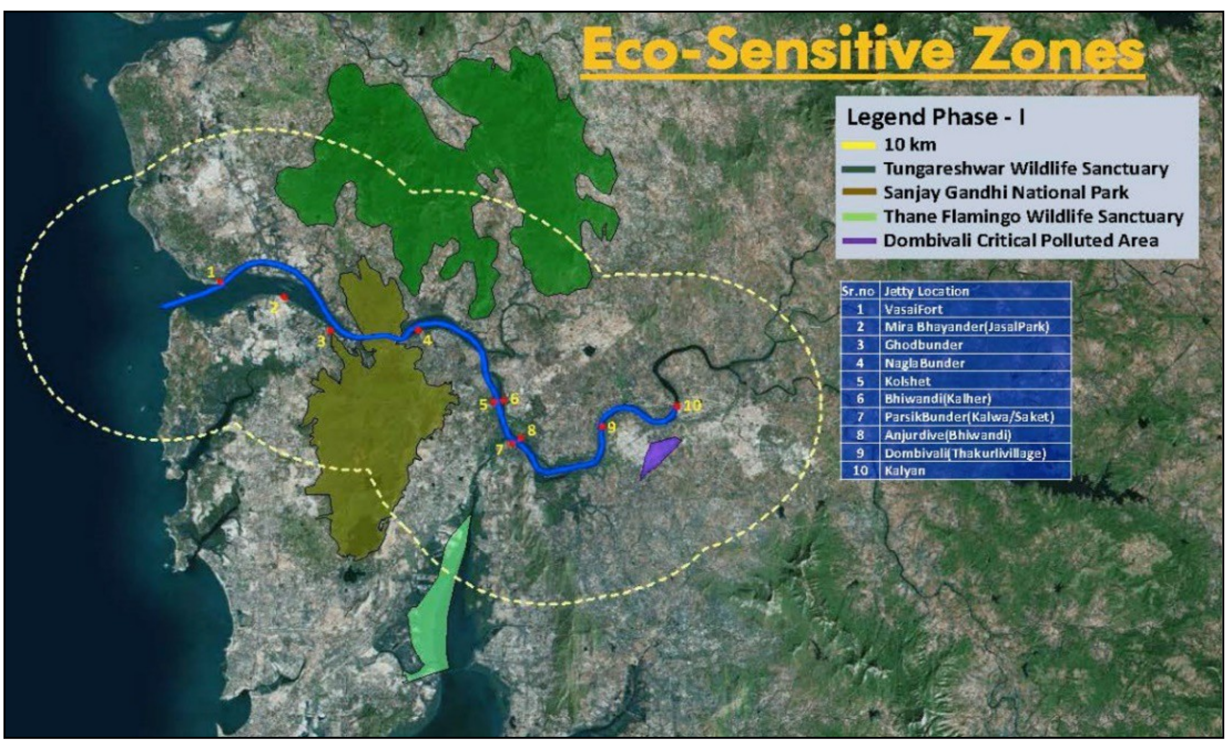


Table 9. 1: Distance of The Terminals From The Eco-Sensitive Zone

(in Kms)

Sr. No.	Site Name	SGNP	Thane Creek WLS	Tungaresh war WLS	Dombivli Critically Polluted Area
1	Vasai Jetty	8.67	> 10.00	7.22	> 10.00
2	Mira Bhayander (Jasal Park)	4.35	> 10.00	5.60	> 10.00
3	Ghodbunder	0.27	> 10.00	6.22	> 10.00
4	Nagla Bunder	1.27	> 10.00	2.54	> 10.00
5	Kolshet	2.38	8.67	6.31	> 10.00
6	Bhiwandi (Kalher)	3.03	8.90	6.39	> 10.00
7	Bhiwandi (Anjudrive)	5.41	6.70	9.45	8.575
8	Parsik Bunder	4.97	6.06	9.70	9.10
9	Dombivli (Thakurli Village)	> 10.00	> 10.00	> 10.00	3.55
10	Kalyan	> 10.00	> 10.00	> 10.00	2.29

9.3.3 Meteorology

The creek sites come under the direct influence of the south-west monsoon and receives heavy and assured rainfall between June and August. The rainfall gradually decreases from Karnataka in the south to Gujarat in the north. The south-west monsoon rainfall is usually very heavy. 90% of the rainfall occurs from June to November. The months from March to May comprise the summer season and in the subsequent months, i.e. from June to September, the area receives rainfall under the influence of south-west monsoons. The months of October and November experience the post-monsoon season and the winter season lasts from December to February. The mean daily maximum temperature varies from 32°C to 37°C. Likewise, the mean daily minimum temperature varies from 15°C to 27°C. The average annual rainfall in the project area is 1173 mm.

The detailed baseline data collection based on the Terms of Reference issued by Ministry of Environment, Forest and Climate Change was carried out and the likely effect of the development on the environment and the social aspects of the area was determined. The findings along with the data collected, likely effects, likely risks and the mitigation measures are discussed in detail in the EIA report submitted separately.

9.3.4 Air Environment

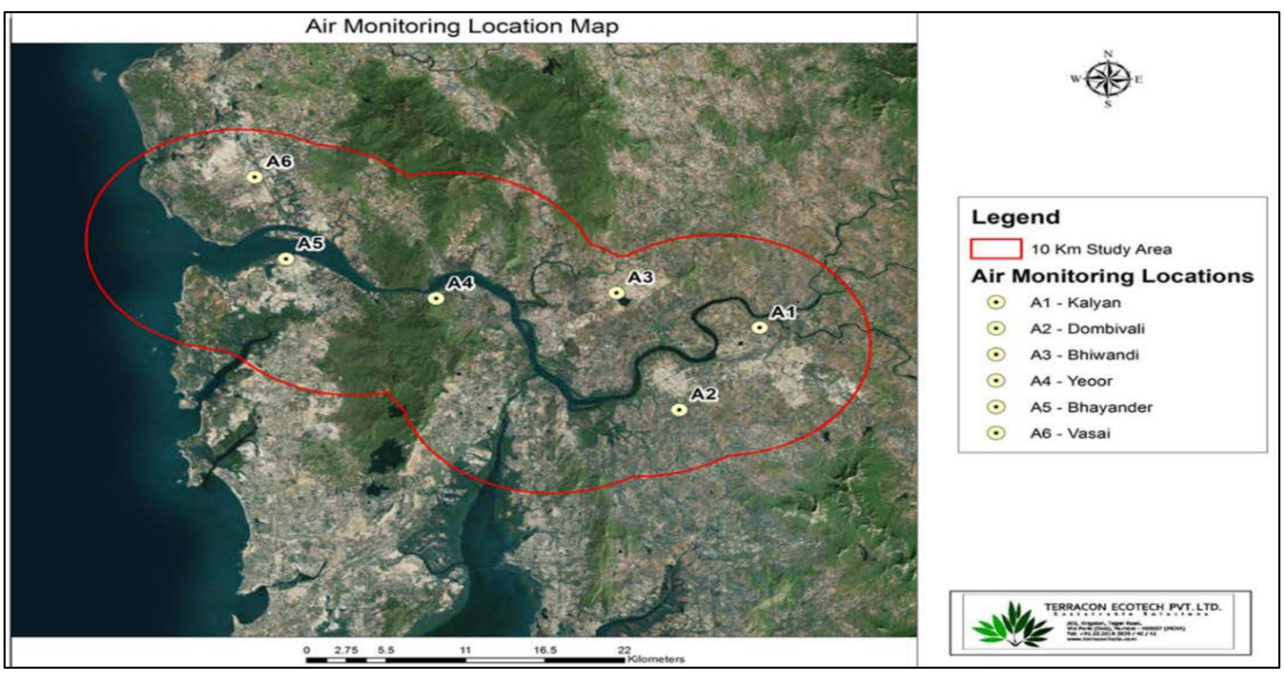
The parameters analysed were Particulate Matter (PM_{10} and $PM_{2.5}$), Sulphur dioxide (SO_2) and Nitrogen Oxides (NOx). The average PM2.5 levels at all the stations was within the permissible limit specified for residential areas (100 µg/m3). Likewise, the ambient SO_2 and NOx concentration at all the stations was within the permissible limit of 80 µg/m3 for the residential areas.

Table 9. 2: Location Of Air Monitoring Stations

Sample Code	Location	Distance (Km)	Direction	Latitudes	Longitudes	Elev (m)	Remarks
A1	Kalyan	3.2 (Kalyan)	NE	19°15'30.08"	73° 8'37.74"	18	Khadakpada Police Station
A2	Dombivli	4.7 (Dombivli)	SE	19°11'29.46"	73° 5'37.92"	19	MIDC Phase II
A3	Bhiwandi	5.9 (Kalher)	NE	19°17'12.05"	73° 3'17.09"	49	P.A.J. Vidhyalay
A4	Yeoor	5.7 (Kolshet)	W	19°14'30.14"	72°56'33.10"	361	Mr. Nilesh Sawant's house
A5	Bhayander	2.9 (Mira Bhayandar)	S	19°18'51.43"	72°50'56.68"	1	Nr. Mandali Lake, Jai Ambe Nagar
A6	Vasai	8.1 (Vasai)	NE	19°22'50.80"	72°49'46.43"	39	Nr. Syndicate bank

The geographical location of the air sample collection stations is shown in Figure 9.3 below.

Figure 9. 3: Air Quality Monitoring Stations



The baseline air quality at Vasai is given in table 9.3, which shows that all the required parameters are within the prescribed limits. Similar results were noticed in other locations as well, including Dombivli.

Table 9. 3: Baseline Air quality At Vasai (Typical)

Date of Analysis Completion	Sampling Location:- AM - Ambadi Road (Syndicate Bank), Vasai											
	Parameters											
	PM10	PM2.5	SO2	NO2	CO	Ozone	Lead	NH3	Benzene	Benz-o-pyrene	Arsenic	Nickel
	Limit as per NAAQS											
	100	60	80	80	4 (1Hr)	180	1	400	5	1	6	20
05.03.2018	44.1	18.6	6.18	15.48	0.39	11.76	0.008	20.3	BDL	BDL	0.48	1.66
09.03.2018	49.6	14.7	9.47	18.32	0.32	11.94	0.004	20.7	BDL	BDL	0.44	1.62
12.03.2018	43.2	12.3	5.32	19.73	0.37	11.52	0.009	19.6	BDL	BDL	0.49	1.60
16.03.2018	48.6	19.7	8.17	14.52	0.31	11.43	0.003	17.9	BDL	BDL	0.42	1.65
19.03.2018	49.7	17.8	4.43	17.66	0.36	11.40	0.010	18.3	BDL	BDL	0.47	1.69
23.03.2018	42.9	15.9	2.98	16.93	0.38	11.75	0.007	19.5	BDL	BDL	0.48	1.78
26.03.2018	48.6	16.5	7.13	21.89	0.39	11.79	0.005	17.3	BDL	BDL	0.46	1.73
30.03.2018	45.9	13.8	4.66	13.98	0.33	11.46	0.002	17.5	BDL	BDL	0.41	1.77
	46.5	**16.1**	**6.04**	**17.31**	**0.35**	**11.63**	**0.006**	**18.8**	**BDL**	**BDL**	**0.45**	**1.68**

For detailed treatise on the air quality, refer the EIA document to be submitted to TMC at the end of the environmental study.

9.3.5 Marine Water Quality

Marine ecological survey was conducted to establish the existing status of the marine water quality in and around the two project alternatives. Sampling was conducted for the pre- monsoon season (8th March, 2018). The monitoring stations are shown in Table 9.3 & Figure 9.4 and the results shown in Table 9.4.

Table 9. 4: Location Of Marine Water Monitoring Stations

Sample Code	Location	Distance (Km)	Direction	Latitudes	Longitudes	Elev (m)
CW1	Kalyan	0	-	19°14'51.76"N	73° 7'0.76"E	0
CW2	Dombivli	0	-	19°13'43.23"N	73° 4'0.45"E	0
CW3	Thane	0	-	19°13'19.30"N	73° 0'25.36"E	0
CW4	Kolshet	0	-	19°14'52.78"N	73° 0'1.60"E	0
CW5	Nagla Bunder	0	-	19°17'52.35"N	72°56'57.25"E	0
CW6	Ghodbunder	0	-	19°17'43.26"N	72°53'40.45"E	0
CW7	Mira Bhayander	0	-	19°19'12.17"N	72°51'55.41"E	0
CW8	Vasai	0	-	19°19'27.97"N	72°49'11.27"E	0

Figure 9. 4: Marine Water Monitoring Stations

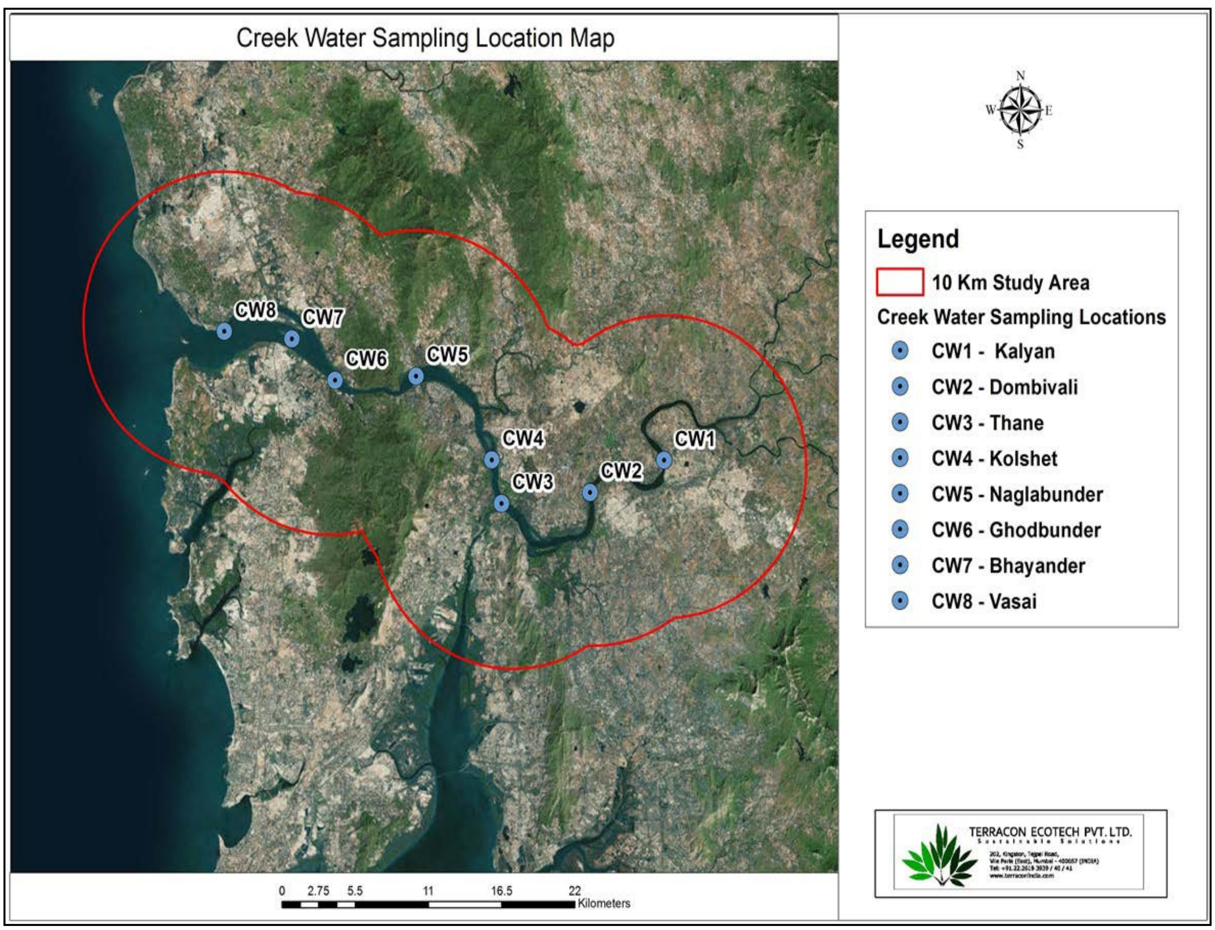


Table 9. 5: Marine Water Quality At Kolshet Station (CW4)

Sr. No.	Parameters	Units	Result	Reference Method
1	pH	-	**6.67**	APHA 23rd Ed. 4500-H+ B
2	Conductivity	mS/cm	**24.3**	APHA 23rd Ed. 2510 B
3	Turbidity	NTU	**97**	APHA 23rd Ed. 2130 B
4	Temperature	°C	**28.1**	APHA 23rd Ed. 2550 B
5	Total suspended solids	mg/L	**78**	APHA 23rd Ed. 2540 D
6	Total dissolved solids	mg/L	**16052**	APHA 23rd Ed. 2540 B
7	Chemical Oxygen Demand (COD)	mg/L	**1195**	APHA 23rd Ed. 5220 B
8	Biochemical Oxygen Demand (BOD) 3 days @ 27 °C	mg/L	**361**	APHA 23rd Ed. 5210 D
9	Oil & Grease	mg/L	**4**	APHA 23rd Ed. 5520 B
10	Sulphate	mg/L	**8**	APHA 23rd Ed. 4500- SO4-2- E
11	Chloride	mg/L	**11433**	APHA 23rd Ed. 4500-Cl- B
12	Alkalinity	mg/L	**2869**	APHA 23rd Ed. 2320 B
13	Boron	mg/L	**< 0.025**	APHA 23rd Ed. 4500-B C
14	Calcium	mg/L	**742**	APHA 23rd Ed. 3500-Ca B
15	Dissolved Oxygen (DO)	mg/L	**1.4**	APHA 23rd Ed. 4500-O- C
16	Fluoride	mg/L	**1.6**	APHA 23rd Ed. 4500-F D
17	Nitrate	mg/L	**< 0.2**	APHA 23rd Ed. 4500-NO3- B
18	Phosphate as PO4	mg/L	**1.1**	APHA 23rd Ed. 4500-P D
19	Salinity	ppt	**21**	APHA 23rd Ed. 2520 B
20	Metal-Chromium	mg/L	**< 0.01**	APHA 23rd Ed. 3111 B
21	Metal-Copper	mg/L	**< 0.01**	APHA 23rd Ed. 3111 B
22	Metal-Iron	mg/L	**< 0.2**	APHA 23rd Ed. 3111 B
23	Metal-Potassium	mg/L	**215**	APHA 23rd Ed. 3111 B
24	Metal-Sodium	mg/L	**617**	APHA 23rd Ed. 3500-Na B
25	Faecal Coliform	CFU/100ml	**19**	APHA 23rd Ed. 9221 E
26	Total Coliform	CFU/100ml	**84**	APHA 23rd Ed. 9221 C

9.3.6 Other Water And Sediment Quality Data

Similar data was collected with regard to the ground and surface water and analysed. The analysis indicates that the base line status of this area does not show any pollution and the parameters are within the prescribed limits. Similarly, the sediment quality data along the creek was analysed and reported in the EIA report.

Amongst, the trace metals, the concentration of zinc, copper and lead was quite low. The mercury and cadmium levels showed lesser concentration, considering the fact that there are no sources of these pollutants in the area. However, the concentration of mercury and cadmium is not alarming.

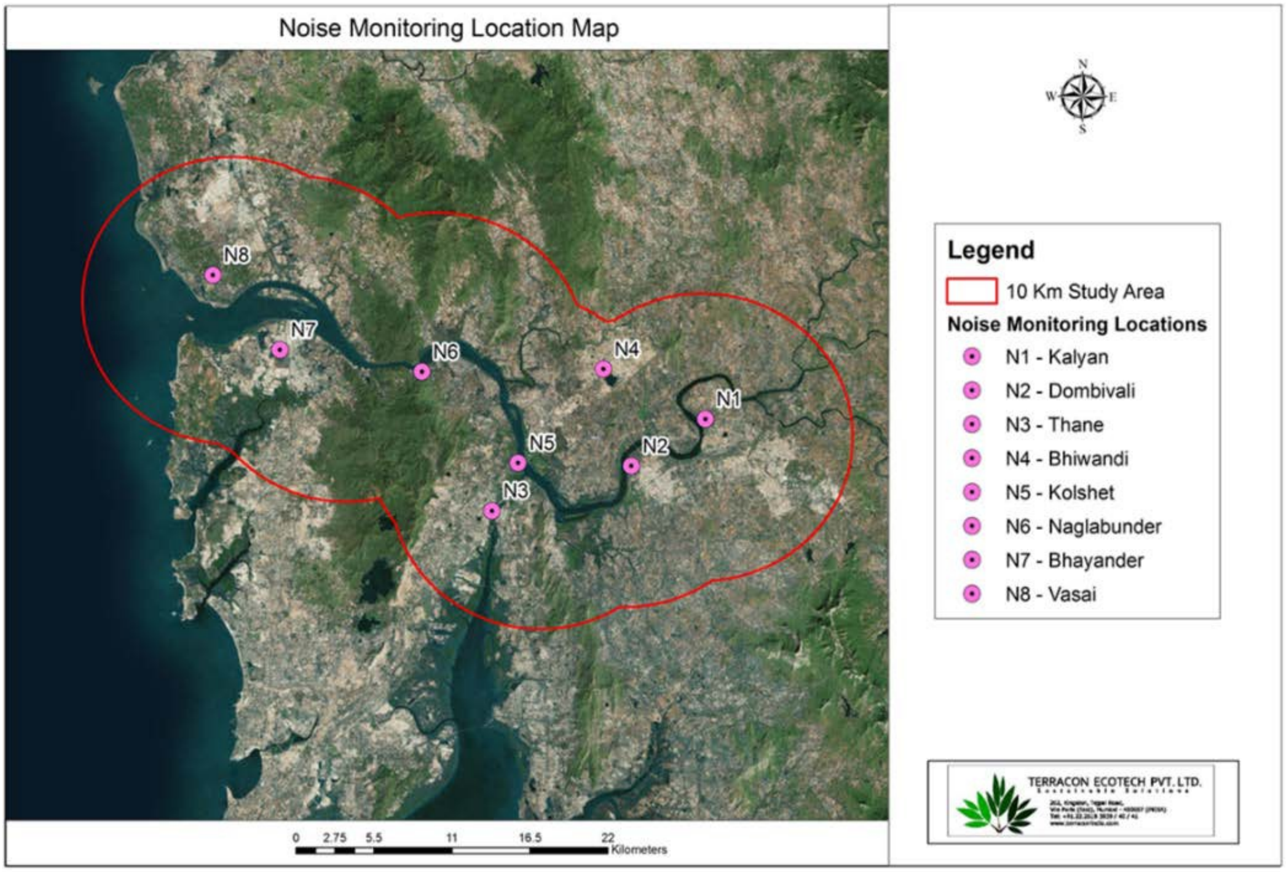
9.3.7 Noise Monitoring

Noise monitoring was carried out at 8 locations for a span of 24 hours as shown in Table 9.4 and Figure 9.5.

Table 9. 6: Noise Monitoring Station

Sample Code	Location	Distance (Km)	Direction	Latitudes	Longitudes	Elev (m)	Remarks
N1	Kalyan	1.3 (Kalyan Site)	NNE	19°15'19.67"	73° 7'9.96"	9	National Urdu High School
N2	Dombivli	0.5 (Thakurli)	ESE	19°13'33.95"	73° 4'21.30"	7	Mukteshwar Mandir, Mothagaon
N3	Thane	3.6 (Parsik Bunder)	WSW	19°11'52.51"	72°59'3.35"	7	Nr. Parsik Bunder site
N4	Bhiwandi	8.4 (Bhiwandi Khaler)	NE	19°17'12.53"	73° 3'17.62"	40	P.A.J. Vidhyalay
N5	Kolshet	-	-	19°13'40.49"	73° 0'2.78"	2	Between Kolshet & Parsik Bunder
N6	Nagla Bunder	1.4 (Nagla Bunder)	NE	19°17'6.18"	72°56'23.63"	20	Jagnath Mahadev Mandir
N7	Bhayander	2.2 (Jasal Park)	NNE	19°17'55.36"	72°50'59.27"	7	St. Jude Thaddeus Church
N8	Vasai	2.4 (Vasai Site)	NNW	19°20'44.38"	72°48'26.26"	9	New English School

Figure 9. 5: Noise Monitoring Stations



The result of the monitoring of Jay Ambe Nagar, Bhayander carried out from 9th to 10th March 2018 is given in Table 9.6 and the limits prescribed by MoEF in the Table 9.7.

Table 9. 7: Noise Monitoring Results of Jay Ambe Nagar, Bhayander

Time	Min. dB (A)	Max. dB (A)	L10	L50	L90	L Day/Night	LEQ dB (A)
Day Time (06.00 am to 10.00 pm)	42.6	59.3	56.7	50.9	45.1	50.7	53.1
Night Time (10.00 pm to 06.00 am)	27.6	48.3	46.8	39.8	30.3	38.9	44.3

Table 9. 8: Noise Monitoring Station

Category Zone	Limits in dB(A) Leq*	
	Day Time Leq dB(A)	Night Time Leq dB(A)
Industrial area	75	70
Commercial area	65	55
Residential area	55	45
Silence Zone	50	40

9.3.8 Land Use Pattern

The land use pattern was studied using digital satellite data, obtained from National Remote Sensing Agency (NRSA), Hyderabad. Both LISS-IV & PAN data for the month of October-November, 2017 were procured and processed using ERDAS Imagine software. The ground truth study was conducted to ensure data precision. As per the satellite data, water bodies account for about 22.8% of the core area. Likewise, 12.1% of the area is under agriculture. About 35.6% of the area is under dense vegetation and the rest covered with residential and commercial area.

9.3.9 Ecology

9.3.9.1 Terrestrial Ecology

The core area, falls inside the SGNP and the Wild Life Sanctuaries. Hence there is forest all around the creek. The major forest type in the core area is southern typical moist deciduous forest and moist teak forest. The major floral species observed in the core area include Tectona grandis (Teak), Terminalia crunulator (Sahad), Dalbergia latifolia (Shisham), Acacia catechu (Khair), etc. Satellite images of the area does show mangrove along the coastline. However, the terminals locations were carefully selected so that no mangrove gets damaged. There are limited wildlife observed during the survey in the core area.

9.3.9.2 Marine Ecology

To ascertain the biological productivity a few biological parameters like Chlorophyll pigments, primary productivity, pheophytin, particulate organic carbon, zooplanktons, phytoplanktons and benthic fauna at the sites were analyzed.

Based on the data of various parameters, the terminal sites can be termed as low to moderately productive.

9.3.9.3 Fisheries

Deep sea fishing activities are being practiced in the villages of the core area. Fishing continues throughout the year except during monsoon months, when the sea is choppy and boats cannot go to the high sea due to higher risk involved. During the monsoon months some of the fishermen families use the creek area for catching fish. The fish catch is not significant, but helps the locals to augment a part of their income during the monsoons.

9.3.10 Socio-Economic Aspects

According census 2011 and DSA 2012-13 data most of the people of the study area are depending on Industrial works, service sector, small business and fishing/fish culture for their livelihood. Business is also one of the major occupations of the people of coastal region. The average household size of the study area (4.3) is slightly lower than the state average (4.6 as per census 20011). The literacy rate in the study area is much higher than the national scenario in both sex male and female.

The Vasai-Virar Municipal Corporation (VVMC) was formed in the year 2010 covering an area of 105 sq km, by merging of Nallasopara, Vasai, Virar and Navghar Manikpur towns and 49 urbanised villages (Out of total 76 villages in Sub region). 27 villages were not merged in the corporation. The Sub-region has annual composite growth rate for the decade 1951 – 2001 for 4 towns stated above was 10.92%. The growth rate has further increased in the decade 2001 – 2011. The population of VVMC as per Census 2011 is 12.21 Lakhs. As per provisional reports of Census India, population of Vasai Virar in 2011 is 1,221,233; of which male and female are 649,535 and 571,698 respectively. The sex ratio of Vasai Virar city is 880 per 1000 males. The decadal growth rate in population has been 58% and 70% during the last two decades i.e., 1981-1991 and 1991-2001. As per census 2001, the population of Vasai Virar was 702723. The projected population is 22.23 lakhs during 2021.

Mira Bhayandar Municipal Corporation (MBMC) formed in 2002 covers an area of 89 sq km. It had a population of 5.20 lakhs in 2001 (2,86,391 males and 2,33,997 females), which has increased to 8.15 lakhs in the 2011 census. It is projected that population would be about 14.74 lakhs, 22.11 lakhs and

28.55 lakhs in 2021, 2031 and 2041 respectively. The annual growth rate is 4.6%. Bhayandar on the western side of the railway line is traditionally residential, and the Eastern was predominantly commercial and industrial activities.

Similar data for the other municipal regions like, Thane, and Kalyan-Dombivli municipal Corporations.

9.3.10.1 Stakeholder Consultation

A summary of issues raised by various stakeholders and how these issues are addressed and incorporated in the EIA report, are shown in below Table 9.9

Table 9. 9: Issues raised by Stakeholders

Stakeholders Type	List of Concerned Raised	Responses and mitigation measures under the project-summary
Shopkeepers	Shopkeepers opined in favour of the project, but they want to see the ferry ghat improved with more facilities such as toilets, sufficient space for shops on a designated area so that they will not be bound to shift their structure frequently. They expressed that the project will increase their business opportunities and new venture of business will be open after completion of the project.	Toilets and drinking water facilities will be included in the design of ferry ghats and river terminals. The designs of terminals will also include shops and while leasing out these shops, priority will be given to the affected communities.
Physically Disabled	There should be special facility for the disabled people in the ferry terminals and water vessels. They want separate place in ghat and ferry terminals for their easy movement. Wheel chair and bed facilities must be available in emergency situation. Disabled persons want proper safety and security in terminal and launch as well. Disabled persons do not know the facilities about river transports. Most of the people think that road transport is easier than river transport especially for the disabled persons as they cannot swim. They want separate space/seat for them in the launch/ferry and easy riding facility such as smooth way, wheel chairs, etc. If such facilities are provided for the disable people, then they may comfortably use the river transport.	Ramps will be provided at the terminals for embarkation and disembarkation of disabled people. Other aspects will be explored in full in the detailed EIA and design studies to be carried out during project implementation.
Fishermen	Fishermen communities are mostly living along the creek or within one km from the creek. They want modern signalling system and safety and security during fishing. Some time they are to face trouble from pirates or even some politically influenced persons who make them bound to pay money for fishing. They welcomed the project but requested to keep in mind about fish moving routes, season and fishing areas during	Navigational buoys/signals will be provided along the navigational channels. Spawning areas of fish, migratory routes and commercial areas for fishing will be avoided for dredge material placement.

Stakeholders Type	List of Concerned Raised	Responses and mitigation measures under the project-summary
	dredging so that their livelihoods will not be disturbed.	
Women	Safety and security, separate space for them in the launch terminals and vessels, separate ticket counter, etc. are their needs.	Separate ticket counters, waiting rooms and toilets will be provided for the women passengers near the terminals. Separate toilets will also be provided at the landing stations. Specific design features to maximize women's needs, comfort and safety in using, will be studied in more depth during the detailed design and EIA stage for river terminals and landings, as well as thorough study to develop a gender action plan and to be carried out during project implementation.

9.4 Impact Assessment

9.4.1 General

Based on the project details and the baseline environmental status, potential impacts that are expected to accrue as a result of the proposed project have been identified and assessed. This Section deals with anticipated positive as well as negative impacts likely to accrue as a result the construction and operation of the proposed project alternatives.

9.4.2 Land Environment

The likely impact on the land environment will be limited, except for the areas earmarked for the Terminals. The terminals and the approaches to the terminals would be constructed afresh and to that extent there will be change in the land use. A total of about 50 acres of land may be required for the terminal and ancillary arrangements. Beyond this there would be no need for land acquisition and so impact on the land environment is limited.

9.4.3 Air Environment

Construction of the jetties and terminal buildings may generate dust, likewise transportation may give rise to vehicular emissions and spillage of raw materials, also loading and unloading activities will generate dust. Increase in the terminal activities and vehicles is likely to increase the vehicular pollution in the area, but the reduction, it is likely to bring, in the overall traffic situation in the area would more than compensate the increase in the air pollution. Also, the use of DG sets and fossil fuels will contribute to emissions during operation phase.

9.4.4 Water Environment (Surface and Ground Water)

There are no manufacturing or water discharge in to the waterway, hence there is no effect on the water environment of the area. The domestic sewerage at the terminals would be treated in a STP and used for horticulture.

9.4.4.1 Marine Environment

The construction of jetties and dredging may disperse the sediment in the water column which increases the water turbidity and light penetration will be affected. The liquid waste which will be generated in the normal day-to-day operations may pollute and deteriorate the creek water quality. The texture of the bed sediment may be locally modified due to settlement of particles suspended in water during dredging and piling operations. Dredged material if not properly disposed would modify the sediment characteristics of the disposal site which in turn affect benthic organisms. Portable toilets will be placed at the work sites which will be regularly serviced. The deployment of construction vessels and machinery will be optimized and the contractor will have to sign an agreement to maintain them regularly. Skilled labour will be employed for the construction works which will reduce the impact on environment.

9.4.4.2 Biological Environement

Marine Ecology

During construction Solid waste disposal, wastewater discharge and oil spills if any could affect the marine ecology of the area. Avoiding any kind of disposal or spillage into the creek/ sub-creek will avoid any effects on marine environment. If any further minor impacts that could occur on marine ecology during construction phase it will get mitigated with time.

Terrestrial Ecology

Few vegetation would have to be cleared during site clearance. Impacts on Flora and Fauna other than in site clearance will be minimal and temporary in nature. Only indirect impacts such as deposition of dust, noise emission, exhaust emission, etc. due to transportation of raw materials (stones and boulders) will be encountered. This will be mitigated by the natural processes like wind. Care will be taken to cause minimal impact on trees/mangroves.

9.4.5 Noise Environment

Minimal effect on the ambient noise condition could be observed due to the increased vehicular movement and ferries. Further, there would be a reduction in the noise quality in surrounding areas because of the reduction in the surface transport.

9.4.6 Socio- Economic Impacts

The types of social issues and possible impacts associated with a project can vary considerably depending on the nature of the project, it's size, location and stages of the project cycle. The following issues provide an overview of the impact may be faced during construction and maintenance of the ferry terminals and other components of the project. The impacts may be considered as intended and unintended following the nature and perspective of the impacts and the social impact is divided into seven main categories:

1. Demographic Impacts (Impacts of the project which may cause changes in the size and makeup of the population of the areas affected by the project)
2. Social Infrastructure (Impacts on the social characteristics of the community including housing, water and power supply, educational, health and recreation, transport and public safety)
3. Land Use
4. Social Relations and Impact
5. Cultural Property (Including religious, historic and archaeological sites)
6. Economic Activity (Primary and multiplier effects)
7. Human Rights and Regulation

Table 9. 10: Potential Socio-Economic Impacts Of Construction Of Ferry Terminals With Vehicle Ferry Ramp

Impact	Beneficial	Adverse
Economic	• Employment generation • Expenditure of wages in local area • House purchase and rental • Equipment and services procurement • Local authority business tax/rates revenue • Increase in property value	Negative Economic impacts are not anticipated
Social	• Indirect beneficial community impacts from employment and provision of skilled workforce • Provide medical services and some educational benefits, as well as training at least for employees and workers • Increase local transport system. • Increase tourism industry in Vassai and Durgadi fort • Positive impact on human life and leaving condition	• Risks of occupational and environmental health issues associated with waste scavenging. • Nuisance to nearby localities due to increased dust, noise, emissions, traffic and level of activities.

Suggested Mitigation Measures during Construction Phase

Mitigation measures must be taken into consideration to ensure the dissemination of the positive socio-economic impacts of the project on the construction and operation phases. The local community in the immediate vicinity of the facility should be given priority in terms of providing job opportunities. As such, economic incentives should be provided to the local community by adopting policies to recruit locally and to hire local contractors as far as possible. An on-the-job training program should be implemented for those that do not have adequate skills. Provision of packages of information to workers moving into the area should help them to integrate into the local community more quickly.

Other key issues for socio-economic mitigation measures include:

- Consultations with the local communities to inform them of about new projects where this will serve to provide sufficient project information, understand the concerns/grievances, manage their expectations, and relay information on how suitable mitigation measures are implemented to reduce residual and cumulative impacts.
- Continuously recognizing the community expectations, in terms of contributing to local economy through infrastructure, welfare and employment generation.
- In order to actively engage with the community, key staff with specific responsibilities and

accountabilities needs to be assigned, such as Environment Manager, Community Relations Officer (CRO), and support team.

- Owing to the quantities and characteristics of materials and goods to be transported to and from the project site by land, a comprehensive Transport Management Plan (TMP) should be implemented by the Transport Manager.
- The project's construction and operational activities might lead to the influx of a number of expatriate people into the area for direct employment in the project as well as for indirect employment with service providing companies and for other business activities, which will have potential impacts on the existing communities. Therefore, it is recommended that TMC provide an adequate induction and introduction to local community for the expats they employ directly to minimize any potential conflicts.

9.4.7 Human Rights

The construction of 10 terminals is expected to have only a positive impact on Human Rights issues in the areas in which it operates by TMC. In keeping with GOI law and ILO guidelines, TMC does not employ anyone below the age of 18. TMC will take the issue seriously and is integrating relevant provisions into its supplier contracts and code of conduct.

TMC will continue to work to implement human rights and labour practices in line with GOI Labour Law, particularly with regard to non-discrimination, freedom of association and child labour.

The construction agencies require complying with laws of the land, which include inter alia, the following:

1. Payment of Wages Act, 1936; 2. Equal Remuneration Act, 1979; 3. Child Labour (Prohibition and Regulation) Act, 1986, 4. Minimum Wages Act, 1948; 5. The Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act, 1996 and the Cess Act of 1996; 6. Workmen's Compensation Act 1923; 7. Contract Labour (Regulation and Abolition) Act, 1970; 8. Inter-State Migrant Workmen's (Regulation of Employment and Conditions of Service) Act, 1979 and Rules, 1996; 9. The Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act, 1995 and Rules, 1996 and 10. Hazardous Wastes (Management and Handling) Rules, 1989.

9.4.8 Socio- Cultural Impacts

According to proposed project component there is no physical or economic displacement of any schedule tribe community involved due to proposed project. Therefore, any socio-economic and cultural impacts that may occur as a result of the project would be in future and the overall severity of impact will be low. The ULBs and the Panchayats have been accorded with powers to decide upon matters of traditional and customary rights and institutional mechanisms have been put in place at the district, state and central level to decide upon community/ individual rights and ownerships.

- Indirect Impacts on Law & Order Situation.
- Indirect impacts on local tradition & culture.

Suggested Mitigation Measures during Construction Phase

- The local law & order authorities will be regularly informed about the construction planning & sites of construction works & activities.
- The construction workforce will be regularly instructed to respect local people & their traditions & culture & to avoid conflict with local people.
- The construction workforce will be regularly instructed to remain within the camps in between 7 pm to 6 am daily unless required for construction works.
- Avoid entering into private premises without informing & without the permission of the property owners.
- Contractors & workforce to be instructed to honour local culture & traditions, & to behave with civility & respect with local population.

9.4.9 Impact On Human Health And Occupational Safety

Safety issues associated with TMC's terminal activities involve improper handling, storing and disposing the waste material and some agricultural chemicals as well as accidents occurring with the operation of moving equipment. While the magnitude of this impact is difficult to quantify, they can be divided into two categories, those confined with on-site and off-site workers. However, the project activities may not prove harmful to human health, but Workers on-site could be affected from different activities:

- Health stress impacts from workers exposure to daily noise emissions from different machines used on-site.
- Health hazards related to cutting activities, improper electrical supply.
- Improper use of the different machinery and the mismanagement of proper spacing of different tools and fuels on-site cause a threat on workers safety.
- The presence of any unstable land prone to slides, erosion and slippery or a deep swale is also a potential threat to human safety.
- The trucks and equipment used to perform the proposed activities could cause a hazard when extensively used without proper maintenance and check-ups.
- Workers' health could be at risk if proper safety and protective gear is not employed against

gaseous and particulate air emissions, noise, and rain, and if proper hygiene is not maintained throughout the worksite.

- Workers' health could have posed at risk if medical precautions and necessary vaccines are not taken.
- Lack of proper controls and signage around potentially hazardous areas.
- Uncontrolled access to the main site including workshop, storage facilities as well as off-site facilities may result in various hazards.

Suggested Mitigation Measures during Construction Phase

Limiting the risk of injury at the sites of operation mainly lies in promoting awareness and good management practices among workers at the main site, especially when it comes to machine operation and chemicals handling, which has serious adverse impacts on those directly exposed to especially during storage, application and disposal. Recommended mitigation measures to be adopted at the main site include the following:

- TMC's construction workforce to be instructed & monitored regularly re: occupational health risks during construction works.
- Provision of first aid kits to all TMC's construction sites.
- Health & safety plans to be prepared & operationalized for entire construction period to safeguard health & safety of construction workforce (and nearby local residents) especially with provisions of rescue in case of accidents.
- Only healthy workers will be employed in the construction workforce.
- Sanitary conditions of camps (e.g., toilets, water supply, solid & liquid waste) to be managed by launching special sanitary programs.
- Construction workforce to be provisioned with free medicine, & given personal health/hygiene information.
- Health services to be provided to construction workforce shall not depend upon local health services.
- Awareness programs will be launched at the beginning of the project operation to the local communities.
- Potential impacts & precautionary measures to be employed to protect oneself from the electrical & electromagnetic fields & stray voltage.
- Provide safety gear to construction workforce & instruct their compulsory use during the construction work.
- Provide appropriate personal protective equipment such as gloves, masks, earplugs, brightly coloured working overalls equipped with light reflecting stripes, safety boots, safety helmets,

etc.

- Provide personal ID cards for all employees.
- Provide appropriate lighting during night-time works.
- Hoarding boards will be placed in critical places along ROW with instructions to safeguard populace from the RCC jetty construction place.

The adoption of appropriate and necessary protective measures can reduce the potential health risks associated with the construction and operation phases. Such measures will become of high significance not only to the facility workers but also to the site management due to the financial savings associated with the reduction of lost days of work and medical treatment for those injured during operation.

9.5 Risk Analysis and Disaster Management

9.5.1 Introduction

Proposed project is located on National Waterway 53, Kalyan-Thane-Vasai, currently the project covers a stretch of 50 km in the Vasai creek-Ulhas river basin. This area is a part of the Mumbai Metropolitan Region (MMR). Currently there is no proper means to connect parts of Vasai to Kalyan except by Road via Ghodbunder Thane.

For any vessel to operate in this stretch of National Waterway 53, the likely impediments may be:

- Draft of the vessel
- Air draft of the vessel
- Width of the waterway (restrciting turning circle)
- Bends in the waterway
- Shallow areas
- Non availablity of suitable terminal/jetty

Therefore, it is desireable to select the right mix of vessels to operate within the available horizontal and vertical clearances under the bridge and available depths in the waterway (after dredging).

9.5.2 Methodology

Risk assessment is the process which associates “hazards” with “risks”. When we know the various impacts a hazard may have on our mission and an estimate of how likely it is to occur we can now call the hazard a risk. Risk is defined as a measure of the threat to safety posed by the accident scenarios and their consequences.

The modeling approach adopted for the quantitative assessment of the risks associated with runway operations involves several methodological steps which are defined as:

- Identification of hazardous conditions and accident scenarios,
- Determination of probabilities of the accident identified; and
- Definition of consequences of such an accident (fatalities and aircraft damages).

9.5.3 Hazard Identification

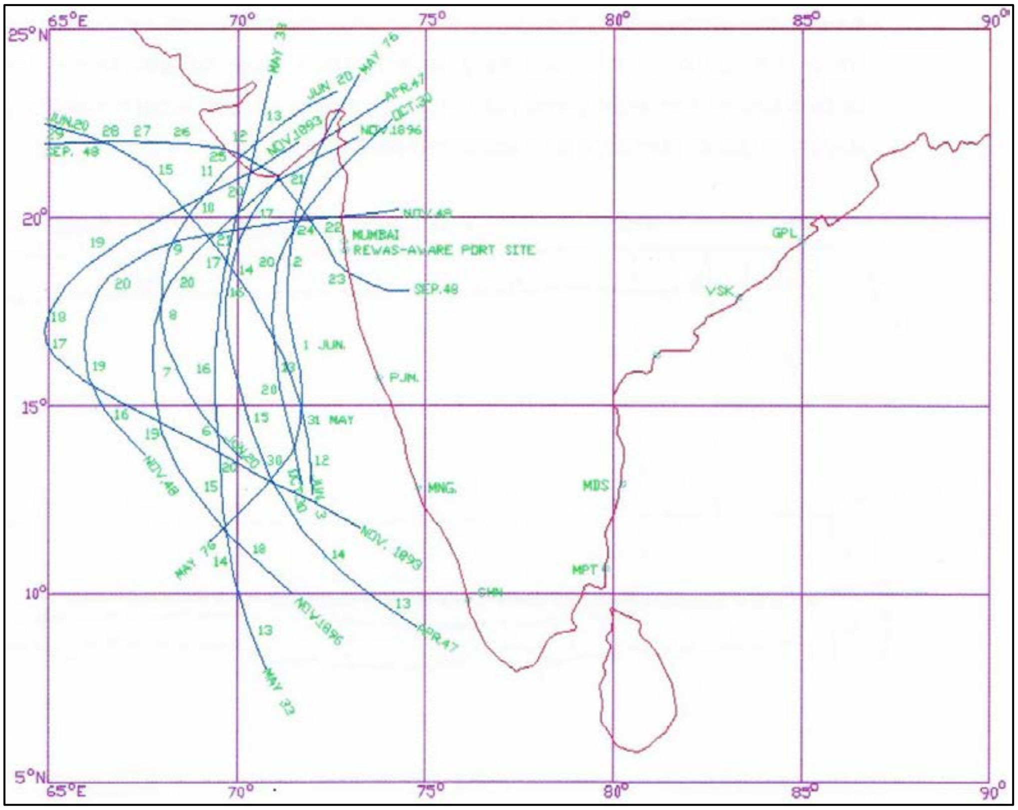
There is a group of factors which have an immediate influence on each Ro –Ro Vessel safety at river/creek and the most important between them are the factors associated with the parameters of the following:

1 Engine Failure of RO-RO Vessel / accidental Ship/Hull, hull, propeller and rudder damages.
2 Vessel accidental collapse/capsize
3 Adverse Environmental condition of wind, waves and current. Natural Disaster such as Tsunami, Earthquake, Cyclone and Flood
4 Manmade threat such as fire,noise, sabotage, Terrorist activities along with likely stampede on narrow boarding/De boarding platform at heavy rush hours
5 Medical emergency to passenger on board.
6 Variation in interrelations between the safety domains and the interrelations between certain hydromechanics characteristics/parameters leads to accidents

9.5.4 Natural Hazards

Natural disasters include earthquakes, tsunami, floods, storms lightening etc. The Tracks of cyclones in Arabian sea from the 1877 to 1992 is shown in Figure 9.6

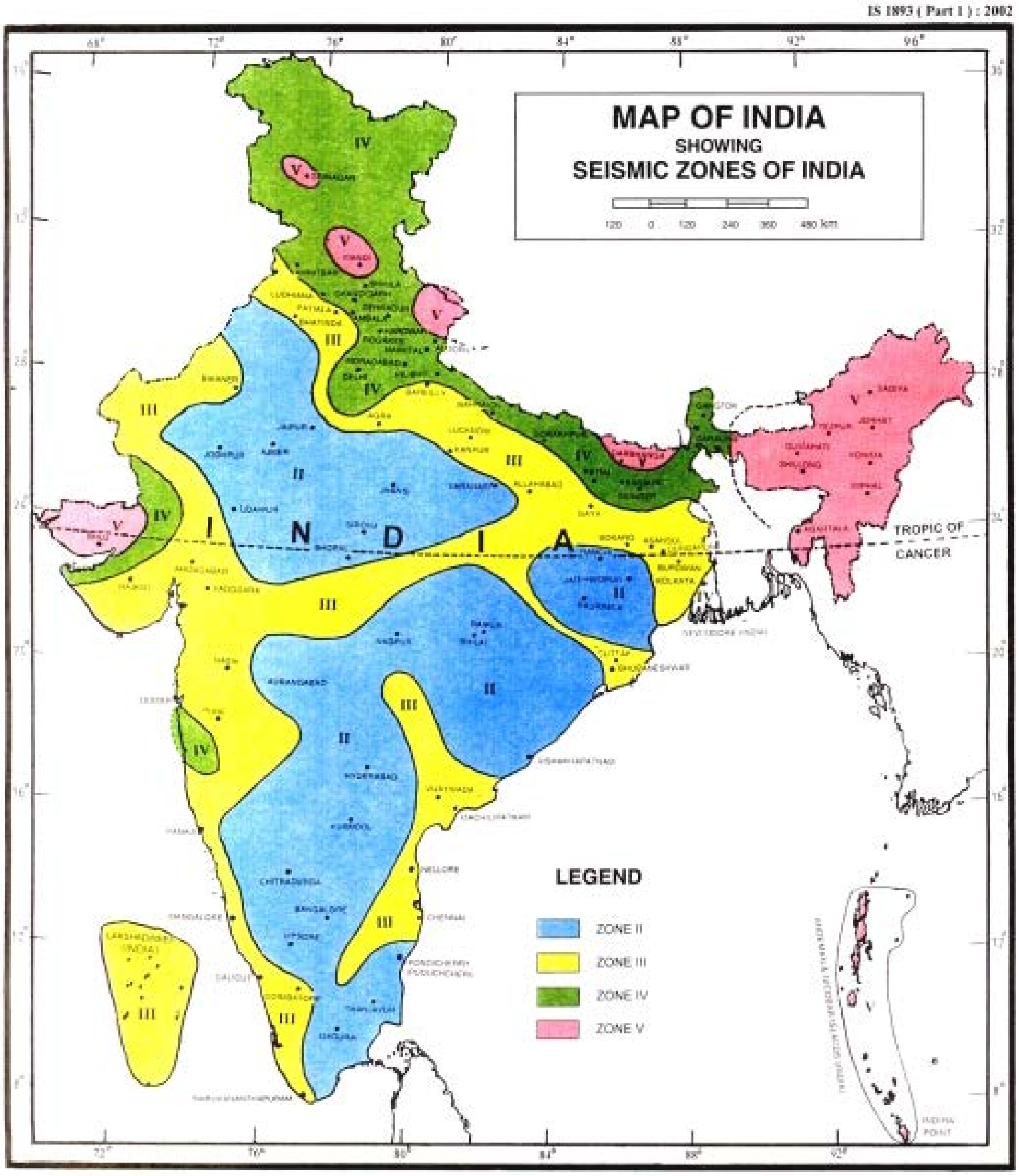
Figure 9. 6: Track of cyclones in Arabian sea from the 1877 to 1992



Source: IMD

As per Seismic Zones of India map published by Survey of India, the proposed project site falls under Seismic Zone III. The Seismic Zones of India map is shown in figure 9.7 below.

Figure 9. 7: Seismic Zones Map of India



NOTE : Towns falling at the boundary of zones demarcation line between two zones shall be considered in High Zone.

- Based upon Survey of India map with the permission of the Surveyor General of India.
- The responsibility for the correctness of internal details rests with the publisher.

9.5.5 Human Caused Occurrences

1. **Man-made occurrences include**

- Fire
- Electrical faults
- Mechanical faults during cargo/container handling, loading/unloading, personal accidents while repair/maintenance works, eye injury etc.

2. **Physical Hazard/Occupational Hazard**

During construction and operation phase at proposed Jetty sites accidents while handling construction materials, vehicular accident may lead to serious injury or fatal accidents. workers/ staffs may expose to occupational, chemical and ergonomic hazards during construction activities. The risk of collision with other navigating ships and vessels as well as risk of grounding increases as ships approach relatively shallow waters and restricted navigation channels.

There is a risk of collision with moored ships, harbor craft and port installations as well in the final approach.

3. **Chemical Hazards**

Contamination of bottom sediment is often measured by the size of sediment particles, pH, colour, smell of sediment, oil and grease percentage contain and concentration of organic nitrogen, phosphorus, sulphide and toxic substances such as heavy metals and pesticides including toxic components of antifouling paints. Location of proposed jetty, construction of breakwaters and dredging may accelerate sediment deposition.

4. **Fire and Explosion Hazards**

There is risk of leakages and explosions associated with handling, transportation and storage of hazardous substances like diesel, oil etc during construction and operation phases.

The figure nos 9.8 and 9.9 show the risk analysis (damage area) of POL fuel storage on the Vasai and Kalyan layout where the fuel storage tanks are proposed.

Figure 9. 8: Vasai Jetty POL Storage Damage Area And Assembly Point During Emergency

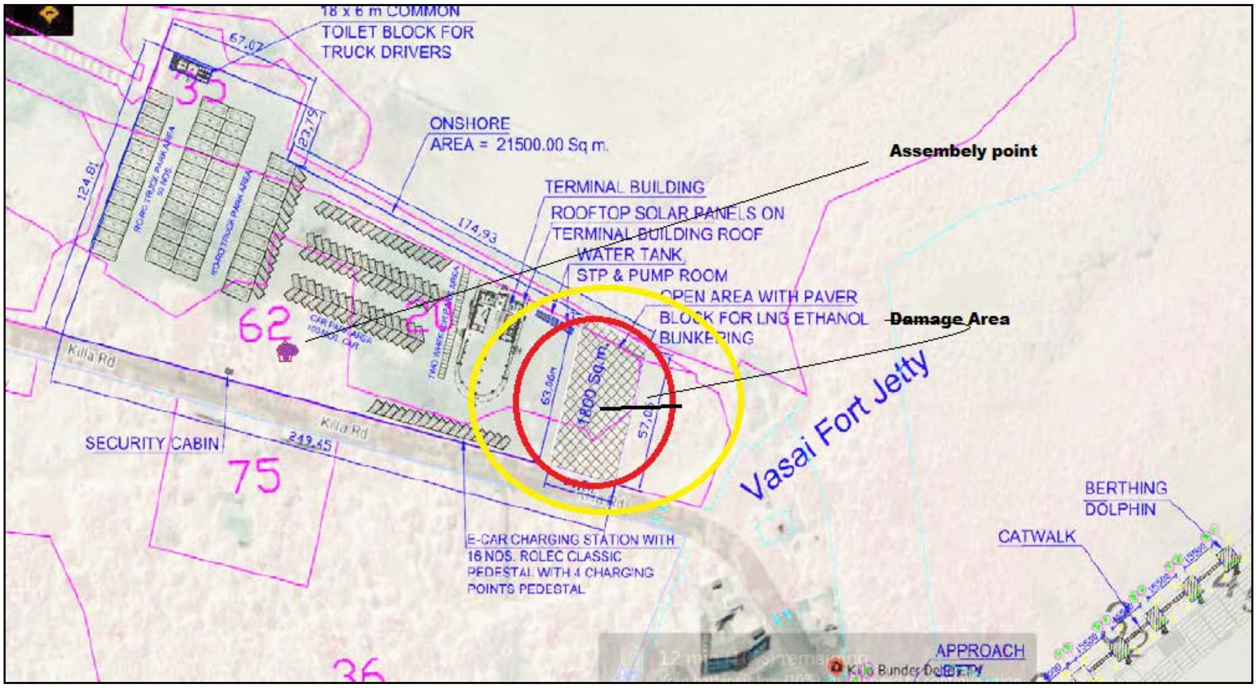
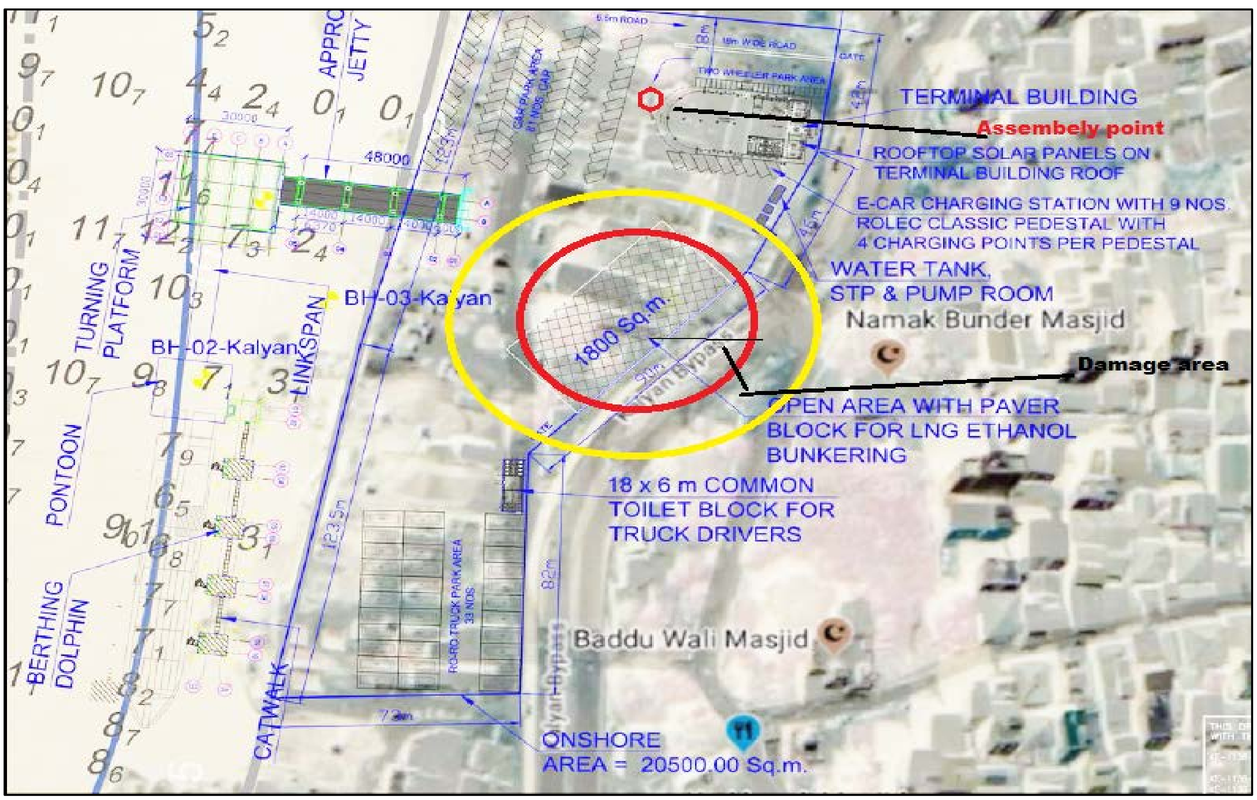


Figure 9. 9: Kalyan Jetty POL Storage Damage Area And Assembly Point During Emergency



5. **Noise Hazards**

High decibel noise may generate during construction phase at proposed jetty and nearby surroundings conveyors, machineries and equipment, shore handling such as machineries and equipment like cranes, tractor trailers, and storage facilities of oil/diesel, workshop equipment.

- Vibration Hazards: During construction phase labors will expose to vibration hazards during working with stone crusher and sand grade separation machine.
- Physical Hazards: Eye injury, body injury, accidents during stone/rock/sand transportation from quarry to wharf site.

9.5.6 Hazards to Environment

Table 9. 11: Potential Hazards During Construction Phase

Potential hazards	Examples of control measures
Shore side /Ground collapse	The use of benching or the installation of ground support (e.g. shoring)
Water in rush	Pumps or other dewatering systems to remove water and prevent build-up
Falls	Safety belt/signees
Hazardous manual task	Ramps, steps or other appropriate access into the excavation
Airborne contaminants	Rotating tasks between workers
Buried contaminants (e.g. asbestos)	Mechanical ventilation to remove airborne contaminants
Underground services	Obtain information from the relevant authorities on the location of underground services.

9.5.7 Hazards to Eco-System during Construction Phase

- Dredging removes bottom biota and dumping of dredged material covers bottom habitat, both of which may reduce fishery resources.
- Settlement of re-suspended sediments on fragile marine fauna and flora damages the ecosystem particularly coral reefs, which are formed by the extra cellular product of symbiotic plants.
- Release of toxic substances and other contaminants are re-suspended through dredging or dumping, they may lead to contamination of fishery and shellfishery resources.
- The great number of coral polyps attached need dissolved oxygen for respiration and the plants need sunlight for photosynthesis. Piles, concrete surfaces, rubble mounds and other similar

structures in water could form new habitats, which may introduce undesirable species.

9.5.8 Hydraulic and Geotechnical Impacts

As proposed jetty locations can be developed as tourist center in future, this may lead to food supply for animal in operation phase. This situation may cause threat to retaining wall safety and flood risk.

1) Seismic Hazards To Proposed Jetties

(i) Deformation and Overtopping

Severe earthquake shaking causes dislocation/loosening of foundation material, thus generating excess pore water pressures (i.e., liquefaction occurs). The increase in pore water pressure reduces the soil's shear strength. This could also occur as a result of loss of strength in sensitive clay.

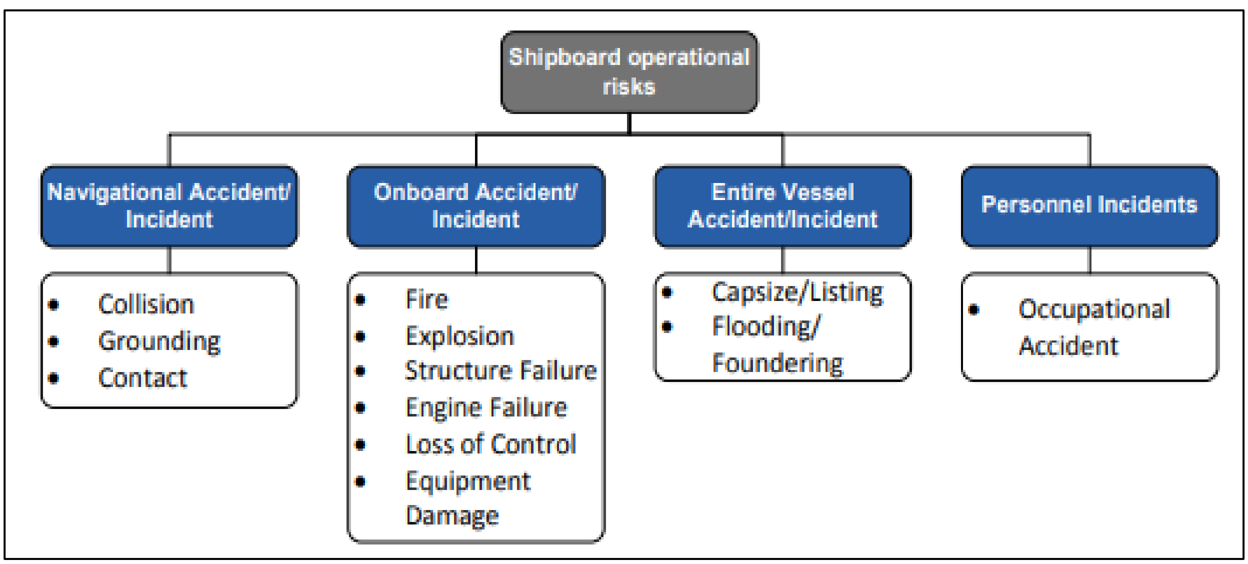
(ii) Liquefaction and Sliding Opening Gaps

Severe earthquake shaking causes loosening of foundation materials to contract under cyclic loading, generating excess pore water pressures (i.e. liquefaction) occurs. The increase in pore water pressure reduces the soil's shear strength.

9.5.9 Risk Assessment of Jetty Operation

Risk assessment is the process of assessing the probabilities and consequences of risk events if they are realized. The factors which have an immediate influence on operation of Ro-Ro Vessels at river/creek. The shipboard operation is subsequently led to the possible risk of accident/incident mention in figure no 9.8

Figure 9. 10: Shipboard Operational Risk



The results of this assessment are then used to prioritize risks score to establish a most-to-least-critical importance ranking. Risk score is product of Severity x likelihood. It is in the range of 1 to 25.

Table 9. 12: Hazard Score vis-à-vis Nature of Hazard

Hazard score	Nature of Hazard
1 to 8	Low hazard
9 to 15	Medium Hazards
16 to 25	High Hazards

Table 9.13 discusses likely Incident/Accidents during project implementation and operations, type of hazards along with Possible Causes and its Consequences using this data Risk score calculated as under.

Table 9. 13: Risk Incidences / Accidents during Project Implementation and Operation

S N	Incident /Accidents	Hazards Details	Possible Causes	Worst Credible Consequence	Risk Score	Remark
1	RO-RO Vessel damage and Collision	Contact with jetty during operation	• Engine Failure of RO-RO Vessel / accidental Ship/Hull, propeller and rudder damages. • Adverse Environmental condition of wind, waves and current. Natural Disaster such as Tsunami, Earthquake, Cyclone and Flood. • Mechanical failure (steering or main engine) • Vessel blackout • Misjudgment by pilot/master • Failure to appreciate weather or tidal effects • Failure to appreciate vessel power to weight ratio (bulk carriers)	• Serious damage to side shell plating of vessel • Serious damage to quay/fenders	18	-
2	Personal Injury	Pilot & passengers boarding in Jetty	• Vessel unable to make a suitable lee • Swell/weather boarding criteria exceeded • Pilot boat coxswain error • Pilot ladder incorrectly rigged • Incorrect clothing (PPE) worn by pilot	• Pilot & passengers falls onto pilot vessel or into the water • Rescue of Casualty required • Fatality	20 18	They may will fall onto the pilot boat and sustain serious injury (not a fatality). If fatality considered the frequency
3	Grounding	Grounding on Bank	• Incorrect assessment taken of vessel's draught and squat during under keel clearance	• Breach of hull plating, resulting in sinking	14	Extent of grounding damage is

S N	Incident /Accidents	Hazards Details	Possible Causes	Worst Credible Consequence	Risk Score	Remark
			calculations • Vessel transiting over bank too fast (increased squat) • Incorrect chart datum assessed (hydrographic survey outdated) • Bank shifted during inclement • Weather	(increased draught) • Tugs required pulling vessel clear		dependent on vessel's speed.
4	Collision	Collision between one inbound, one outbound vessel in the vicinity of Bank	1) Non-compliance with collision regulations. Human error, improper lookout, lack of communication, radio channel congestion, equipment breakdown, incomplete passage plan, Third party vessel interfering with planned ships/vessels movement Local congestion, difficulty in communication, maneuvering to Disembark pilot, absence of VTS control. Multiple vessel convergence, especially in poor visibility. 2) Power failure on tug, Misjudgment by tug master, Poor forward visibility on Inbound vessel.	1)Serious damage to vessels (T-Bone collision) Breach of hull integrity, Vessel(s) stranded, Port closure 2)Tug holed in engine room Sinks. Fatalities	18 16	Sub-standard crews of vessels required to be identified by Pilot during Pilot/Master exchange. Bow wave of vessel may interact with forward tug when making fast. Tugs normally make fast when vessel proceeding approximately 6 knots.
5	Fire and explosion	POL Stock CNG/LPG handing/transpiration Hazards	1) Static Charge Generation 2) Accidental ignition to flammable stock 3) Grass/Jungle Fire 4) Electrical Fires	Serious damage to POL/Chemicals. Fuel tank area Fatalities due to Explosion shock wave damages	20	Active Fire Protection. Detection Alarm, Sprinklers system Public Address. Communication systems

SN	Incident /Accidents	Hazards Details	Possible Causes	Worst Credible Consequence	Risk Score	Remark
						introduced Hydrant network with SCADA system introduced

9.5.10 Mitigation Measures

1) **Tsunami Preparedness**

- Prepared emergency evacuation plan. Display evacuation route at hotel, school, and workplace at prominent location.
- Arrange Periodic mock drill of evacuation plan for preparedness.
- Periodic checks of Tsunami communication system/Public address system.
- Tourist's should covered by Travel insurance .Property insurance advisable for minimum financial investment risk.

2) **Protection of Eco system:** Undertake careful survey of a fragile marine and coastal ecology. This survey is essential for appropriate planning of construction work, dredging, and disposal of dredged material. Selection of port site is the key to minimize adverse effects. Since adverse effects usually result from bottom contamination and deterioration of water quality during construction of additional wharf, approach to berthing wharf & retaining wall with back-filling.
3) Protection of the agricultural land from erosion and damage after constructing the retaining wall and jetty which will have a positive development in the area.
4) Mitigating and safeguarding measures to prevent excessive dust will be taken up by the contractor.
   - They might affect the stability or safety of the works or adjacent property.
   - They might interfere with natural or artificial drainage or irrigation.
   - They may be environmentally unsuitable.
   - Systematic planning of the movement of vehicles and restrictions on construction workers movement and adequate monitoring.
5) All existing roads used by vehicles of the contractor or any of his suppliers of material shall be maintained during construction period.
6) Ensure the place is not polluted due to the storage of oils/fuels used for construction.
7) Train the staff in handling and recovering the materials. Provide proper lighting, sanitation and drinking water facilities for the workers and staff.
8) Maintenance in Operation Phase; Restoration of banks earthwork, repair and maintenance of

inspection path and service roads, removal of grass, shrubs and bushes from the wharf.

9) Repair and maintenance of all structures (viz. drainage sluices, toe and slope, protection measures) in the wharfs handed over for operation and maintenance.

10) During restoration/annual maintenance, the existing drain and structures should not be blocked. Necessary care will be taken so that there is no drainage congestion in the area and any debris or material left in the drain shall be cleared immediately.

11) No construction vehicles/earth moving machineries should be washed near project site to avoid oil & grease spillage.

12) Contractor shall ensure proper compaction during earthwork as per specification.

13) Mitigation Impact on Air Quality: Deterioration of air quality would be mainly due to fugitive dust emission from wharf construction activities, and gaseous emissions from construction equipment's and vehicular movements.

14) **Prevention from Occupational Hazards**: The Contractor while working in the wharfs shall;

(i) Ensure trucks carrying soil, sand and stone will be duly covered to avoid spilling.

(ii) Ensure adequate dust suppression measures such as regular sprinkling of water especially at the time of construction.

(iii) Ensure that all construction equipment and vehicles are in good working condition, properly tuned and maintained to keep emissions within permissible limits.

15) In order to reduce Noise Impacts

(i) Ensured that all construction equipment's, vehicles used in construction shall strictly conform to the MoEFCC / CPCB standards.

(ii) All vehicles exceeding the limits shall be fitted with exhaust silencers.

(iii) Regular servicing of all construction vehicles and machinery shall be done Provide exhaust silencers to protect natural habitat.

(iv) Activities such as operation of DG sets and any high noise construction equipment's shall be stopped during night time between 10.00 pm and 6.00 am.

16) **Jetty Construction Phase**: Safety Measures

The construction contractor will be required to develop and implement site specific safety and health plan which include measures like:

- Proper safety measures while working in narrow stretches.
- Introduce Construction safety management system for hot work, working on height, working in confinement place vied Work Permit system.
- Ensuring all workers are provided with and use of Personal Protective Equipment (PPE) as per

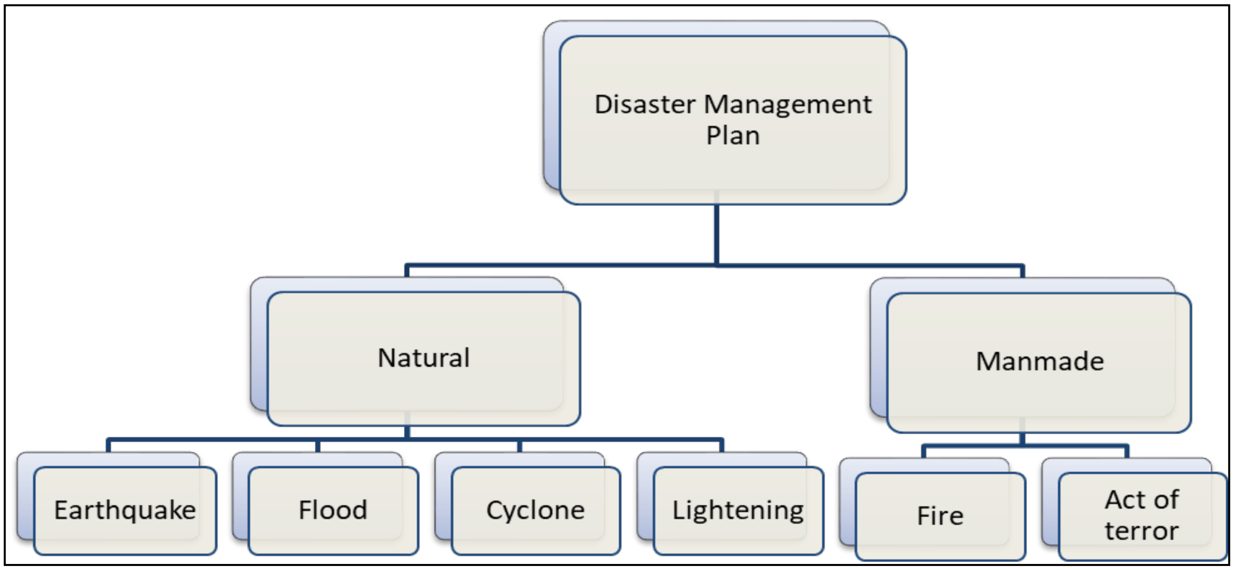
the requirement.

- Contractor ensuring all workers follow the documented procedures and providing health and safety training to the workers providing first aid kits at the work sites at all times.
- Providing insurance including medical coverage for workers.
- Providing basic amenities like drinking water, clean eating areas, sanitation etc. along with safety and security of the work sites.
- Providing proper lighting arrangement.
- Moving equipment's and vehicles equipped with back alarms or flag men, maintaining equipment's properly and ensuring the workers are not exposed to high noise level and use of hearing protection devices etc.
- Provide appropriate sign boards while excavation/construction works.
- Providing proper barricades for preventing people and animals.
- Community Health and Safety: Ensure that the materials dumps or equipment installs will not obstruct the movement of local people. Ensure proper safety measures in the areas and take dust suppression measures adequately to prevent dust pollution etc.
- Electrical equipment/power lines shall be shifted by taking appropriate permission and even the Contractors while working shall also ensure all precautions and prevent any danger and inconvenience.
- Implementation of safety management system in jetty vides The Directorate General of Shipping, India Guidelines 2010.
- All jetty workers to be covered under The Dock Workers (safety, Health & Welfare) Regulations, 1990

9.5.11 Disaster Management Plan

Disaster Management Plan (DMP) should be prepared to effectively deal with all kinds of port/jetty related hazards during all shipping activities and also is in a state of preparedness to respond to such events and their adverse effects to the on-site as well as off-site population.

Figure 9. 11: Basic Structure of DMP



DMP should cater to worst disaster scenario with reference to specific cases like Tsunami, fire, explosion, toxic gases dispersion, oil/chemical spills, including floods, cyclones, terrorist attacks etc. The disaster management plan should include early detection of emergencies (like fire explosion, toxic gas release, natural calamities like cyclones, earth quakes etc.), as follows:

- River Navigation system will be provided for safe inland traffic
- Emergency escape routes and Boarding and De boarding safety signs will be displayed in all Jetties/ Terminal. The emergency escape routes have been provided for in all terminals. Vasai, Kolshet and Kalyan terminals showing the escape routes are given in figure no 9.12, 9.13 and 9.14.
- Provisions of emergency stops of vessel and evacuation of passengers and transfer to nearby safe location will be provided during vessel accident/breakdown.
- Appropriate mitigation plan will be prepared for Ro-Ro vessel anchoring arrangement during natural disasters such as Flood, Cyclone, Tsunami and Earthquake. Early warning System for Tsunami issued by Navi Mumbai Corpoartion is shown in figure 9.15
- Public/Govt agencies support system in case of vessel/ship accident, such as drowning in Ulhās River.
- High Safety practices during storage and handling of underwater blasting explosives during

dredging

- Address and Contact no of site controller, Hospital/Police Stations/Civil Defence/Army Camp/Doctors /Transport arrangement etc will be displayed at control rooms of 10 Terminals.

Figure 9. 12: Emergency Escape Plan for proposed Vasai Terminal

Figure 9. 13: Emergency Escape Plan for proposed Kolshet Terminal

Figure 9. 14: Emergency Escape Plan for proposed Kalyan Terminal

Figure 9. 15: Early Warning System for Tsunami by Navi Mumbai Corpoartion

Threat Status	Actions to be taken	Dissemination to
WARNING	Public should be advised to move inland towards higher grounds. Vessels should move into deep ocean	MoES, MHA, NDMA, NCMC, NDRF battalions, SEOC, DEOC, public, media
ALERT	Public should be advised to avoid visiting beaches and low-lying coastal areas Vessels should move into deep ocean	MoES, MHA, NDMA, NCMC, NDRF battalions, SEOC, DEOC, public, media
WATCH	No immediate action is required	MoES, MHA MoES, MHA, MEDIA, NCMC, NDRF battalions, SEOC, DEOC
THREAT PASSED	All clear determination to be made by the local authorities	MoES, MHA, NDMA, NCMC, NDRF battalions, SEOC, DEOC, public, media

9.5 Environmental Management Plan

The aim of the Environmental Management Plan (EMP) is to ensure that the stress/load on the ecosystem is within its carrying capacity. Moreover, EMP also aims to maximize the beneficial impacts and minimize the anticipated adverse impacts likely to accrue as a result.

9.6.5.1 Environment Management Plan for Construction and Operation Phase

An environment management plan has been developed for managing environmental as well as health and safety issues associated to the project.

9.6.5.2 Construction Phase

The most severe environmental impacts of any development occur during the construction stage. An EMP contains on-site guidelines for contractors specifying appropriate construction practices pertaining to the environmental components.

The Table 9.14 describes activities with their objectives, time frame, resources and responsibility for proper implementation of the plan during construction phase.

Table 9. 14: Environment Management Plan For Construction Phase

S. no.	Environment management aspects	Measures to be monitored	Action plan	Frequency	Resources required	Responsibility
1.	Dust dispersal control	Efficiency of sprinklers	Maintenance of the sprinkler system	Regularly during construction stage	Sprinkler system	Project Proponent (HSE officer)
2.	Construction waste management	Proper disposal of construction waste	Maintain waste movement logbook to ensure regular handover to authorised carrier	Regularly during construction stage	Licensed carriers to transport waste to landfill	Project Proponent (HSE officer)
3.	Increase in Noise level	Effectiveness of acoustic enclosure Vehicle maintenance	Monitoring of Noise level to check	Once a week	Calibrated Noise meter	Project Proponent (HSE officer)
4.	Disturbance to Biological environment	Standard work practice	Instruction to workforce about no misuse of intertidal area.	Regularly during construction stage	Skilled workforce	Site in-charge
			Strict implementation of standard work practice by workforce	Regularly during construction stage	Skilled workforce	Site in-charge
		Standard practice of raw material transport	Covering of particulate raw material during transport	Regularly during construction stage	Tarpaulin sheets	Site in-charge

An EMP for the construction and operational phases has been developed for managing environmental as well as health and safety issues associated to the proposed project of inland water transport.

The following are some of the points included in EMP during construction phase:

1. Vehicles carrying construction materials to be covered with tarpaulin sheets.
2. Portable toilets to be provided and maintained with adequate water supply, chemicals in holding tank etc. Holding tank to be regularly evacuated and taken to municipal STP.
3. Dredged spoil to be used for leveling / shore protection and not dumped in the estuary.
4. Compensatory plantation to be carried out if the trees are cut.
5. Green belt to be developed.
6. Site to be regularly sprinkled with water.
7. Vehicles to be properly maintained.
8. Workers to use PPEs like helmet, gum boots, etc.
9. Fishermen to be consulted prior to restricting fishing in the activity area.
10. Emergency Preparedness Plan to be available at the site and mock drills to be conducted.

Some of the points included in EMP during operation phase:

1. Garbage bins for disposing biodegradable and non-biodegradable waste to be provided at strategic locations in the terminal and on jetties.
2. Traffic movement to be regulated properly.
3. Sewage, domestic wastewater, washings etc to be treated in STP.
4. Treated water to be used for green belt development, gardening and flushing.
5. Trees along the approach road to the terminal, at the periphery of car parking areas and terminal buildings to be planted.
6. DG sets for power backup to have adequate stack height.
7. DG Sets to be provided acoustic enclosure.
8. Dustbins to be provided in boats and at jetty areas.
9. Fire detection and sprinkler network to be installed in the terminals.
10. Boats to have fitness certificate from MMB.

9.6.5.3 Operational Phase

The operation of the proposed developments will be guided by environmental management systems. Environmental plans will be developed for all entities of the township. In addition, each precinct head will be responsible for implementation of these plans. The main focus in developing these plans will be on:

- Water conservation
- Minimising waste generation
- Preventive maintenance
- Emergency response planning
- Environmental awareness

The Table 9.13 describes activities with their objectives, time frame, resources and responsibility for proper implementation of the plan during operation phase.

Table 9. 15: Environment Management Plan for Operation Phase

S. no	Environment management aspects	Measures to be monitored	Action plan	Frequency	Resources required	Responsibility
1	Creek water quality in wharf region	Adherence to MARPOL 73/78 norms by berthing boats	Mandating to maritime transport controller for adherence to MARPOL 73/78 norms	During berthing hours	-	Project Proponent/ Maritime transport controller
2	Creek sediment quality					
3	Air pollution		Mandating to Maritime transport controller for using cleaner fuel and following standard operating practice by boats.	During berthing hours	-	Project Proponent/Maritime transport controller
4	Disturbance to marine biology		Mandating to Maritime transport controller for adherence to MARPOL 73/78 norms	During berthing hours	-	Project Proponent/Maritime transport controller
5	Waste generated by passengers / tourists	Waste management at jetty	Placing of dustbins and instruction boards in jetty areas for its use by passengers/tourists	During berthing hours	Dustbins, Instruction boards	Project Proponent

9.7 Environmental Monitoring Program

It is suggested that critical parameters be regularly monitored during project operation and construction phases. The details have been presented in table 9.16

Table 9. 16: Details of Critical Parameters

Component	Parameters	Location	Frequency	Methodology
Ambient Air Quality	PM_{10}, $PM_{2.5}$, SO_2, NO_2 and CO	Minimum 6 locations in the vicinity of terminal area	Six monthly	As per NAAQS, 2009.
Noise Level	Noise intensity in dB(A) Day & Night, Leq, Lmin, Lmax, L10, L90, L50	Minimum 8 locations within 500 m representing different receptors	Six monthly	24 hour reading as per standards.
Ground Water Quality	Colour, turbidity, electrical conductivity, total dissolved solids, total suspended solids pH, salinity, DO, alkalinity, BOD, COD, nitrate, sulphates, phosphate, calcium, heavy metals (chromium, copper, arsenic, zinc, cadmium, lead and mercury), chlorides, boron, fluorides, total coliform	6 locations in the vicinity of terminals	Six monthly	Grab sampling and analysis using standard methods.
Surface Water Quality	Colour, temperature, turbidity, electrical conductivity, total dissolved solids, total suspended solids pH, salinity, DO, alkalinity, BOD, COD, nitrate, sulphate, phosphate, calcium, heavy metals (chromium, copper, arsenic, zinc, cadmium, lead and mercury), chlorides, boron, fluorides, , total coliform	6 locations in the vicinity of terminals	Six monthly	Grab sampling and analysis using standard methods.

Component	Parameters	Location	Frequency	Methodology
Marine Water Quality	Temperature, pH, salinity, turbidity, DO, BOD, total suspended solids, phosphate, nitrate, nitrite, ammonia, chloride, sulphate, heavy metals, oil & grease, phytoplankton (species and their density), zooplankton (species and their density), phytoplankton (species and their density), zooplankton (biomass, species and their density), total coliform	8 locations in the vicinity of jetties	Six monthly	Grab sampling and analysis using standard methods.
Marine Sediment Quality	Size and Texture, colour, pH, oil & grease, organic content, nitrogen, phosphorus, sulphide, heavy metals (arsenic, chromium, iron, lead, zinc, cobalt, copper, cadmium, nickel, mercury), petroleum hydrocarbons. Total coliform, macrobenthos (biomass, species and their density)	8 locations in the vicinity of jetties	Six monthly	Grab sampling and analysis using standard methods.
Terrestrial Soil Quality	Soil texture (sand, silt and clay), pH, sodium, nitrates, phosphates, organic content, potassium, electrical conductivity, boron	At 8 locations	Six monthly	Grab sampling and analysis using standard methods.
Ecology	Survey of flora & fauna including mangroves	At pre-decided transects	Once a year avoiding monsoon season	Using standard methods.

9.8 Clearances Required For the Project

The following clearances would be required for the starting of the project;

Table 9. 17: Clearance list for project

Sr. No.	Clearances Required
1.	CRZ clearance from the Maharashtra Coastal Zone Authority for the terminals and structures, under CRZ notification, 2011
2.	Consent to establish and Consent to Operate from Maharashtra Pollution Control Board
3.	Since this is a Category A project, the Environmental and CRZ clearance is from the MoEF& CC, under EIA notification, 2006.
4	Fire clearance for the Terminals
5	Classification society and DG Shipping for the Vessels
6	Maharashtra Maritime Board for the waterway channel and notification of the waterway
7	Requirement of Wildlife Clearance under Wildlife Protection Act, 1972

9.9 Cost Estimates

The cost estimates for implementing EMP for project shall be ₹ 25.00 million (Table 9.18) which includes ₹ 6 million for Equipment cost, ₹ 7.5 million for EMP and ₹ 11.5 million for Area development activities.

In addition to above, ₹ 21.50 millions/year (Table 9.19) is likely to be spent over EMP and Area Development Activities.

Table 9. 18: Cost during construction phase

Sr. No.	Activity	Cost (₹ million)
1	Environment Management Plan (EMP)	7.5
2	Area development activities	11.5
3	Equipment Cost	6
Total		**25**

Table 9. 19: Cost during Operation Phase

Sr. No.	Activity	Cost (₹ million/year)
1	Environment Management Plan (EMP)	5
2	Area development activities	16.5
Total		**21.5**

The breakup of EMP cost during construction and operation phase is presented in table 9.20.

Table 9. 20: EMP Cost Breakup

SN	Parameter	Construction phase Total Cost (₹ million)	Operation phase Total Cost (₹ million)
1	Pollution Control Measures (Water sprinklers for dust control, Acoustic enclosures etc.)	1.0	-
2	Occupational Health & Safety Measures Personal Protective Equipment Health Check Up Fire Management Sign/instruction boards	1.0	0.4
3	Temporary Sanitary provision	2.0	-
4	Sewage management system: STP (10 no.) and annual maintenance	-	1.2
5	Solid waste management	1.0	1.2
6	Environmental Monitoring (As per CPCB norms)	1.5	0.6
7	EHS Training Programs	-	0.5
8	Site maintenance	0.5	0.6
9	Miscellaneous	0.5	0.5
Total cost		**7.5**	**5.0**

The details of proposed cost of area developement during construction and operation phases are given below in table 9.21:

Table 9. 21: Proposed Cost of Area Development in the Command Area

Sl. No.	Activities	Construction Amount (₹million/Year)	Operation Amount (₹million/Year)
1	Upgradation of health Care and Policing of Coast	4.0	5.0
2	Coastal Policing for safety at all project site	0.5	1.5
3	Scholarship to 200 school students @ ₹500/month	0.6	1
4	Scholarship to 50 local college students including hostel facilities, if they opt to study at some other place @ ₹2000/month	0.6	1
5	Free medicine to local hospital	1.0	1.5

Sl. No.	Activities	Construction Amount (₹million/Year)	Operation Amount (₹million/Year)
6	Free medical check ups	1.0	1.5
7	Child immunization programs	0.7	1
8	Alternative livelihood etc.	1.6	2.0
9	Food and supplements women	1.5	2.0
		11.5	**16.5**

The detailed list of Monitoring Equipment to be purchased is given in table 9.22 below

Table 9. 22: List of Monitoring Equipments

Sr. No.	Name of Equipment	Quantity
1	Portable STP	10
2	Air Sampler (PM10 and PM 2.5)	5+1(standby)
3	Noise Meter	2+1(standby)
4	Marine Instruments	
	a. Niskin Water Sampler	2
	b. Grab Sampler	2
	c. Plankton Net	2
	d. Others (Chemicals and Glassware)	
5	Automated Weather Monitoring Station	2+1(standby)

10 Institutional Requirements

10.1 General

Successful project operation invariably precede a well planned and coordinated implementation programme, due to variety of reasons. First, faster implementation controls the cost and preventing any over budgeting. Second, better coordination could enable partial running of the facility, if possible, concurrently with the construction starting an auxiliary revenue stream. Faster commissioning, albeit partially, brings the operational problems to the fore and takes care of all the teething problems before the full service operation commences.

This is a project of a great social relevance. In a way this would be the first full passenger service, any where in the country. Hence, lack of experience could be a handicap as well as a boon, because it will start without any baggage. There is no river authority in India, akin to Thames River Authority which controls the passenger, pleasure and cargo traffic. Therefore, this project if implemented as planned, could be the torch bearer of all the proposed projects planned all over the country. The proposed Institution for the waterway, therefore would have the option of borrowing from the experience of other waterways around the world, aclimatise for Indian condition for effectiveness.

It must be remembered that a new Institution would have to be built with in the Government System for running and maintaining the waterway. Logically this body should be an independent/autonomous body, and try and make the organisation financially independent. This would bring better operational control on the waterway with transparency. In order to achieve this objective, a well defined organisation needs to be created. In this chapter the suggestions for the Institution building shall be discussed.

10.2 Organizational Set Up / Establishment

10.2.1 Organisational Philosophy

Government of India in Ministry of Shipping, through an act of the Parliament, has declared Vasai Creek – Ulhas River waterway as the National Waterway no. 53. There is a need to have a clear understanding between the states and the central authorities, on the management and operation of the waterways, since the waterways is in the concurrent list of the Constitution. Though there should be national policy for the administration of the waterways, for the present, it is understood that the Thane Municipal Corporation (TMC) has been entrusted with the responsibility of development and operation of water transport in National Waterway – 53 (Vasai Creek-Ulhas River). Indications from the state and the central authorities (represented by the Inland Waterways Authority of India (IWAI)) suggests that there will be operational Memorandum of Understanding (MoU) between the JNPT (representing GOI), TMC (representing the state of Maharashtra) and IWAI. Where as, the IWAI would provide the necessary technical and financial assistance for development, TMC through a suitable mechanism would implement and then operate the waterway.

Hence, it is suggested that for this purpose, a **Special Purpose Vehicle (SPV)** be created for the implementation and later operation of the Project. Though the profile of the SPV is to be decided by the participating organisations and governments, it is suggested that besides IWAI, MMB, and TMC all the Municipal Corporation bordering the waterway should participate. Participation of the Municipal Corporations would ensure easier land acquisition, terminal connectivity and provision of other utilities. In addition, the involvement of all the Municipal Corporations, JNPT and IWAI would ensure participation of Government form the Central to the Local level.

A suggested outline of the SPV based on the above philosophy is given in the following Paragraphs.

10.2.2 Outline of the SPV

A Special Purpose Vehicle is recommended to be created with the following taking part in its formation and can be named as **Vasai Creek Waterways Authority (VCWA).**

1. Thane Municipal Corporation (TMC)
2. Inland Waterway Authority of India (IWAI)
3. Jawaharlal Nehru Port Trust (JNPT)
4. Maharashtra Maritime Board (MMB)
5. Mira-Bhayander Municipal Corporation (MBMC)
6. Vasai-Virar Municipal Corporation (VVMC)
7. Kalyan Dombivli Municipal Corporation (KDMC)
8. Bhiwandi Nizampur Municipal Corportion (BNMC)

The authority would be administered through a Board of Governers, headed by Commissioner Thane Municipal Corporation as chairman. The board will consist of one member each from the organisation mentioned above. Additionally, the CEO of the waterway will be the Member Secretary of the Authority, nominated from the TMC in consultation with other participating agencies or a professional manager to run the waterway on behalf of the Authority. The Authority would be over all policy making body for the waterway, which will align its policies with the national/state policy for uniformity.

At the behest of the Authority a technical committee may be appointed to advise the Board of Governers with regard to the modalities of development and help in over coming operational challenges.

The SPV will be provided money from the Government for development and operationalising the waterway including the cost of 10 vessels. This could be a grant from the Jal Marg Vikash Project or Ministry of Shipping, as deemed fit. Thereafter the SPV will generate revenue from the operations of the waterway and the terminals to become self sustainable in the long run. Initially the Government/ TMC may be required to do hand holding of the Authority by giving grant/loan.

Having decided the broad outline of the waterway authority, the suggested Organogram for the authority along with the man power planning is given in the following sections.

Organogram of the SPV

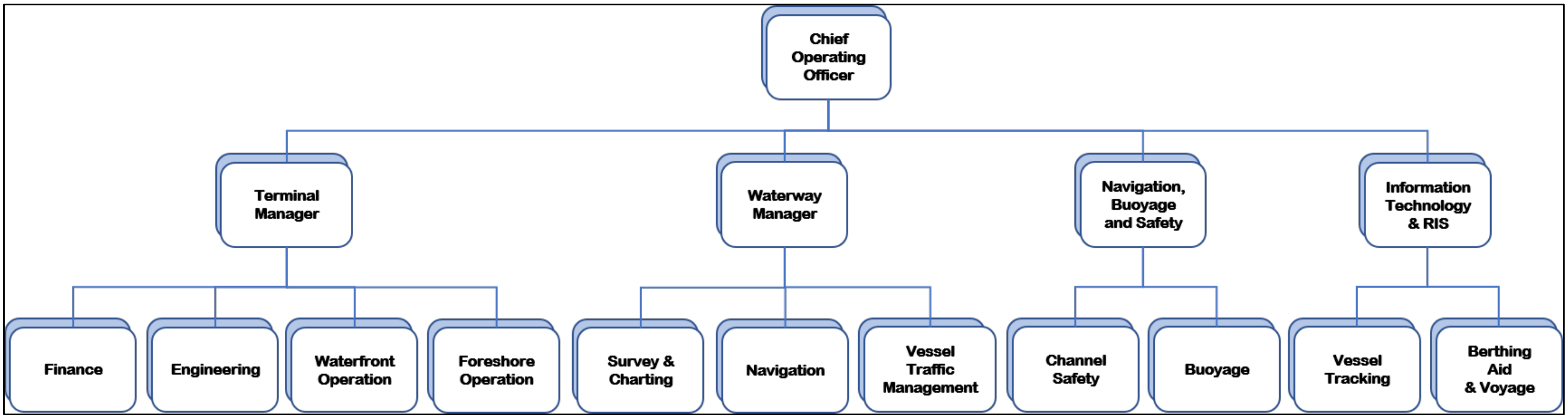
The SPV under the administrative control of the CEO, would be broadly divided in to four distinct functions, namely,

A. Waterway Operations
B. Engineering and Maintenance
C. Finance
D. Ship Yard Operation

A. Waterway Operations

The waterway operation will involve management consisting of waterway operations, Terminal Operations and RIS. The waterway operation would be headed by a Chief Operating Officer (COO). He will be assisted by the Waterway Managers and Terminal Managers. There will be an Information Technology Cell under COO to take care of the waterway information, vessel tracking, buoyage systems, terminal controls and vessel traffic management. Under the central IT cell there will be Terminal Cells in each of the terminals which would also manage the terminals and the vessel traffic as well integrating the other modes of transport to the waterway. For example, the system integration between the vessel arrival and the bus service to the terminal would enable passengers to continue seamless journey. So the Organogram for the waterway operations is as follows

Figure 10. 1: Organogram For Operations



B. Engineering & Maintenance

The Engineering department would have the primary responsibility of implementing the Project initially and maintenance in the operational phase and can be created by drawing personnel from existing TMC Engineering organization for implimenting the project. The Department would be headed by a Director Engineering equivalent to the COO, and would be responsible for preparing the preliminary designs and tenders for the various work packages. The director would be assisted by Work managers, Designers, Tender experts and Commercial negotiators.

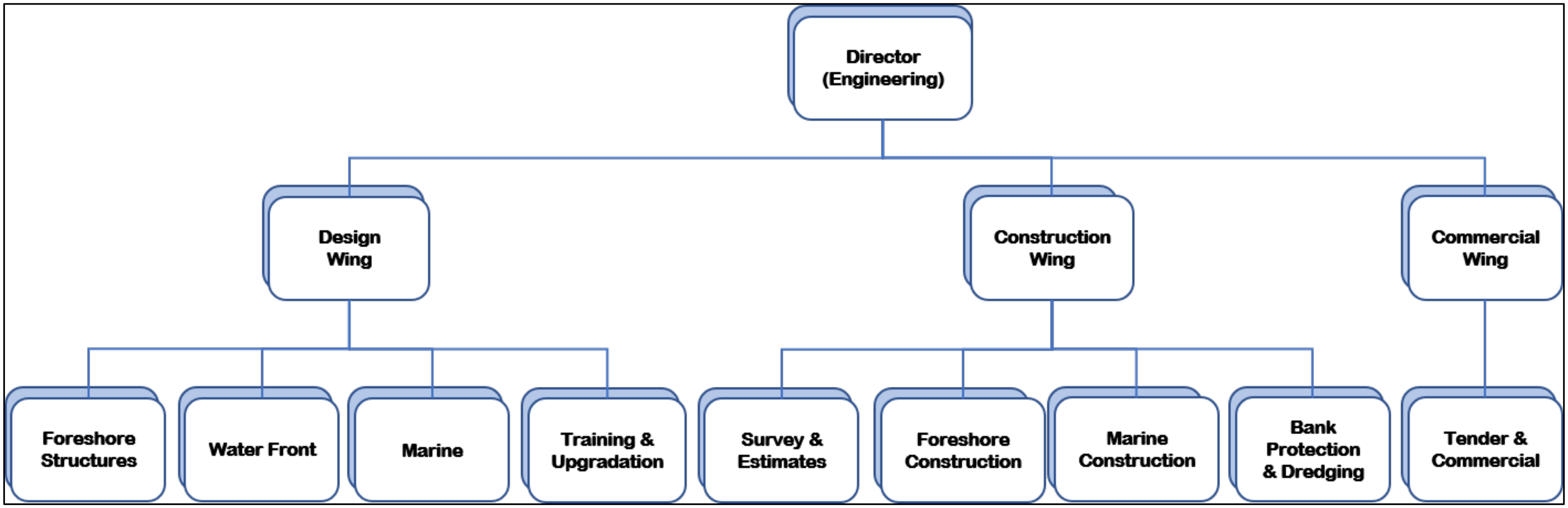
Under the Director Engineering there will be three wings, namely Design wing, Construction wing and Tender and commercial wing.

The design wing would endeavour to make the designs standard so that the initial implementation and later expansions are mostly modular. The Terminal Buildings and the other structures such as parking area, Horticulture and Parking facilities would also be standardised. The design wing also shall be deciding on the waterway depth, river training and bank protection measures and the requirements of bridge crossings during navigation (fendering the piers) etc.

The Construction wing will endeavour to divide the works in to similar types of works so that correct expertise could be hired for implementation. Ideally, the works could be divided in to foreshore construction, marine construction and dredging etc.

The third wing would look after tendering and tender negotiations. Accordingly, the Organogram for this department would be as follows;

Figure 10. 2: Organisation Chart For The Project Implementaions



In addition to the above, there will be a Training and upgradation centre for training of the Vessel masters, water front operators and other technically qualified personel who are in short supply under the Design wing.

C. Finance and Administration

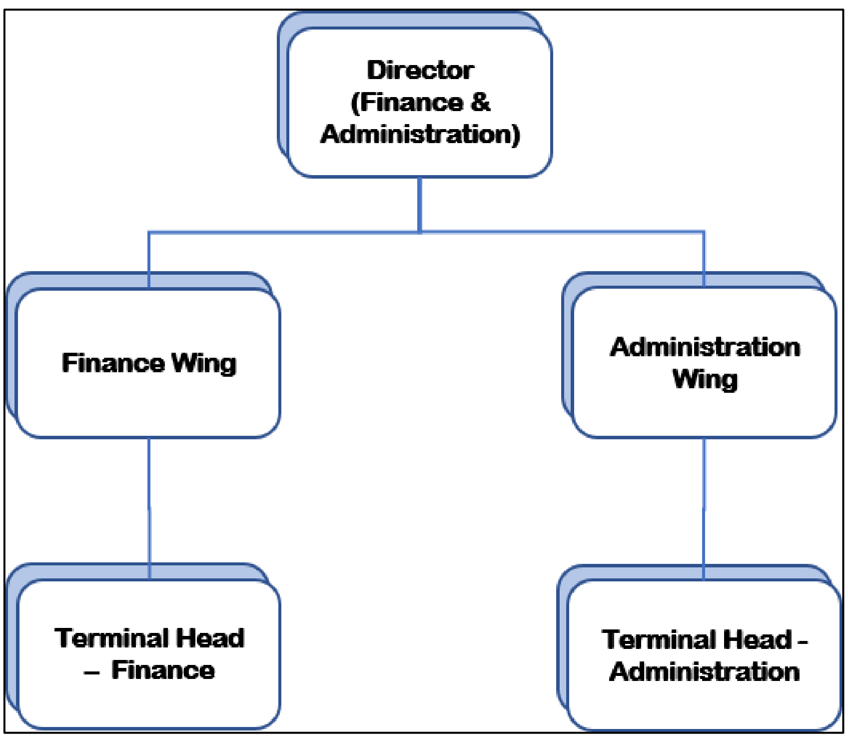
The controls of the finance and the administration would be under the Director Finance and Administration. He would be assisted by a Finance and Administrative wing.

The Finance Wing would be controlling the financial aspects involving, project finance, control of expenditure and revenue accruals during operations.

Similarly, the administration wing would be dealing with the administrative and Human Resources aspects.

The Organogram would be as follows;

Figure 10. 3: Organisation Chart For The Finance & Administration



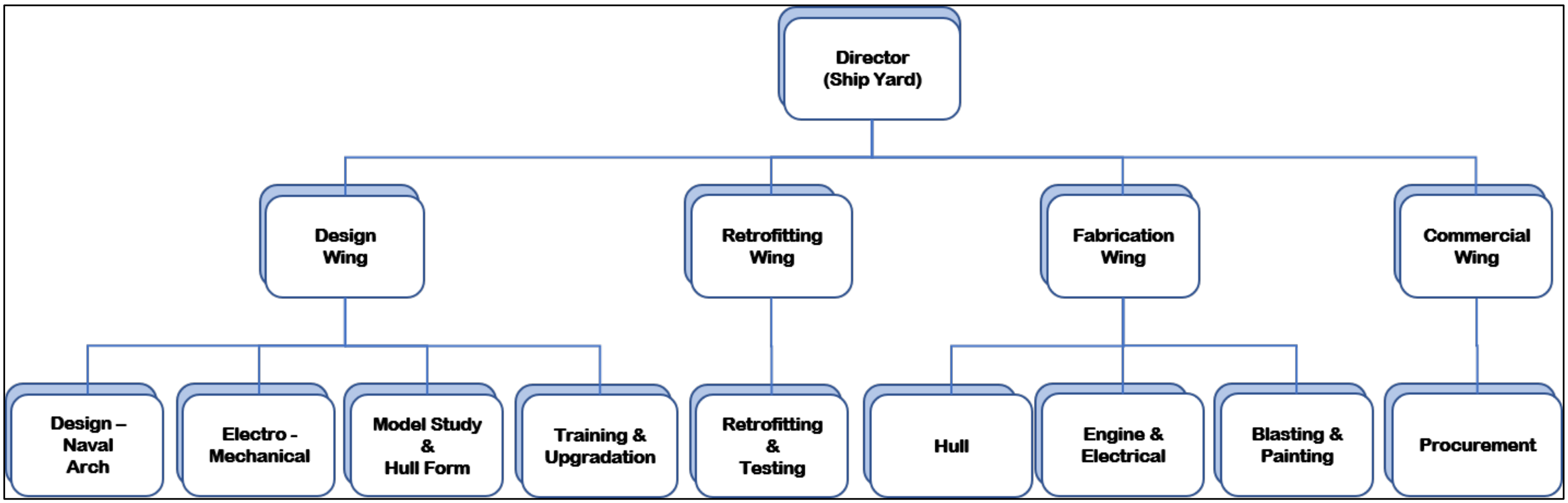
After the project implementation is completed, the finance would look after the revenue collection, and other sources of revenues, like pleasure traffic, amusement, and advertisement.

D. Ship Yard and Ship Repair

In order to supply the waterway with the specially designed vessels, it is envisaged that the initial 10 vessels shall be fabricated in the existing public sector/ private shipyards. However, it is suggested that concurrently, a ship yard may be established in the Kolshet terminal. This terminal would look after maintenance of the vessels operating in the waterway and can also start building the vessels, after its establishment along with the other ship yards for future requirements. This would enable this shipyard to build capacity and attain the necessary experience.

The suggested organogram is shown in Figure 10.4

Figure 10. 4: Shipyard And Ship Repair



It must be remembered that along with new buildings, there will be facilities for repair, retrofitting and vessel upgradation. A unit of the ship yard would be dedicated and specialised in retrofitting of the existing vessels including the ones used for fishing with newer and better fuels such as LNG.

10.3 Man Power Requirement

There are two basic models on which the human resources planning in the organisation are in general being planned. The first model encourages to hire all the required manpower for the organisation, and carry out all the chores starting from house keeping to the production. This model has been followed thus far by all major Government departments. The major disadvantage of this model is that it requires maintaining a large work force and carry out functions, which are not even related to the core functions of the organisation. The second model is the present day model, which is based on the presumption that all the functions must be carried out by only specialised and experienced people. For example, the house keeping function must be carried out by an agency which specialises in that and it is not necessary to maintain a work force like the earlier model. This function could be out sourced. Similarly, transportation, Jetty operation, Terminal parking, and such other activities that are not central to the expertise required for the water way functioning may be out sourced. This model, has the advantage of a lean work force and thereby resulting in lesser human issues.

In the Vasai Creek waterway project, the later model is proposed. Therefore, it is suggested that all the non-essential functions be outsourced and only the core functions carried out in house.

10.3.1 Waterway Operations

A. Waterway Operation

The 'waterway operations' is controlled from the head quarters by the COO, through advanced communication and control systems. Information on the vessels, navigation, channel position, depths, marine conditions with regard to wave, tide and current, terminal occupancy and functions, terminal connectivity, passenger amenities etc. would be assimilated and displayed for monitoring.

Similar control rooms are proposed in each of the terminal, at the terminal control room. The core services of the waterway operation would involve, control and safety of the navigation and navigation channel, hardwares of the channel, navigational aids and maintenance. The following services are proposed to be out sourced;

1. **Vessel operation and Maintenance**, the first 10 vessels would be owned by the Waterway Authority and maintained on contract. Only the operation services would be monitored. Subsequent vessels would be owned and operated on PPP mode.

2. **Terminal Operation**: The terminal operation that could be out sourced are;
   a. Berth operations
   b. Parking
   c. Food Services and Cafeteria
   d. Bank and ATM
   e. Bus Services for connectivity
   f. Fuel services (Petrol, Diesel and LNG filling stations)
   g. Electric vehicle charging station
   h. Solar panel maintenance and operation

3. **Maintenance of Navigation Buoys**

COO will exercise his duties from the head quarters suggested to be located at Kolshet. He will be assisted by an IT team who will assemble all the information and advise the COO through the Waterway Manager. The Terminal activities would be controlled through a Terminal activity Manager (TM) stationed at the head quarters, who would coordinate with the terminal heads. The WM would be coordinating with the service partners and regulate their activity and monitor through 3 to 4 assistants. Similarly, the terminal activities shall be monitored through the TM by about 4 assistant TMs. About 2 to 3 data entry operators and 2 to 3 assistants for travel and other HR works would complete the department

The IT department head would be working under the direct control of the COO. He would have about 12 people working in 3 shifts for assimilating all the information and collating them for monitoring and use in posterity.

B. Terminal Control

Each of the terminals would be headed by the Terminal Head (TH), who would be working under the COO. The TH would be responsible for the following operations

i. Operation at the berth
ii. Passenger Safety
iii. Ticketing and Passenger comfort at the terminal
iv. Ancillary terminal activities
v. Terminal communication
vi. Bunkering
vii. Fuel centers and other facilities

viii. Parking and Connectivity
ix. Others, amusements, recreations etc.

Most of the operations except for the terminal communications and ticketing would be outsourced. Hence a total of 10 people in the general shift and 8 in the night shift will suffice per terminal.

C. Navigation & Buoyage

This activity would be controlled remotely and in the field through a Nautical Manager (NM), who at the aid and advice of the others would allow and permit vessel to transit the waterway. The NM would be based in the headquarters. He will have 4 assistants to control the 4 most important aspects of navigation, namely,

1. Marine environment, viz. Tide, Wave Current etc.
2. Channel depth and conditions
3. Vessel position and tracking
4. Terminal Position and occupancy

Based on the advice the channel navigation shall be controlled through the RIS and information passed on to the individual ships transiting.

D. Information Technology

This is probably most important department under the COO and would be entirely manned by in house personnel. They will have the responsibility of collecting and monitoring all minute operations in the waterway and the terminal and keep records.

10.3.2 Engineering And Maintainance

A. Project Implementation - Designs

The project implementation is an outsourced activity both in the design as well as the construction phase.

The Commercial and tendering department will issue tender for design of the various work components, both for tendering and execution. The design wing will receive the designs from the consultants and the designs would be vetted inhouse for optimality. The designs would be standardised where ever possible so that execution also becomes standard. Since the ship sizes and the other berthing conditions are known.

B. Project Implementation - Construction

Once the design is finalised and the construction tenders received, the project implementation team will take over. There will be phased construction initially, with important terminals numbering to about 4-5, namely Parsik Bunder, Anjur Dive, Kolshet, Kalher and Ghodbunder be constructed first and then the other terminals would be taken up subsequently. Since, the waterway would not need construction team except for skeletal staff at each terminal, it is proposed to take suitable experts from the participating municipal corporation or other Government departments on deputation during initial days, so that immediate recruitment is avoided.

C. Maintenance

During the operation phase, each terminal will maintain a team of engineers for maintenance of the services so that no disruptions ever happen. This department would work under the Construction Wing.

The Designs wing would be entrusted the charge of research, training and capacity building.

10.3.3 Administrative And Finance

Shall be responsible for the overall administration of the fairway operation and finances. Apart from creating the revenue policy, would be responsible for identifying additional revenue sources, such as advertising, adventure sports, tourism and amusement parks etc. Also evaluate and recommend to the engineering department for water front beautification, bringing in water sports and other activities for making the waterway financially viable.

10.3.4 Ship Yard And Ship Repair

The ship yard is located at Kolshet. The shipyard would be capable of maintaining the vessels operating in the waterway and will also be able to build new vessels to operate in the waterway. The shipyard will have one slipway, to cater for vessels upto 110 m long. Though the major infrastructure would be owned by the Ship Yard, part of the works can be outsourced. Only core divisions such as designs, building and quality control may be inhouse. The various departments under the Director are, Ship Designs, Ship testing, Hull fabrication, Engine and other infrastructure, Ship trials and hand over. Each department would be manned by suitable experts and the routine works shall be outsourced, which are mainly semi skilled.

Similarly, for repairs, adequate expertise shall be built in house.

10.4 Training Requirement / Capacity Building

10.4.1 Requiremnent Of Training

The Vasai Creek/Ulhas River waterway is a pilot project of this type developed entirely for the passengers albeit with modern amenities and facilities. As some portion of the waterway passes within 10 Km of the Wild Life Sanctuaries, there is a need to sensitise and train the manpower, involved in the operation of waterway, on environmental issues. The vessels are new or leased with state-of-the-art gadgets, the terminals, the navigation aids, the navigation using electronic chart and DGPS. RIS, berth and berth aid systems make navigation a safe but educative experience. In this context, it must be recognised that there are no ready manpower available for running such a waterway equipped with advanced communication and control systems. Hence, there will be a great need for trained man power for each of the activities that are conceivably occurring in the waterway.

Admittedly, such quality man power is not readily available and most of the locally available man power although experienced are not trained for the level of service expected for the proposed waterway. In addition, the vessel masters and the other mariners are to be trained to the highest level of competency for passenger safety and comfort including environmental issues.

Further, the speed of vessel vis-à-vis the maneuverability needs to be examined in the river model, which would train the vessel masters to test their skills. The berth operation is another area which needs close scrutiny.

Accordingly, it is envisaged to have a centralized training center under the aegis of the Waterway Authority for various disciplines including environment, or have a facility in association with other specialised institutes such as Indian Maritime University. This training institute would help training local youths in various skills related to navigation and help them secure jobs in the proposed or other similar areas.

10.4.2 Need for Capacity Building

Any modern waterway of this nature needs to build on the human resources and equipments. Though any fledgling organisation would have to build from the scratch. In this context, it is easy to acquire equipment, but having the people to run it would be harder to find in the current level of the talents available in the country. Hence, for the success of the enterprise, the capacity building by way of acquisition of the requisite expertise is a pre-requisite.

10.4.3 Proposed Training Facilities For Capacity building

The following areas are core to the operation of the waterway and hence require more attention due to unavailability of quality manpower.

1. River navigation for Pilot Training
2. Training of the Vessel Masters and Seafarers
3. Use of RIS
4. Survey and Charting
5. Environment

10.5 Infrastructure

10.5.1 Training Institute

The training Institute would work under the overall control of the COO/Director Engineering (Design Wing). There will be an institute with the following facilities;

1. Simulation Model with the Model of the waterway for testing the vessels and the pilots
2. Models for testing and honing the expertise of the vessel masters
3. Survey and Charting
4. Information Technology and use of RIS

Apart from the physical Infrastructure of computers, simulators and data processors, well qualified trainers also shall be requisitioned on a permanent basis or from the institutes like Indian Maritime University (IMU). Alternatively, private players like M/s ARI in New Delhi, could be entrusted the Job of establishing and training the instructors. Once trained, these instructors would take care of the future needs of training.

10.5.2 Ship Yard And Ship Repair

Ship building and repair is an essential activity for the waterway for several reasons. The vessels to be used in the waterway are special passenger vessels and therefore demand necessary expertise and quality control in their fabrication process. A well equipped ship yard would therefore be essential for the growth of the waterway, enabling a steady supply of these vessels.

In addition, ship yard would cater to the dry docking requirements of the waterway vessels and repair and retrofitting based on need. Therefore, capacity building in this area is essential and would be carried out through agreements and collaborations with Indian and/or Foreign ship builders.

10.5.3 Other Infrastructure

The Waterway Authority head quarters would be located at the Kolshet terminal. The head quarter will have adequate space for the Board members. The COO would be accommodated in one floor with the four different departments accommodated in the same or a floor below. In addition, to this, latest communication devices and audio-visual facilities shall be installed for better control on the waterway assets.

10.6 Cost Implications

The capital cost for the Infrastructure is included under the respective functionalities and no separate cost for the creation of the administrative infrastructures has been considered. However, an operational cost of ₹ 280.00 million is considered in the overall costing.

11 Project Costing

11.1 General And Financial Assumptions

11.1.1 General

Success of an infrastructure project depends on its technical soundness and economic viability. The technical aspects of the project for handling of the projected traffic has been discussed in the previous chapters. The present chapter would mainly deal with the cost estimates and financial evaluation of the project.

The first step leading to any financial evaluation is to determine the capital as well as operation cost to a reasonable degree of accuracy, because the accuracy of the evaluation process would be dependent on them. Accordingly, cost estimates for various components and sub-components are derived by detailed working of quantities and collection of prevailing market prices through budgetary quotes. In certain cases, the actual rates were worked out from basics.

11.2 Basis Of Costing

The Civil structures estimates are based on PWD SSR 2017-18 with GST @ 12% and contingency of 3%. Therefore, the cost estimates for the proposed facilities could be considered accurate within the permissible and acceptable limits.

The cost of various equipment and machinery were arrived at based on different methods. These are broadly classified into following categories depending on the margin of error in their assessment:

i. Based on budgetary quotations
ii. Based on rates for individual items from works of similar nature
iii. Based on rates collected from actual vendors
iv. Based on best judgement

For each estimate, the category to which it can be assigned is not indicated, but since the major portion of the cost estimates comes under category i, ii and iii, the margin of error in the overall estimates is likely to be small. The component of Goods and Services tax is taken as 12% for the civil works and indigenous items and that of customs and other duties in respect of imported items are included in the overall cost. Similarly, in the case of pollution mitigation measures, many items such as sewage disposal, dust control are included in the estimates for the respective civil, mechanical or electrical estimates.

The provision for cost of bunkering facility is not included in the capital cost estimates, since it would be provided, operated and charged for, quite independent of terminal passenger operations. The cost of providing accommodation for all the staff with supporting facilities like schools, hospitals, clubs, guests houses etc. have not been included in the capital costs. The PDC/PMC has been considered at 6% and contingencies have been considered at 3% of the total capital cost including cost of vessels (except terminal development) and mentioned in cost table.

11.3 Development Capital Cost

The Capital costs for infrastructure development have been worked out and are placed below. There will be a need to dredge the channel at some stretches to ensure all time operations of the ferries and ro-ro vessels. An estimated quantity of 0.71 million cubic meters of soft and hard dredging is anticipated, of which about 25904 m³ is hard dredging. The anticipated cost of dredging has also been worked out in Table 11.1 below:

Table 11. 1: Cost Of Infrastructure And Fairway Development

Sr.no	Details	Amount in Million ₹
1	Terminal Development (10 nos)	3615.63
2	Land Acquisition	221.57
3	Road connectivity	60.00
4	Dredging (for 3.0 m CD)	363.00
5	Bridge dismantling (Old Rly Bridge at Vasai)	50.00
6	Erosion control	5.00
7	Fairway Development (Navigational Aids/RIS, etc)	160.00
8	Environmental issues	25.00
9	PDC/PMC charges (@ 6% including cost of vessels)	360.01
10	Contingencies (3%) including cost of vessels and except on Sr.no 1 above	82.34
	Total	4942.55

Table 11. 2: Cost Of Vessels For Fairway Development

Sl.no	Details	Amount in Million ₹
1	10 Vessels	1500.00
	Total	1500.00

In the Table 11.1 land acquisition cost of ₹221.57 Million is considered, against the actual cost of about ₹710 million. This gap would be bridged through Transferable Development Rights (TDR). The cost of the vessels also may vary depending on the place of manufacture. As indicated before, the Vessels would be manufactured initially using one or several public sector/ private enterprises and hence may cost less than the assumed cost given in Table 11.2.

11.4 Operational And Maintenance Expenditure

As a guiding principle about 5% cost of the infrastructure is recommended for maintenance purposes every 3 years. However, as the terminals would be in regular use for IWT operations it is recommended that we may cater about 1.5% cost of the infrastructure as maintenance cost per year. The operation and maintenance cost of other activities are separately worked out and listed below in Table 11.3 and 11.4. The Vessel operating cost would include the cost of crew, fuel and routine maintenance.

Dry docking cost for major overhaul is not considered in the present computations. The cost on this account would be charged to the revenue accruals from the vessels.

Table 11. 3: Operation & Maintenance Cost Of Terminals

Sl.no	Details	Amount in Million ₹
1	Infrastructure at 1.5 %	54.23
2	Dredging	25.00
3	Erosion control	0.50
4	Navigation and Channel safety	154.00
5	Environment	21.50
6	Institutional (Terminal operations)	280.00
	Total	535.23

Table 11. 4: Operation & Maintenance Cost Of Vessels

Sl.no	Details	Amount in Million ₹
1	O & M of vessels (Crew + Fuel + Others)	1045.00
	Total	1045.00

11.5 Concluding Remarks

The capital cost of the development is given in Table 11.1 and 11.2. These costs are indicative and based on the costs obtained from similar projects elsewhere. Therefore, an allowance for the same may have to be made. The costs of the vessels considered in the estimates are based on the quotations from the International market. It was not possible to get cost quotations form either Public Sector or Private Sector ship builders in the country. The cost component on account of the capital cost of the vessels are likely to vary, atleast in the beginning when about 10 vessels would be required by the waterway. In addition, fabrication in the ship yard to be set up on the waterway may reduce the cost further. However, for this to happen the important components for the vessel, namely the Engines, Rudders, etc. may have to be purchased in bulk for obvious reasons.

Similarly, the waterway could consider owning atleast one crawler cat or similar amphibian dredgers, for not only helping in the Capital dredging but continue the maintenance dredging year after year. These dredgers are not very expensive and may cost around ₹ 150 million.

The cost of the restaurant equipment, floating hotels, water parks, fueling stations, solar panels are not considered in the capital cost estimates because they are independent business propositions and likely to be self sustaining.

The cost of building infrastructure of the shipyard has been considered whereas specialized machinery/ equipment have not been considered in this estimate and separate financing mechanism may have to be devised for this largely self sustaining business.

12 Implementation Schedule

12.1 Time Frame

12.1.1 General

The development of the waterway facility in the creek mainly comprises of creation of terminal facilities like navigational channel, onshore facilities, and Dredging etc. Development of Fairway could be carried out in three or more phases although, in this phase the following activities would be included;

i. Navigation Channel dredging up to 3.0 m CD depth
ii. Development Terminals
iii. Onshore Development
iv. Procurement of vessel
v. Installation of navigational aids and bank protection/Erosion control

A short recap of the construction shall be given below leading to the allotment of time frame.

12.1.2 Dredging And Reclamation

About 0.71 million m3 of soft and hard material would be dredged for making the 100 m wide channel navigable for the proposed vessels giving a 3.0 m CD depth at all stages of tide. The dredged material especially the hard material shall be used for erosion control and bank protection works. The soft materials obtained from the dredging, could be used for bank protection, erosion prone area protection, use as construction material under licence as discussed in chapter 3, section 3.4.2.5.

The estimated quantity of the dredging can be completed in about 12 – 18 months' time, with majority of the times estimated for the removal of hard material. The waterways being ecologically sensitive, water bodies are generally not permitted to have blasting as a mode of removal of hard strata. Therefore, with no blasting the removal of the hard materials would be limited to controlled drilling, chemical cracking and breaking, use of hammers and removal of broken rocks by back hoes. This process is time consuming and estimated to take about 8 months of time.

For the soft solid, crawl cat dredgers/cutter suction dredgers with less head room or/and dismantlable dredgers carried through land transport can be used for dredging. This would enable dredgers reaching the inner part of the creek without much difficulty. This must however, be remembered that these dredgers would be of low capacity with limited output and hence time taken shall be more. On the other hand, the good part is that the dredging requirement is mostly concentrated in the upstream stretches and partially functioning of the waterway covering almost 80-90% of the stretch could commence immediately.

12.1.3 Terminal Construction

Construction of berth approaches involves piling from the land side and subsequent development of turning platform and then the dolphins. Berth is located in shallow waters and therefore construction may not be arduous task. The superstructure construction would be mainly cast in situ and there will be no soffit shuttering. This would also enable the construction of superstructure on the piles already completed.

The superstructure shall be laid only after attachment of link span and other appurtenances. With deployment of multiple fronts and enough resources, it is possible to complete the terminals and the bank protection associated with it in a period of 12 to 16 months as detailed in Figure 12.1.

It is envisaged to complete the infrastructure for passenger operations quickly in a period not spanning more than 12 months. It is possible to give the passenger ferry operation a quick start at 4 sites namely, Parsik Bunder, Anjur Dive, Kolshet and Kalher by deploying prefabricated floating structures like link-span and turning platform with minimal civil works as adequate depths are already available as per costs and works discussed in sec 12.2. This would enable the passenger ferry operation stabilizing before the actual operation commences.

12.1.4 Equipment and Onshore Development

It is envisaged that the delivery and installation of equipment as well as the onshore development can be done in synchronization with the execution of marine works. These works can be carried out to suit the complete commissioning of the facilities. Construction of the approach road to the terminals needs to be taken up on priority basis to aid the construction.

The ro-ro services destinations could be commenced with the passenger operation. The onshore construction including the approach roads could be completed in 12 months' time.

12.1.5 Procurement Of Vessels

This is perhaps the most time-consuming activity. Fabricating these vessels would not be less than 30 to 36 months, unless special arrangements with multiple agencies are made. However, from the date of laying of the keel, 18 to 24 months is generally assumed on the conservative side. Therefore, the following steps are recommended for quick start of the operation and sustenance of the operation,

1. Standarise the vessel design of various categories recommended for the waterway

2. Consider awarding the work to specialised and multiple agencies for vessel fabrication
3. Centralised procuring of engines and other vital vessel equipments for hastening the process and effecting economy
4. Construct the shipyard slipway at Kolshet and establish the shipyard, which could be used for fabricating the new vessels complementing the external efforts. This would also enable the shipyard to cope with the future demands.
5. In the interim, after the completion of the dredging of the channel in the downstream reaches, (in about 4 to 6 months with out the hard starta dredging) leased vessels from the national/ international markets could be requisitioned for commencing passenger ferry operation.

It is therefore possible to start the opertaion in about 6 months to 1 year's time from commencement of work, if the planning is adequate and methodical.

12.1.6 Navigational Aid And Fairway Development

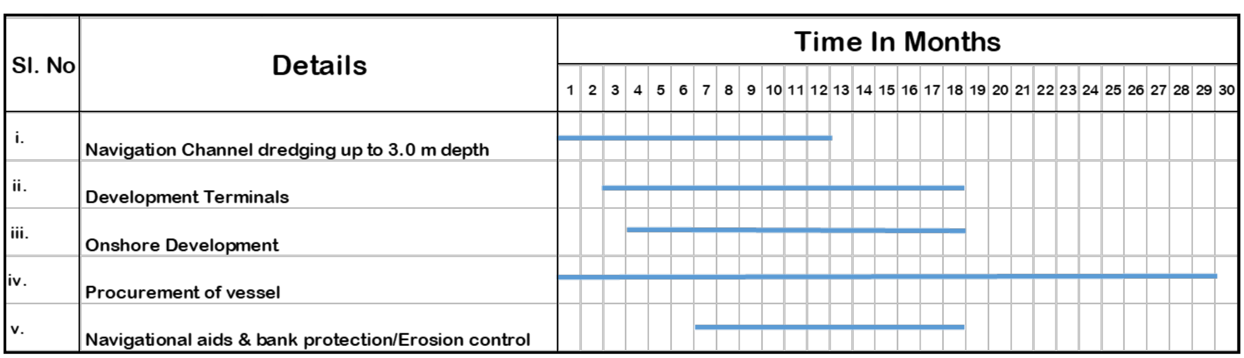
After completion of the dredging, the navigational buoys would be installed and the channel is notified before any commercial operation commences. This time also shall be utilised for installing and calibrating the communication systems.

12.1.7 Dismantling of the Cross Structures

As it is indicated in Chapter 2 and Chapter 3, the old railway bridge (made of iron) near Bhayander, is required to be dismantled for enabling ferry operation. Though complete dismantling would be desirable, dismantling of the middle span would be immediately carried out. This could be accomplished in a matter of 4 to 6 month's time, at the most.

The proposed time schedule is given in Figure 12.1.

Figure 12. 1: Implementation Schedule



12.2 Phasing

The present proposal is limited and is for the first phase of development. It is however possible that there could be sub-phases of development that may be included in the plan so that passenger service could be started quickly. For example, some of the terminals could be deferred and taken up at a later stage, concurrent with the operations. Vasai, Dombivli and Kalyan could be taken up a little late. Kalyan terminal needs rock dredging and so may take a little more time, which the other terminals may not need. Hence, the entire facility may not wait for the development of one single terminal.

The authorities may consider starting of passenger services (across) at 4 selected sites by installing the pre-fabricated floating structure, namely linkspan with minimal civil works. The selected sites may be Parsik Bunder, Anjur Dive, Kolshet and Kalher. The costing details for the proposed infrastructure to give a quick start to the project, location wise are as follows:

Table 12. 1: Infrastructure cost for Kolshet Jetty

Name of Work: Kolshet Jetty		
Recapitulation Sheet		
1	Approach Jetty	65922601.02
2	Turning Platform	65233133.59
3	Floating Pontooon and Linkspan assembly	82500000.00
4	Bollards and Fenders	7860000.00
5	Parking Area	10000000.00
6	Ticketing Shops	3700000.00
7	Electrification Work	7000000.00
	Total	242215735.00
	Add 3% contengencies	7266472.05
	Sub-Total	249482207.05
	Add 12% GST	29937864.85
	Total Cost	279420071.90 Say ₹ 279.42 Million

Table 12. 2: Infrastructure cost for Kalher Jetty

Name of Work: Kalher Jetty		
Recapitulation Sheet		
1	Approach Jetty	30802990.21
2	Turning Platform	63768752.73
3	Floating Pontoon and linkspan assembly (including Cathodic Protection)	82500000.00
4	Bollards and Fenders	7860000.00
5	Parking Area	10000000.00
6	Ticketing Shops	3700000.00
7	Electrification Work	7000000.00
	Total	**205631743.00**
	Add 3% contengencies	**6168952.29**
	Sub-Total	**211800695.29**
	Add 12% GST	**25416083.43**
	Total Cost	**237216778.72** **Say ₹ 237.21 Million**

Table 12. 3: Infrastructure cost for Parsik Jetty

Name of Work: Parsik Jetty		
Recapitulation Sheet		
1	Approach Jetty	36081724.91
2	Turning Platform	46461684.41
3	Floating Pontoon and linkspan assembly (including Cathodic Protection)	82500000.00
4	Bollards and Fenders	7860000.00
5	Parking Area	10000000.00
6	Ticketing Shops	3700000.00
7	Electrification Work	7000000.00
	Total	**193603410.00**
	Add 3% contengencies	**5808102.30**
	Sub-Total	**199411512.30**
	Add 12% GST	**23929381.48**
	Total Cost	**223340893.78** **Say ₹ 223.34 Million**

Table 12. 4: Infrastructure cost for Anjurdive Jetty

Name of Work: Anjurdive Jetty		
Recapitulation Sheet		
1	Approach Jetty	50010870.58
2	Turning Platform	48001742.37
3	Floating Pontoon and linkspan assembly (including Cathodic Protection)	82500000.00
4	Bollards and Fenders	7860000.00
5	Parking Area	10000000.00
6	Ticketing Shops	3700000.00
7	Electrification Work	7000000.00
	Total	**209072613.00**
	Add 3% contengencies	**6272178.39**
	Sub-Total	**215344791.39**
	Add 12% GST	**25841374.97**
	Total Cost	**241186166.36** **Say ₹ 241.18 Million**

The above costs have been summarized in table no 12.5

Table 12. 5: Cost Summary

Summary of costs for quick start of project at four selected sites		
1	Kolshet	279420071.90
2	Kalher	237216778.72
3	Parsikbunder	223340893.78
4	Anjurdive	241186166.36
	Total Cost	981163910.75 Say ₹ 981.16 Million

Similarly, though it would be ideal to start with 10 vessels, the operation could be started with lesser numbers, taken on lease, and progressively the fleet could be expanded.

12.3 Suggested Implementation Mechanism

The project must be implemented by the same SPV which is intended to run it. That would entail the capacity building of the SPV and responsibility for development and then operation.

The respective departments could own the responsibility of their department. For example, the terminal control would be responsible for the terminal development as well.

13 Economic And Financial Analysis

13.1 General

Financial and economic analyses are important Project Feasibility Study (PFS) components to quantitatively and qualitatively assess the financial and economic benefits and impacts of transport infrastructure investments. They allow decision making agencies to identify, quantify, and value the economic and financial benefits and costs over a multiyear timeframe. With this information, agencies are better able to target scarce resources to their best uses in terms of maximizing benefits to the public and to account for the many different phases of the transportation decision-making process. These analyses can inform many different phases of the transportation decision making process, and in particular, provide information and analysis in order to assess the following;

a. Assess the economic and/or financial viability of the project from a societal standpoint (should the project be constructed or not?); what levels of economic and financial return would the project generate?
b. Identify the tariffs, user charges, taxes and other funding sources needed to recover costs and provide for long term sustainability.
c. Identify possible funding options.
d. Assess the affordability of the proposal in terms of ability and willingness to pay.
e. Frame a marketing plan through which the necessary financing may be mobilized.

Project economic analysis and financial evaluation both involve the identification of project benefits and costs during the years in which they occur and converting all future cash flows to their present value using the technique of discounting. Both analyses generate net present value (NPV) and internal rate of return (IRR) indicators, termed economic NPV (ENPV) and economic IRR (EIRR) in the case of economic analysis and financial NPV (FNPV) and financial IRR (FIRR) in the case of financial evaluation.

Economic analysis is carried out from the perspective of the entire economy, and it assesses overall impact of a project on the welfare of all the citizens of the country concerned. The purpose of project economic analysis is to assess whether a project is economically viable for the country. Financial evaluation is carried out from the perspective of the project and considers incremental cash flows (both revenues and costs) generated by the project. The purpose of financial evaluation is to assess the ability of the project to generate adequate incremental cash flows to recover its financial costs (capital and recurrent costs) without external support. Financial evaluation is based on market prices that are actually paid or received by a project, and it focuses on financial values of project costs and benefits.

This work has been performed at the pre-feasibility stage, in which investments have been identified in concept only, and prior to completion of technical designs and detailed feasibility assessment. For this reason, the characteristics of each project, project costs, and the economic and financial analyses and benefits are subject to considerable uncertainty and modification. Nevertheless, a best effort attempt has been made at this stage to identify the costs and benefits of the investment as a guide to moving forward with the investment. Also, the assumptions followed and data used are indicated so as to assist in further stages of analysis.

13.2 Assumptions

The economic analysis included the following assumptions and criteria:

A period of 30 years was used for the economic evaluation as follows:

i. Base Year (2018)
ii. Construction period (2018 and 2019)
iii. Project opening for passengers (2019)
iv. Project operating period (2019-49)
v. End of the analysis period (2049)
vi. Consideration of Salvage Value (2049)

Appropriate excel based models were developed to quantify the relevant project benefits life cycle costs, project net benefits and to calculate the economic feasibility criteria (EIRR and ENPV).

The Updated Road User Cost Study was used to assess resource cost savings for diverted traffic. The study inputs were updated using unit rates of VOC and travel time for different vehicle categories. Wherever possible, estimation of these input variables was made region-specific using available secondary data.

The investments were evaluated using the economic internal rate of return (EIRR) and economic net present value (ENPV). For the ENPV, the discounted cash flow (DCF) was calculated using an economic opportunity cost of capital (EOCC) of 12%. This is the normal rate applied by ADB where capital is constrained. The EIRR must be compared with the economic opportunity cost of capital, when determining project feasibility.

The financial analysis included the following assumptions and criteria;

(i) The financial analysis was undertaken in accordance with ADB's Framework for the Economic and Financial Appraisal of Urban Development Sector Projects. Financial analysis was conducted to assess the financial viability of the various component of the investment proposal

(ii) The FIRR have been independently estimated for each of the investment proposal components at constant financial prices considering the incremental cost and benefit streams over the anticipated useful life of all direct revenue earning investments and tested with the sensitivity analysis under given variables. The proposal will be considered financially viable if the FIRR is more than the weighted average cost of capital (WACC).

(iii) The proposed fare levels were assessed to ascertain their affordability to the beneficiaries, in particular the low-income groups and poor households, i.e. those below the poverty line. Financial projections for the Corporation were also performed to determine the financial capability of Corporation to deliver and operate the investment proposal on a sustainable basis.

13.3 Economic Analysis / EIRR

13.3.1 Process

There are four broad steps in project economic analysis:

i. Identify gross project benefits and costs
ii. Quantify and value the benefits and costs, initially in market or financial prices
iii. Adjust the costs and benefits to reflect their economic values
iv. Compare gross economic benefits with economic costs

Economic analysis involves analyzing a number of issues related to the economic viability of a project. Economic analysis should justify both the choice of public involvement and the form it takes. It requires that a project is designed such that its net economic benefits are sustained during the project's economic life.

The economic analysis covers the estimation of the likely traffic, the identification and quantification of the implied project cost and benefits; economic feasibility analysis results; and sensitivity analysis. The investment proposal consists of ten ferry routes with required amenities. These components will directly benefit the existing ferry passengers as well as passengers who transfer to ferry services from buses and private road vehicles. Accordingly, the economic benefits considered include:

1. Value of Travel Time Savings

For the passengers diverted from road to ferry services

2. Value of vehicle operating cost (VOC) savings

For the passengers diverted from road to ferry services

In the absence of detailed traffic modelling, assumptions were made regarding impact of improvements in the ferry and road network performances. These assumptions addressed those benefits including savings in travel time and related costs as well savings in vehicle operating costs (VOC). The basis of these assumptions is as follows:

(i) The average travel speed is assumed to increase from the existing levels (this increase in speed/service level can be achieved by reduced delays to general traffic caused by overcrowded buses loading at overcrowded bus stops. Even though increased speed levels are expected more, a 25 percent improvement is assumed on conservative side. This improvement in travel speed has been used to estimate the savings in travel time and further costing the time saved.

The value of the VOC savings and travel time savings for general traffic through increased use of the ferry services has been calculated using unit rates for time value, and established VOCs for different vehicle categories. These have been estimated from the guidelines stipulated by Indian Roads Congress (IRC), and relevant study reports. The calculations include the following assumptions:

- Average vehicle occupancy – the number of passengers by vehicle type
- Traffic composition – the percentage of each vehicle type in the traffic stream
- Passenger composition – the percentage of each socio-economic category using each vehicle type and the percentage of passengers who are in the workforce
- Savings in VOC and travel time – estimated on the basis of the VOC savings generated by the reduction of existing travel speeds and average VOC in congested travel conditions through the impact of this investment proposal
- Unit cost of VOC and travel time for different vehicle users – based on background study data and reports with unit time costs

13.3.2 Value Of Time

Value of Travel Time (VOT) plays a crucial role in the cost benefit analysis in transport planning process. It quantifies the importance of time with respect to cost which is employed in economic evaluation of travel time saving.

The most standard procedure suggests value of time as a trade-off ratio between coefficient of travel time and travel cost.

VOT is the ratio between the derivative of utility with respect to time and the derivative of utility with respect to cost, mathematically this is expressed in equation (1)

$$VoT = \frac{\partial Vi}{\partial Timei} \Big/ \frac{\partial Vi}{\partial Costi} \quad (1)$$

Table 13. 1: Value Of Time

Mode	VOT/min	VOT/hr
Train	0.97	58.2
Bus	0.86	51.6
Auto	1.02	61.2
Shared Auto	1.06	63.6
Two Wheeler	1.01	60.6
Car	1.5	90
IWT	0.4	24

Note: Estimated using utility equations obtained from Nlogit

13.3.3 Vehicle Operating Cost

The implementation of the identified components will improve the speed and capacity of the road corridors. This will improve the service quality in terms of reduced vehicle operating costs. Savings in VOC are assumed from the following:

- Improvement in traffic flow through reduced congestion levels
- By effecting modal shift from private vehicles to the ferry services

Updated unit VOC rates have been adopted for the analysis based on

- VOC rates per vehicle km
- Savings per vehicle km for different vehicle categories.

These rates are shown in Table 13.2

Table 13. 2: Details Of Road User Cost Adopted For The Study

Vehicle Category	VOC (Vehicle Km)	
	2008	2018
Train	30	40
Bus	16.4	33
Auto	4	8
Shared Auto	4.5	9
TW	1.4	3
Car	4.1	9

Source:

1. *Approach for Economic and Operation Assessment for Identified Urban Roads and Transportation Sub-projects, Working Paper No.: WP-05, Comprehensive Transportation Study for Chennai Metropolitan Area, May 2008*
2. *Escalated to 2010 with 7% annual growth.*

Table 13. 3: Estimation Of VOC savings

Vehicle Category	VOC	Saving in VOC (%)	Saving in VOC(Rs/Vehicle Km)
Train	40	50.04	21
Bus	33	42.04	14
Auto	8	23.14	2
Shared Auto	9	23.14	3
TW	3	23.14	1
Car	9	29.51	3

Note: *Estimated using HDM-4 Economic Analysis Model for an urban road condition with widening option of to four lanes.*

These savings in VOC along with the shift per vehicle type gives the overall general saving in Vehicle Operating Cost. For computing the shift from different modes to IWT N-Logit software was used. The sample result obtained from the N-Logit software package is shown below in Figure 13.1. It is observed from the Figure below that 2.8%, 1.3%, 1.3%, 0.3%, 0.5%, 1% of commuters shifted to IWT respectively from local train, bus, auto, shared auto, two wheeler and car. Similarly, the shift from each location is added to get the final shift from each mode.

Figure 13 1: Sample Model Outputs From The N-Logit Software

```
Specification of scenario 1 is:
Attribute  Alternatives affected            Change type              Value
---------  -------------------------------  -------------------  ---------
TT         IWT                              Scale base by value       .750
TC         IWT                              Scale base by value       .750
---------------------------------------------------------------------------
The simulator located   2092 observations for this scenario.
Simulated Probabilities (shares) for this scenario:
+----------+--------------+--------------+------------------+
|Choice    |    Base      |   Scenario   | Scenario - Base  |
|          |%Share Number |%Share Number |ChgShare ChgNumber|
+----------+--------------+--------------+------------------+
|LOCAL     | 15.583   326 | 13.197   276 | -2.386%      -50 |
|BUS       | 16.205   339 | 14.838   310 | -1.366%      -29 |
|AUTO      | 16.252   340 | 14.920   312 | -1.332%      -28 |
|SHARED    | 11.950   250 | 11.730   245 |  -.221%       -5 |
|TW        | 11.855   248 | 11.323   237 |  -.531%      -11 |
|CAR       | 15.774   330 | 14.766   309 | -1.008%      -21 |
|IWT       | 12.380   259 | 19.225   402 |  6.845%      143 |
|Total     |100.000  2092 |100.000  2091 |   .000%       -1 |
+----------+--------------+--------------+------------------+
```

Table 13. 4: Estimation Of Value Of Time

Details		Unit	Value	Datum Year	Annual Growth	2018
Net state domestic product at factor cost for Maharashtra state(NSDP)	A	₹ Million	634828	2009-10	7	1090753
Population	B	Million	112	2011	0.9	119.2494
Working Population: main	C	%	44	2011	0.9	21.04506
Working Population: marginal and unemployed	D	%	11.5	2011	0.9	5.500414
Working Population: FTE	E=C+D/2	%	49.75	2011		23.79527
Computed						
Assumed NSDP(50%) to household	F=A*0.50	₹ Million				545376.3
Average Income per FTE worker	G=(F/B)/E	₹/Year				19219.83
Average Income per FTE worker[2]	H=G/2400	₹/Hour				8.008261
Work time value, with 33% overheads	I=H*1.33	₹/Hour				10.65099
Non-work time value at 30%	J=H*0.30	₹/Hour				3.195296

Note:

1. *Full Time Equivalent Workers (FTE), assuming marginal workers are employed half-time*
2. *Assuming 2400 worked hours per year*

Source:

1. *Statistical Hand Book of India, Reserve Bank of India*
2. *Census of India 2011, Provisional Tables, Registrar General of India*

These values of work time value and non-work time values, along with the shift per vehicle type gives the overall general saving in travel time. Shift from different modes to IWT was computed using N-Logit software.

These savings in vehicle operating cost and travel times forms the revenue for economic analysis. Table 13.6 gives the consolidated details of the economic analysis of the entire project.
Details of EIRR for each Jetty location per direction of travel is given in Appendix A.

13.3.4 General Methodology

The financial and economic analyses include the determination of the EIRR, FIRR. These are based on streams of benefits and costs resulting from the construction, installation, and operation of the project components over their economic lives. The benefits and costs and the EIRR and FIRR are determined separately for all components. The potential project benefits for each component are projected over its economic life and are presented in quantitative terms. To test the economic viability, the EIRR was calculated based on the incremental cost and benefit streams associated with each project. The FIRR is obtained by equating the present value of investment costs (as cash out-flows) and the present value of net incomes (as cash in-flows).

Table 13. 5: EIRR For The Ferry Services

Discounted rate (%)	12						
Year	**Capital cost**	**O&M cost**	**Revenues (Inflow)**	**Total Cash Flow (Net Revenue)**	**Time period**	**NPV**	**IRR**
2018	3865.53			-3865.53	0	-3865.5	7.1%
2019	2577.02			-2577.02	1	-2300.9	
2020		535.23	1319	783.77	2	624.8	
2021		535.23	1412	876.77	3	624.1	
2022		535.23	1511	975.77	4	620.1	
2023		535.23	1617	1081.77	5	613.8	
2024		535.23	1731	1195.77	6	605.8	
2025		535.23	1853	1317.77	7	596.1	
2026		535.23	1983	1447.77	8	584.7	

Discounted rate (%)	12						
Year	Capital cost	O&M cost	Revenues (Inflow)	Total Cash Flow (Net Revenue)	Time period	NPV	IRR
2027		535.23	2122	1586.77	9	572.2	
2028		535.23	2271	1735.77	10	558.9	
2029		535.23	2430	1894.77	11	544.7	
2030		535.23	2601	2065.77	12	530.2	
2031		535.23	2784	2248.77	13	515.4	
2032		535.23	2979	2443.77	14	500.0	
2033		535.23	3188	2652.77	15	484.7	
2034		535.23	3412	2876.77	16	469.3	
2035		535.23	3651	3115.77	17	453.8	
2036		535.23	3907	3371.77	18	438.5	
2037		535.23	4181	3645.77	19	423.3	
2038		535.23	4474	3938.77	20	408.3	
2039		535.23	4788	4252.77	21	393.6	
2040		535.23	5124	4588.77	22	379.2	
2041		535.23	5483	4947.77	23	365.1	
2042		535.23	5867	5331.77	24	351.3	
2043		535.23	6278	5742.77	25	337.8	
2044		535.23	6718	6182.77	26	324.7	
2045		535.23	7189	6653.77	27	312.0	
2046		535.23	7693	7157.77	28	299.7	
2047		535.23	8232	7696.77	29	287.7	
2048		535.23	8809	8273.77	30	276.2	
2049		535.23	9426	8890.77	31	265.0	

Note:

1) Traffic is assumed to grow 7% annually (According to Comprehensive Mobility Plan of Mumbai,2016)

2) Revenue generated is the result of savings in general Vehicle Operating Cost and Travel Times

The EIRR is calculated as 7.1% for the project. This rate compares favourably with the 6% benchmark for social sector projects that primarily generate environmental benefits, substantiating the economic viability of the project.

In addition, the EIRR for each Jetty location was also calculated in order to make selected OD pairs operable based on demand and/or viability in the Table 13.6.

In the Table 13.6 the base year of development is taken as 2018. The construction completes in the Year 2019. The EIRR for up (upstream direction) and down traffic is computed separately.

Table 13. 6: EIRR Computation For The Jetty Locations (All Figures In Million ₹)

Year	Capital Cost	Operating Cost	Revenue-Up	Revenue-Down	EIRR Up (%)	EIRR – Down(%)
Vasai						
2018	221				18	19
2019	147					
2020		6	131	157		
2049		6	321	321		
Mira-Bhaynader						
2018	207				8	2
2019	133					
2020		6	70	44		
2049		6	188	125		
Ghodbunder						
2018	231				-8	-7
2019	154					
2020		6	13	17		
2049		6	50	58		
Nagla Bunder						
2018	190				-6	-7
2019	126					
2020		5	14	11		
2049		5	52	46		
Kolshet						
2018	374				21	5

Year	Capital Cost	Operating Cost	Revenue-Up	Revenue-Down	EIRR Up (%)	EIRR – Down(%)
2019	249					
2020		10	259	107		
2049		10	631	274		
Kalher						
2018	209				10	8
2019	139					
2020		6	85	76		
2049		6	220	200		
Anjur Dive						
2018	188				15	13
2019	126					
2020		5	98	92		
2049		5	254	238		
Parsik Bunder						
2018	199				-6	-4
2019	133					
2020		5	20	35		
2049		5	64	107		
Dombivli						
2018	175				-6	-4
2019	117					
2020		5	13	19		
2049		5	50	62		
Kalyan						
2018	208				-4	1
2019	139					

Year	Capital Cost	Operating Cost	Revenue-Up	Revenue-Down	EIRR Up (%)	EIRR – Down(%)
2020		6	26	42		
2049		6	80	44		

13.4 Financial Analysis

A financial analysis was carried out using a fare structure designed depending on the distance to be travelled. The fare structure considered for the analysis is given in Table 13.8 below. For analytical purpose, an increase of 15% every third year has been considered in respect to fees. The assumptions and approach used in the calculation of FIRR include:

i. All revenues and costs are stated at constant prices
ii. All revenues and costs are calculated on incremental basis

The results of FIRR calculations are summarized as follows in Table 13.9.

Both economic and financial analysis relies on the assumed patronage being achieved. In general following investment parameters are being assumed for Financial Analysis:

Table 13. 7: Investment Parameters Are Being Assumed For Financial Analysis

Revenue assumptions	
Number of Passenger Ferries at each Jetty Location:	3
Number of Trips per day	Taking capacity of 160 passengers
Number of Passengers per day	Estimated Traffic
Fare Increase proposed	15% every 3 years

Table 13. 8: Fare Structure

To	From	Distance (km)	Ticket Fare
Vasai	Jasal Park	4	12
	Ghodbunder	9	15
	Nagla Bunder	15	21
	Kolshet	26	32
	Kalher	27	33
	Anjur Dive	30	36
	Parsik Bunder	31	41
	Dombivli	39	51
	Kalyan	47	55

To	From	Distance (km)	Ticket Fare
Jasal Park	Ghodbunder	5	12
	Nagla Bunder	12	18
	Kolshet	23	29
	Kalher	24	30
	Anjur Dive	27	33
	Parsik Bunder	28	34
	Dombivli	36	47
	Kalyan	44	57
	Vasai	4	12
Ghodbunder	Nagla Bunder	7	13
	Kolshet	18	24
	Kalher	19	25
	Anjur Dive	22	28
	Parsik Bunder	23	29
	Dombivli	31	42
	Kalyan	39	52
	Vasai	9	15
	Jasal Park	5	12
Nagla Bunder	Kolshet	11	17
	Kalher	12	18
	Anjur Dive	15	21
	Parsik Bunder	16	22
	Dombivli	24	30
	Kalyan	32	43
	Vasai	15	21
	Jasal Park	12	18
	Ghodbunder	7	13
Kolshet	Kalher	1	5
	Anjur Dive	4	12

To	From	Distance (km)	Ticket Fare
	Parsik Bunder	5	12
	Dombivli	13	19
	Kalyan	21	27
	Vasai	26	32
	Jasal Park	23	29
	Ghodbunder	18	24
	Nagla Bunder	11	17
Kalher	Anjur Dive	3	8
	Parsik Bunder	4	12
	Dombivli	12	18
	Kalyan	20	26
	Vasai	27	33
	Jasal Park	24	30
	Ghodbunder	19	25
	Nagla Bunder	12	18
	Kolshet	1	5
Anjur Dive	Parsik Bunder	1	5
	Dombivli	9	15
	Kalyan	17	23
	Vasai	30	36
	Jasal Park	27	33
	Ghodbunder	22	28
	Nagla Bunder	15	21
	Kolshet	4	12
	Kalher	3	8
Parsik Bunder	Dombivli	8	14
	Kalyan	16	22
	Vasai	31	41
	Jasal Park	28	34
	Ghodbunder	23	29

To	From	Distance (km)	Ticket Fare
	Nagla Bunder	16	22
	Kolshet	5	12
	Kalher	4	12
	Anjur Dive	1	5
Dombivli	Kalyan	8	14
	Vasai	39	51
	Jasal Park	36	47
	Godhbunder	31	42
	Nagla Bunder	24	30
	Kolshet	13	19
	Kalher	12	18
	Anjur Dive	9	15
	Parsik Bunder	8	14
Kalyan	Vasai	47	55
	Jasal Park	44	57
	Godhbunder	39	52
	Nagla Bunder	32	43
	Kolshet	21	27
	Kalher	20	26
	Anjur Dive	17	23
	Parsik Bunder	16	22
	Dombivli	8	14

The results of consolidated FIRR calculations of entire project are summarized as follows in Table 13.9.

Table 13. 9: FIRR Computations For The Ferry Services

Discounted rate (%)	12						
Year	Capital cost	O&M cost	Revenues (Inflow)	Total Cash Flow (Net Revenue)	Time period	NPV	FIRR
2018	3865.53		1084	-3865.5	0	-3865.53	4.1%
2019	2577.02		1084	-2577.0	1	-2300.91	
2020		535.23	1246	548.8	2	437.4761	
2021		535.23	1246	548.8	3	390.6036	
2022		535.23	1433	710.8	4	451.7072	
2023		535.23	1433	710.8	5	403.31	
2024		535.23	1648	897.8	6	454.8382	
2025		535.23	1648	897.8	7	406.1056	
2026		535.23	1896	1112.8	8	449.4291	
2027		535.23	1896	1112.8	9	401.276	
2028		535.23	2180	1360.8	10	438.1315	
2029		535.23	2180	1360.8	11	391.1889	
2030		535.23	2507	1644.8	12	422.1715	
2031		535.23	2507	1644.8	13	376.9388	
2032		535.23	2883	1971.8	14	403.4632	
2033		535.23	2883	1971.8	15	360.235	
2034		535.23	3316	2347.8	16	382.9721	
2035		535.23	3316	2347.8	17	341.9394	
2036		535.23	3813	2780.8	18	361.6102	
2037		535.23	3813	2780.8	19	322.8662	
2038		535.23	4385	3277.8	20	339.7958	
2039		535.23	4385	3277.8	21	303.3891	
2040		535.23	5043	3849.8	22	318.1547	
2041		535.23	5043	3849.8	23	284.0667	
2042		535.23	5799	4507.8	24	296.9814	
2043		535.23	5799	4507.8	25	265.1619	
2044		535.23	6669	5263.8	26	276.4575	
2045		535.23	6669	5263.8	27	246.837	

Discounted rate (%)	12						
Year	Capital cost	O&M cost	Revenues (Inflow)	Total Cash Flow (Net Revenue)	Time period	NPV	FIRR
2046		535.23	7669	6133.8	28	256.8165	
2047		535.23	7669	6133.8	29	229.3004	
2048		535.23	1084	7133.8	30	238.1104	
2049		535.23	1084	7133.8	31	212.5986	

Sensitivity Analysis

Sensitivity analysis of Project IRR has been carried out with respect to the key project parameters. ► Capital cost

- Operation and Maintenance Cost
- Revenue

The IRR is most sensitive to changes in the revenue, followed by changes in the capital cost and then the Operation and maintenance cost. The decrease in revenue by 5% reduces the EIRR and FIRR by 3.6% and 0.6% respectively. However, reduction in O&M cost by 5% increases both the EIRR and FIRR by 0.2% only.

Table 13. 10: Sensitivity Analysis of EIRR and FIRR

	Percentage Increase / Decrease	EIRR	FIRR
Capital Cost	-5%	7.6%	4.6%
	0%	7.1%	4.1%
	5%	6.6%	3.7%
	10%	6.1%	3.3%
Operation & Maintenance Cost	-5%	7.3%	4.3%
	0%	7.1%	4.1%
	5%	6.9%	3.9%
	10%	6.7%	3.7%
Revenue	-5%	3.5%	3.5%
	0%	7.1%	4.1%
	5%	7.8%	4.8%
	10%	8.6%	5.4%

13.5 Possible Ancillary Revenue

Apart from the regular passenger revenue stream and possible future cargo revenue stream, the waterways in the western countries depend on many other ancillary sources of revenue to bolster the revenue stream further. It must be recognised that there would be fierce competition, with the other modes in the initial years, and hence other revenue streams may be handy. The additional sources of revenue also shall add to the viability of the mode. Hence, it will be endeavored to identify additional resources for generation of revenues.

Some of the suggested revenue sources are indicated below;

1. Advertising along the waterway and on vessels
2. Development of water sports and integrated town ship with theme parks integrating the waterway
3. Licensing for water borne restaurants and water sports
4. Leasing waterfront government lands for development of resorts and hotels
5. Leasing areas inside the terminals for restaurants
6. Advertisements at the Terminals and buildings
7. Revenues accrued from the fueling stations, and other businesses

13.6 Risk Factors And Mitigation

The risk of development of the waterway could be broadly listed as follows;

1. Popularity of the waterway with the users in line with the assumption
2. Revenue collection in the line of projections

Simply put, it is difficult to predict the popularity of the waterway, and the willingness of the passenger to pay the revenue suggested. Considering the transportation scenario of the MMR, these may not be a risk, since other modes are running much above their capacities and this new mode would be welcomed if the two simple steps are followed

1. Frequency of service matching the demand
2. Keeping the schedules.

It has been already ascertained that if the quality of service is good, tariff is not likely to be a real issue. Hence, with little deftness, the waterway development could be made a financial success as well.

The proposed Ro-Ro service would succeed.

13.7 Project Financing Aspects / Transaction Structuring

It is proposed that the initial financing for the advance payments and starting of construction post creation of SPV should be in form of grants from the Government. Subsequently, financing could be taken up with upfront grants/loans from Government / TMC with a tax holiday in the initial years for operation of the project.

13.8 Necessity Of Govt. Support (VGF / PPP)

Government support in the initial years may be necessary for running the waterway, before popularisation of the waterway. Hence, initial fairway development, or vessel procurement could be based out of government grants.

14 Conclusion & Recommendations

14.1 Conclusion

Vasai Creek - Ulhas river starting from the Arabian Ocean up to the Kalyan, a distance of about 50 km, is declared as National Waterway no 53, is a developable proposition. About 80-90% of the existing waterway from the Arabian sea upstream is more or less navigable with little or no dredging. Most of the waterway has a depth of more than 2.5 to 3 m. Hence, the first ingredient for the waterway is in existence. The other ingredients, namely, low wave heights, milder current and ample area for development of Terminals do exist. The river is mostly bereft of erosion and bank instability issues.
Most of the cross structures are also having desirable air draught, for permitting passage of design vessels except for the singular Bhayander old railway bridge, which is abandoned and needs to be dismantled. In short, an ecosystem for providing an alternative mode of transportation does exist and require adequate planning for ensuring the same. In this scenario, it was proposed to develop a 3.0 m CD deep, 100 m wide, navigable waterway for providing a credible alternative mode.

Accordingly, 10 terminal locations were selected in the proximity of the Population centers. These terminals are so selected so as to provide not only seamless connectivity to the local population, but a cheap and environmentally acceptable mode of communication.

The terminals and the waterway would be provided with the latest and most advanced communication and navigational markings for ensuring safety of the vessels and the passengers. The communication network would be hooked on to the River Information System (RIS), for integrating to a global platform.

Five different vessels types were chosen for achieving the ultimate target of the passenger transport. In addition, vessels and the terminals would be equipped to handle ro-ro vehicles carrying vehicular traffic. The terminals at selected locations would be provided with fueling centers for the vehicles and charging centers for electric cars. In addition, they would be provided with restaurants, children play area and elaborate passenger waiting area for comfort of the passengers. The terminals would be provided solar panels for solar energy to further reduce the carbon foot prints. The terminals will have recepetion facilities for garbage, waste oil, grey water, bilge water and disposal through authorized agencies.

All the vessels would have dual fuel engines and would be capable of running on natural gas in addition to MDO or IFO/Ethanol. In future vessels operating on electric power will be pressed into service as the technology becomes available.

The portion of the water way between the Nagla Bunder and the Kolshet terminal would be dedicated for water sports and floating restaurants, owing to its natural ambience and the water depths. Resorts and other amusement facilities are already existing along this stretch, especially close to the Nagla Bunder area, because of the breathtaking and scenic backdrop it provides. Infrastructure at the terminals would be provided for supplementing the proposed facilities on water.

The waterway would be run by a SPV created with the participation of the TMC, IWAI, JNPT, MMB, MBMC, VVMC,KDMC and BNMC. Funds for developing the waterway will (could) be provided from the Government as a grant. Procurement of vessels also could be an arduous task and therefore should be taken up immediately. Indian shipyards should be approached to take this task of fabricating vessels for the waterway. In addition, the shipyard on the waterway would be enabled for the Job so that the inhouse expertise is also developed.

All the terminals would be provided with Solar panels and electric vehicle charging terminals for the benefit of the users. LNG/CNG filling station for bunkering of vessels also shall be provided.
The financial evaluation indicates that the ferry services investment proposal is expected to be economically viable as:

1. It represents the most efficient option to achieve the intended project outcomes.
2. It generates an economic surplus above its opportunity cost.
3. It will have sufficient funds and the necessary institutional structure for successful operation and maintenance.

The general criterion for accepting a project is achieving a positive ENPV discounted at the minimum required EIRR, or achieving the minimum required EIRR. ADB's newly adopted minimum required EIRR is 9%. However, for social sector projects, selected poverty-targeting projects and projects that primarily generate environmental benefits (such as pollution control, protection of the ecosystem, flood control, and control of deforestation), the minimum required EIRR can be lowered to 6%.

Economic analysis of this project generated a positive economic net present value (ENPV) using the minimum required economic internal rate of return (EIRR) as the discount rate. The calculated EIRR values exceeded the economic opportunity cost of capital. The calculated EIRR value fulfils ADB's minimum criteria even though it is conservative, as there are a number of economic benefits that have not been quantified, such as tourism benefits, and reduced pollution leading to a cleaner city.

14.2 Recommendations

The following recommendations are made for making the development and facilitating smooth operations of the Inland water transport in the proposed waterway.

12. Vessels designed for running on shallow water depths and air draft are recommended to help reduce the dredging cost.
13. A shipyard facility should be created nearby Kolshet jetty location by taking government land on lease for maintenance and manufacturing of vessels.
14. Integration of facilities like approach road, parking, commercial area etc. should be planned for Jetty and intermodal hub (at Kolshet).
15. Considering a higher level of environmental protection and conservation, for incremental benefits, use of Liquefied Natural Gas (LNG) or Ethanol/Methanol operated vessels instead of diesel operated vessels is recommended. As the technology for electrical propulsion becomes available for smaller vessels, electrically operated ferries should be pressed into service.
16. Facilities for seaplanes should be created to accommodate future requirements of takeoff and landing at Nagla Bunder jetty site
17. Last mile connectivity should be considered as priority. Charging stations for battery operated feeder vehicles should be provided at terminals to improve last-mile connectivity.
18. For safe movement of vessels in the river/creek, traffic systems like River Information System (RIS) should be installed.
19. Solar Panels for the vessels and the terminals must be made mandatory.
20. Green fuels should be used in the vessels as far as practicable.
21. Clearance from 3 Wildlife Sanctuaries/National Park, namely Sanjay National Park, Tungareshwar WLS and Thane Flamingo WLS should be obtained in addition, to the clearance from CRZ and MoEF&CC authorities, being a Category A project.
22. A quick start to the project should be given by providing pre-fabricated structure with minimal civil works at Kolshet, Kalher, Parsik Bunder and Anjur Dive at an estimated cost of ₹ 981.16 Million, as per details given in section 12.2.

The Security deposit shall be refunded after completion of defect liability period prescribed for this contract.

Name of Work :- "APPOINTMENT OF CONSULTANT FOR CARRYING OUT DETAILED STUDY AND PREPARATION OF DETAILED PROJECT REPORT (DPR) FOR AN INLAND WATER TRANSPORT (IWT) IN CREEK CHANNELS CONNECTING VASAI VIRAR, MIRA-BHAYANDER, THANE, KALYAN-DOMBIVALI AND BHIWANDI MUNICIPAL CORPORATION AREAS IN MUMBAI METROPOLITAN REGION (MMR)"

APPENDIX- A

TERMS OF REFERENCE (TOR)

(SCOPE OF SERVICS)

1. The Consultant/JV will have to give a written notice of 30 (thirty) days prior to the date from which he wishes to discontinue / withdraw from the TMC work.
2. The right to drop the Consultant/JV from TMC work without assigning any reason at any point of time by giving 8 (eight) days notice what so over is reserved by Commissioner, Thane Municipal Corporation, Thane.

Scope of Work:

The Consultant/JV shall undertake the following activities as part of the project.

1. General

Transportation is an important gradient of infrastructure development. Along with road & rail transport, water based transport is an effective mode of transporting people and cargo. Inland Water Transport (IWT) is more sustainable, compared to other modes of transport, in view of its low operating cost and being environment friendly.

Inland waterways refer to rivers, canals, lakes, etc. with an overlap with coastal shipping, involving tidal rivers & creeks. Maharashtra has 35 creeks and rivers spread across 720 km. long coastal line. The State Government has recognized the importance of Inland Water Transport and has set-up multi-dimensional organisation structure to develop & operate various projects.

Rapid growth in Mumbai Metropolitan Region has resulted in increased pressure on existing infrastructural resources and is expected to grow in future. In view of this, an integrated multi-modal transportation system shall be an effective & sustainable solution. In view of the availability of various creeks, tidal rivers & coastal network, Inland Water Transport in Kalyan-Thane-Mumbai region, may offer a viable, cost effective & sustainable option.

Present Terms of Reference is prepared for carrying-out techno-commercial feasibility studies and preparation of Detailed Project Report (DPR) & Construction Design (Terminals) for the development of IWT in Thane-Mumbai region.

Route	**Vasai – Mira Bhayandar – Thane (Kolshet) (Ghodbundar Road – Saket – Deva) as Intracity transport system) – Dombivli – Kalyan - Bhiwandi**

Distance	Approx. 25 nautical miles
No. of Transport Hubs	1 (Kolshet, Thane)
No. of Jetties	8

2. Scope of Works

Scope of works shall include all material, labour, equipment, software, transport, office expenses, overheads, etc. for the identification of potential routes for carrying out techno-commercial feasibility studies and preparation of DPR for viable, cost effective and sustainable development of IWT and respective feasibility study. The scope shall also include the collection/study/analysis of all available secondary data/reports. Following fresh activities shall be performed for the feasibility studies:

A. Field Activities

Field activities shall include detailed hydrographic/bathymetric survey, topographic survey, traffic survey along the selected streams/creeks/tidal/stretches and would also include selection of terminal locations:

2.1 Traffic Studies & identification of Potential Routes

Scope shall include detailed traffic survey for the entire MMR based on industrial surveys. This shall be used for assessment of projected traffic at an interval of 5 years, upto 20 years from the present and the quantum of traffic of vessels/cargo on any particular route.

In order to develop Inland Waterway Transport as a part of integrated transportation system, mathematical models/traffic simulation studies covering the affected areas of proposed waterway, shall be developed to evaluate modal shift and the respective impacts on travel times and congestion in traffic as well as all modes. The model shall also cover zone-wise origin-destination interactions.

Potential routes shall be identified on the basis of zone-wise origin-destination interactions, to be covered in the model, cost benefit impact of waterway transport and any potential bottlenecks that might arise due to shift in demand & modal shares.

This survey shall be under-taken in conjunction with hydrographic surveys so that the costs of alternative proposals & their respective techno-economic feasibility can be taken into account while formulating the recommendations.

2.2 Hydrographic & Hydro-morphological survey

This shall include but not limited to the following:

2.2.1 Reference Benchmarks

MST - KEPL

The consultant shall obtain the details of existing benchmarks in the vicinity of the region from MMB or any other authority. These benchmarks shall be used as reference for horizontal/vertical control for the hydrographic/bathymetric survey.

2.2.2 Water Level Measurements

Water level measurements shall be done for non-tidal reaches of finalized streams. Scope shall include the fixing of water level gauges at every 10 km interval along the river and at upstream and downstream of any river structures, such as Dams, barrages, etc.

Water level observations shall be taken at 1 hr interval for 12 hours in a day (6 AM to 6 PM) for the entire duration of survey. The gauges are to be connected to nearest Bench Mark by levelling and its "zero level value" shall be established w.r.to MSL. At least 2 gauges (one U/s and one D/s at 10 Km apart) shall be read simultaneously and soundings to be carried out within the gauge stations. Soundings are to be reduced for zero of a gauge for 5km length of the river on both side of a gauge.

2.2.3 Bathymetric Survey

Bathymetric survey shall be carried out as per the prevailing International Standards for finding the potential of inland navigation. Major considerations shall be as follows:

a) The detailed hydrographic survey is to be carried out in WGS'84 datum.
b) The horizontal control shall be made using DGPS with minimum 24 hours observations at some platform/base.
c) The vertical control shall be established with respect to the chart datum / sounding datum.
d) Chart datum/sounding datum shall be determined from the following methods:-

   i) For tidal reaches - Chart datum/ sounding datum already established by Nearest Port Authorities (Chart Datum) and further inside the channel creek at every 10 Km by transfer of sounding datum method.
   ii) For non-tidal reaches – Average minimum water level of last years, as observed by Central Water Commission / State Irrigation Department at their gauge stations along the river.
   iii) Minimum water level observed during water level measurements at installed gauges, as per 2.2.1 above.
   iv) Standard method shall be adopted for transfer of datum.

e) To select the potential navigation channel complete creek survey shall be carried out with conducting Bathymetric survey for minimum 100 m. wide corridor at the centre of the proposed waterways, i.e. 50m width on both side from the centre line of the channel.

f) Cross-section sounding lines / levelling shall run from bank to bank at spacing of 50 m., to identify the navigable channel.

g) Continuous soundings are to be taken by running the sounding boat at constant speed along the cross-section so as to get smooth contours. Intermediate line is to be run at bends, if the line spacing is more than the specified above.

h) For cross-sectional bathymetric survey more than 60m in proposed Inland Waterways, spot levels at line spacing of 20m. Spot levels should also cover 20 m. length grid on both banks. If any island or sandchur exist in the middle of the waterway, spot levels on the same at the same spacing should also be taken and indicated in the charts along the same cross-section line.

i) The soundings are to be reduced to the chart datum/ sounding datum established at every gauge stations.

2.2.4 Velocity & Discharge Measurement

Velocity & discharge measurement shall be done as per the following:

a) Velocity shall be measured by current meter at every 10 km interval, once in a day during the survey period.

b) Current meter observations should be taken at 1m below water surface or 0.5d (if depth is less than 1m), where d is measured depth of water.

c) Measurements at different depths may be taken by single equipment over three different time spans.

d) Current velocity at different depth is to be measured for at least 25 hours or as per listed calibration period of the equipment.

e) Current velocity and discharge can also be measured with the help of ADCP (Acoustic Doppler Current Profilers) during survey, at every 10km interval. Discharge can be measured either by ADCP or standard formulas.

2.2.5 Water and Bottom Soil Tests

Water and soil samples are to be collected from bottom of the deepest route at every 10 km interval and are to be tested. Soil sample can be collected by a grab and water sample at 0.5d (d-measured depth of water) by any approved systems.

The following tests are to be performed for Bottom soil samples:

a) Grain size distribution
b) Specific gravity,
c) PH value
d) Cu, Cc
e) Percentage Clay silt

Water samples should be tested for Sediment concentration.

2.2.6 Topographical Features

All topographical features located in the survey area to be captured and presented in the survey charts & report. Details of various features are as follows:

a) Photographs of the prominent features along with its position.

b) Permanent structures located within this corridor are be indicated on the charts.

c) All prominent shore features (locks, bridges, aqueducts, survey pillars if available etc.) and other conspicuous objects to be fixed and location indicated on the chart

d) Cross structures, obstructing navigation to be identified.

e) Details (horizontal and vertical clearances above High Flood Level in non-tidal area and High Tide Level in tidal area) of bridges, aqueducts, electric lines, telephone lines, pipe lines, cables en-route to be included in the report along with their co-ordinates and location.

f) Details of water intake/ structures

g) Existing berthing place, jetty, ferry ghats, approach roads etc.

h) Detailed condition of the banks are also required to be collected along with protection details (pitched/protected or eroded). Estimated length of bank protection required for eroded banks to be included in the report.

i) Approachable roads / rails / places outside the corridor may be incorporated from Topo-sheets/Google Map/Google Earth.

2.2.7 Preparation of Survey Charts

Survey charts shall be prepared as per the following specifications:

a) Scale of the chart shall be as follows:

Waterway width	Scale
Less than 100 m.	1:1000
From 100 m. – 300 m.	1:2000
From 300 m. – 500 m.	1:5000
Above 500 m.	1:10000

b) Contours of 0m, 1m, 2m, 3 m, 5m and 10 m are to be indicated on the charts with respect to Chart Datum / Sounding Datum.

c) Spot level values are to be given w.r.t. Mean Sea Level (MSL) & Soundings w.r.t. Chart Datum / Sounding Datum. A separate file (xyz) (soft copy only) is also to be created for spot levels w.r.t. Chart Datum / Sounding Datum for dredging calculation purpose.

M/S K P L 119, HIMALAYA HOUSE PALTON ROAD MUMBAI-400001

d) On completion of the cross-sections, dredge channel for the proposed class of waterway shall be identified/ established by linking deepest soundings on the cross-sections. Dredging quantity is to be estimated accordingly.

e) Dredging quantity is to be indicated in the report for each km length of the waterway.

f) Minimum & maximum reduced depth and length of shoal for each km length of the waterway to be indicated in the report.

g) Shallow patches /shoal and submerged sand-chur having less than 1.0 m depth, rocky outcrops, rapids and other navigational impediments are to be indicated on the charts.

h) The charts shall also show all prominent land features from the Topo-sheets/site.

i) All raw data and processed data of Automatic Hydrographic Survey System are required to be submitted. Standard procedure is to be adopted for data processing. All RAW, EDIT, SORT and field data are required to be submitted by the Contractor.

j) All surveyed field data including levelling data (csv file) are required to be submitted.

k) All position data of ground features, waterway structures are to be submitted in both hard copies and soft copies.

B. Detailed Project Report

Based on the results of above survey & studies, the scope of studies shall be (but not limited) to carry-out the following details:

2.3 Waterway Development

2.3.1 Suggest the proposed Class of waterway in reference to IWAI (classification of inland waterways in India) Regulation 2006, for horizontal and vertical clearances for the cross structures such as bridges, cables etc.

2.3.2 Optimum dimension of the navigation channel which can be developed by undertaking river conservancy work (dredging, bandalling), river training, bank protection etc. Report shall include the requirement of dredging and bandalling (with details of calculation) for providing and maintaining navigation channel of the selected Class.

2.4 Terminals

2.4.1 Location for the terminals or jetties shall be decided on the basis of the selected potential routes, type of services envisaged and other considerations necessary for locating an IWT terminal/jetty. For each selected terminal, two alternative sites shall be studied, assigning first and second priorities.

2.4.2 Report shall also provide the details of land ownership etc. with source and supporting documents. Topographic survey for the terminal shall cover the complete land-side amenities and layout plan shall be prepared for all suggested locations clearly indicating all facilities e.g. jetty, approach to jetty, bank protection and travel related facilities, such as waiting areas, ticket sales counter, parking, luggage handling services, coffee shop, ATM, security of men &

material, etc. Details of bunkering facility, water facility, turning circle for IWT vessels location of depth contours of 2m and 2.5m in the river near the terminal sites etc. shall also be provided.

2.4.3 Preliminary engineering design, and drawings for setting up of terminals or jetties with related facilities including boarding/de-boarding of passengers. Further, the inter-modal transfer facilities, if required at any terminal, shall be indicated.

2.4.4 Geo-tech investigation is to be carried out as per standard guidelines if required at selected site.

2.4.5 Prepare cost schedule for modification improvement of cross-structures cables etc. if required.

2.4.6 River/Creek training/bank protection works particularly for those stretches where either the channel is narrow and needs to be widened by dredging or where it is anticipated that the bank may be erode due to continuous movement of vessels.

2.5 Navigational Aids

2.5.1 Sufficient details of the navigational aids, required for 24 hrs. navigation facilities including day marks, buoys with lights, lights on masts at banks, DGPS stations, etc., along with their drawings and numbers with justification.

2.5.2 Types of communication facilities required on the ferry/vessels etc.

2.6 Type of Ferries/Vessels

2.6.1 Suggestions for economical size of ferry/vessel for the proposed service as assessed as per traffic studies. Work out details of the type of vessels, their number and cost.

2.6.2 Cost of vessels shall not be included in the cost of development of the waterway, in case, it is proposed that the vessels shall be owned and operated by separate agency.

2.7 Other facilities

Suggest in adequate details, other required infrastructural facilities such as repair facilities, fuel and fresh water bunkering, channel patrol, security, enforcement of rules and regulations, pilotage, issue of navigation notices, navigation charts, warnings, rescue and salvage, pollution control measures etc.

2.8 To prepare preliminary engineering designs, the data about soil characteristics shall be collected from the local sources based on the structures constructed nearby. In addition, wherever required, consultant may obtain soil data through trial pits/plate load test etc. and preliminary design shall be based thereon.

2.9 To assess the environmental impacts due to these development works and suggest suitable environmental management plan (EMP) to mitigate the adverse impacts, if any, including its cost. All necessary information should be given in the report required for statutory environmental clearance from concerned authorities for undertaking the works proposed in the DPR, if so required.

2.10 To prepare cost estimates for the entire proposed infrastructure for the proposed route. The cost components shall include dredging, jetties, approach roads, inter-modal transport facility (if any), vessels and other allied facilities with proper justification that the suggested solution is the optimum one. In case, phase-wise implementation is proposed, cost estimate shall be prepared accordingly.

2.11 To provide estimated cost of annual recurring/maintenance works with sufficient basis/justification.

2.12 To prepare detailed time schedule for the whole project indicating the time requirement of the various components of the project from inception till commissioning. Suggestion shall also be given for executing the project in different phases with split up of the works and the costs thereto, traffic potential and EIRR/FIRR for each phase independently.

2.13 To study and recommend necessary project organizational structure and manpower required for execution of the project and its maintenance thereafter.

2.14 To study the existing freight and tariff structure for rail, road and IWT mode and recommend a suitable freight structure for IWT together with its basis and subsidies, if any, that may be necessary in the initial years.

2.15 Suggest user charges for using the waterway, terminals and other infrastructural facilities, which can be levied by the Authority on the operators/users without adversely affecting the commercial viability of IWT operations.

2.16 Workout Economic Internal Rate of Return (EIRR) considering the employment generation, fuel saving, saving in noise pollution and accidents, carbon credit which can be earned, savings in repair and maintenance of roads, saving in land acquisition etc. compared to road and railways for the projected traffic potential by IWT mode. Detailed working sheets should be given for this.

2.17 Workout Financial Internal Rate of Return (FIRR) for the following options:

a) For the operators – Considering the rate they can charge for transportation of the goods by inland vessels and the user charge they shall pay to the Authority.

b) For the Authority - Based on user charges proposed to be levied by Authority from the operators for use of waterway, terminal etc.

2.18 In order to develop Inland Waterway Transport as a part of integrated transportation system, mathematical models/traffic simulation studies covering the affected areas of proposed waterway, shall be developed to evaluate modal shift and the respective impacts on travel times and congestion in traffic as well as all modes. The model shall also cover zone-wise origin-destination interactions.

2.19 Detailed geotechnical investigations for various structures &components shall be carried out to establish the soil & rock strata along with their properties in sufficient detail for engineering and construction by using the organizations/Institutions/firms expert in the relevant field.

2.20 Geophysical survey (seismic) as dredging may be required, Geotechnical investigation (boreholes) to co-relate with seismic data and to design jetties and terminals.

2.21 Engineering and other allied studies shall be carried out to ensure that the benefits envisaged are sustainable over a long period besides quality aspects and operational requirements based on the Geotechnical Investigation.

2.22 The Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) report as a part of Detailed Project Report (DPR) shall be prepared considering all the relevant notifications issued by Minisby of Environment and Forest (MoEF) or any other competent authorities (viz. EIA notification, 2006 and subsequent notifications/amendments issued time to time) and in accordance to all the relevant guidelines issued by MoEF or any other competent authorities. The EIA report will be prepared considering all these notifications/guidelines required for obtaining Environmental Clearances from the regulatory/statutory authorities besides the requirement of Impact Assessment Agency (IAA) spelled out during the review of the EIA report. The study shall be carriedout in an integrated manner considering the impact of interlinking for both the connected basins.

As outlined in the notification cited above, Public hearing shall be carried out as per the requirements of the fulfillment of EIA notification as a part of consultation with civil society. Guidelines for EIA & EMP and Methodologies for data collection and monitoring as specified in the "Guidelines for Preparation of EIA and EMP" by MoEF Shall be followed.

ANNEXURE D

USER SURVEY QUESTIONNAIRE

1. Gender
   - Male
   - Female
2. Age Group
   - 10-20
   - 20-35
   - 35-50
   - 50+
3. Visited As
   - Group
   - Individual
4. Purpose of Visit
   - Office
   - Business
   - Shopping
   - Leisure
   - Others
5. Frequency of Visit
   - Daily
   - Weekly
   - Monthly
   - Occasionally
6. Mode Used to Reach Place
   - Train
   - Bus

- Auto
- Shared Auto
- Two Wheeler
- Car
- Walk
- Cycle

7. Time taken to reach
    - Upto 30min
    - 30min to 1 hour
    - 1-2 Hours
    - More than 2 Hours
8. Distance Travelled (in Km): …………
9. Rating of Transport Facility in the area
    - Excellent
    - Very Good
    - Good
    - Bad
    - Very Bad
10. Monthly Household Income(₹.)
    - <10000
    - 10000-25000
    - 25000-50000
    - >50000
11. If Inland Water Transport is provided as an alternative, would you use it?
    - Yes
    - No
12. Any other mode you would like to shift to?