Mormugao Port Trust

Techno-Economic Feasibility Study for the Proposed Capital Dredging of the Port for Navigation of Cape Size Vessels

Draft Report

December 2014

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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

GCZMA ....Goa Coastal Zone Management Authority

GIDC ....Goa Industrial Development Corporation

MLDB ....Main Lighting Distribution Board

MoEF ....Ministry of Environment and Forests

MoS..................Ministry of Shipping

GPCB ....Goa Pollution Control Board

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

OCIMF.............The Oil Companies International Marine Forum

PINAC .... Permanent International Association of Navigation Congress

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

SoI………………Survey of India

2 Proper names and organisations – Other

BA ....British Admiralty

BR ....Beckett Rankine

BS ....British Standard

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

1 Introduction

1.1 Background

Mormugao Port Trust (MPT) is strategically located to cater to the needs of the coal requirement of steel and power plants of its hinterland in Karnataka. The main user for MPT is currently JSW steel. JSW steel imports about 7 million tons of coal and exports about 1 million ton of finished steel products through MPT. However their coal requirement is in excess of 15 million tons and they have to depend on ports on the Eastern Coast like Krishnapatnam for coal imports despite the fact that MPT is closer to their steel plant situated at Toranagallu. Coal imports for JSW at MPT are carried out at Berth No.6 which is operated by South West Port Ltd, a group company of the JSW. Another Coal Berth No.7 has recently been made operational by Adani Port Terminal Ltd. which serves a number of users. Coal Importers stand to gain significantly in terms of freight benefit if imports are done through Capesize vessels. MPT, taking into account the growing competition from private ports and other Major Ports in the vicinity has decided to deepen the Approach Channel to suit the navigational requirements of Capesize vessels. The outer Channel which is presently dredged to -14.40 m is to be deepened to -19.80 m and the inner Channel from -14.10 m to -19.50 m. This will facilitate navigation of Capesize Vessels at any state of the tide. The apparent difference between the inner and outer channel depths are due to the fact that inner channel is calmer than the outer channel and hence the vertical motions of the vessels under the environmental conditions are far lesser than the outer channel.

Goa has large deposits of iron ore and at its peak in 2010-11, MPT exported about 40 million tons of iron ore with Panjim also exporting about 15 million tons during the same period. The iron ore exports came to a grinding halt after the ban on exports imposed by the Supreme Court in October 2012. The ban has now been relaxed. However, iron ore exports are yet to gain steam. Worldwide, iron ore prices have slumped. Since the iron ore markets continue to be depressed and also taking into account that iron ore exports are unlikely to achieve the former glory, exports of ore through Capesize vessels has not been considered in this report. Another aspect is that, Berth No.9 which is the dedicated iron ore berth cannot be deepened for Capesize vessels unless suitable strengthening of the jetty is undertaken. Hence at this stage the port is not contemplating to make any investment for strengthening of Berth No.9. Accordingly, Capesize vessels can be topped up at stream after partial loading at berth, a procedure which was earlier adopted.

MPT expects that substantial growth in coal traffic can be achieved if larger vessels can be serviced. However, a very big factor for MPT's growth is the doubling of the South Western Railway (SWR) network which is presently choked. The SWR has already awarded doubling for a part of this rail network.

Doubling of the rail network coupled with MPT's expansion plan will open up a lot of exciting opportunities for investments in the hinterland particularly for the steel sector and power sector.

1.2 Scope of Work

The scope of work of this work includes;

- Analysis of the available data and the data obtained from the field;
- Design of the Approach channel of the Port in light of the deepening
- Identify appropriate methodology of dredging and equipment for the soil encountered in the port
- Computation of the quantum of the Capital Dredging of the navigational channel, turning circle and the berth pockets.
- Block cost estimate based on the latest quotations received for similar work and Carry out financial analysis
- Synthesis of feasibility report based on collected data and available reports

1.3 Intent of the report

The purpose of this report is for the MPT, Goa to assess the suitability and the modalities for deepening the approach channel, Turning Circle and the other port areas in order to handle Cape Size carriers. These vessels provide the economy of scale and at today's prices, the differential works out to about USD $7.00 per ton of material handled through a Cape size vessel vis-à-vis a Panamax Vessel. Assuming the port handled a reasonable 20 million tons of cargo per annum, the saving works out to whopping USD 140 million or about INR 840 crores. This is substantial and may help recovering the cost of additional dredging in a year or two.

Accordingly, MPT, Goa is proposing to increase the depth in the channel so that the Cape Size vessel could use the same. This would have an added advantage that the efficiency of the port as whole would increase. With this in mind, this report is part of the two reports being currently prepared for ascertaining the technical as well as financial viability of the project. While WAPCOS India Limited, A Government of India Undertaking, has been entrusted to carry out the technical analysis and evaluation of the project, SBI Capitals are awarded the Job of preparing the financial evaluation of the project.

1.4 Format of the report

With the above objective, the report is arranged as follows:

Chapter 1: Introduction

Chapter 2: Site Condition

Chapter 3: Traffic forecast

Chapter 4: Site Investigations

Chapter 5: Shipping Trends

Chapter 6: Design of Channel

Chapter 7: Dredging Methodology and Plan

Chapter 8: Implementation Schedule

Chapter 9: Estimation of Dredging and Block Cost estimate

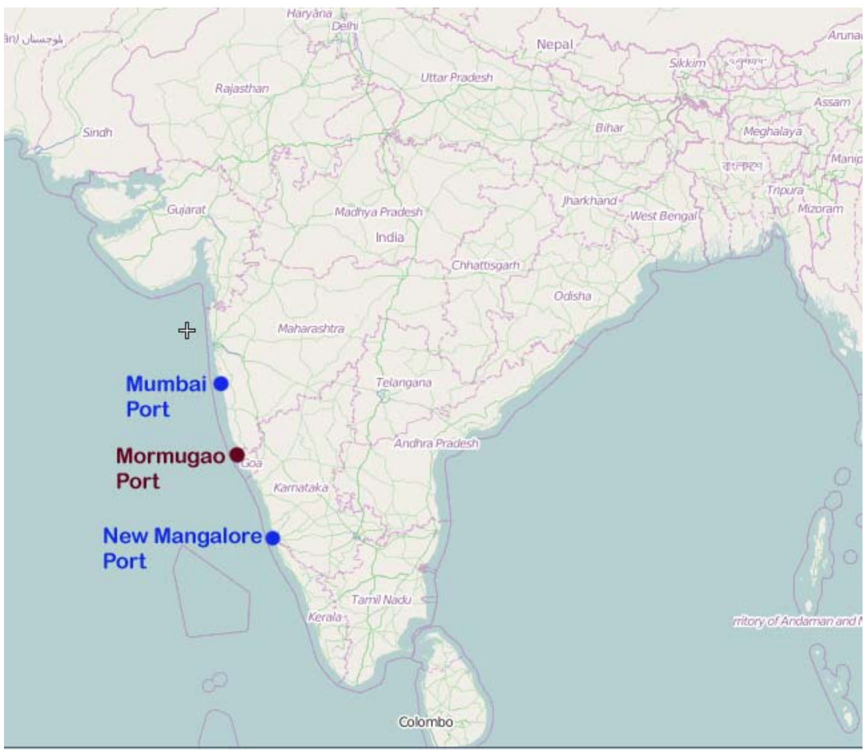
Chapter 10: Conclusions and Recommendations

2 Site Characteristics

2.1 Geographical Location

The port of Mormugao, one among the twelve major ports in India, is situated in the State of Goa, on the west coast of India, between the Major ports of Mumbai and New Mangalore. It is located at the mouth of the river Zuari at latitude 15^0 25' North and longitude 73^0 47' East. Mormugao is an open type natural harbour and has a natural promontory known as Mormugao Headland. The harbour is protected by a breakwater of 550 m long and a mole of 270 m long. The approach channel is about 6 km long.

Figure 2-1: Location of the Mormugao Port on the West Coast of India



This port was envisaged using the protruding headland which provides partial shelter from the SW winds and monsoonal waves.

The Harbour is fairly well protected and tranquil. In the monsoon season however, due to disturbed outer sea, the notified draft in the channel is reduced. This reduction is also attributable to the high rate of monsoon siltation due to the seasonal littoral drift.

Figure 2-2: Google Image of Mormugao Port

2.2 Topography and Bathymetry

The existing port stretches from the breakwater area to berth no. 11 close to the Vasco city. The proposed area to be developed is situated west of the existing breakwater. The only land available consists of the foreshore area. Immediately behind the foreshore area is the Headland slope. Towards the south is the approach channel. The land between the Headland slope and the approach channel has to be reclaimed to meet the necessary back up area requirement.

2.3 Oceanographic Data

2.3.1 Tides

The nature of tide prevailing at Mormugao is mainly semi-diurnal exhibiting two high and two low waters in a tidal day. The mean tidal variation is of the order of 1.6m at spring tide and around 0.7m at neap tides.

Based on Indian Naval Hydrographic Chart No. 2020, the tide levels with respect to chart datum at Mormugao Harbour are as follows.

Higher High water at Spring	+2.3 m
Mean Higher High Water (MHHW)	+1.9 m
Mean Lower High Water (MLHW)	+1.8 m
Mean Higher Low Water (MHLW)	+1 m
Mean Lower Low Water (MLLW)	+0.5 m
Mean Sea Level (MSL)	+1.3 m

2.3.2 Waves

A number of wave observations have been made at and around Mormugao harbour at different times, including both ship observations & those made from the shore and the measured wave heights by installing a wave rider buoy. Mormugao harbour on the Southern side where berths are located is protected by a breakwater and mole and generally it is the waves from directions between SW and NW that could affect the tranquillity in the harbour. The deep water waves from NW generally have a small % probability exceedence and do not affect harbour tranquillity significantly since their heights get reduced by the time they reach the harbour. Wave periods during the monsoons tend to be longer than during the rest of the year when NW winds prevail.

During the master plan study, HOWE India constructed the wave rose diagram from the visually observed wave heights during the period 1949 to 1962, from the area bounded by Latitude 10°N to 20°N and Longitude 70°E to 80°E. These wave analyses indicated that the yearly average probability of exceedence of the wave height of 2 m for the Westerly direction would be

Direction	**Exc. Hs = 2 m**
SW	4.7 %
W	4.5%
NW	0.4 %

Frederic R Harris (FRH) during their master plan study in 1997 carried out further additional wave climate analyses based on wave observations made during the period 1961-1980 bound by Latitude 13° N to 16°N and Longitude 70°E to 74°E and arrived at the following results for deep water wave climate and wave heights at harbour entrance;

Table 2-1: Deep Water Wave Climate

(Probability of exceedance in % of time)

HS =	1.0 m	2.0 m	3.0 m	4.0 m
SW	12.2	8.7	4.7	2.2
W	21.6	13.6	7.4	3.0
NW	8.4	2.0	0.6	0.2

Due to refraction, shoaling and breaking, the wave direction and wave height will change while travelling from deep water to the harbour entrance. Generally by refraction the waves from NW turn to WNW. Waves from W and NW reduce in height. All wave conditions higher than Hs = 4 m are reduced by wave breaking. The operational wave climate at the harbour entrance is presented here below;

Table 2-2: Operational Wave Climate at Harbour

(Probability of exceedance in % of time)

HS =	1.0 m	2.0 m	3.0 m	4.0 m
SW	12.2	8.7	4.7	2.2
W	21.6	13.6	7.4	3.0
NW	8.4	2.0	0.6	0.2

The extreme wave climate at the harbour entrance is as follows:

Frequency of occurrence	Hs
10/year	4.7 m

1/year	5.0 m
1/10 years	5.4 m
1/100 years	5.8 m

Extreme wave conditions at harbour entrance will occur mainly during the monsoon period. The period of the extreme waves varies between T = 7 S and 13 S.

2.3.3 Currents

The currents in the region outside the sheltered harbour have been found to be generally less than one knot, during fair season and are mainly caused by tidal ebb and flow. Within the sheltered harbour, indicated current strengths are of the order of 30 to 40 cm/sec. During heavy monsoon rains the current pattern is altered from that during the fair season but the current strengths do not get appreciably altered.

As a part of the field observations in Vasco bay, current observations were earlier taken at two locations (CM1 – 15° 26' 00"N, 73° 48' 18" E , CM2 – 15°24' 21"N, 73° 48' 42" E). A summary of the current measurements is given in Table 2.3.

Table 2-3: Current Measurements

	CM1 (Water depth, 7 m)			CM2 (Water depth, 3.5 m)
	Near surface	Mid depth	Near bottom	Near bottom
Maximum Speed (cm/sec)	68	31	29	57
Minimum Speed (cm/sec)	0	0	0	0
Predominant Direction	ESE _ WNW	ESE _ WNW	ESE - WNW	ESE

Measurements at open location (CM1) indicate that the predominant flow is in the ESE - WNW direction, while at the location (CM2) close to the shore, the predominant direction is ESE. The flow of currents is predominantly due to the tidal currents. During flood water, flow is towards Zuari River while during the ebbing, the reversal of flow takes place.

The maximum current velocity was observed as 68 cm /sec.

2.3.4 Wind

The mean sea wind varies from 2 on the Beaufort scale in November to 4 in July, the annual mean sea wind speed being 13.6 Kmph. In an average year, there are 316 days with wind varying between 0 to 3 on the Beaufort scale and 48 days with winds varying between 4 to 7 on the Beaufort scale.

The predominant wind direction changes with the time of the year. During the period June – September, wind blows from the west and south- west. During the remaining period, the wind direction is from NE, ESE during the evening. The highest speed is 105 km recorded in June 1994. Winds of force more than 10 on the Beaufort scale are not expected.

2.4 Meteorological and Oceanographic Conditions

The climate of Goa is moderate, with variations in temperature ranging between 16°C and 35°C. July to September is the months when monsoon lashes this state with good rainfall.

The current section illustrates the meteorological observations at the site location and its propensity towards rainfall, cyclone and visibility.

2.4.1 Temperature

The mean of the highest air temperature recorded in Panaji is 35^0 C in the months of March, April and May while the mean lowest is 20^0 C recorded in the month of January. Mean daily maximum and minimum temperatures are 31^0 C and 24^0 C respectively. Goa has a short winter season between mid-December and February. These months are marked by nights of around 21 C (70 F) and days of around 28°C (82°F) with moderate amounts of humidity. Further inland, due to altitudinal gradation, the nights are a few degrees cooler.

2.4.2 Rainfall

Goa features a tropical monsoon climate under the Köppen climate classification. Goa, being in the tropical zone and near the Arabian Sea, has a hot and humid climate for most of the year.

The average yearly rainfall is about 2926 mm, of which 2720 mm (93.66%) occur during June to September. Usually maximum average monthly rainfall of 709 mm occurs in July. There is practically no rainfall from December to April. Average rain fall days are around 92 days. June July are the maximum rainfall days.

2.4.3 Relative Humidity

Mean yearly relative humidity at 0830 hours is 77% while the same at 1730 hours is 71%. The monthly average is lowest in February (62%) and highest in July to September (85%).

2.4.4 Visibility

Sometimes mist develops during sunrise on the West Coast, above latitude 16° N, but disperses thereafter. Smog hangs over the land at Goa from November to March obscuring everything in view mostly after sunrise and occasionally in the evenings. However, the smog lasts only for short durations. Visibility is generally good for most part of the year.

2.5 Hydrographic Data

The general hydrographical characteristic of the harbour regions are available from a number of sources like Indian Naval Hydrographic Chart Nos. 214, 2020, 2022 & 2078 and the Admiralty Chart No.74 covering the Mormugao Harbour and its approaches.

As a part of the field investigations in Vasco Bay, hydrographic and seismic surveys were carried out during 6th to 10th November 2014, by Geo Star Surveys India Private Ltd. A brief summary of these investigations is enumerated bellow:

2.5.1 Bathymetry

The current bathymetry chart shows that in the outer channel the proposed dredge level of 19.8 m is available at a distance of 10 km away from the inner channel. And a depth of the order of 14 m exists at the entrance of the inner channel and towards the harbour basin and turning circle area the depth is reducing up to 13.1 m. A detailed discussion on the bathymetry is covered in the Chapter 4.

2.5.2 Seabed Features

The sea bed exhibits an even low to medium level of reflectivity, indicative of silty clays and sands, with a few patches of higher reflectivity indicating the presence of isolated highly weathered bed rock. In the outer channel, highly weathered bed rock patches are also seen above the dredging limit of 19.8m.

2.6 Existing Berthing Facilities

The physical features of the present berth facilities are summarized Table 2.4.

Table 2-4: Present Facilities

Berth No.	Length (m)	Dredge Depth (m)	Year of Construction	Type of cargo	Capacity Million Tons
Cruise Berth	450	9.50	2012	Cruise vessels	-
Mole Berth	250	9.50	2012	Non cargo vessels	-
1,2,3	-	9.00	1995	Ship repair facility	-
4	194	8.00	2012	Port crafts	-
5	200	14.10	2004	General Cargo	7.50
6	250	14.10	2004	Coal	
7	300	14.50	2014	Coal	-
8	298	13.10	1976	Liquid bulk	1.50
9	357	14.10	1978	Iron ore	11.50
10	250	13.10	1985	General cargo	2.65

11	270	13.10	1994		
Mooring Dolphins	6 no	14.10	2003-2011	Bulk Cargo	10.00

2.7 Existing Navigation Facilities

The Port of Mormugao has a 250 meter wide channel that is 5.2 kilometers long in the Outer Channel and 2.3 kilometers long in the Inner Channel. Channel depths range from 14.1 meters in the Inner Channel to 14.4 meters in the Outer Channel. Beyond Berth No. 9 (iron ore berth), the channel and mooring areas shoal to 13.1 meters.

Figure 2-3: MPT Navigation Chart

Source: Indian National Hydrographic Office Chart #IN4 2022

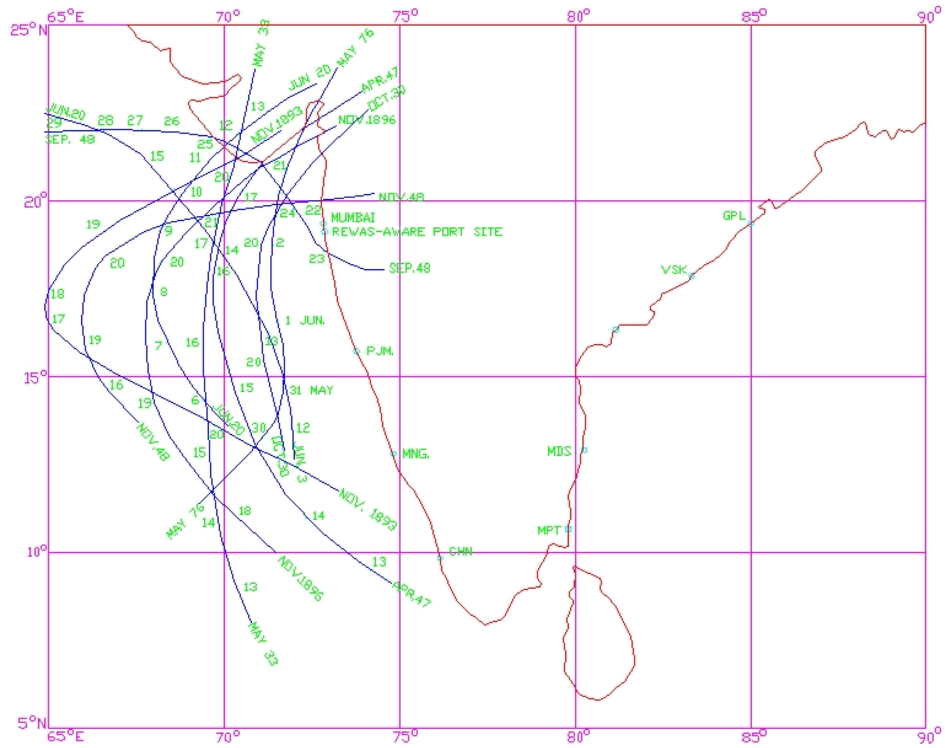
The maximum fully laden vessel draft that can be accommodated within the harbour at all stages of the tide is 13.4 meters allowing for under-keel clearances. However, vessels are sometimes loaded up to 14.1 meters draft, departing only on the high tide. In the region of Berth 10 and Berth 11, the design channel and turning basin depth is 13.1 meters.

2.7.1 Cyclone

In general the west coast of India is less prone to cyclonic storms compared to the east coast. From the information reported by India Meteorological Department (IMD) a total of 1034 disturbances occurred in the Bay of Bengal during the period 1891 to 1970 of which 363 intensified to cyclonic storms, the rest being 'depressions'. On an average the number of cyclonic disturbances per year during this period was about 13. However, if the data is updated to 1990, the number of cyclonic events per annum works out to be 16, varying from a minimum of 8 to a maximum of 18.

The above cyclones may be divided into two broad categories. The first group consists of cyclones that originate in the Bay of Bengal and cross the East coast at certain locations. These storms pass over the Indian landmass and lose their strength before crossing the West coast. The second group consists of cyclones that cross over to the Arabian Sea at the southern tip of the Indian Peninsula and veer northwards towards Saurashtra. These cyclones are much stronger and more dangerous for the west coast and normally occur during the transition months of May and November. Tracks of the cyclones in the Arabian Sea from 1877 to 1992 are presented in Figure 2.4. It may be seen there from that only 10 storms endangering the Mumbai coast have occurred in the above said period that is at a frequency of once in 12 years.

Figure 2-4: Storm tracks applicable for the region (Source IMD)



2.7.2 Sediment Transport

Unlike the East coast, the West coast exhibits very low rates of “Littoral Drift”. This is primarily due to the high tidal range, where the waves act on different parts of the flat offshore lower beach and the action on the beach above the high tide level are restricted to a very short time interval. Under such circumstances, it is difficult to discern the direction of the net drift as this is likely to change with local shoreline configuration.

2.8 Air Connectivity

Goa International Airport is a civil enclave at INS Hansa, a Naval airfield located at Dabolim near Vasco da Gama. The airport caters to scheduled domestic and international air services.

2.9 Road

Goa has four National Highways passing through it. NH-66 (ex NH-17) runs along India's west coast and links Goa to Mumbai in the north and Mangalore to the south. NH-4A running across the state connects the capital Panjim to Belgaum in east, linking Goa to cities in the Deccan. The NH-366 (ex NH-17A) connects NH-66 to Mormugao Port from Cortalim. The new NH-566 (ex NH-17B) is a four-lane highway connecting Mormugao Port to NH-66 at Verna via Dabolim Airport, primarily built to ease pressure on the NH-366 for traffic to Dabolim Airport and Vasco da Gama. NH-768 (ex NH-4A) links Panjim and Ponda to Belgaum and NH-4. Goa has a total of 224 km (139 mi) of national highways, 232 km (144 mi) of state highway and 815 km of district highway.

2.10 Rail

Goa has two rail lines — one run by the South Western Railway and the other by the Konkan Railway. The line run by the South Western Railway was built during the colonial era linking the port town of Vasco da Gama, Goa with Belgaum, Hubli, Karnataka via Margao. The Konkan Railway line, which was built during the 1990s, runs parallel to the coast connecting major cities on the western coast.

3 Traffic forecast

3.1 General

MPT has 7 cargo handling berths and 6 Mooring Dolphins. Berth-wise cargo and vessel details at Mormugao Port during the year 2013-14 are detailed in Table 3.1

Table 3-1: Cargo handled at various berths at MPT

Berth	Cargo	Capacity (MTPA)	No. of Vessels	Tonnage handled 2013-14	Average Parcel size 2013-14	Owned & Operated
Berth No.5	HR Coil, Steel slabs, steel plates	7.5	57	1083468	19008	SWPL
Berth No.6	Coking coal, R.P.Coke		106	7492222	70681	SWPL
Berth No.7	R.P.Coke	4.61	2	15992	7996	Adani Port Terminal
Berth No.8	Ammonia, C.Soda Liquids	1.50	78	552917	7089	MPT
Berth No.9	Granite, HR Coil	11.50	11	84996	7727	MPT
Berth No.10	Bauxite, Container Coils, granite woodchips, fertilizers etc.	2.65	84	752201	8955	MPT
Berth No.11	Bauxite, Container, Coils, granite, woodchips, fertilizers etc		80	985249	12316	MPT
Mooring Dolphins	Coal/ Pig iron	10.00	17	679326	39960	MPT

Cargo handled during the past 3 years through MPT is given in Table 3.2

Table 3-2: Cargo handled during the past 3 years at MPT

Sl.no.	Commodity	2011-12	2012-13	2013-14
	Exports			
1	Iron ore & pellets	29208319	7491518	196923
2	Bauxite	0	70397	153400
3	Containers	86569	110369	122062
4	C.P.Coke	20659	10185	0
5	Granite	53471	194160	364367
6	H.R.Coils	381255	787369	1204153
7	Iron & Steel	119270	12831	59746
8	Maize	0	27500	0
9	Pig Iron	0	0	271936
10	Sugar	0	0	60988
11	Wheat	0	31500	43713
12	POL	0	0	4623
9	Misc. Gen. Cargo	23582	2319	4811
	Total Export	29893125	8667751	2333322
	Imports			
10	Liquid Bulk	1363459	1032792	859889
11	Fertilisers	93495	77950	179478
12	Pet. Coke	163188	176943	347968

13	Met. Coke	192296	87325	0
14	C.P.Coke	0	152371	0
15	Coking Coal	5668863	6605889	7517587
16	Thermal Coal	1163116	767785	0
17	Containers	144230	147571	113567
18	Edible Oil	4970	5001	0
19	Wood Chips	0	0	386344
19	Misc. Gen. cargo	314721	16766	615
	Total Imports	9108338	9070393	9405448
	Total Traffic	39001463	17738144	11738770

From the above Tables it is evident that Coal and Coke is the main contributor to the traffic at MPT. It can also be seen that cargo volumes have reduced only on account of depletion in iron ore traffic. Coal imports show an increasing trend. SWPL has commissioned Rapid in Motion Silo facility in July 2014. Also Coal Berth No.7 operated by Adani Ports has become operational in June 2014. Adani Ports have also installed Rapid in Motion Wagon handling facility. Hence the coal traffic is set to rise further.

3.2 Assessment of the Traffic Potential Attributable to Deepening of the Harbour

Coking coal is mainly imported by steel plants located in the hinterland of the port. The traffic volume in respect of this cargo is dependent upon the capacity of steel plants, their production program and policy with regard to using imported coal. At Mormugao Port, during the last 5 years, there has been a steady increase in coal imports as can be seen from the Table 3.3. In the recent years the International Price for Iron Ore has gone down appreciably. This has made import of the Iron Ore at low prices to the Indian Sub-continent affordable. With Western Australian and Brazilian Iron Ore with higher Iron content has made the life of Steel makers' lot easier. Accordingly, berth 5 and 6 belonging to the JSW group is likely to see an increase in the import capacity of Iron Ore as well as Coal. Since both are similar type of cargo handling them with the same material handling systems would not be difficult.

Table 3-3: Coal Imported through Mormugao Port

Year	Qty in M.T.
2009-10	4.71
2010-11	6.56
2011-12	6.83
2012-13	7.38
2013-14	7.52

The main importer of coal through Mormugao Port is JSW Steel located at Toranangallu, Karnataka. There are other smaller players also for which coal is imported through Mormugao Port. Most of these steel companies are poised for major expansion and the demand for coal is set to go up in the near future.

In addition to steel plants, coal imports through Mormugao Port can also serve power plants which will come up in the hinterlands.

At present Coal meant for JSW are brought in gearless vessels of about 75,000 DWT. Coal importers stand to gain substantial freight advantage by deploying Capesize vessels. The deepening of the navigational channel will not only provide impetus for existing steel companies to increase their capacities, but also encourage new steel plants to come up. The Capesize ships will be in the region of 185,000 DWT.

One aspect that needs to be specially mentioned is the congestion in the South Western Railway Network. The SWR has taken up the doubling work. Once this is completed it will open up a whole lot of opportunities for the steel and power sector as coal transportation will become hassle free. However, even at this stage, the SWR has not set any timeframes for completion of the line doubling work. Hence, realistically, assuming that SWR takes up operational issues and minor modification works to augment the capacity of the lines, about 12 million tons of coal traffic would be possible within the next few years. This can gradually go up to 14 million tons.

As indicate above there will be mix of Iron Ore and coal in the JSW cargo projection hence the traffic projection should be nomenclature as Bulk cargo import rather than Coal import. In this it may be mentioned that the traffic projection would be rather conservative since inclusion of Iron ore in the imported cargo would increase the total import, weight wise per annum. However, for the purpose of this project, the following bulk traffic projections have been made as shown in Table 3.4, considering only coal imports.

Table 3-4: Coal Traffic Projection

2015	2016	2017-18	2019-20	2021-23	2024-2026	2027-2029
9.00	10.00	12.00	12.00	12.00	13.00	14.00

4 Field Investigations

4.1 Introduction

To proceed with the dredging activities site specific data / information was required to validate the present conditions. To gather site specific information / data, the following field studies / investigations were commenced:

1. Marine Geotechnical Investigation for Dredging
2. Geophysical Survey along Proposed Channel

4.2 Marine Geo-Technical Investigation

4.2.1 Introduction

The work for marine geotechnical investigation was awarded to M/s DBM Geotechnics and Construction Pvt. Ltd, Mumbai (DBM) vide work order QBD-12-JSW-MarineGeoInv-Mormugaon. The field work and laboratory tests were completed in May and June 2014.

4.2.2 Objective

The objective of the investigation was to complete a thorough assessment of the sea bed profile to finalize the dredging up to the required dredge level and also check the suitability of the dredge material for structural fill purposes.

4.2.3 Scope of Work

The following provide a brief on the agreed scope of work with M/s DBM

i. Complete 14 marine bore holes (MBH-1 to MBH-14)
ii. Conduct Standard Penetration Tests (SPT) tests at specified depths
iii. Obtain Undisturbed Soil Samples (UDS) in cohesive soils
iv. Conduct laboratory tests
v. Submit report

4.2.4 Location of Marine Bore Holes

The marine bore hole locations are tabulated below. The marine bore hole location map is also shown below the table for reference.

Table 4-1: Details of Bore hole Locations in the Port area

Bore Hole No.	Co-ordinates		Borehole Location	Bed Level CD (m)	Borehole Termination Level wrt CD (m)
	Northing	Easting			
MBH-01	1704881.30	370156.80	Break Water Area	(-)11.75	(-) 26.05
MBH-02	1705344.20	370865.10	Channel Area	(-)14.47	(-) 20.47
MBH-03	1705399.40	370550.10	Channel Area	(-)14.63	(-) 20.63
MBH-04	1705035.80	368931.50	Channel Area	(-)16.09	(-) 21.09
MBH-05	1705049.50	369292.30	Channel Area	(-)15.78	(-) 21.78
MBH-06	1705156.20	369594.60	Channel Area	(-)15.50	(-) 21.50
MBH-07	1705232.30	370137.70	Channel Area	(-)15.32	(-) 21.32
MBH-08	1705012.30	371160.10	Turning Circle	(-)16.02	(-) 22.02
MBH-09	1704673.10	371574.60	Turning Circle	(-)13.80	(-) 21.80
MBH-10	1704736.90	371025.80	Turning Circle	(-)15.45	(-) 21.45
MBH-11	1704459.80	371242.10	Turning Circle	(-)15.50	(-) 21.50
MBH-12	1704124.00	363442.00	Channel Area	(-)17.34	(-) 22.34
MBH-13	1704872.80	369376.20	Break Water Area	(-)12.25	(-) 20.60
MBH-14	1704715.50	369686.10	Break Water Area	(-)12.04	(-) 28.59

4.2.4.1 *Summary of Sub-surface Conditions*

The subsurface profile generally consists of marine deposits overlaying weathered bedrock. Encountered soil layers are described in detail below

i. LAYER I: MARINE DEPOSITS

LAYER IA: SAND/ SILTY SAND (Reference BH. No: MBH-01, MBH-04 MBH-05, MBH-06, MBH-12, MBH-13 & MBH-14)

Marine deposits, consisting of Sand or silty sand, were encountered directly at sea bed level in few boreholes. Based on Standard Penetration Tests (SPT) conducted in this layer, relative densities of the granular soils (silty sand), ranged between medium dense to very dense. Lower boundary of this sand layer ranged between -21.09m (wrt. CD) and -24.05m (CD) below bed level.

Figure 4-1: Location of Bore holes carried out for the Proposed Deepening of the Harbour

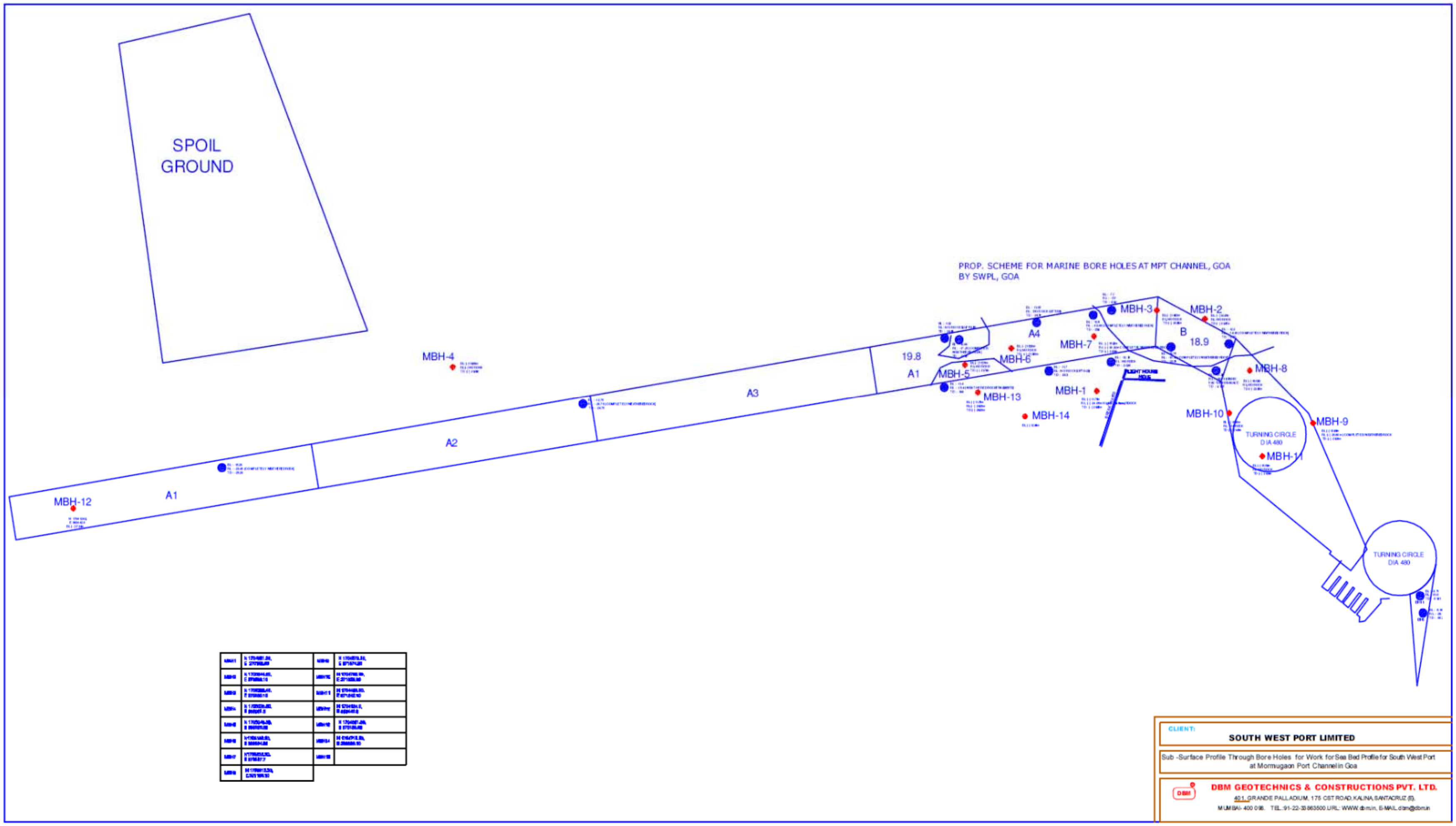

SPOIL GROUND
PROP. SCHEME FOR MARINE BORE HOLES AT MPT CHANNEL, GOA
BY SWPL, GOA
MBH-1
MBH-2
MBH-3
MBH-4
MBH-5
MBH-6
MBH-7
MBH-8
MBH-9
MBH-10
MBH-11
MBH-12
MBH-13
MBH-14
A1
A2
A3
A4
B
19.8
18.9
TURNING CIRCLE DIA 480
CLIENT:
SOUTH WEST PORT LIMITED
Sub -Surface Profile Through Bore Holes for Work for Sea Bed Profile for South West Port at Mormugao Port Channel in Goa
DBM GEOTECHNICS & CONSTRUCTIONS PVT. LTD.

Table 4-2: Details of Bore hole Locations in the Port area (IA)

Property	Layer IA Sand / Silty Sand
Classification	SP-SM/SM
R.L to Upper Boundary	-11.75m to -16.02m (wrt. CD)
R.L to Lower Boundary	-22.34m to -24.05m (wrt. CD)
Range of SPT N Value	29 to >50
Cohesion Cu (t/m²)	0
Friction angle (from SPT values) (degrees)	30° to 34°

ii. LAYER IB: SANDY CLAY/SILTY CLAY

(Reference BH. No: MBH-02, MBH-03, MBH-07, MBH-08, MBH-09, MBH-10 & MBH-11)

Marine deposits, consisting of silty Clay or sandy SILT, were encountered at the sea bed level in few boreholes. Based on Standard Penetration Tests (SPT) conducted in this layer, consistencies of the cohesive soil (clay) within this layer, ranged between soft to hard, generally improving with depth. The Boreholes were terminated in this layer at depths of - 20.47m (CD) and -21.78m (CD) below bed level.

Table 4-3: Details of Bore hole Locations in the Port area (Layer IB)

Property	Layer IB Sandy Clay / Silty Clay
Classification	CI/CH
R.L to Upper Boundary	-14.47m to -16.02m (wrt. CD)
R.L to Lower Boundary	-20.47m to -21.78m (wrt. CD)
Range of SPT N Value	9 to >50
Undrained cohesion (from SPT N-values) t/m²	6 to 32

iii. LAYER II: COMPLETELY WEATHERED ROCK

(Reference BH. No: MBH-1, MBH-7 MBH-9, MBH-13 &MBH-14)

Completely weathered bedrock was encountered in boreholes at depths between -19.32m (CD) and -26.54m (CD) below bed level. This layer is formed by the complete in-place disintegration of parent bedrock material, but still partially retains the original rock mass structure. Core Recoveries were less than 21%and Rock Quality Designations

(RQDs) were NIL. The Point Load index of rock samples are 2.22 kg/cm2. SPT tests encountered refusals. The lower boundary of the layer encountered at the depths between -21.32m (CD) and -28.59m (CD) below bed level.

Table 4-4: Details of Bore hole Locations in the Port area (Layer II)

Property	Layer II Completely Weathered Rock
Classification	CWR (Grade V)
R.L to Upper Boundary	-19.32m to -26.54m (wrt. CD)
R.L to Lower Boundary	-21.32m to -28.59m (wrt. CD)
SPT N Value	>50
Friction angle (from N values)	>40
Point Load Index kg/cm^2	2.22 to 7.23

4.2.5 Sea water Levels

Water heights at borehole locations were monitored during and after completion of drilling activities. Height of Water at borehole locations ranged between 11.80m and 17.10m above bed level. Significant tidal fluctuations were measured at each borehole location. Annual and seasonal fluctuations in water levels can be expected to occur.

4.2.6 Engineering Recommendations

(Reference Boreholes: MBH-02, MBH-03 MBH-04 MBH-05 MBH-06 MBH-07 MBH-08 MBH-09 MBH-10 MBH-11 and MBH-12).

Dredging is planned up to maximum level of -19.8m (CD) along the existing MPT channel to create deeper water for receiving vessels. Subsurface profile consists of marine deposits (silty Clay or silty Sand) up to planned dredge level. Any mechanical or hydraulic or cutter suction type dredging equipment is suitable for dredging the marine deposits.

Dredging in marine deposits will result in excavation side slopes on the order of 6:1 to 3:1(horizontal to vertical).The dredged marine clay soils are not suitable for use as structural or general-purpose fill or for reclamation purpose.

The purpose of these confirmatory boreholes was checking the soil profile and continuity of bed rock along the existing MPT channel where the dredging has to be done. Type of dredge material are given in the table below

Table 4-5: Details of Thickness of Material in Bore hole Locations in the different Port area

Bore Hole No.	Sea Bed level (m) wrt CD	Type of strata up to dredge level	Dredged Depth	Thickness of Dredged material	Completely Weathered rock level (m) wrt CD	Location
MBH-01	(-)11.75	Very dense silty sand	(-)19.8	8.05	(-)24.05	Break Water
MBH-02	(-)14.47	Very stiff silty clay/ sandy Silt	(-)19.8	5.33	Not Encountered	Channel Area
MBH-03	(-)14.63	Stiff silty Clay	(-)19.8	5.17	Not Encountered	
MBH-04	(-)16.09	Dense silty sand	(-)19.8	3.71	Not Encountered	
MBH-05	(-)15.78	Dense silty sand	(-)19.8	4.02	Not Encountered	
MBH-06	(-)15.50	Dense silty sand	(-)19.8	4.30	Not Encountered	
MBH-07	(-)15.32	Stiff silty clay	(-)19.8	4.48	(-)19.32	
MBH-08	(-)16.02	Stiff silty clay	(-)19.8	3.78	Not Encountered	Turning Circle
MBH-09	(-)13.80	Stiff silty clayY	(-)19.8	6.00	(-)20.80	
MBH-10	(-)15.45	Medium stiff silty clay	(-)19.8	4.35	Not Encountered	
MBH-11	(-)15.50	Medium stiff silty clay	(-)19.8	4.30	Not Encountered	
MBH-12	(-)17.34	Dense silty sand	(-)19.8	2.46	Not Encountered	Channel
MBH-13	(-)12.25	Very dense silty sand	(-)19.8	7.55	(-)18.60	Breakwater Area
MBH-14	(-)12.04	Very dense silty sand	(-)19.8	7.76	(-)26.54	

Further details such as bore logs, water level measurements and test results are shown in Annexure I.

4.3 Geophysical Survey

4.3.1 Introduction

The work for bathymetry and geophysical survey was awarded to M/s Geo-star Surveys India Private Ltd. The survey covers an area of approximately 11.5 km along the proposed channel and turning circle.

Suitable personnel and equipment were used to obtain, interpret and report on bathymetry, morphological and shallow stratigraphy within the survey corridors. DGPS positioning System, Single Beam Echo-Sounder, Side Scan Sonar and Sub-Bottom Profiler System were deployed for carrying out surveys. Side scan sonar was operated with range scale of 100m either side of survey line. Observed tides provided by the client were used to reduce raw water depth to chart datum.

The surveys were carried out between 06/11/2014 and 10/11/2014 from the vessel “PAPA DANIEL” and “M L VAILKANNI”. Quality control, processing and preliminary data interpretation were undertaken at the site and on-board the survey boat during the operations, ensuring that the survey specifications were fully met with.

4.3.2 Scope of Work

1. To carry out geophysical surveys along the proposed channel and turning circle of total length app. 11.5 km off Goa, West Coast of India.
2. Longitudinal survey lines were spaced at 50metres intervals and the transverse (cross) lines at 50metres intervals covering a total corridor of 500 metres along the proposed channel and a corridor of radius 600 metres at the Turning Circle.
3. Single-beam dual frequency echo sounder, side scan sonar and sub bottom profiler were to be deployed on all the survey lines.
4. Observed tides provided by the client to be used for reducing the row water depth to chart datum

The table below provides details of the survey area

Table 4-6: Details of the Survey Area

Channel Co-ordinates		
Datum WGS 84, CM 75, Zone 43		
Point	Easting	Northing
P1	360477.27	1703703.905
P2	370108.52	1705345.953
P3	371000.99	1705497.541
P4	371278.31	1705273.436
P5	372251.49	1704018.994
P6	371819.02	1703762.441
S1	360519.30	1703457.547
S2	369745.79	1705030.891
S3	370531.59	1705104.716
S4	370639.55	1705064.201
S5	370695.38	1705005.346
S6	370706.08	1704984.511
S7	370713.37	1704958.657
S8	370714.77	1704927.912
S9	370708.55	1704897.312
S10	370624.26	1704696.344
S11	370665.11	1704664.798

4.3.3 Summary of the Results

4.3.3.1 Bathymetry

KP's are assumed to start from the west corner of the survey area i.e. KP 0.00 and ends at KP 11.800 in the East part of the turning circle and Approach Channel. All water depths mentioned below refer to chart datum.

General bathymetry within the surveyed area presents a smooth seabed with a gentle slope towards west. Contours drawn at 1metre intervals are almost equidistantly placed and follow a general trend in East–West direction.

Minimum water depth recorded within the survey corridor is 6.4 metres recorded at near KP 9.315 on profile line no 1 and the maximum water depth of 22.0metres is recorded near KP 0.33 on profile line no 6.

Between KP 1.00–KP 3.00 maximum water depth of 22.0meters is recorded near KP 0.33 on profile line no 6 and minimum water depth of 17.2meters is recorded near KP 3 on south of profile line no 3. Between KP 3.00–KP 6.00 maximum water depth of 17.6meters is recorded near KP 3.00 on profile line no 5 and minimum water depth of 14.2meters is recorded near KP 5.718 on profile line no 1. Between KP 6.00 – KP 9.00 maximum water depth of 14.8meters is recorded near KP 6.00 on profile line no 4 and minimum water depth of 17.2meters is recorded near KP 8.640 on profile line no 2. Between KP 9.00 – KP 11.80 maximum water depth of 14.6meters is recorded near KP 9.00 on south of profile line no 4 and minimum water depth of 6.6meters is recorded near KP 10.865 on profile line no 1.

Water depth recorded at the centre of turning circle (Dia 600 and Dia 480) location is 13.5 meters and below chart datum.

No other bathymetric anomalies such as coral outcrops, sub marine channels, blow out craters etc were recorded at any point within the survey corridor.

4.3.3.2 Seabed Features

In general, Side scan sonar reveals a seabed with varying reflectivity as follows:

Type-1: Low To Medium Reflective Sediments (Unconsolidated silty clays occur between KP 0.0 and KP 5.5)

Type-2: Medium Reflective Sediments (Silty sands slightly admixed with clays occur as patches in the northern and southern parts of the survey corridor between KP 0.0 and KP 2.0, along the southern edges of between KP 6.0 and KP 10.5 and northern part of the survey corridor between KP 5.5 and KP 11.75)

Type-3 : Very high reflectivity (Very hard sediments / Highly weathered bedrock, occur 50 metres north of KP 8.6 of the channel corridor and along the southern edges of between KP 8.2 and KP 8.5)

Type-4: Disturbed seabed / Dredged areas (Occur all along the survey corridor between KP 5.5 and KP 11.8 except in the areas where the seabed sediments categorized as Type 2 sediments appear)

Other features recorded on the side scan sonar records between KP 0.0 and KP 5.5 are small and highly reflective patches interpreted as localized dense sandy sediments.

Some other linear features recorded within the survey corridor are anchor scars/drag marks which can be attributed to the fishing activities.

No major sonar contacts were recorded within the survey corridor. There are no pipelines or cables recorded within the survey corridor.

Apart from this no other significant features / items of debris were found within the survey corridor which could be hazardous to the proposed dredging operations.

4.3.3.3 Shallow Stratigraphy

The shallow sedimentary sequence within the surveyed area represents shallow marine fluvio-deltaic sedimentary environment. The stratigraphic sequences within the survey area indicate primarily Silty Clays underlain by sands with different densities admixed occasionally with clays / silts. Geological profiles have been produced for six longitudinal and ten transverse survey lines in such a way that they represent the whole surveyed area.

The shallow geological successions within the window examined by the analogue data within the surveyed area can be differentiated into essentially five units viz. Unit

Unit A

The shallowest of the sedimentary sequences identifiable within the survey corridor is designated Unit A and occurs all along the channel & turning circle survey corridor with a weak/discontinuous base, except between KP 6.0 and KP 9.0. From the available borehole information within the areas where this Unit A sediments are recorded, it is interpreted that this type of sediments comprise of unconsolidated Silty Clays. While this surficial unit occurs as a veneer with an undulating base in the eastern half of the survey corridor, thickness of these sediments increases with depth towards in the western half i.e, towards offshore.

Unit B

This unit occurs over the entire length of survey corridor between KP 0.0 and KP 9.0. Between KP 9.0 and KP 11.5, base of this unit could not be seen on the records and recorded as very weak/intermittent at places. From the available borehole information within the areas where these Unit B sediments are recorded it is interpreted that this unit comprises of horizontally & vertically varying Clays/Silts/Sands in varying densities & proportions. Internal diffractions at places within this unit also indicate the presence of gravels & pebbles.

This unit underlies Unit A sediments within major portion of the survey corridor and occurs on the seabed surface between KP 5.0 and KP 9.0 where Unit A sediments are absent. Base of this unit is not very strong, continuous or clear from the survey records in the eastern part of the survey corridor which is indicates that that the sediments of the unit lying below this unit do not comprise of any major changes in sediment strata except for a difference in the density & strength of the sediments.

Unit C

Underlying Unit B is Unit C. Medium to high acoustic impedance to the seismic energies with faint and scattered internal reflectors, similar to the overlying unit, indicates that the sediments of this unit do not comprise of any major changes in sediment strata except for a difference in the density & strength of the overlying sediments of Unit C and interpreted to comprise of horizontally & vertically varying stiff to hard Clays with varying proportions of Silts/Sands in varying densities. Base of this unit could not be deciphered clearly from the records due to seismic energies getting either absorbed or attenuated or scattered within these sediments there by inhibiting further delineation of the underlying layer.

Unit D

Underlying Unit C is Unit D. Since the surface of this unit is not identifiable from the records. However, with the help of available borehole information within the survey areas, it is represented in the geological profiles as an inferred reflector and is interpreted as an acoustic basement indicative of highly weathered/fractured bed rock.

4.3.3.4 Conclusion and Recommendation

General bathymetry presents a smooth seabed in major part of the survey corridor with a gentle slope towards west. Seabed undulations are recorded within the dredged areas in the turning circle. No other bathymetric anomalies were recorded at any point within the survey corridor.

Side scan sonar records present soft seabed sediments in the western half of the survey corridor and disturbed/dredged areas on the eastern half. No major sonar contacts were recorded within the survey corridor. There are no pipelines, cables or significant features / items of debris within the survey corridor which could be hazardous to the proposed dredging operations.

Shallow geology presents unconsolidated silty clays up to the dredging limits of 19.8 metres between KP 0.0 and KP 3.0. In the rest of the areas within the proposed channel & Turing Circle corridor, unconsolidated silty clays occur as a veneer with undulating base with a maximum thickness of 2 metres in a major part between KP 9.0 and KP 11.5 underlain by horizontally & vertically varying Clays/Silts/Sands in varying densities & proportions admixed with gravels & pebbles at places within the the dredging limits of 19.8 metres. However, with the help of available borehole information within the survey areas, two areas (about 150 metres diameter at KP 7.5 and the area between KP 9.36 and KP 9.95) within the proposed channel limits is interpreted as an acoustic basement indicative of highly weathered/fractured bed rock. Hence, it is recommended to carry out detailed geophysical survey at close grid spacing and borehole investigations within these areas prior to dredging operations.

Further details / data on Geo-Physical Surveys are shown in Annexure II.

5 Shipping Trends

5.1 Ship types and sizes

5.1.1 Bulk carriers for Iron ore and coal

Scatter diagrams of the global dry bulk carrier fleet indicate a spread across the following tonnage groups:

- Handy size : 15,000 to 35,000 DWT
- Handymax: 35,000 to 58,000 DWT
- Panamax : 60,000 to 80,000 DWT
- Capesize : 110,000 DWT and larger

Most Handy size and Handymax vessels are geared, i.e., they have on-board cranes to load and unload cargo. However, except for a very small number of Panamax bulk carriers, Panamax and Capesize bulk carriers do not have on-board cranes or other mechanical handling equipment for loading/discharging cargo or transhipping cargoes at sea. International fixtures are clustered in the ranges 45,000 t to 70,000 t (Handymax Panamax) and 120,000 to 150,000 t (Capesize). The following table shows the range of principal bulk carrier dimensions for 50% and 75% confidence limits:

Table 5-1: Typical bulk carrier dimensions

Ship type	Type	DWT range	Typical DWT	LoA (m)		Beam (m)		Max. draught (m)	
				50%	75%	50%	75%	50%	75%
Dry bulk carrier	Handy size	20,000- 40,000	30,000	176	181	26.1	27.0	10.3	10.6
	Handymax	40,000- 50,000	50,000	204	209	32.3	32.3	12.0	12.4
	Panamax	50,000- 80,000	70,000	224	231	32.3	32.3	13.3	13.7
	Aframax	105,000	100,000	249	255	42	43	13.5	13.8
	Capesize	100,000- 180,000	150,000	279	287	37.9	44.5	16.7	17.1
	VLBC	>180,000	200,000	303	311	47.0	48.7	18.2	18.6

Source: Permanent International Association of Navigation Congress (PIANC) Report of Working Group 33

Since there is a distinct cost advantage accrued due to the economy of scale of a larger carrier, only Cape Size vessels shall be considered for the purpose of this report. This carrier would be utilised for import of the entire bulk material of the port. Design bulk carrier sizes considered for Iron ore and coal traffic are as follows:

Table 5-2: Desgin ship dimensions for coal

Ship size	Capesize
Capacity	180,000 DWT
Length overall	287 m
Maximum beam	44.5 m
Full load draught	17.1 m

As indicated above, the vessel population generally follows a distribution, which could be fitted in to a standard distribution pattern. Coupled to this assumption, it is also true that the number of vessels belonging to the various categories would be difficult to assess at this moment. Therefore, the vessel mentioned in the Table 5.2 above would be considered as the design vessel for the purpose of this report.

5.1.2 Break Bulk and Steel Products

This cargo is generally obtained through costal shipping as well as international voyage and therefore the range of vessels widely varies. Mostly handled in vessels of 30,000 to 70,000 DWT vessels and for planning purposes the following vessel is assumed. For planning purpose 50,000 DWT vessels would be considered.

Table 5-3: Typical Lime stone ship sizes

Carrying capacity (DWT)	Length overall (m)	Beam (m)	Maximum draught (m)
30,000	193	27.8	11.9
40,000	211	30.2	13.0
50,000	224	32.3	13.5

5.1.3 Container

As far as MPT is concerned, the container volumes are not much and therefore this is a secondary container port. Only smaller carriers with drafts up to 12 to 13 m are expected to navigate this channel. This is not expected to determine the depth or the width of the approach channel.

5.2 Ship types and sizes

It could be seen that, as far as Mormugao port is concerned, the only commodity that will immediately be benefited from deepening of the port channel is Coal and/or Iron Ore, especially since there is a global shift in the transportation of the Iron in larger carriers. Accordingly, the maximum ship sizes for various commodities are given at Table 5.4.

Table 5-4: Recommended maximum Ship sizes

Sl.No	Cargo	Maximum ship size (in DWT)
1.	Break bulk cargo	50,000
2.	Containers (a) Main Line (b) Feeder	 8,000 TEUs 1500 TEUs
3	Iron Ore (a) Coastal traffic (b) International traffic	 65,000 150,000
4	Thermal coal (a) Coastal traffic (b) International traffic	 65,000 185,000
5	Coking coal	1,85,000
6	Crude Petroleum oil (a) Handled at SBMs (b) Sheltered terminals	 300,000 150,000
7	Petroleum products	60,000
8	LNG	67,500
9	LPG	40,000

10	Fertilisers and raw materials, other dry and liquid bulk and break bulk cargo	50,000

6 Channel of Approach Design

6.1 General

In this section the required dimensions of navigation channel are determined based on the accepted norms for the design vessel. The approach channel will be designed for vessels 1, 85,000 DWT. The environmental data as available MPT and the PIANC Guidelines and BSI codes have been considered to arrive at the recommended channel dimensions. The local navigator's views pertaining to constraints in navigation have been also considered.

6.2 Existing Harbour

The Features of the existing channel as follows:

Approach channel (from open sea to the tip of breakwater)

Length	- 6200 m
Width	- 250 m
Depth	- -14.40 m CD
Basin Area	
Length	- 2500 m
Width	- 220 m to 400 m
Depth	- -14.10 m CD

Turning circle No.1&2 of diameter 480 m and depth of – 14.10m and 13.10 CD respectively

6.3 Theoretically Desirable Channel Dimensions

6.3.1 Factors involved in Channel Design,

Basically the factors can be divided into three groups. The first group covers the inherent design characteristics of the ships. The other two groups consist of factors resulting from the effect of constrained water flowing past the hull form, causing certain behavioural characteristics, which will vary with the ship's design,

Those in Group A, being chosen at the design stage of the ship, and therefore are constant. Those in Group B will change during the ship's operation and so are termed as variable. While those in Group C, are beyond the ability of the ship to alter and therefore called external.

6.3.1.1 Group A – Fixed (related to Design Ships)

i. Fullness of the hull i.e. block co-efficient,
ii. Length to breadth ratio
iii. Breadth to maximum draught ratio
iv. Longitudinal radius of gyration
v. Position of the rudder(s) relative to the propeller(s)
vi. Type and area of the rudder(s)
vii. Position of the longitudinal centre of buoyancy

6.3.1.2 Group B – Variable (related to operation of ship)

i. Speed and propeller revolutions.
ii. Rudder activity
iii. Loaded state
iv. Trim

6.3.1.3 Group C – External (related to environment)

i. Currents and tides.
ii. Wind
iii. Waves and swell
iv. Navigational aids
v. Bank of the channel
vi. Water depth
vii. Level of cargo hazard
viii. Bottom surface of channel

ix. Human response

The understanding of likely ship behaviour in the navigation channel is essential to plan and design a navigation channel. To appreciate and predict ship behaviour it is necessary to understand ship motions which have six degrees of freedom i.e. pitch, heave, roll, sway, surge and yaw. Horizontal and vertical ship motion governs the channel design.

6.3.2 Horizontal Motions

Much of the research to date deals with the individual factors and most factors connected with ship manoeuvres were found to cause ship motion in the horizontal plane. Few research findings have resulted in quantified information suitable for application in the ports and much of it being of a qualitative nature.

Within the few research findings with objective recommendations considerable disparity existed probably due to the research methods employed and the non-consideration of scale effect in model tests. Also, in the past much of the work has been based on assumption that the ship behaves as if it were moving through an infinite sea, thus not reflecting the water flow phenomena of a restricted port approach channel.

The work to date may be assessed in terms of hydrodynamic and environmental factors, relating to the water flow effects imposed upon a ship within a restricted waterway.

The factors may be grouped under three broad headings, i.e. hydrodynamic, environmental and operational.

6.3.3 Hydrodynamic Factors

These may be described briefly as follows:

i. Ship lane or directional stability which is the width required to allow for the oscillating track produced by the ship maintaining its course.
ii. Bank suction, which is the clearance to allow between the hull and channel banks for the turning moment caused by the asymmetrical flow of water around the ship, attracting the stern of the ship towards the bank.

iii. Channel bend allowance, which is the additional width to accommodate the "sweep" of the ship's track, as it experiences a moment and sideways force while negotiating the bend.

iv. Ship to ship interaction causing yaw and course deviation to occur, thus requiring a minimum safe clearance between ships passes either in the opposite, or same direction.

v. Stopping and turning distances which vary with reduced under-keel clearances. In the case of turning distances, it is known that decreasing under-keel clearances will increase a ship's turning circle diameter dramatically.

6.3.4 Marine Environmental Factors

These environmental factors, however,, lend themselves more readily to quantification when their forces are constant. The effect of cross-current for example, causes a ship to "crab" along its chosen path and thus requires a width of track in excess of its beam. This is a well-known effect, and can be simply calculated as a relationship between ship and water current speeds.

The effect on ship depends on such factors as:

i. The ratio of wind speed to ship speed

ii. The direction of wind relative to ship's heading.

iii. Whether the ship is light or laden.

The resultant forces on a ship will thus have two main effects. Firstly, these will cause a turning moment requiring the ship to apply helm to counteract the drift, including a further "crabbing" effect similar to that for cross-currents.

A conventional ship with a single rudder normally has a maximum helm angle of 35" When considering the effect of wind or the maximum relative wind speed that can be tolerated in any given transit, thought must be given to the amount of helm angle that can be dedicated to counteracting wind. The amount needs to be balanced against the helm required by the ship handler for normal navigational control and course-keeping and for collision avoidance during a port transit. However, it should be noted that not only a suitably safe equilibrium helm angle must be considered, but also the response of the helmsman and steering system of the ship must be taken into account

6.3.5 Summation of Factors

If the relevant individual factors can be defined and quantified, it would then seem reasonable to combine them into what may be termed a "Total Beam Factor". Summation of all these factors showed err but on the side of safe provision. From this conclusion can be drawn regarding the required channel width for a given ship or conversely, the largest size of ship acceptable in a given channel. The Total Beam Factor will be greatest when the cross-current and wind are in the same direction, making their effects additive.

6.3.6 Vertical Motions

Any ship, if it is to stay afloat must be allowed a depth of water in excess of its static draught to cater for vertical motions, and this allowance for under-keel clearance for the large ships falls in the range of 9% to 15% of its static draught at most ports. However, it is a fact that at most of the ports accepting the large ships, although the individual factors may have been recognized and considered but these have not been objectively related to vertical motion.

The factors relevant for under-keel requirement are as follows:

i. Any ship speed and size, causing changes in trim and squat.

ii. The nature of channel e.g. the extent to which it is exposed to swell

iii. Changes in water density or salinity

iv. Extent of siltation.

v. The accuracy and frequency of dredging and hydrographic surveys.

vi. Operational factors such as inaccuracy of tidal height readings or unpredicted cuts in tidal height during the port transit.

vii. Nature of sea bed.

The above factors need to be considered while dredging the depth in channel and manoeuvring areas.

6.4 Channel Design

6.4.1 Methodology

The methodology adopted involves:

- Establishment of the design criteria with respect to vessel size and environmental conditions
- Assessment of the horizontal dimensions of navigation channel and manoeuvring areas.
- Assessment of the vertical dimensions of the navigational channel and manoeuvring areas.

Generally the navigational studies are carried out in two phases which are:

- Phase 1 – Concept design, based on desk study.
- Phase 2 – Detailed design based on a more elaborate evaluation which may utilize physical, mathematical and real time ship manoeuvring simulator studies.

In this report, only studies covered under Phase 1 have been carried out based on published data and technical literature (such as PIANC, BIS codes etc.) This phase-1 study gives fair estimate of channel width and depth and also the alignment for the channel.

The second phase of study when done will further optimize these parameters and add to the confidence of navigators which can be taken up at a later stage.

6.4.2 Design Vessel

The channel has been designed for 185,000 DWT bulk carriers. The typical dimensions of design vessels area as follows:

Table 6-1: Design Vessel

Vessel size (DWT)	Length (m)	Beam (m)	Draft (m)
1,85,000 (bulk carrier)	300	45.0	18.5

6.4.3 Channel Width

Navigation channel has been designed based on the two approaches

i. Theoretical, considering design vessel and oceanographic conditions and

ii. On the basis of operational constrains of vessel and oceanographic conditions.

The channel width is calculated on the basis of these two approaches and the larger value of channel width is adopted for the channel.

6.4.4 Width on the Basis of Theoretical Approach

A typical one way channel width would comprise of a basic manoeuvring lane, additional widths (to allow for the effects of wind, current, etc.) and bank clearance.

The factors considered in channel width design are:

i. Ship manoeuvrability
ii. Vessel speed
iii. Environmental factors like cross wind, current, waves etc.
iv. Aids to navigation
v. Type of cargo (hazardous or otherwise)
vi. Depth of channel
vii. Type of bottom surface
viii. Bank clearance

There are no rational formulae, which explicitly include all the above parameters to arrive at appropriate widths. The width of channel is expressed in multiple of beam of the design ship. The channel width is designed for one way traffic taking into account the characteristics of the design vessel. The navigational width is estimated using the PIANC

'Guidelines for Design of Approach Channels. Width provisions for various factors are calculated separately which are described hereunder:

6.4.4.1 *Width of Basic Manoeuvring Lane*

Moderate ship manoeuvrability, experienced pilots with ability of quick response in interpreting the visual cues indicating position and that of the ship in reacting to the rudder have been assumed

Basic width of manoeuvring lane equal to 1.5 times the beam of vessel (B) is considered.

6.4.4.2 Additional widths for straight channel sections due to effects of Environmental Factors

The factors and considered additional width for shore facilities are as follows:

a. Vessel speed

Vessel speed of 11 knots has been considered in approach channel and thus no additional width is proposed.

b. Cross winds

The prevailing cross wind is of the order of 25 knots, which is considered moderate and hence additional width of 04B for- approach channel is considered.

c. **Cross and longitudinal currents**

As per the recorded data, the maximum current is in the order of 1.00 knots. Hence an additional width of 1.0 B is considered.

d. Wave Height

Wave height in the approach channel is about 2 m. Hence an additional width of 1.0B has been considered.

e. **Bottom surface of channel**

An additional width of 0.1 B has been considered since the sea bed is considered smooth and soft.

f. Depth of waterway

An allowance of 0.4B has been considered assuming depth to draft ratio as less than 1.15.

g. Additional width for bank clearance

An allowance of 0.5B has been considered on either side of the channel. The width allowances for the design vessel as discussed under them above are summarized in Table 6.2 and the required channel widths in Table 6.3.

Table 6-2: Width Allowance for the channel

Sl.No.	Factors	Allowances
1	Manoeuvrability	1.5B
2	Speed	0
3	Cross wind	0.4B
4	Cross current	1.0B
5	Waves	1.0B
6	Bottom surface	0.1B
7	Depth	0.4B
8	Bank clearance	0.5B
	Total width	4.9B

Table 6-3: Theoritical channel width

Design Vessel Size	Approach channel width
185,000 DWT	206m

At present the approach channel has a width of 250m which is adequate.

6.4.5 Depth of Channel

For the determination of the required depths in the navigation channel and the manoeuvring areas, the methodology as described earlier is used and various parameters are superimposed to arrive at the design depths.

6.4.5.1 Vertical ship motions due to waves

Waves cause a ship to pitch, roll and heave. Wave climate in the region is generally mild except during cyclones. The limiting wave height is taken as 2.5 m in outer channel. The half wave height has been considered for fixing channel depths.

6.4.5.2 Net under keel clearance

There is no hard and fast rule to calculate the UKC. As per BIS recommendation (IS 4651 Part V) an allowance of 0.60 to 0.75 m is given when the channel bed is soft. and 1.0 m when the channel bottom is hard.

6.4.5.3 Squat

Squat is estimated by using CORELS equation as under:

Squat (m) = 2.4

Where, V = Volume of displacement in m^3

$= C_B L_{pp.}\ B \times Df$

F = Froude Depth Number

V = Speed of vessel in metre/ second

h = Water depth in metres

g = acceleration due to gravity = 9.81 m/Sec2

L_{pp}= Length of ship between perpendiculars

B = Beam of ship

D_f= Draft of ship

C_B= Block coefficient

6.4.5.4 Tidal Variation

Tidal variation is of the order of 1 m. If this' advantage is taken the vessel navigation will not be throughout the tidal cycle. Therefore considering vessel, navigation throughout the tidal cycle tidal variation advantage has not been taken.

6.4.5.5 Trim

As per the conservative practice, the trim at the stern is taken as 15 mm for every 10 m length of vessel.

6.4.5.6 Dredging Tolerance

In addition to the advance maintenance dredging an additional 0.2m below the selected dredging depth is generally provided as a dredging pay item because of the inability to dredge at uniform depth with a fluctuating water surface.

6.4.5.7 Proposed Depth

The proposed depth of the channel has been arrived at as follows.

Draft for 185,000 DWT vessels	- 18.50 m
Under keel clearance	- 1.30 m
Total depth required	- 19.80 m.

Hence the depth for the approach channel will be -19.80 m CD. The inner channel and turning circle no.1 will be dredged to -19.50 m CD.

7 Dredging Plan for Deepening of the Port

7.1 General

Generally the navigational studies are carried out in two phases which are:

- Phase 1 – Concept design, based on desk study.
- Phase 2 – Detailed design based on a more elaborate evaluation which may utilize physical, mathematical and real time ship manoeuvring simulator studies.

Based on the phase 1 studies carried out by MPT, and design vessel size of 1,85,000 (bulk carrier) having length = 300m, beam = 45 m, draft = 15.8m, the proposed depth of the channel has been arrived at and as follows.

Draft for 1, 85,000 DWT vessels	-	18.50m
Under keel clearance	-	1.3 m
Total required depth	-	19.80m

Hence the depth for the approach channel will be -19.80 m CD. The inner channel and the turning circle no. 1 will be dredged to -19.50 m CD.

7.2 Dredging Plan

In this section a dredging plan has been prepared considering the various available equipment and site conditions. The dredging quantities for deepening the approach and entrance channel and manoeuvring areas have been estimated on the basis of recommended dimension of channel. The maintenance dredging requirement is also discussed.

The characteristics of the soil strata in the dredging channel is as follows

7.2.1 Outer channel

- Top layer composed of unconsolidated silty / sandy clay with silt and sand content increases with depth.
- Next layer is medium to dense and very dense silty fine to medium sand.

- Weathered to hard rock is seen in a few places.

7.2.2 Inner channel and Turning circles

- The top layer consists of unconsolidated silty / sandy clay
- Next layer is stiff to hard silty clay
- Rock layer is present below the dredging limit of 19.5 m

Since the presence of rock is found in the navigational channel area, apart from normal dredging, controlled under water drilling and blasting techniques are required to be carried out.

7.2.3 Dredgers

There are various types of dredging equipment available for executing capital dredging works. These include the following;

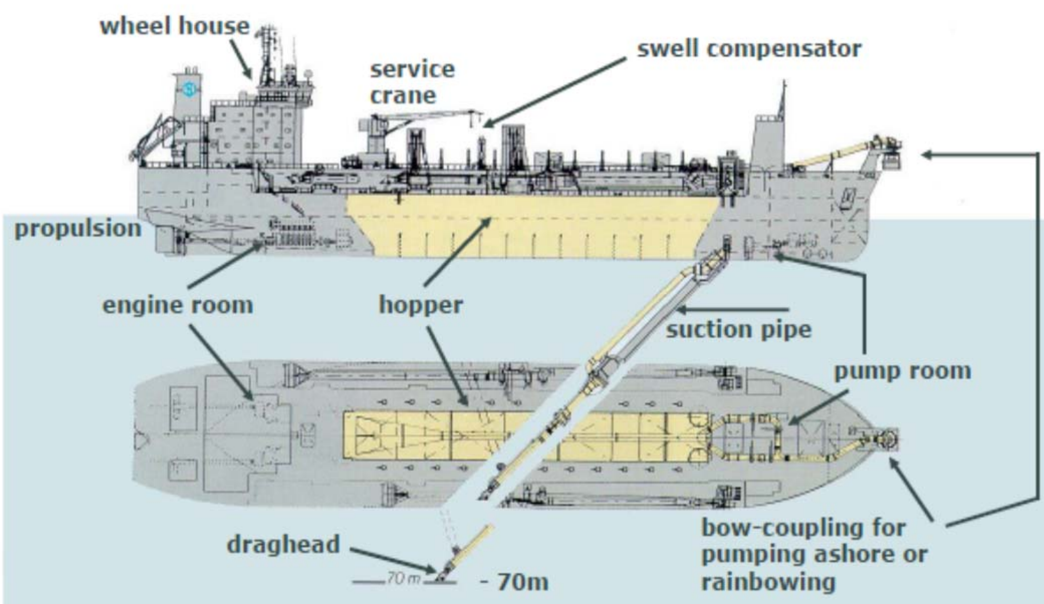
- Trailer Suction Hopper Dredger (TSHD)
- Cutter Suction Dredger (CSD)
- Bucket Dredger
- Grab / Clamshell Dredger
- Backhoe Dredger

The most common type of dredgers used for large scale works are TSHD and CSD. It is proposed to deploy this equipment at Mormugao Port to carry out the dredging work. The features of these dredgers are discussed hereunder;

7.2.3.1 Trailer Suction Hopper Dredger (TSHD)

The TSHD is a sea-going self-propelled vessel which is equipped with trailing suction heads provided on the sides of the vessel which can be lowered to the sea bed. The suction pipes terminate at the lower end in a drag head which is provided to draw the maximum amount of sea bed material and discharge it into a hopper in the vessel. The TSHD is a very versatile dredging unit. This equipment is most suitable for deployment in busy navigational channels. It can dredge material varying from sand, silt gravel and soft to medium clay. It can work in exposed conditions with wave heights up to 3 m. The material dredged can be used for reclamation either by pumping through pipelines or rain-bowing technique. Typical details of trailer suction hopper dredger are shown in Fig 7.1.

Figure 7-1: Typical details of TSHD



7.2.3.2 *Cutter Suction Dredger (CSD)*

The CSD comprises a rotating cutter head mounted at the end of a suction pipe and connected to a dredging pump in the main body of the dredger. The dredger pivots around a spud located at the rear of the dredger by using a system of anchor wires and winches. The cutter head cuts the material on seabed and then the material is sucked up through the suction pipe by the dredger pump and discharged through a pipeline. The CSD can dredge a variety of different type of soils, including clay, silt, sand and weak rocks. It is sensitive to wave conditions and can operate for significant wave conditions up to 1 m. Hence deployment of CSD at Mormugao Port should be during fair weather seasons when the sea is relatively calm. A Cutter suction dredger is shown in Fig 7.2.

Figure 7-2: Typical cutter suction Dredger

7.2.4 Choice of Dredger for Mormugao Port

Major part of the dredging work can be accomplished by deployment of the TSHD. However, there could be some stiff clay and rock patches for which a CSD can be deployed. Hence for the dredging project, a CSD and TSHD will be deployed. But CSD being a stationary type of dredger, if lots of shipping activities are going on it will affect the vessel traffic.

7.2.5 Methodology

The analysis of sea bed using seismic profiling studies by M/s Geo Star Surveys India Private Ltd. and some of the data on boreholes indicated that in the inner channel the sea bed is composed of silty and sandy clay layer which is followed by medium to dense and stiff clay mixed with gravels and pebbles. In the outer channel loose and unconsolidated clay forms the top layer and below that stiff to dense silty / clayey sand is found. Some patches of weathered rock were also seen in the outer channel. By taking sections at 200 m interval and assuming side slope of 1 in 4 and by using trapezoidal and prismoidal formula, the capital dredging quantity has been worked out. The capital dredging quantity works out to be approximately 15 million meter cube.

It is proposed to dredge this quantity using combination of Trailing Suction Hopper Dredger and Cutter suction dredger. The proposed dumping ground as per CWPRS studies is located at 14 kms away from the breakwater head at 27 m depth contour on 1 km north from the offshore end of the approach channel. Assuming a dredger speed of 10 Knots and filling of hopper requiring half an hour, one dredging cycle can be completed in 3 hours (filling half an hour + travel time of one and a half hour to and fro to the dumping ground +emptying of hopper of half an hour). Hence in a day approximately 50000 cum will be disposed off. Hence for completing capital dredging of 15 million cum, approximately 10 months is required.

As the dredging operations will be progressed in offshore area, the time for dredging cycle will be reduced. Some patches of weathered rock have also been noticed. The quantity of hard rock is approximately 0.142 million cum. Hence it is proposed to remove the hard by means of drilling and controlled under water blasting. The loosened rock fragments will be removed by using Backhoe dredger.

7.2.6 Dredging of rocks

For dredging in highly weathered rock area, controlled rock blasting is required. The fragmented rocks can be removed using a Backhoe dredger. Backhoe dredging involves dredging by mechanical means from a stationary platform and loading to attendant barges. A typical backhoe dredger is shown in Fig 7.3.

Figure 7-3: Typical backhoe dredger

7.3 Disposal of Dredged Spoil

The dredge spoil can be used for reclamation of the area west of the breakwater where MPT is proposing for its future development. If this does not materialize, the dredge spoil will have to be disposed of in the offshore disposal area. CWPRS has carried out hydrodynamic studies and dispersion studies for finding out a suitable location in offshore to dispose of the dredged material. As per CWPRS recommendations a disposal area of 2 X 2 km, located at a distance of 1 km north from the intersection of the centre line of the outer approach channel with the -20 m contour at a depth of about -27 m CD. The location of the disposal area is show in Fig 7.4.

7.4 Capital Dredging Volumes

The total capital dredging calculated for enabling navigation of Vessels in the channel is given in Table 7.1.

7.5 Maintenance Dredging

Desk studies were undertaken by CWPRS to estimate maintenance dredging in the approach channel. Knowledge of velocity field outside the channel, suspended sediment concentration and fall velocity of the sediment will help in computation of likely siltation. The flow field in offshore area is at right angles to the approach channel. The flood velocity is northerly and the ebb velocity is southerly. Assuming continuity equation at right angles to the approach channel, there will be reduction in flow velocity due to deepening of approach channel. Hence the carrying capacity of the flow will be reduced. The trapping of sediment can be computed by the knowledge of velocity field and the fall velocity. In order to account for turbulence due to wave action and other factors some empirical constant is required which can be estimated from earlier maintenance dredging data. The estimated quantity of maintenance dredging works out to 6 million cum per annum.

Table 7-1: Quantity of Dredging required for the MPT channel

Sr.no	Description	Design Depth m	Tolerance m	Dredged Quantity M^3	Tolerance Quantity (M^3)	Total Quantity (M^3)	
Quantity Upto Berth 5A & 6A (SWPL)							
1	Berthing Pocket (492M)	19.8	0.3	163098	15498	20.1	178596
2	Inner Channel (up to Berth no.6)	19.5	0.3	3085432	173440	19.8	3258872
3	Outer Channel	19.8	0.3	10261819	768861	20.1	11030680
Total				13510349	957799	14468148 (14.5Mil CBM)	
Quantity Upto Berth 5A, 6A (SWPL)& 7 (ADANI)							
1	Berthing Pocket (758 M)	19.8	0.3	251277	23877	20.1	275154
2	Inner channel (up to Berth 7)	19.5	0.3	3894964.8	217966.1	19.8	4112931
3	Outer Channel	19.8	0.3	10261819	768861	20.1	11030680
Total				14408061	1010704	15418765 (15.4 Million m^3)	

Note: Highly Weathered Bedrock expected in Outer channel at Two locations and Quantity is 1,25,000 CBM, has been included in the Outer Channel Quantity

8 Project Implementation Schedule

8.1 Introduction

Project Implementation schedule is a techno-economic process and must be planned judiciously in order to achieve overall economy and efficiency. It must be recognised that construction of a project would precede careful planning, and pre engineering, so that, the dredging activity could proceed without any hindrance. The following sections would define the activities and the milestones involved in the implementation of the project.

8.2 Basic Considerations for Implementation

The Project Implementation Schedule has been accordingly prepared and indicated in Table 9.1 for the project implementation.

Table 8-1: Project implement dates for Phase – I (existing facility)

Sr.	Activities	Duration	Year
1	Request for Qualification	0	5th January, 2015
2	Feasibility and EIA Report	0.5	20th January, 2015
3	Request of Proposal	5	20th May, 2015
4	EIA Clearance	5	20th May, 2015
5	Commencement of Dredging	8	20th August, 2015
6	Completion of Dredging	11	20th November , 2014

8.3 Pre-Development Activities

The pre development activities in the Public Private Participation Projects would involve MPT floating a Request for Qualification (RFQ) document to short list bidders wishing to participate in the Bid. Concurrently technical feasibility document and Concession Agreement consisting of financial statements and project evaluation statement would be prepared. While the technical feasibility report is being prepared by WAPCOS India Limited, A Government of India undertaking, and the Concession Agreement is being prepared by SBI Capitals. These documents along with the Request for Proposal document would be issued to the shortlisted bidders. The bids would be received and evaluated and the successful bidder shall be issued the concession for dredging of the channel.

Another big land mark for the project would be the required environmental clearance for the project, for which the Terms of Reference has been issued.

The various broad activities in the pre-development phase are as follows.

Technical Closure (Preparation of FR etc.)	- 1 months
Financial Closure	- 4 months
Identification of lending agencies,	
Project appraisal by Financial Institutions	
Application and clearances	- 8 months
Tendering Process	- 3 months
Dredging activity	- 8 months

8.3.1 Technical Closure

Technical closure of the project means the completion of all the studies and reporting including the detail engineering and drawings.

8.3.2 Financial Closure

Financial closure is part of the Feasibility Report and the Document prepared by SBI Capital would include detailed cost estimate, financial model, financial evaluation and financing. This process also includes identification of the lending agencies and project appraisal by the lending agency selected.

8.3.3 Tendering Process

The tendering process for the project would be carried out is stages in different small packages. Initially tendering would be carried out for the civil works such as Breakwater/embankment and dredging. The tendering process for the other works would be taken up in stages based on the need and as indicated in the Project Schedule chart.

8.3.4 Application to for clearances

Construction of any kind would require clearances from multiple agencies such as;

- State Pollution Control Board
- State coastal zone regulatory authorities
- Ministry of Environment and Forest

The reporting and the clearance process would take almost 8 months and the process has already commenced.

8.4 Development Activities

8.4.1 Dredging

- **Dredging - 4.5 months**
  - ❖ Mobilization - 1 months
  - ❖ Dredging - 3 months
  - ❖ Demobilization - 0.5 months

8.5 Commencement of Project

The project commencement would include testing and commissioning of the facilities and obtaining permission from statutory Authorities for starting of the commercial operation.

9 Cost Estimates and Financial Analysis

9.1 Cost Estimates for Capital Dredging

9.1.1 Basis of Cost Estimates

An estimate of the capital cost for the proposed capital dredging is made. The cost arrived at are based on the budgetary quotes and in house database available on cost estimates. The rates for dredging work have been prepared on the basis of current rates prevailing in major ports in India. Most of the rates were taken based on the recent dredging activities of similar proportions being undertaken at the JSW Jaigarh Port. The detailed Bills of Quantities is given in Table 9.1.

9.1.2 Dredging Cost Estimates

The dredging estimates include quantities for approach channel, turning circle, berth pockets and harbour basin. The details for dredging are presented in the Figure 9.1.

9.1.3 Maintenance Dredging

In general the maintenance dredging is about 10 % of the Capital dredging quantity. However, in order to accurately determine the quantity of the maintenance dredging, mathematical model study was carried out at CWPRS Pune. The finding of the model study including the dispersal ground is enclosed separately as Annexure III.

As per the computations about 6 million m^3 of maintenance dredging would be required after the deepening of the channel and the port basin.

It may also be remembered that the existing maintenance dredging quantities is about 3 million m^3.

Table 9-1: Capital Cost Estimate for the Dredging of the MPT Port for Cape Size Vessel Navigation

Sl. No.	Description	Details as Per Work order			
		Qty.	Unit	Rate (in Rs.)	Amount (in Rs.)
1	Mobilization:				
1A	Mobilization of 35000CBM TSHD or Similar capacity to commence its operation from specific date after providing reasonable proof of movement of the dredger to Mormugao Port	1	LS	160,000,000	160,000,000
1B	Mobilization of CSD or BHD to commence its operations to dredge hard patches from specific date after providing reasonable proof from the movement of the dredger to JSW Mormugao Port.	1	LS	90,000,000	90,000,000
2	De-mobilization of aforesaid Dredging equipment.	1	LS		
3	Dredging in all soils in the outer channel from the existing sea bed (-) 16.5m CD average to (-)20.1m CD including 0.3m vertical tolerance, to the width and side slopes 1:4 as per lines and levels of the drawing and as directed by the Engineer. The dumping of the spoil in the designated area beyond -27m contour i.e. 7.5NM distance approximately towards 1km North side of the approach channel.	10,850,000	cu.m.	175.00	1,898,750,000
4	Dredging of all soils in the inner channel, Turning Circle, Berth Approaches and berth pocket from the existing sea bed [approx. (-) 14.3 m C.D average to (-) 19.8 m C.D. including 0.3m vertical tolerance, (for berth pocket (-)20.1 including 0.3m vertical tolerance) to the width and side slopes 1:4 as per lines and levels of the drawing and as directed by the Engineer and dumping the spoil in the designated area beyond -27m contour i.e. 7.5NM distance approximately towards 1km North side of the approach channel.	4,000,000	cu.m.	145.00	580,000,000
5	Dredging of decomposed and highly weathered rock below -19.0 to -19.6m average CD in two patches at outer channel area to be dredged up to (-) 20.1 m CD including 0.3m vertical and 1m horizontal tolerances.	150,000	Cu.M	1,800.00	270,000,000
	Total In INR	15,000,000			2,998,750,000

10 Conclusions and recommendations

10.1 Conclusions

MPT one of the thriving major ports on the west coast of India, has recently lost its business substantially due to the closure of the Iron Ore mines in the State of Goa. In order coming back to stream and regain its old lustre one of the activities that is planned is the deepening of the Channel to enable navigation of Cape Size Vessels. This would enable effecting economy of scale and therefore would reduce the sea freight rates, attracting port users to use the port and save effective costs of logistics. The process would be carried out through PPP route. It is expected that the 14.5 million m3 of Dredging shall be completed in 3 to 4 months employing high capacity TSHD and CSHDs. Back hoe dredger may be deployed for soft rock dredging.

Required field investigations have been carried out at site and the estimation of the quality and quantity of the dredged material has been worked out based on those data. Model studies have been carried out for determining the disposal ground and the tranquillity inside the harbour, which shows positive result, and indicates no loss of tranquillity due to the deepening of the channel.

10.2 Recommendations

The identified dumping ground east of the existing dumping ground should be used for dumping. Otherwise there would be a chance of dredged sand moving back to the approach channel. The channel should be suitably buoyed in the deep waters.

ANNEXURE – I

Geo-Technical Study Report

ANNEXURE – II

Geo-Physical, Side Scan And Bathymetry Study Report

ANNEXURE – III

Mathematical Model Study