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NATIONAL CENTRE FOR COASTAL RESEARCH (NCCR)

&

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES (INCOIS)

MINISTRY OF EARTH SCIENCES

GOVERNMENT OF INDIA

IMPACT OF BREAKWATERS AND TRANSPORT CARRIER ON THE EROSION/ACCRETION FOR THE VADHAVAN PORT, MAHARASHTRA

Submitted to

JAWAHARLAL NEHRU PORT AUTHORITY

GOVERNMENT OF INDIA

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1. INTRODUCTION

The Government of India (GOI) has proposed to develop a major Greenfield, all-weather port at Vadhavan through a joint venture between Jawaharlal Nehru Port (JNP) working under the Ministry of Surface Transport, GOI and Maharashtra Maritime Board (MMB) of the Government of Maharashtra (GoM). The location of the proposed port is 19 55.8" N, 72" 39.6' E in Dahanu Taluka, Palghar district of Maharashtra state and is about 110 km North of Mumbai. It has been proposed to develop this port offshore of the headland at Vadhavan and the port limit extends up to 26 m depth below CD in the deeper part of the Arabian Sea. The Northern limit of the proposed Vadhavan Port is on the southern side of the entrance to the Dahanu creek while the southern limit is about 3 km southward from Vadhavan Headland. The port will have an entrance through the navigational channel from the Arabian Sea.

The proposal was amended and submitted to MoEF & CC infra-I MoM of the 324th meeting. It was recommended by the committee that additional studies on the impact of the breakwaters and transportation on erosion and accretion be taken up by the National Centre for Coastal Research (NCCR). Accordingly, JNPA approached NCCR to take up shoreline change and morphology studies for the study area. In this regard, NCCR has prepared this report based on the previous studies carried out for this project with secondary data available at the project site.

2. SCOPE

The objectives of the present study are to analyze the impact of breakwaters and transport carrier on erosion/accretion for Vadhavan Port, Maharasthra.

The scope of this work includes:

1. Review of the reports submitted by JNPA on this project.
2. Shoreline change analysis for the proposed port of Vadhavan based on the shoreline change atlas prepared by NCCR for the Indian coast.
3. Impact analysis of breakwaters on erosion/accretion by suitable means, if any.

3. STUDY AREA

The location of the proposed port is 19 55.8" N, 72" 39.6' E in Dahanu Taluka, Palghar district of Maharashtra state, and is about 110 km North of Mumbai. It has been proposed to develop this port offshore of the headland at Vadhavan and the port limit extends up to 26 m depth below CD in the deeper part of the Arabian Sea. The Northern limit of the proposed Vadhavan Port is on the southern side of the Dahanu Creek entrance while the southern limit is about 3 km southward from Vadhavan Headland.

4. SUMMARY OF STUDIES RELEVANT TO SHORELINE

The details pertaining to the various studies carried out were received vide ref. to letter dated 30.05.2023 and the following assessment has been made herewith.

STUDY REPORT	INSTITUTE	REMARKS
Mathematical Model Studies for Assessment of Wave Tranquility for the development of modified Final Layout for the Proposed port at Vadhavan, Maharashtra	CWPRS, Pune	Wave tranquility
Mathematical model studies for tidal hydrodynamics and siltation for the revised layout of Phase-I and Master Plan for Port at Vadhavan	CWPRS, Pune	Circulation pattern and siltation in the port basin
Assessment and evaluation of the impact of setting up of Port on the overall ecology of the Dahanu taluka	NCSCM, Chennai	Shoreline change assessment
Mathematical model studies for shoreline changes for the development of the proposed port at Vadhavan, Maharashtra	CWPRS, Pune	Evolution and shoreline morphology

4.1 WAVE TRANQUILITY

Wave tranquillity studies for the final master plan layout was carried out using MIKE. Wave height has been propagated from deep water to -24 m water depth using MIKE -SW and then propagated into the port area using the MIKE-BW model.

The hydrodynamic parameters adopted indicate an offshore maximum wave height (at -60 m depth) of 4.5 m with SSW, SW, WSW, W, WNW, and NW as the predominant direction with 55% of the wave from the West for the duration of January and December. The significant wave height of 2.5m (West Direction) is observed at -24 m water depth with W, WNW, and NW as the predominant direction (Figure 4.1.2). The tidal data adopted indicates the highest water level (HWL) of 5.5 m as per the feasibility study report. The bathymetry in the model is presented in Figure 4.1.1.

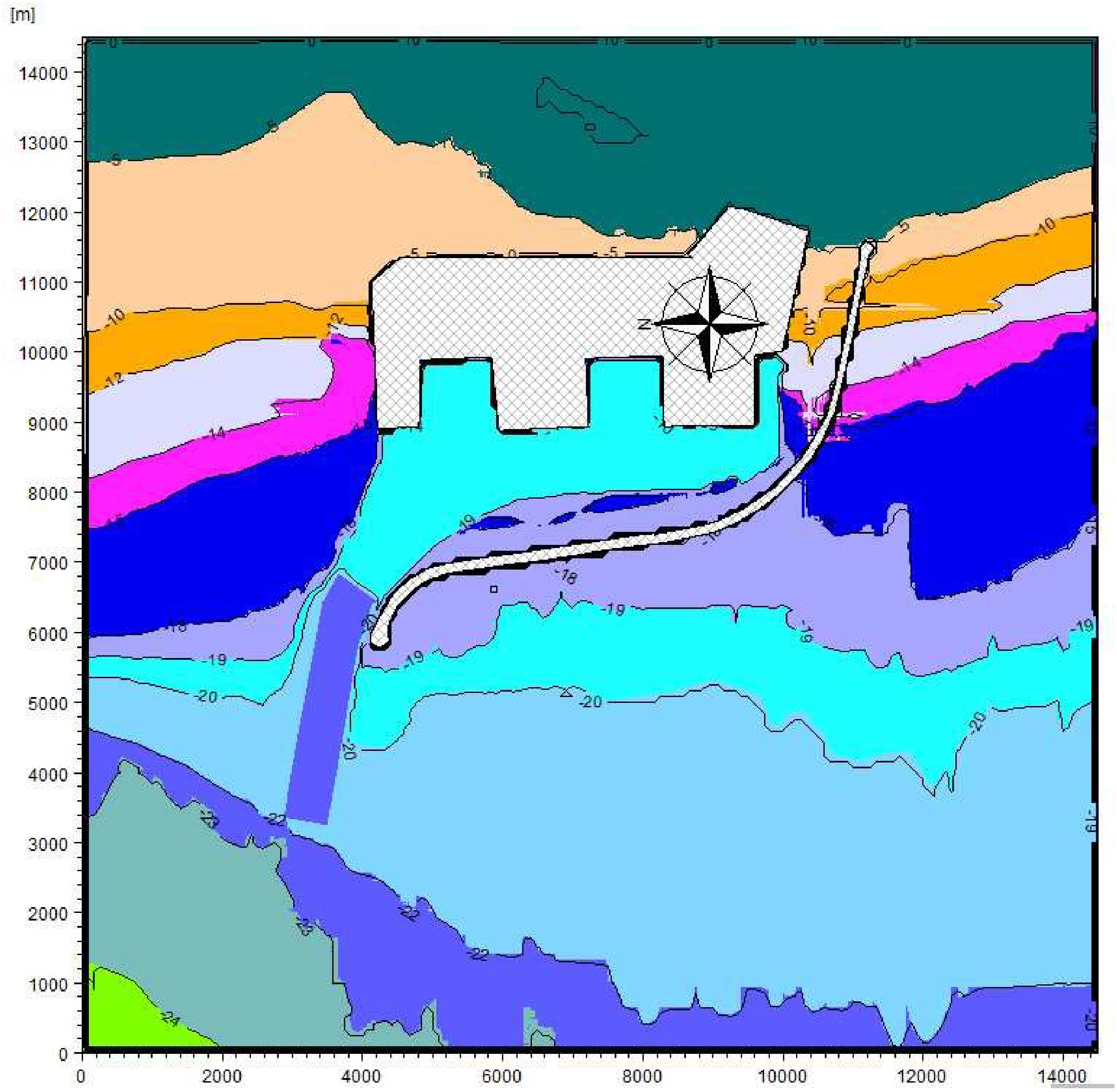
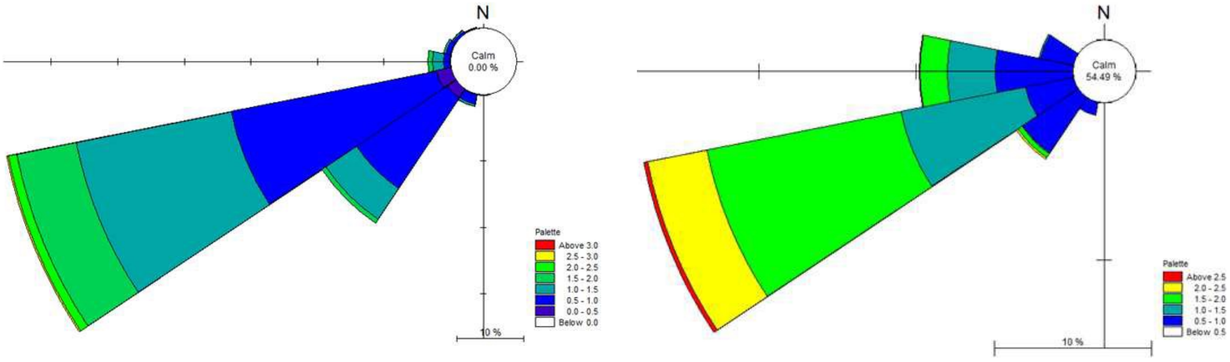


Figure 4.1.1: Bathymetry for the model



(a) UKOMO data at -60 m depth

(b) Modeled wave rose at -24 m depth

Figure 4.1.2 Wave Rose for model studies

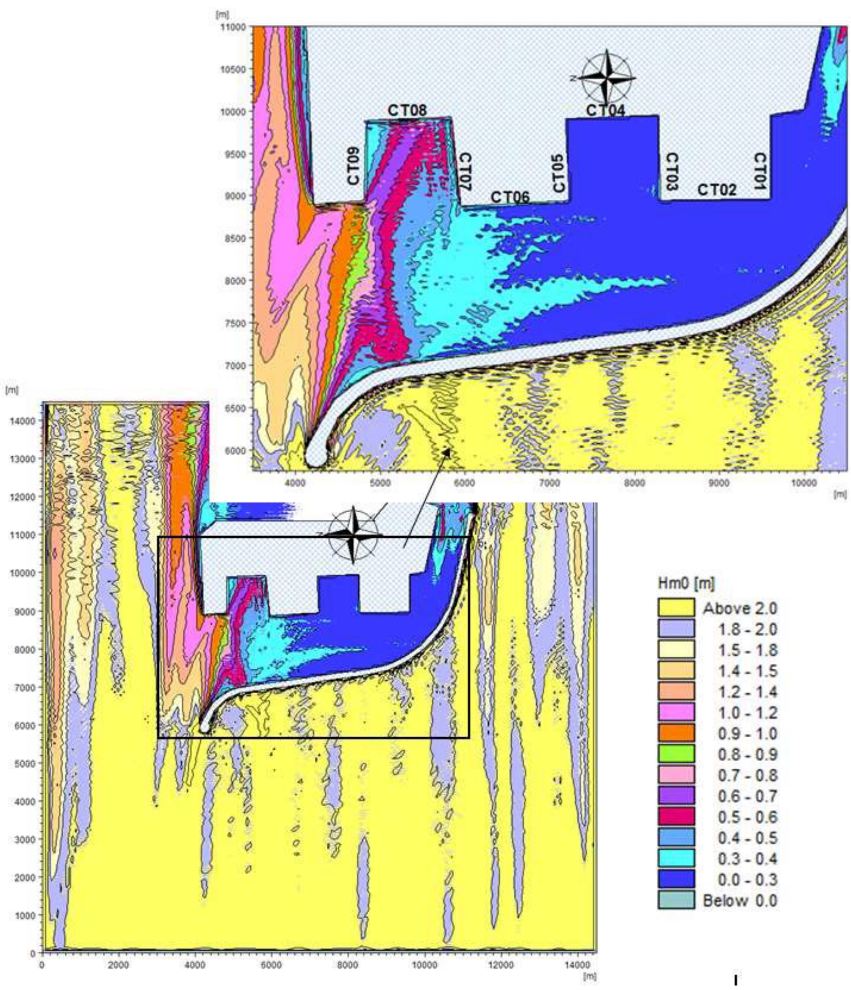


Figure 4.1.3: Wave transformation from West Direction

The nearshore wave transformation inside the port near the berths have been carried using MIKE 21 BW model with the SW model output as input. This study adopted a permissible wave height of 0.65 m near berths and 1 m in the turning circles.

The nearshore wave transformation indicates a maximum significant wave height of 1 m with a peak wave period of 10 seconds when the wave direction is NW with the wave height slightly higher than the limiting wave height of 0.7 m in the WNW direction wave at CT08. All the other observed wave data are within the limits (Table 1). The wave transformation in the west direction is represented in Figure 4.1.3.

Table 4.1.1: Significant wave height for Final Modified Master Plan Layout

Wave direction/ Wave height	Average Significant Wave height (m) at Jetties								
	CT01	CT02	CT03	CT04	CT05	CT06	CT07	CT08	CT09
270 (West)/2.5m	0.25	0.25	0.25	0.28	0.30	0.35	0.63	0.60	0.40
292.5 (WNW)/1.5m	0.20	0.30	0.30	0.25	0.25	0.45	0.65	0.70	0.40
315 (NW)/1.5m	0.20	0.30	0.30	0.25	0.25	0.65	0.95	0.50	0.30
Peak wave period T_p: 10 sec									

The study suggests a tranquil condition inside the port basin and also since the breakwater is constructed offshore, blockage of sediments along the coast cannot be anticipated. However, there could be a possibility of the formation of a salient behind and south of the proposed port, which needs to be monitored.

4.2. TIDAL HYDRODYNAMICS AND SILTATION

The final Master Plan and Phase I layout was finalized after detailed study and modifications by the expert committee. The plan has undergone detailed modifications ranging from changing of breakwater length, placement of current deflecting wall, placement of berths, and area of reclamation land.

The oceanographic data used for the purpose of mathematical model study includes; the monsoon (September- October 2020) and non-monsoon (January- February 2017) period. The maximum tidal range is about 5.87m during spring tide and 2.1m during neap tide. The current direction with respect to the North varies between 3^0 – 23^0 and 204^0 – 215^0 during the flood and neap tides respectively during the non-monsoon season and varies between 16^0 – 23^0 and 203^0 – 210^0 during the flood and neap tides respectively at monsoon season. The maximum significant wave height is 1.19m during the non-monsoon season and the waves approach from the N-W quadrant whereas it is 2.3 m and waves approach from the SW-WNW quadrant during the monsoon season. Suspended Sediment Concentration (SSC) indicated 380 mg/lit – 170 mg/lit for non-monsoon season and 473 mg/lit – 105 mg/lit for monsoon season. The grain size analysis observed the presence of 58% of silt and 26% of clay in the study area.

The mathematical model studies were carried out using TELEMAC software covering areas of the proposed port extending from Gholvad in the North and Nandgaon in the South and up to a depth of 30m in the West.

A revised master plan inclusive with the breakwater of length 10.3 km, offshore reclamation, and dredging footprint viz. proposed reclamation area (offshore 1262 Ha. & Shore connected 222 Ha) with 1210 Ha of the dredged area was finalized as shown in figure 4.2.1. The location of various berths as in the finalized Master Plan is given in Figure 4.2.2. From the hydrodynamic and siltation studies, it was confirmed that the tidal flow conditions are suitable at all container berths and manoeuvring areas and also consider the width between the breakwater and multipurpose berth to 670m.

The hydrodynamic and siltation studies of this Master Plan were carried out and it was observed that the maximum current strengths at the container are within 0.15 m/s. The flow approaches at an angle varying between 4^0 and 7^0 along oil berths and LPG terminals. With these flow conditions, it was reported that the currents would bypass the sediments to the North of the proposed port. The total quantum of likely siltation in the dredged areas will be about 8.45 million cum per annum as per the siltation studies. With the advised maintenance dredging of 6.45 million cum for phase I, a volume of 0.15 Mm^3 from this maintenance dredging can be used for beach nourishment to the immediate North of the port.

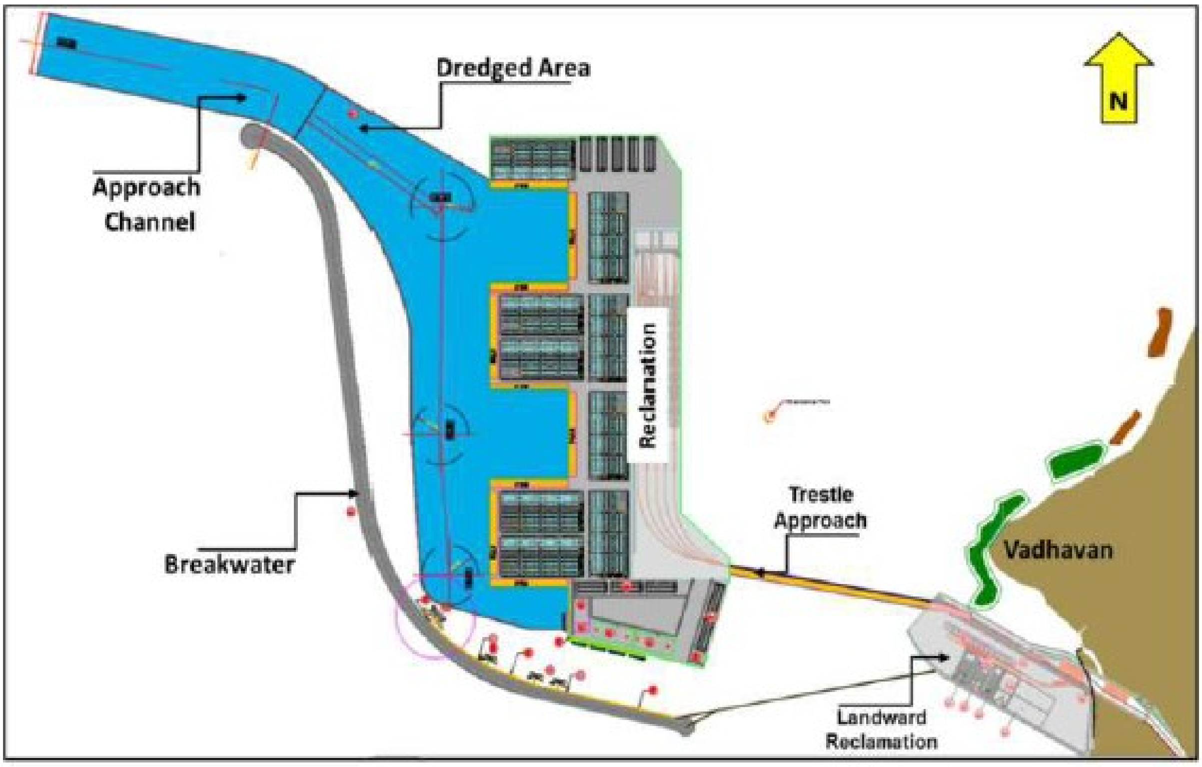


Figure 4.2.1: Modified revised Master Plan Layout

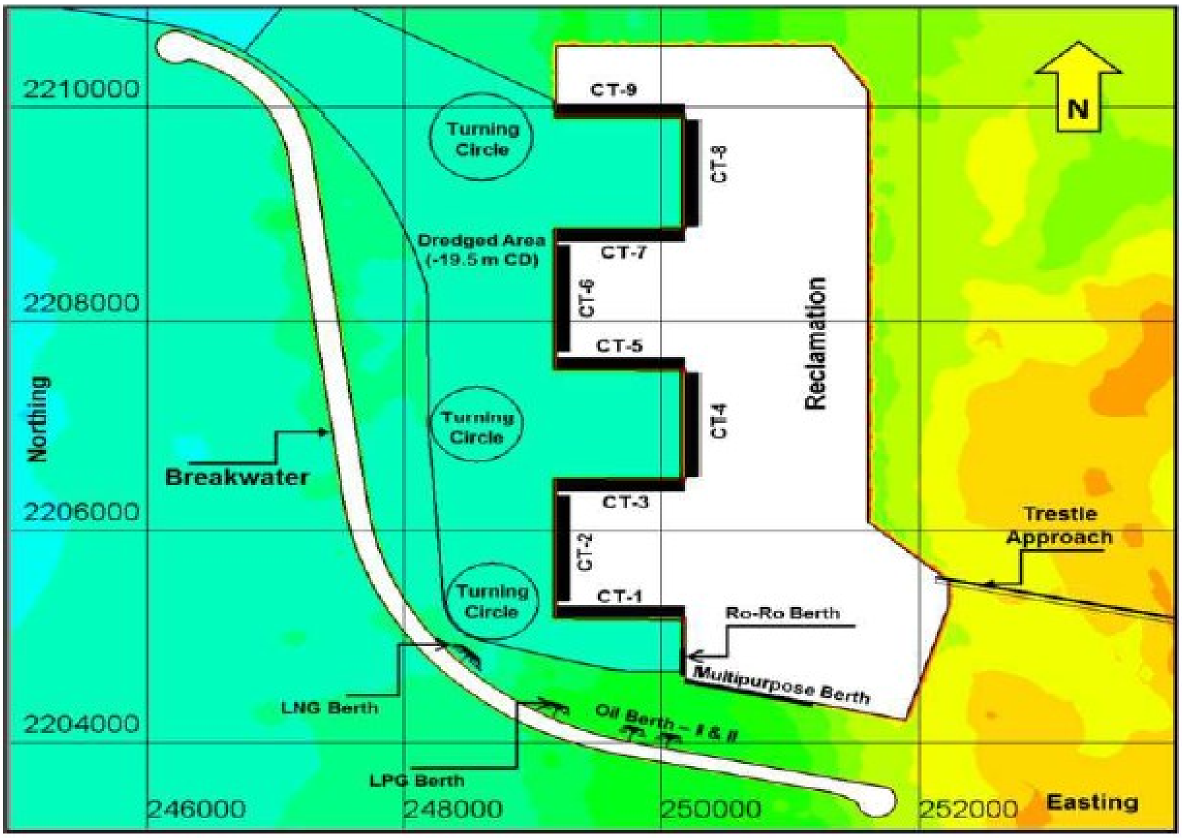


Figure 4.2.2: Locations of various berths in Modified Revised Master Plan Layout

4.3 SHORELINE CHANGE ASSESSMENT

The study on shoreline change assessment was carried out and submitted to JNPA in April 2022. The analysis covered long-term (1975-2022) and short-term (2000-2022) shoreline changes using historic satellite images and aerial photographs from 2012 (Table 2). In the long term, 61% of the coast was stable, while in the short term, 50% of the coast was considered stable, with some stable areas transitioning to low erosion. Additionally, areas of low accretion in the long term were gradually trending towards low erosion. Figure 4.3.1 illustrates the presented analysis results.

It is seen that from Khonda Creek to the North of the proposed port area, the shoreline trend indicates the shoreline transferring from broadly stable to low accretion coast. At the port location and reclamation area, the shore has shifted from broadly Stable to low accretion coast. South of the location till the Varor region, a significant proportion of the regions range from low erosion to medium erosion.

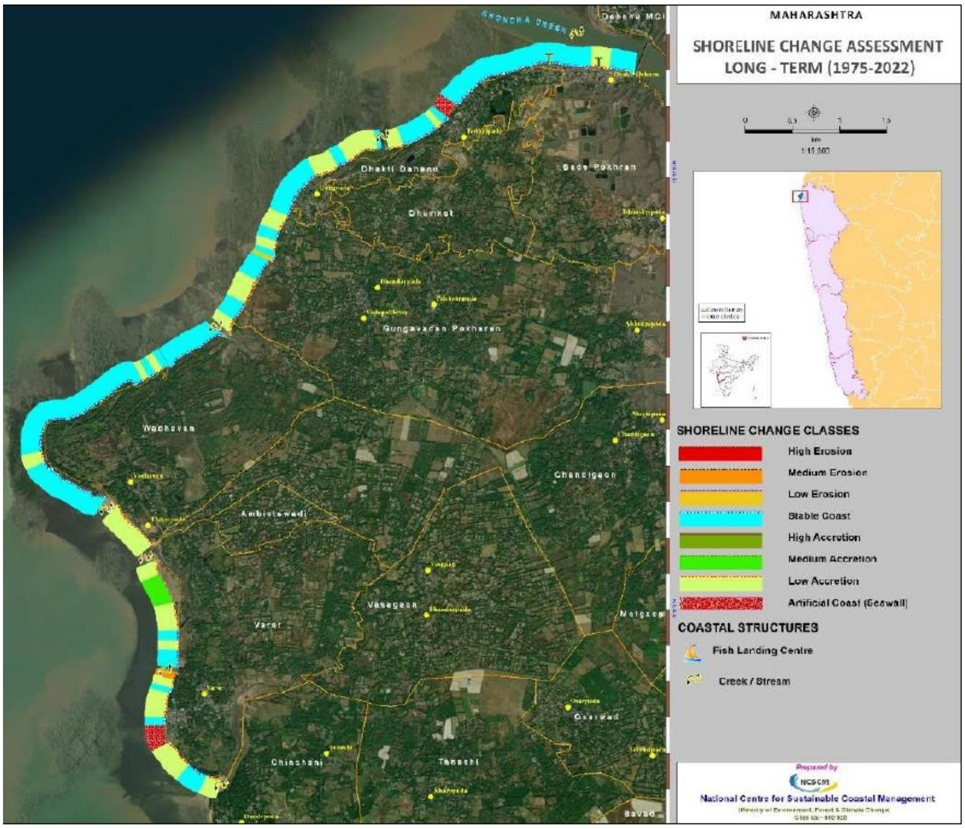
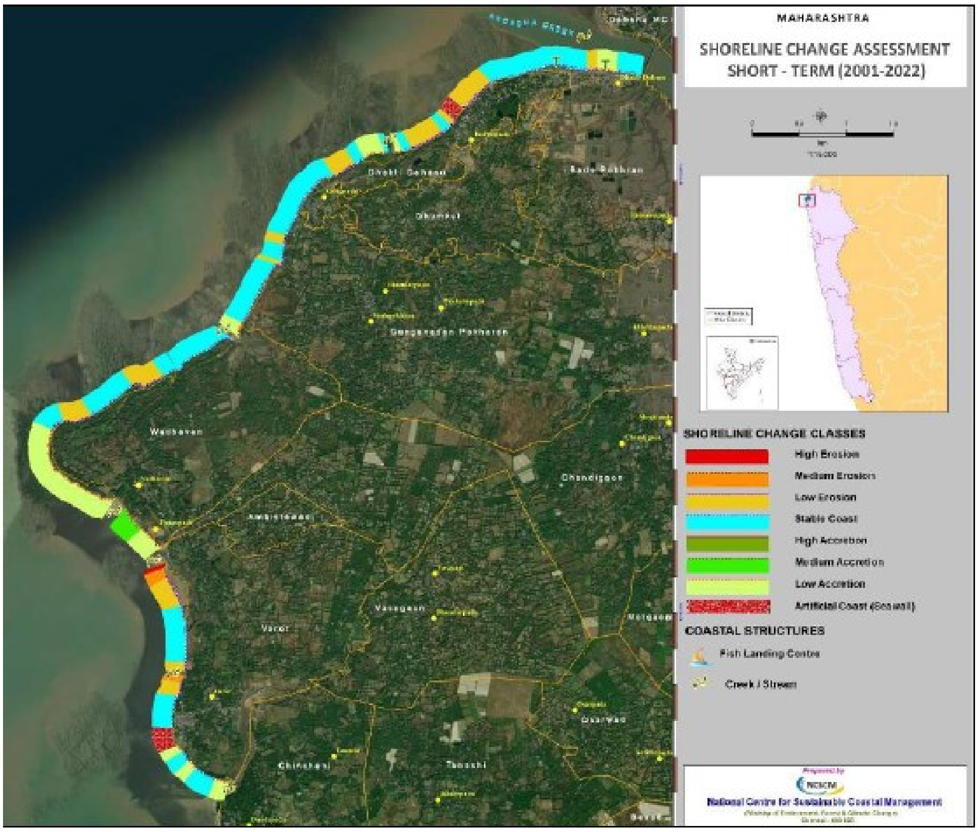


Figure 4.3.1: Shoreline Change Analysis by NCSCM (1975-2022)



(b)

Figure 4.3.2: Shoreline Change Analysis by NCSCM (2001-2022)

4.4 SHORELINE MORPHOLOGY CHANGES

The alongshore movement of sediments or the 'littoral drift' plays a significant role in emanating the shoreline morphology of the area. With the introduction of an artificial structure along the coast or offshore, the drift pattern may be altered due to the dynamics of the nearshore area. The shoreline morphology change was thereby studied for understanding the effect on construction of port breakwater in the adjacent shorelines. Mathematical model study was carried out using LITPACK modules; LITDRIFT and LITLINE of the MIKE 21 software.

The oceanographic data used for the study includes 14-year offshore wave data from the year 1999 to 2012 off Vadhavan sourced from Ship observations by India Meteorological Society and tide data near Dahanu was sourced from JNPA. The Highest High Water (HHW) is about 5.5m, the Mean High Water Spring (MHWS) is 5.0m and the Mean Low Water Spring (MLWS) is 0.7m.

Mathematical model studies for obtaining the wave climate in the nearshore area were carried out using MIKE 21- SW model and the outputs were extracted at -24m and -10 m water depth. The nearshore rose diagram at -10m water depth is given in Figure 4.4.1. The predominant wave direction is between 220^0 – 300^0 with a maximum significant wave height of 2.5m. The estimation of littoral drift distribution and simulation of the shoreline was carried out using a one-dimensional LITPACK model.

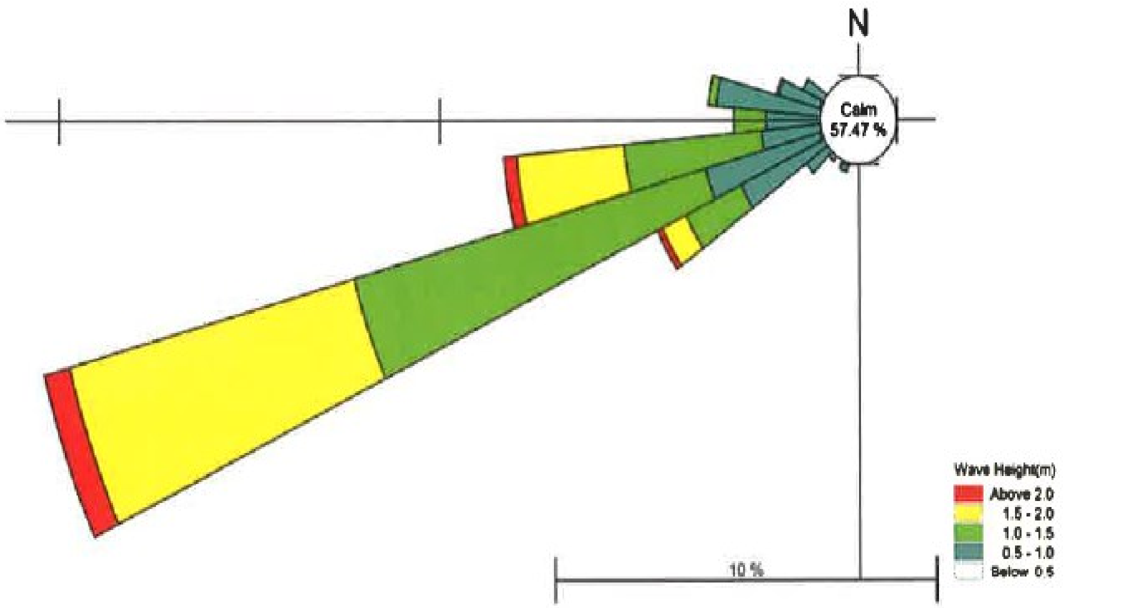


Figure 4.4.1: Near shore wave rose at -10m depth

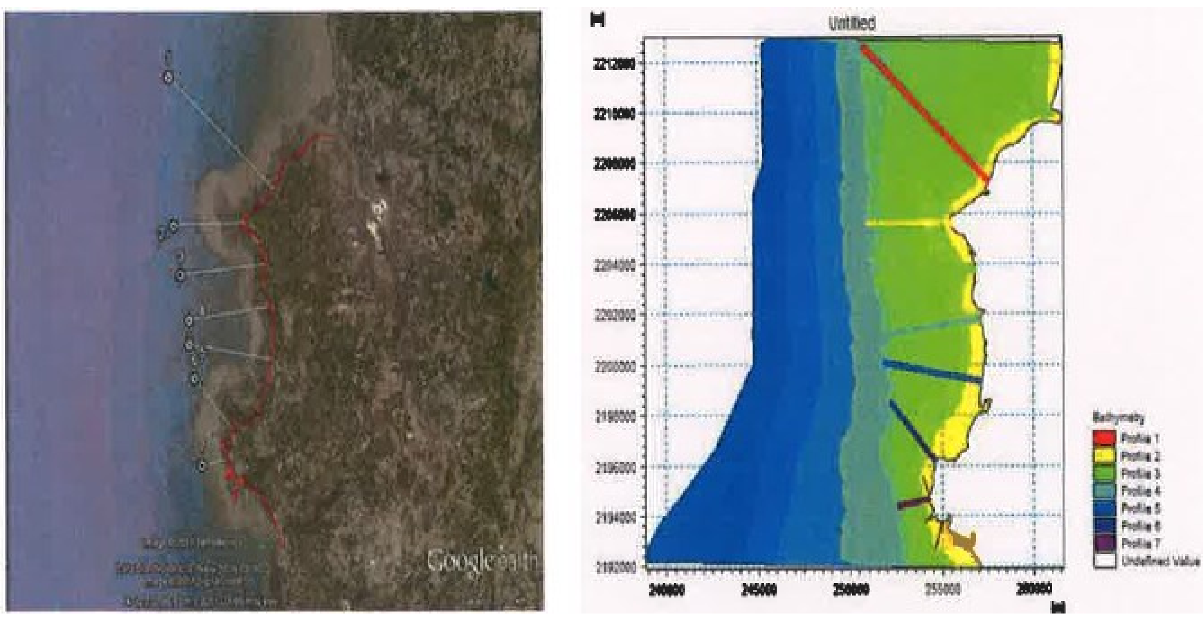


Figure 4.4.2: Cross-shore Profile Locations

4.4.1 Estimation of Littoral Drift Rate

In order to estimate the littoral drift rate, eight different profiles along the shore were considered for the study and the locations are given in Figure 4.4.2. The model was run for annual nearshore wave climate based on -10m water depth for profiles from 1-7 and based on -24m water for profile 8. The Northward, Southward, Net, and Gross transport were computed based on the data aforementioned and given in Table 3.

Table 4.4.1: Littoral Transport Rates (m^3)

Profile No	Northward	Southward	Net	Gross	Drift Direction
P1	102950	50	102900	103000	North
P2	70630	1410	69220	72040	North
P3	104750	3450	101300	108200	North
P4	79610	3440	76170	83050	North
P5	130850	1350	129500	132200	North
P6	46450	0	46450	46450	North
P7	32625	1815	30810	34440	North
P8	32805	25	32780	32830	North

The net drift direction was observed to be Northwards at all profile locations and there is negligible southward drift at P6. The annual Northern and Southern Littoral drift for various cross-shore profiles indicate the extent of drift up to 2 m – 3m water depth. The average net transport in a year is in the order of 0.07 million cum and is directed towards the North.

4.4.2 Shoreline Evolution

The LITLINE module of the LITPACK software is used for assessing the impact of ports on the coastline. The shoreline length for the study extends for 20 km and the nearshore annual wave climate at -24m water depth was considered for the shoreline evolution of 1, 2, 4, and 6 years with the proposed breakwater and reclamation. The model output is shown in Figure 4.4.5.

The study concludes negligible shoreline advancement with the proposed breakwater at Vadhavan and the shoreline evolution after 1, 2, 4, and 6 years was drawn. This study also concludes that there will be negligible impact on the adjacent shoreline of the proposed port area.

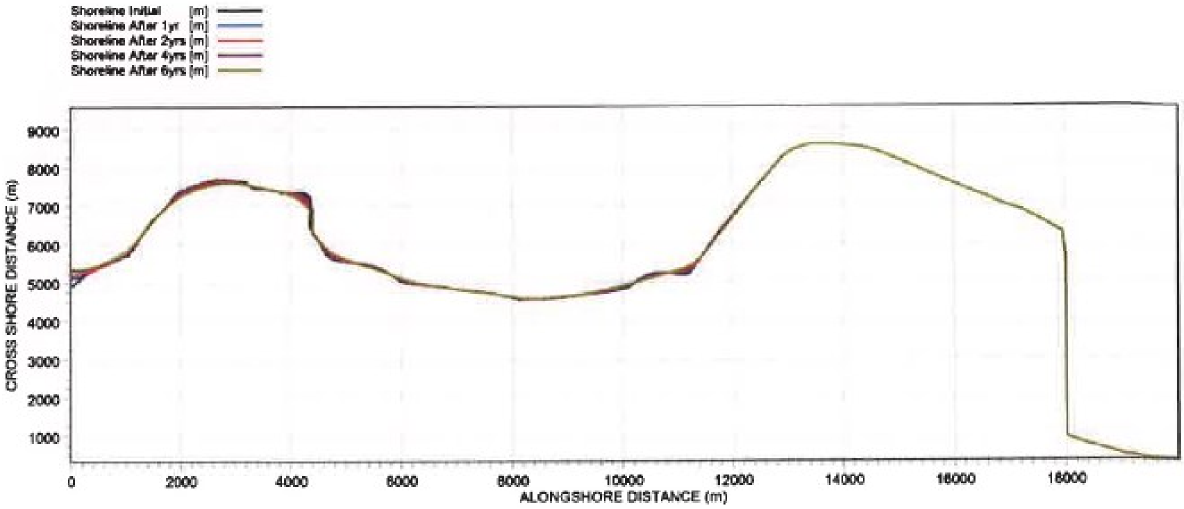


Figure 4.4.3: Model Output for Shoreline Evolution

5. SHORELINE CHANGE ANALYSIS BY NCCR

Shoreline change analysis is carried out for long term (1973 to 2023) using Landsat-MSS (60 m), Landsat-TM (30 m), ResourceSat-I LISS-III (23.5 m), CartoSat-1 PAN (2.5 m), ResourceSat-II LISS-IV (5.8 m) and Sentinel-2A (10 m) satellite images (Table 4). The satellite image processing and shoreline change analysis was carried out as per the methodology adopted in National Assessment of Shoreline Changes along Indian Coast (www.nccr.gov.in) as detailed. In the ArcGIS v.10.3 platform, long-term shoreline geo-database was created.

Table 5.1: Details of satellite data used (1973 to 2023) for shoreline change analysis

Year	No. of data	Satellite data	Resolution (in meters)
1973	1	Landsat-MSS	30
1990	1	Landsat-TM	30
2001	1	Landsat-TM	30
2006	1	Cartosat-1 (PAN)	2.5
2008	1	RS-1 (LISS-III)	23.5
2012	1	RS-2 (LISS-IV)	5.8
2013	1	RS-2 (LISS-IV)	5.8
2014	1	RS-2 (LISS-IV)	5.8
2015	1	RS-2 (LISS-IV)	5.8
2016	1	RS-2 (LISS-IV)	5.8
2017	1	RS-2 (LISS-IV)	5.8
2018	1	RS-2 (LISS-IV)	5.8
2019	1	Sentinel-2A	10
2020	1	Sentinel-2A	10
2021	1	Sentinel-2A	10
2022	1	Sentinel-2A	10
2023	1	Sentinel-2A	10

Table 5.2: Estimation of Shoreline Change Analysis for 1973-2023

Shoreline Change Analysis (1973-2023)		
Status	Long term	
	Length (in km)	%
High Accretion	0	0
Moderate Accretion	0	0
Low Accretion	0.12	1.2
Stable	1.2	12
Low Erosion	6.36	63
Moderate Erosion	2.06	20
High Erosion	0.34	4
Total	**10**	**100**

Figure 5.1: Shoreline Change Analysis of long term (1973 - 2023)

The baseline layer was generated with a buffer distance of 300 m landward from the oldest shoreline, and seaward transects (perpendicular lines) were generated at every 20 m interval along the coastline. Shoreline change statistics is evaluated using the approaches in Digital Shoreline Analysis System v.4.0 (Thieler et al. 2009): Long-term (1973 to 2023) analysis calculated using the weighted linear regression (WLR) method which considers the uncertainty field to calculate the rates of shoreline change. A shoreline change assessment was carried out for long term (1973–2023) period to understand the changes on the shoreline. The rate of shoreline changes from 1973-2023, signifies that among the study area of 10 km, 2.06 km (20%) of the coast and, 0.34 km (4%) were observed to have moderate and high erosion during the 1973-2023 period (Table 5). Long-term analysis of shoreline change is shown in Figure 5.1.

6. DISCUSSIONS AND CONCLUSION

The existing reports on wave tranquillity, hydrodynamics, shoreline change assessment, and shoreline morphology study were analyzed and shoreline change analysis was carried out by NCCR. The following were the outcomes of the study:

1. The maximum significant wave height in the port basin is 1.0m in the Final Master Plan Layout as compared to 2.5 m height offshore. Due to the presence of offshore breakwater, blockage of sediments along the coast is not anticipated. However, there could be a possibility of the formation of a salient behind the proposed port, which needs to be monitored.
2. The Tidal Hydrodynamic and Siltation study finalized the Master Plan Layout for favorable operation and maneuvering conditions with minimum effect on the morphology. The maximum current strengths at container terminals are within 0.15 m/s and flow approaches at an angle varying between 4^0 and 7^0 along oil berths and LPG terminals. These hydrodynamic conditions allow the bypassing of sediments towards the North of the port area.
3. The shoreline morphology study reveals that a net transport of about 0.07 Mm^3 is transported just North of the proposed port area. Although Northerly transport is not fully hindered, maintenance dredging of the port can be utilized for nourishment in the North of the port. A minimum of 0.15 Mm^3 of sand shall be used for nourishment of the North which will be dredged from the port basin as a part of maintenance dredging.
4. The littoral drift and shoreline evolution comparing the original shoreline and proposed port indicates an insignificant effect on the adjacent shoreline.
5. The shoreline change analysis by NCCR suggests that a stretch of 2.4 km of the study area is in a moderate to high erosion state for long-term analysis. The construction of the port breakwater is likely to reduce erosion in the south.

7. RECOMMENDATIONS

The existing studies carried out in regard to hydrodynamics, morphology, and shoreline change analysis for the proposed Greenfield port at Vadhavan in Maharashtra were analyzed from the impact of the port on the adjacent coast. The study indicated that the presence of offshore breakwater has less impact on the coastline compared to shore-connected breakwater. However, 0.15 Mm^3 of the 6.45 Mm^3 of maintenance dredging can be used for beach nourishment towards the immediate North of the port. The shoreline morphology and maintenance dredging are to be monitored periodically.

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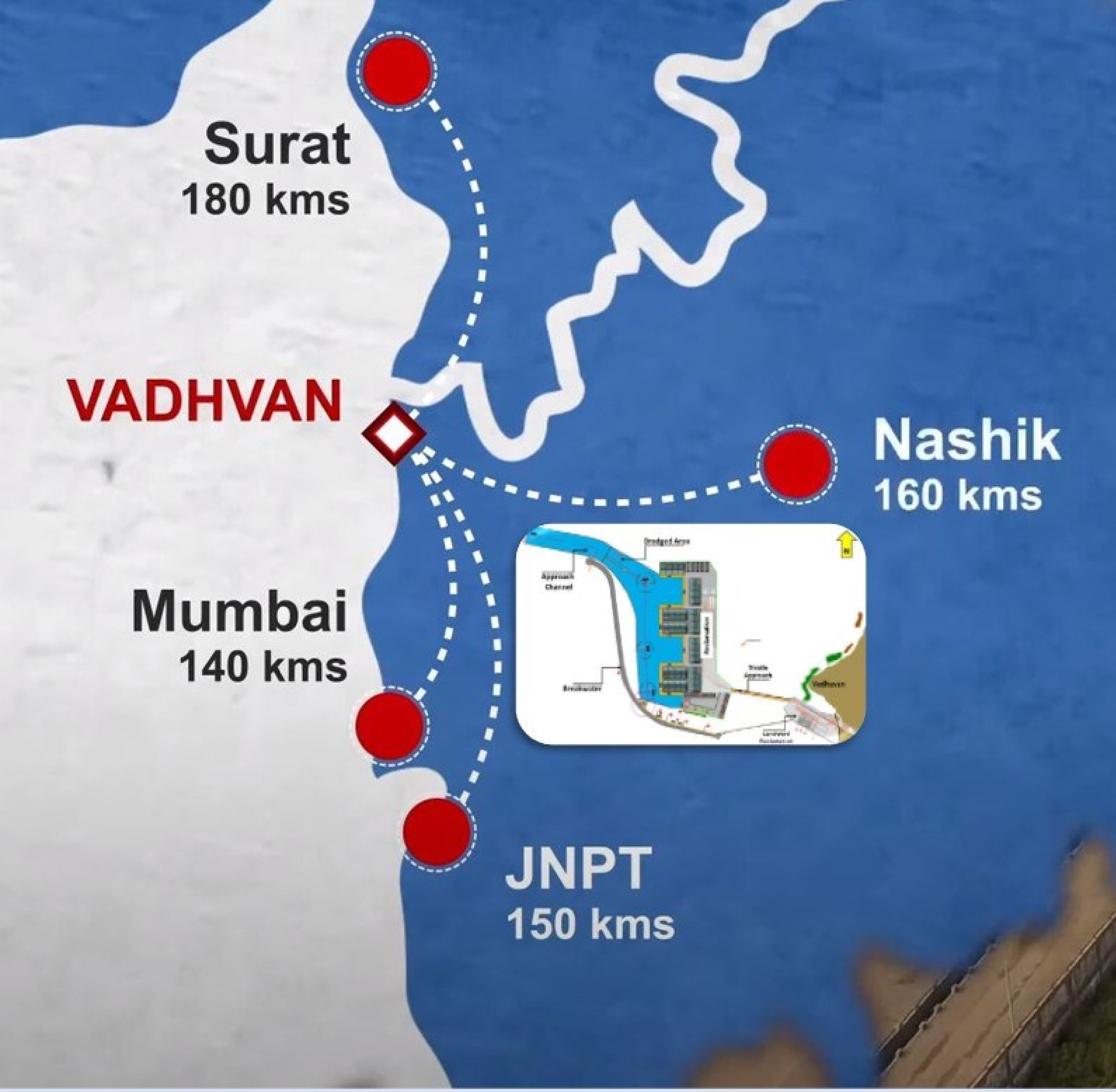

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