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Ministry of Water Resources,
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भारत सरकार
जल संसाधन, नदी विकास
और गंगा संरक्षण मंत्रालय

Technical Report No: 5667

January 2019

MATHEMATICAL MODEL STUDIES TO ASSESS THE IMPACT OF PROPOSED PORT AT VADHAVAN ON SILTATION AT TARAPUR ATOMIC POWER STATION FOR JN PORT

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COASTAL AND OFFSHORE ENGINEERING LABORATORY

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Technical Report No: 5667 **Date:** January 2019

Title: MATHEMATICAL MODEL STUDIES TO ASSESS THE IMPACT OF PROPOSED PORT AT VADHAVAN ON SILTATION AT TARAPUR ATOMIC POWER STATION FOR JN PORT

Officers Responsible for conducting the studies:

The studies were carried out by Shri A. A. Purohit, Scientist-D with the assistance of Shri. M. M. Vaidya Scientist-C and Shri. K.R. Karambelkar, Research Assistant and the studies were completed under the overall Supervision of Dr. J.D. Agrawal, Scientist-"E".

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The Chief Manager, (PPD)
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Synopsis:

The Government of India (GOI) have a proposal to develop a major all-weather greenfield port at Vadhavan in the state of Maharashtra through a joint venture between Jawaharlal Nehru Port (JNP) working under Ministry of Surface Transport, (GOI) and Maharashtra Maritime Board (MMB) of Government of Maharashtra (GOM). The location of proposed port is at Lat. 19^0 55.8'N, Long. 72^0 39.6' E in Dahanu Taluka, Palghar district of Maharashtra state and is about 12 km north of Tarapur Atomic Power Station(TAPS) on the open coast facing the Arabian Sea. The port is proposed to be developed on the seaward side of the headland at Vadhavan and stack yard will be formed by reclaiming an area of about 1428 ha in the intertidal zone at Vadhavan point. The proposed port site being in the close vicinity of Tarapur Atomic Power Station (TAPS), Department of Atomic Energy has requested JNP to assess the impact of proposed port development on TAPS and studies were entrusted to CWPRS. This report describes the mathematical model studies carried out to assess the impact of proposed port at Vadhavan on TAPS from tidal hydrodynamic and siltation considerations at intake/outfalls of TAPS-1&2 and 3&4. The oceanographic data collected by JNP during non-monsoon season (2017) near the proposed port site was used for the studies. Similarly field data collected by CWPRS in January 2018 in the vicinity of TAPS was used for validation of the model. The hydrodynamic model calibrated for the field data of non-monsoon season reveals that the model is reasonably well calibrated and also validated. The tidal hydrodynamic studies carried out for existing as well as with proposed final port layout reveal that due to the development of proposed port at Vadhavan there will be reduction in the current strength by about 9% in relatively deeper depths near TAPS, while it will be about 11% on north side of northern outfall channel of TAPS-1&2 and about 2% on southern side of outfall of TAPS-3&4. On the other hand, in the guided portion of intake channels, forebays as well as outfalls of TAPS-1&2 and 3&4, there will be insignificant impact on current strength (<2%) as well as in water depths (<1%) in forebays, pumpbays of TAPS-1&2 and 3&4. Hence, it can be concluded that there will not be any significant impact on intakes/outfalls of TAPS due to proposed port development at Vadhavan from tidal hydrodynamic consideration. The siltation studies carried out reveal that the deposition of siltation observed in model for both TAPS-1&2 and 3&4 is in good agreement with site data as reported by TAPS. The siltation studies with & without proposed port development at Vadhavan reveal that there will not be increase in quantum of siltation at TAPS-1&2 and 3&4 for prescribed pumping rates of intakes as well as outfall discharges. Hence it is concluded that there will not be adverse impact of proposed port development on siltation at intake/outfall channels, forebays as well as pump-bays of TAPS-1&2 and 3&4.

Key Words: Calibration, Intake, Outfall, Port, Siltation, Tidal Hydrodynamics

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1. INTRODUCTION

The Government of India (GOI) have a proposal to develop a major Greenfield port at Vadhavan situated at about 12 km north of Tarapur Atomic Power Station (TAPS), while it is about 110 km north of Mumbai in the state of Maharashtra. The port is proposed to be developed through a joint venture between Jawaharlal Nehru Port (JNP) and Maharashtra Maritime Board (MMB). The proposed port will be a modern all-weather port at Vadhavan. The location of proposed port is at Lat. 19^0 55.8' N, Long. 72^0 39.6' E in Dahanu Taluka, Palghar district of Maharashtra state and is on the open coast facing the Arabian Sea as shown in FIG.1.

The port is proposed to be developed on the seaward side of the headland at Vadhavan and stack yard area will be formed by creating an artificial land in the foreshore area by reclaiming about 1428 ha in the intertidal zone at Vadhavan point. The entrance to the port will be from the navigational channel facing the Arabian Sea and breakwater is proposed in order to protect the berthing facilities for waves predominant from North-West & South-West quadrants. The tides in this region are of macro type with tidal range of about 6 m and its pattern is semi-diurnal in nature.

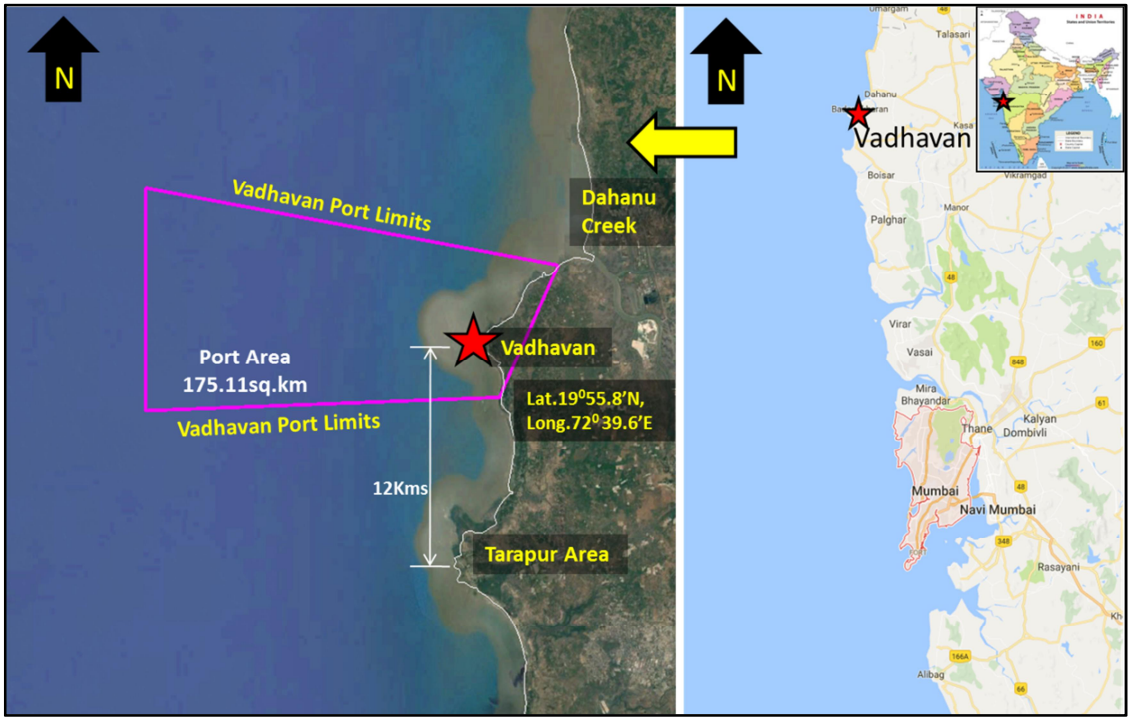


FIG.1: Location Plan of Proposed Port at Vadhavan & Tarapur Area

In view of proposed port site being in the close vicinity of Tarapur Atomic Power Station (TAPS), Department of Atomic Energy has requested JNP to assess the impact of proposed port development on TAPS through institute like CWPRS. Accordingly, JNP approached CWPRS

through e-mail dated 5th march 2017 to hold the discussions with CWPRS officials regarding the issue raised by TAPS. A meeting was held at JNP on 10th March 2017 between officials of CWPRS and JNP. Based on the discussions, JNP requested CWPRS vide their letters JNP/PPD/Vadhavan/2017/422 and JNP/PPD/ Vadhavan/ 2017/426 both dated 10th March 2017 to carry out the various hydraulic model studies to assess the impact of proposed development on TAPS and also to finalize the concept layout for the proposed port at Vadhavan through model studies. Accordingly, based on the meeting held at CWPRS on 22nd March 2017, it has been proposed to carry out studies in two phases namely:

I) Studies to finalize the layout of proposed port at Vadhavan and

II) Assess the impact of proposed port at Vadhavan on TAPS.

In this context, following studies were entrusted to CWPRS as Phase-I:

- Hydrodynamics and siltation to finalise layout of port and estimate the siltation
- Wave transformation and tranquility for assessing wave conditions at berths
- Shoreline changes and littoral drift
- Design of breakwaters – Wave flume studies

Based on the layout finalized through tidal hydrodynamics and siltation as well as tranquility studies, it is proposed to consider the final layout to assess the impact of proposed port development on intake/outfall facilities of TAPS as Phase-II:

- Hydrodynamic and siltation studies to assess the impact of proposed port at Vadhavan on TAPS
- Thermal model studies to assess the dispersion of hot water due to proposed port development

The data required for the studies to assess impact of proposed port at Vadhavan is to be provided by JNP. CWPRS vide letter No. TC/2017/391/706 and TC/2017/392/707 both dated 03rd April 2017 submitted the study proposals indicating the data on various oceanographic parameters viz. tides, current, suspended sediment concentration for season viz. monsoon and non-monsoon, bed samples, borehole log data, bathymetry survey for area between TAPS and Vadhavan, Dahanu creek, project site etc. Also, the data regarding detailed dimensioned drawings of intakes/outfalls and its bathymetry (TAPS-1&2 and 3&4) alongwith pump/outfall discharges, quantity of silt being removed from intake/forebays as well as outfalls per annum for TAPS-1&2 and 3&4 is to be provided by JNP.

This report describes the studies carried out to assess the impact of finalized layout of proposed port at Vadhavan on tidal hydrodynamics and siltation at TAPS –1&2 and 3&4.

2. FIELD DATA FOR MODEL STUDIES

The field data was collected by M/s Pentacle Consultants (I) Pvt. Ltd. in January-February 2017 (Non-Monsoon) for JNP and this data was submitted to CWPRS to carry out the model studies. However, the data was only for Non-Monsoon season and this aspect was discussed in the meeting held at CWPRS on 3rd July 2017 and it was decided that the studies will be carried

out for Non-monsoon season only. The field data submitted by JNP was utilized for TAPS studies. The data provided is briefly described as follows:

1. Bathymetry survey of proposed port site as well as area near TAPS
2. Tide data collected at 3rd pier of Dahanu Creek Bridge (one location) at the entrance of Dahanu creek for one-month duration from 10/01/2017 to 10/02/2017.
3. Tidal current data at one location in the port limit from 10/01/2017 to 05/02/2017.
4. Sea water temperature, density and salinity at one location
5. Geotechnical investigations – borehole data (61 locations)

The location of oceanographic field data collected is shown in FIG. 2. The field data like suspended sediment concentration (SSC), grain size analysis of suspended sediments, bed samples and its grain size analysis in the proposed port area was provided later by JNP vide their letter No. PPD/M/Vadhavan Port/2018/152 dated 23/01/2018 and e-mail dated 14/12/2017 and is discussed in detail in paragraph 5 of this report.

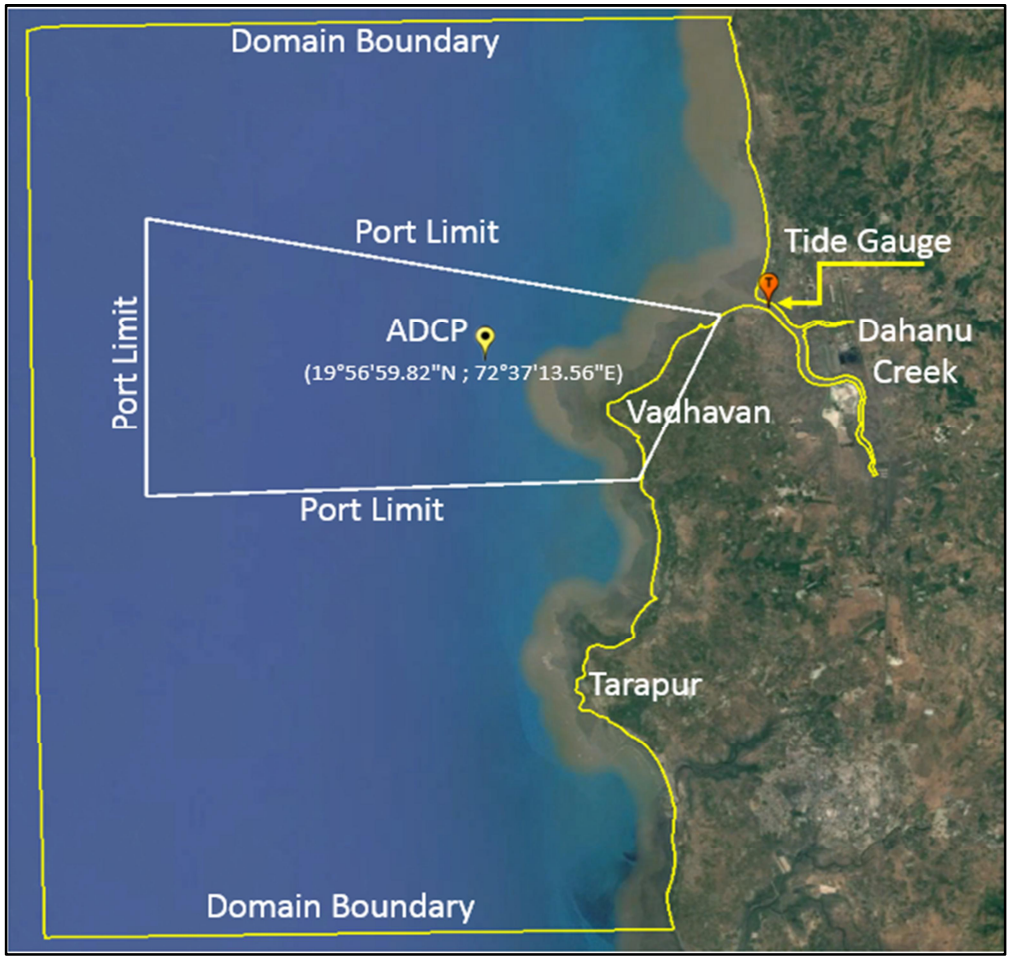


FIG.2: Locations of Oceanographic Field Data Measurements for Proposed Port at Vadhavan

2.1 Bathymetry Survey for Proposed Port Site & TAPS Area

The hydrographic survey for the proposed port area within its limit is carried out by project authorities during December 2016 to March 2017 (Ref-8 & 9 of CWPRS TR No. 5583 of March 2018) and the same is shown in FIG.3 (A).

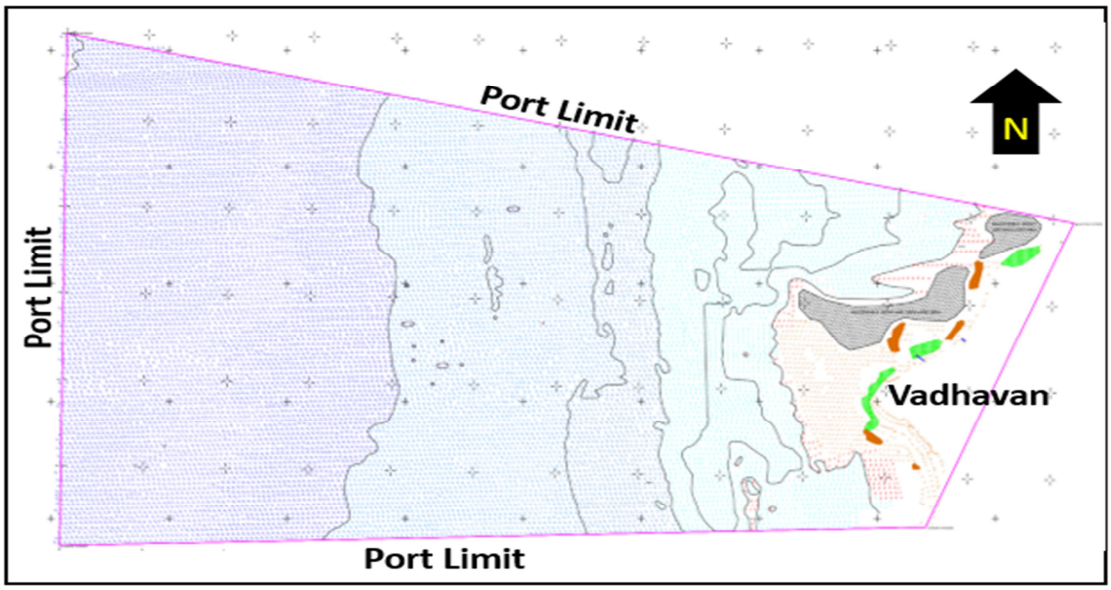


FIG.3(A): Bathymetry Data for Proposed Port at Vadhavan

The depths within the port limit vary between -26 m and +2 m w.r.t. CD of Vadhavan area. The data shows some patches of rocky outcrops and areas of mangrove coverage near the shoreline. The bathymetry in the areas like Dahanu creek, Vadhavan, Tarapur area was provided by JNP and part of this data is based on the hydrographic charts prepared by MMB in year 2003 for Tarapur site and Vadhavan headland area, while for Dahanu creek in year 2009 and is shown in FIG.3(B) and 3(C).

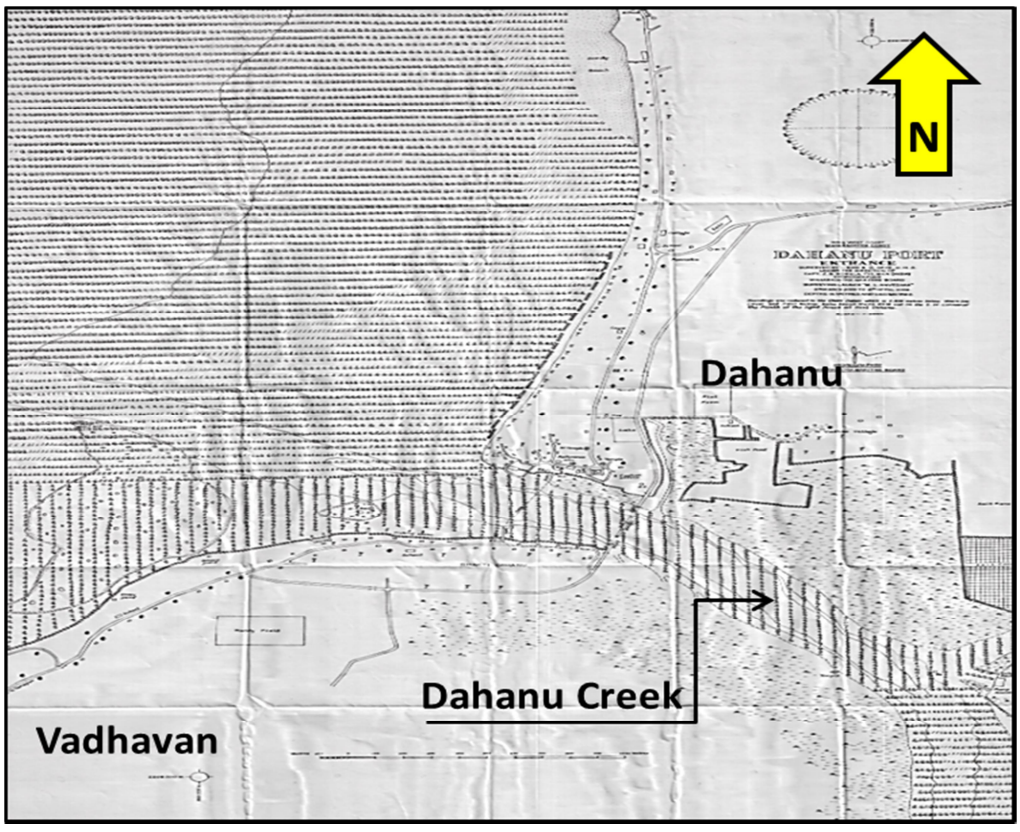


FIG.3(B): Bathymetry Data for Dahanu Creek Area

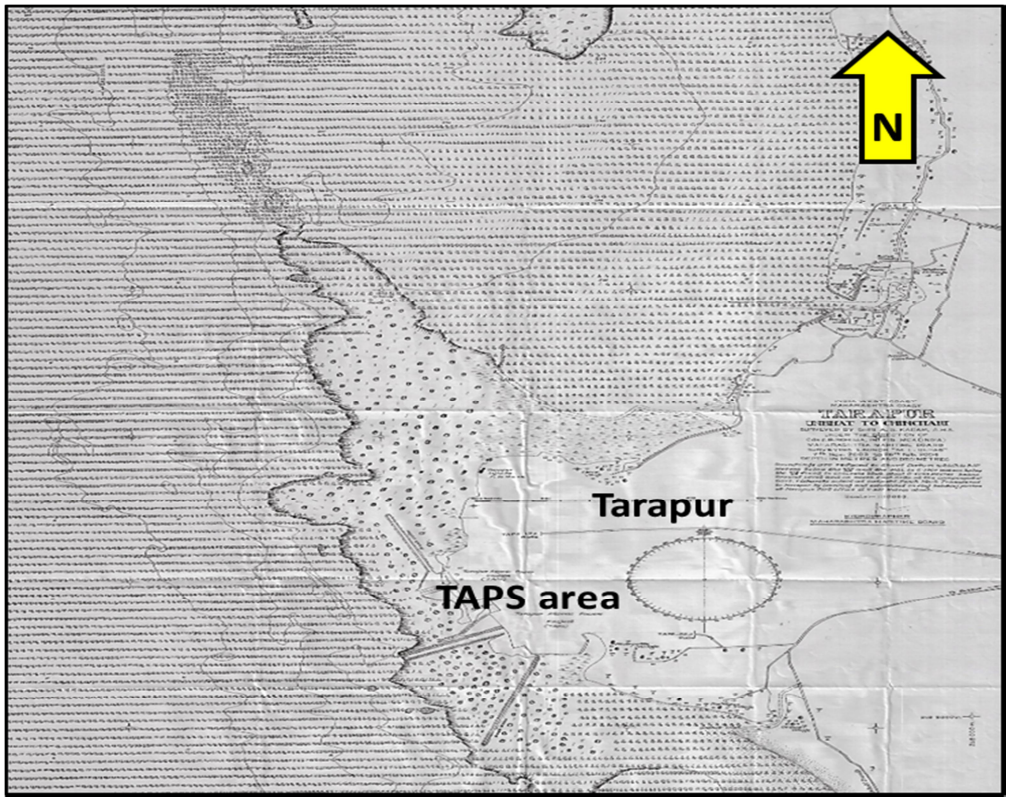


FIG.3(C): Bathymetry Data for Tarapur Area

2.2 Tide Data

The tidal data was collected at 3rd pier of Bridge on Dahanu Creek for the duration of one month from 10/01/2017 to 10/02/2017 and is correlated with CD of Vadhavan area. The CD was correlated w.r.t. Benchmark established on the Light House at Dahanu. The plot of Tide data collected is shown in FIG. 4.

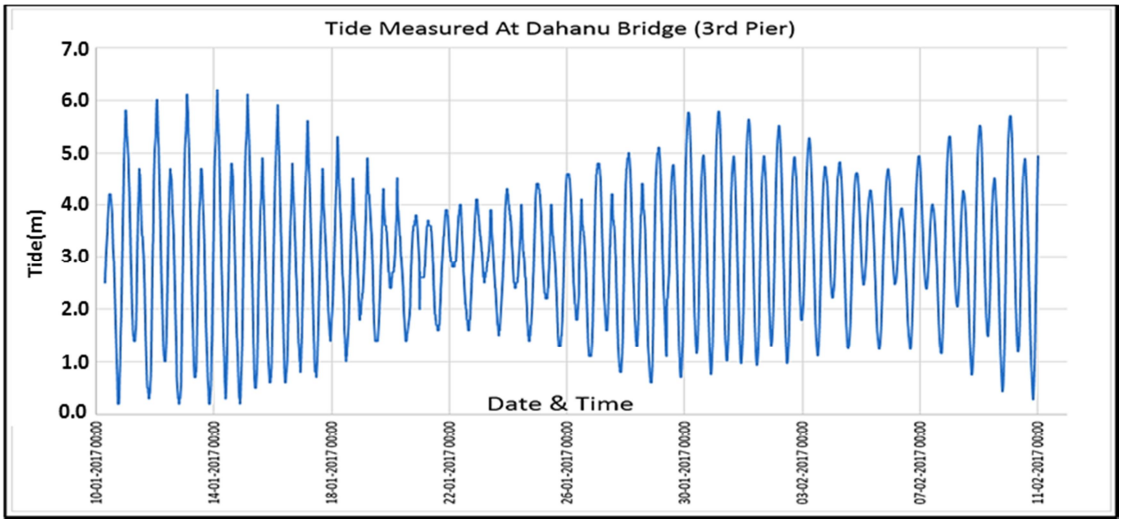
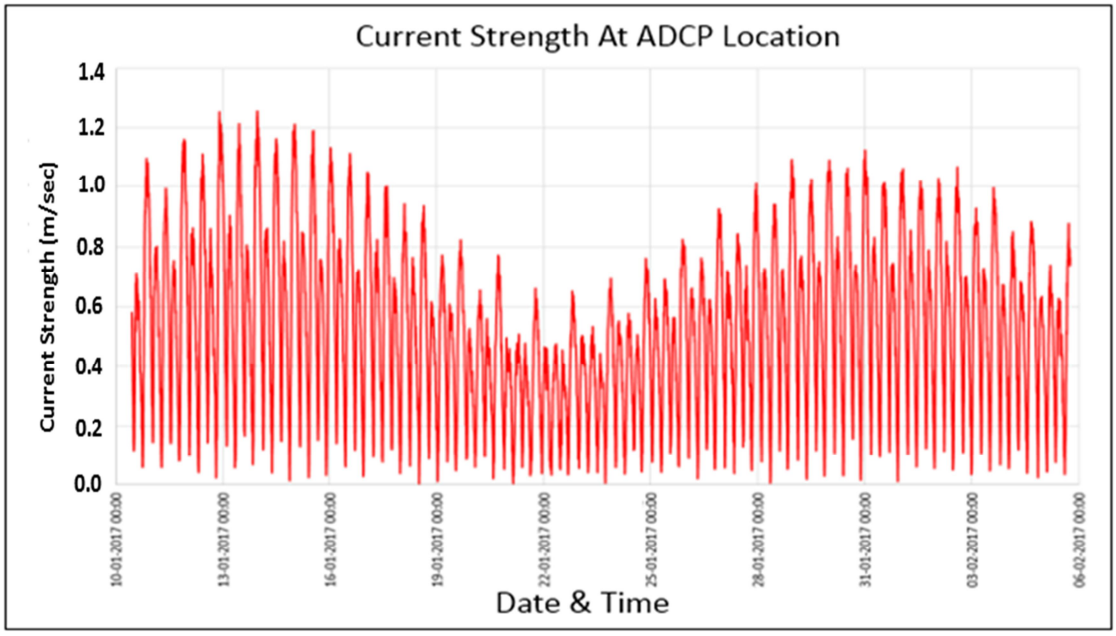


FIG.4 : Measured Tide Data at Dahanu Bridge Location (10/01/2017 – 10/02/2017)

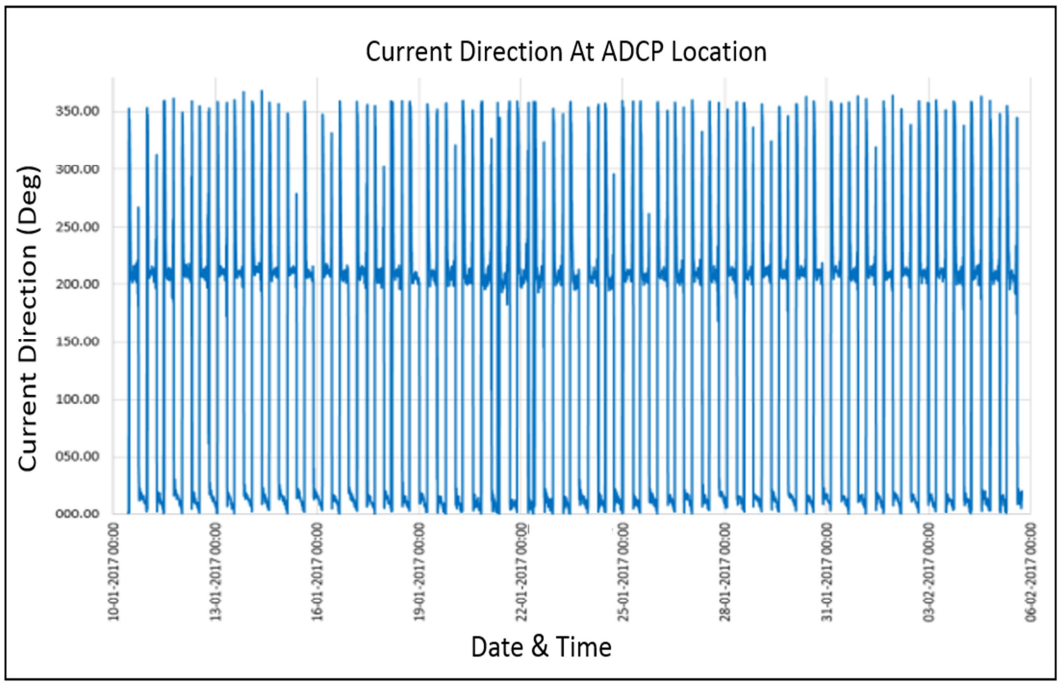
The analysis of measured tidal data is carried out and it reveals that the tides are semi-diurnal in nature with diurnal inequality. The spring tide occurred on 14/01/2017 has a tidal range of 5.87 m, while neap tide occurred on 21/01/2017 has tidal range of about 2.10 m.

2.3 Current Data

The ADCP deployed at Lat.19^0 56' 59.85" N, Long.72^0 37' 13.59" E for the measurement of current (strength & direction) was bottom mounted with equipment resting on steel frame. The plot of measured current data (strength & direction) at mid depth is shown in FIG. 5(A) & (B).



(A) Current strength at Mid depth



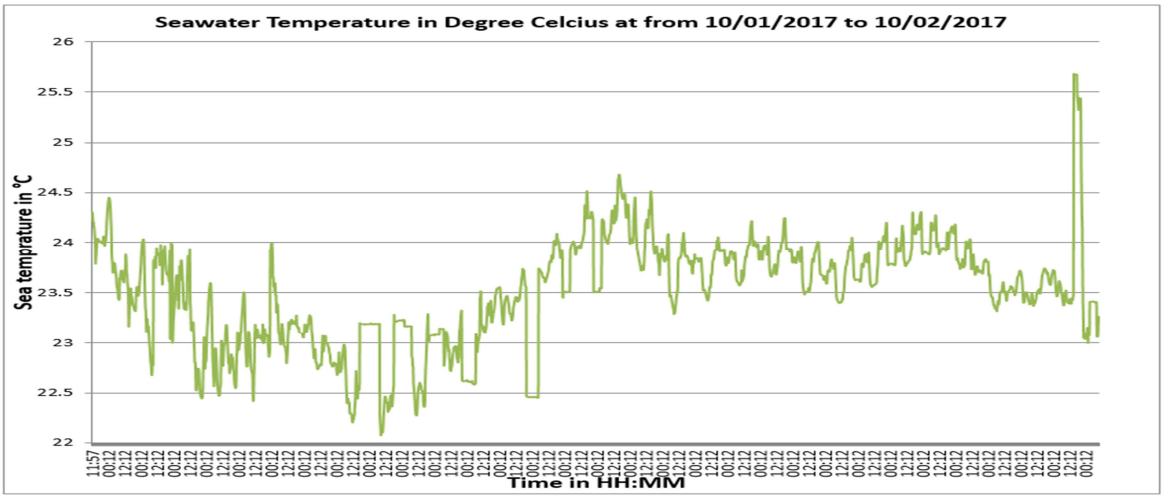
(B) Current Direction at Mid depth

FIG.5 : Measured Current at ADCP Location (10/01/2017 – 05/02/2017)

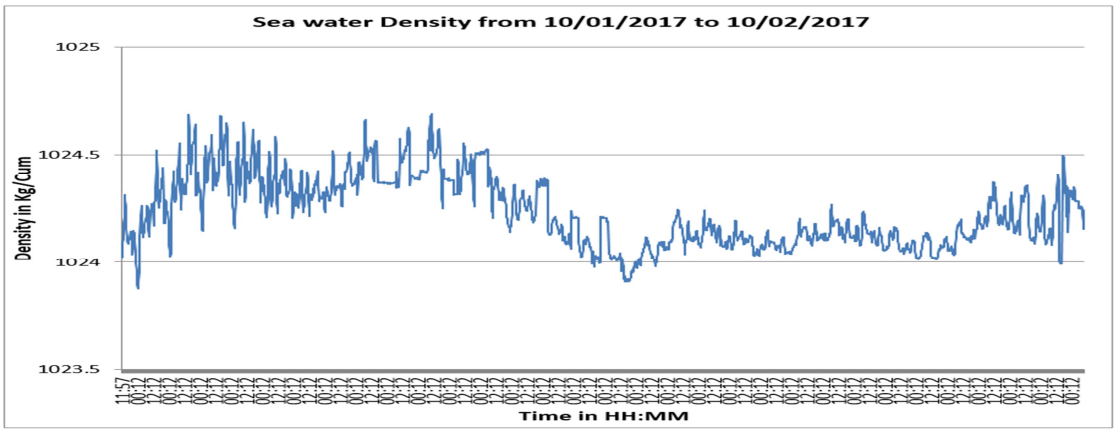
The analysis of current data reveals that maximum current strength observed is 1.25 m/s during spring tide, while it is 0.66 m/s during neap tide. The current direction w.r.t. north varies between 3^0 and 23^0 during flood tide, while it is between 204^0 and 215^0 during ebb tide.

2.4 Sea Water Temperature, Density and Salinity

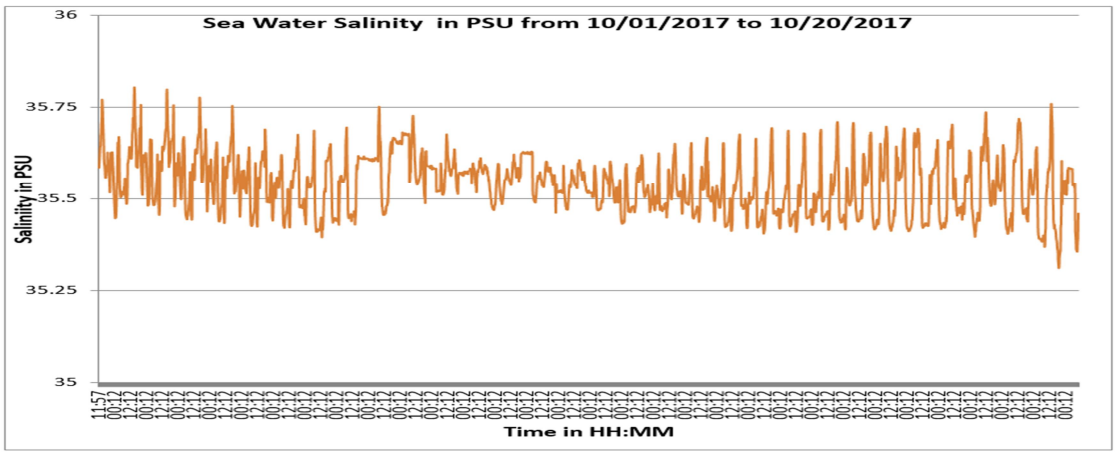
The plots of sea water temperature, density and salinity measured at site are presented in FIG.6 (A-C).



A) Measured Sea Water Temperature at Dahanu (10/01/2017 – 10/02/2017)



B) Measured Sea water Density at Dahanu (10/01/2017 – 10/02/2017)



C) Measured Sea water Salinity at Dahanu (10/01/2017 – 10/02/2017)

FIG.6 : Sea Water Temperature, Density, Salinity at Dahanu

From the above plots, it may be inferred that average sea water temperature is 23.5^0 C, average sea water density is 1024 kg/cum and average salinity is 35.5 PSU.

2.5 Data Related to TAPS

The CWPRS vide letter No.TC/2017/391/706 dated 03.04.2017 submitted the proposal for studies and the data required. In response to this the JNP vide email dated 21.04.2018 forwarded the data received from TAPS. However, in view of discrepancies in the data, CWPRS officials along with JNP official visited TAPS in October 2018 and forwarded the record of discussions held at TAPS vide CWPRS letter No. PH-III/2018/907/2530 dated 14.11.2018.

The information about intake/outfall channel dimensions, forebays, pumpbays & their bed levels etc. was provided by JNP for TAPS-1&2 and 3&4 vide email dated 30th November 2018 (TAPS letter No. TAPS 3&4/TSS/2018/S/121 dated 30.11.2018). The TAPS has provided the bed levels in intake channel, branch channel, forebays and pumpbays for TAPS-3&4 and 1&2 along with correlation of these levels with chart datum (CD) at different chainages. This data was used to simulate the bathymetry of TAPS intake and outfall structures by linear interpolation in between different levels. The daily discharges for intake/ northern outfall of TAPS-1&2 are 30.55 cum/sec, while for intake / outfall of TAPS-3&4 are 77.78 cum/sec. It is also reported that the seabed at intake and outfall channels of TAPS-1&2 and 3&4 is rocky. The de-silting was carried out in intake channel up to traveling screen of TAPS-1&2 and about 362 cum of silt was removed for the last year (2017-18). Similarly, de-silting of pump-bays of TAPS-3&4 is being carried out once in every two years for unit 3 & unit 4 and about 1100 cum of silt is removed from each unit (TAPS-3 & TAPS-4). It is also mentioned that no dredging activity is carried out in intake / outfall channels of TAPS-3&4. It is also reported in said letter that the deepening and smoothing of intake channel of TAPS-3&4 was carried out in year 2011-12 and after 2012-13 about 11,081 cum of silt was removed from branch channel. The information provided by TAPS is utilized to simulate the layout of intake/outfall channels, forebays and pumpbays in the mathematical model as well as the information on quantum of silt deposition is used to calibrate the silt model wherein the de-silting is carried out for TAPS-1&2 and TAPS-3&4 regularly. The parameters such as friction coefficient, tidal lag, sediment characteristics etc. were adopted to calibrate the model to assess the impact of port at Vadhavan on the existing hydrodynamics and siltation at TAPS by carrying out mathematical model studies after incorporating the final layout of proposed port at Vadhavan in the model domain.

The study to assess the impact of proposed development of port at Vadhavan on the dispersion of hot water was entrusted to CWPRS as described in Phase-II studies given in paragraph 1. The data on oceanographic parameters such as velocity data at mid depth was collected at location ‘C’ (19º49’34.90”N; 72º38’34”E) alongwith temperature observations in the vicinity of TAPS during the period of 23rd January to 25th January 2018 by CWPRS [Ref. CWPRS Tr.No.5615 of August 2018]. The location of velocity data collected is shown in FIG.7 and is used for the validation of flow field near the TAPS area.

FIG.7: Location of Current Data Measurement near TAPS

3. MATHEMATICAL MODEL STUDIES

The mathematical model study provides the information on simulation of tidal hydrodynamics for the area in the vicinity of proposed port at Vadhavan including TAPS in the Arabian Sea. The studies were carried out by using TELEMAC-2D software available at Central Water & Power Research Station (CWPRS), Pune. The TELEMAC-2D is finite element software, which considers solution of hydrodynamic equations of Saint Venant's. The model considers depth-averaged velocities. The equations are solved by solving matrices element by element at number of nodes of finite element, which is an unstructured triangular mesh.

The TELEMAC-2D code solves the following four hydrodynamic equations simultaneously

$$\frac{\partial h}{\partial t} + \vec{u}.\vec{\nabla}(h) + h\,div(\vec{u}) = S_h \quad \text{----------} \quad \text{Continuity}$$

$$\frac{\partial u}{\partial t} + \vec{u}.\vec{\nabla}(u) = -g\frac{\partial Z}{\partial x} + S_x + \frac{1}{h}div(h\nu_t\vec{\nabla}u) \quad \text{----------} \quad \text{Momentum along x}$$

$$\frac{\partial v}{\partial t} + \vec{u}.\vec{\nabla}(v) = -g\frac{\partial Z}{\partial y} + S_y + \frac{1}{h}div(h\nu_t\vec{\nabla}v) \quad \text{----------} \quad \text{Momentum along y}$$

in which,

h	(m)	----------	depth of water
u,v	(m/s)	----------	velocity components
g	(m/s^2)	----------	gravity acceleration
ν_t	(m^2/s)	----------	momentum diffusion coefficient
Z	(m)	----------	free surface elevation
t	(s)	----------	time
x,y	(m)	----------	horizontal space coordinates
S_h	(m/s)	----------	source or sink of fluid
S_x, S_y	(m/s^2)	----------	source and sink terms in dynamic equations

u, v are the unknowns

The equations are given in Cartesian Co-ordinates. They can also be processed using spherical co-ordinates.

S_x and S_y are source terms representing the wind, Coriolis force, bottom friction, a source or sink of momentum within the domain. The different terms of these equations are processed in one or more steps (in case of advection by method of characteristics).

1. Advection of h, u and v
2. Propagation, diffusion and source terms of the dynamic equation

3.1 Discretisation of the Domain Area

The domain area of the model for the present study covers area like Vadhavan, Tarapur and Dahanu Creek. The model is extended up to Gholvad on north and Satpati on south side with depth of about 30 m in deeper part of Arabian Sea on the west-side. The model domain is discretized using finite elements (FE) and is developed for the existing bathymetry condition. The total domain area considered is about 870 sq. km. The mesh generated for the domain is shown in FIG. 8(A). The triangular finite elements with fine resolution near shoreline/Dahanu creek area (50mX50m), intake & outfall channels as well as in fore-bays & pump-bays of TAPS (1mX1m) were adopted for true simulation of steep slopes, rocky outcrops and channel cross sections. The coarser mesh in deeper areas (500mX500m) to optimize the number of elements for minimizing the simulation time was adopted. Thus, mesh generated can effectively reproduce hydrodynamic conditions without compromising on the quality of results. The variable element sizes in proportion to bathymetry were also adopted to schematize the navigational channels, deeper depths and land boundaries. The bathymetry data supplied by JNP for proposed port area, C-map data (MIKE-21 software) for deeper part of the sea and charts prepared by MMB for Dahanu Creek (Year 2009), Tarapur and Vadhavan (Year 2003) were used for reproducing the bathymetry in the domain area under consideration along with reproduction of bed levels in intake / outfall channels, forebays, pump bays etc. of TAPS. The bathymetry of the Vadhavan area along with the Tide/Current data measurement locations is shown in FIG. 8(B).

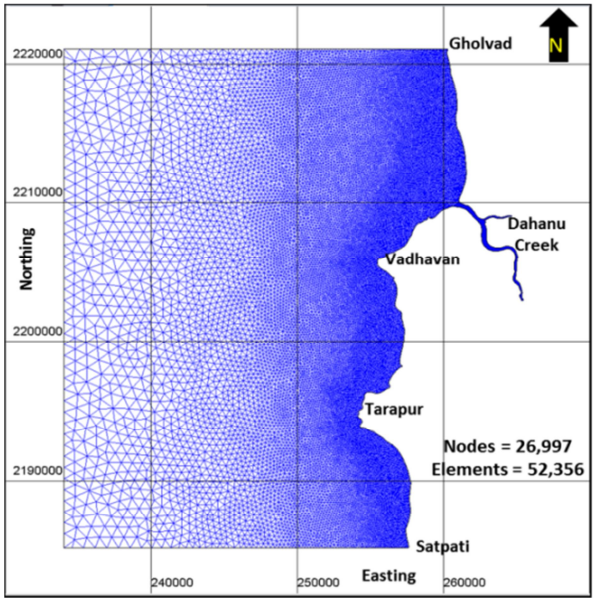


FIG.8(A): Mesh for Vadhavan Model

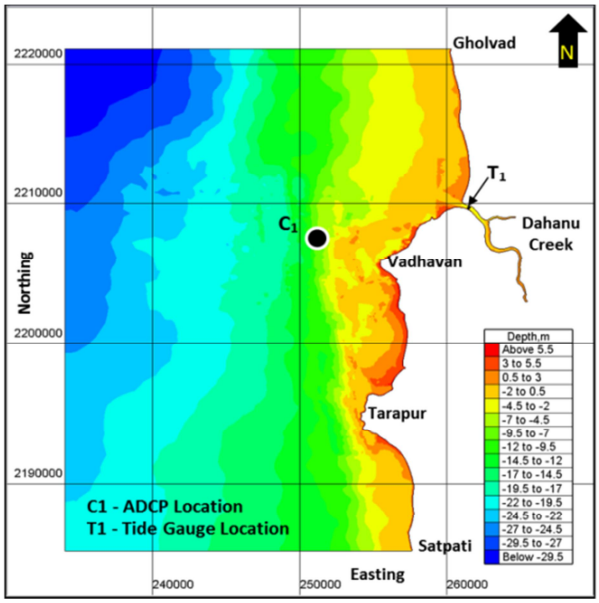


FIG.8(B): Bathymetry of Vadhavan Area

The interpolated depths were assigned at nodal points of the finite elements to represent the depths in model and hydrodynamic equations in terms of water depth and velocity are solved. Thus, mesh generated can effectively reproduce hydrodynamic conditions prevailing at site.

3.2 Simulation and Calibration of Model for "Hydrodynamics"

The observed tidal data is used as northern boundary condition and tidal data with lag is adopted as southern boundary condition for existing bathymetry scenario to simulate the hydrodynamics prevailing in the domain area by mathematical model. Information on grain size of bed samples provided by JNP is used to consider the appropriate bed friction in the domain as well as rocky outcrop area with higher friction near TAPS area and Vadhavan headland is adopted to simulate the prevailing flow in the model. The current and water level data in the model were extracted at locations wherein field data for current at ADCP location & tide data at Dahanu bridge site is measured. The comparison of water levels and current (strength & direction) observed in mathematical model and that prevailing at site based on field data is shown in FIG.9 (A) & (B) respectively.

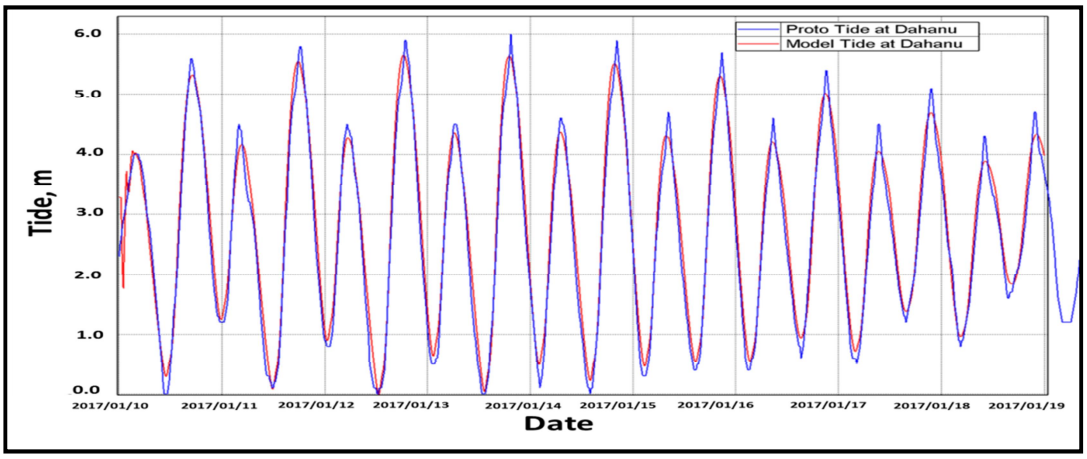


FIG.9 (A): Comparison of Proto and Model Tide at T1 Location

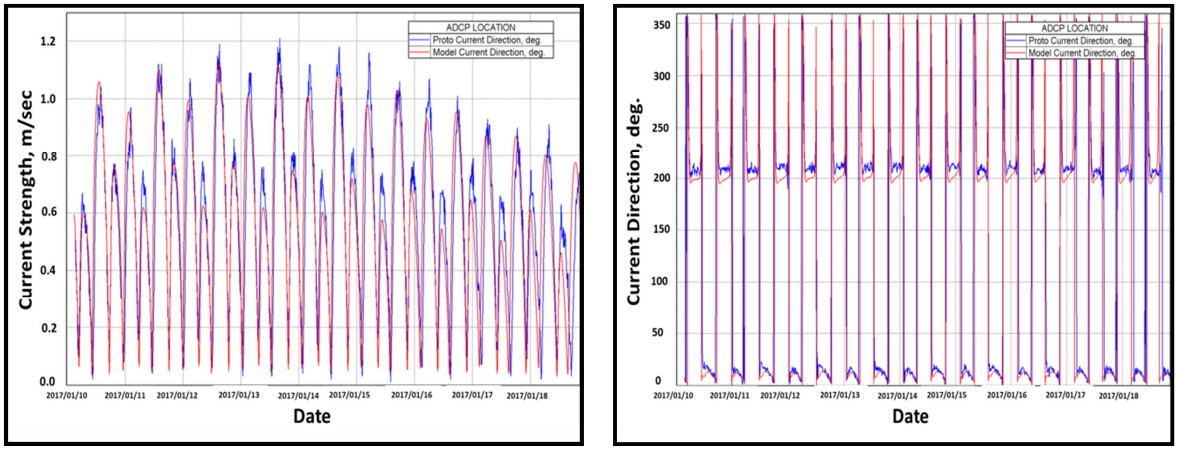


FIG.9 (B): Comparison of Proto and Model Current at C1 Location

It can be seen from the above figures that the measured and computed water levels as well as velocity at corresponding locations compares well. Hence, it can be inferred that mathematical model is reasonably well calibrated with respect to water level and velocity in the

area under consideration. The flow patterns observed in model during Flood & Ebb are shown in FIG.10.

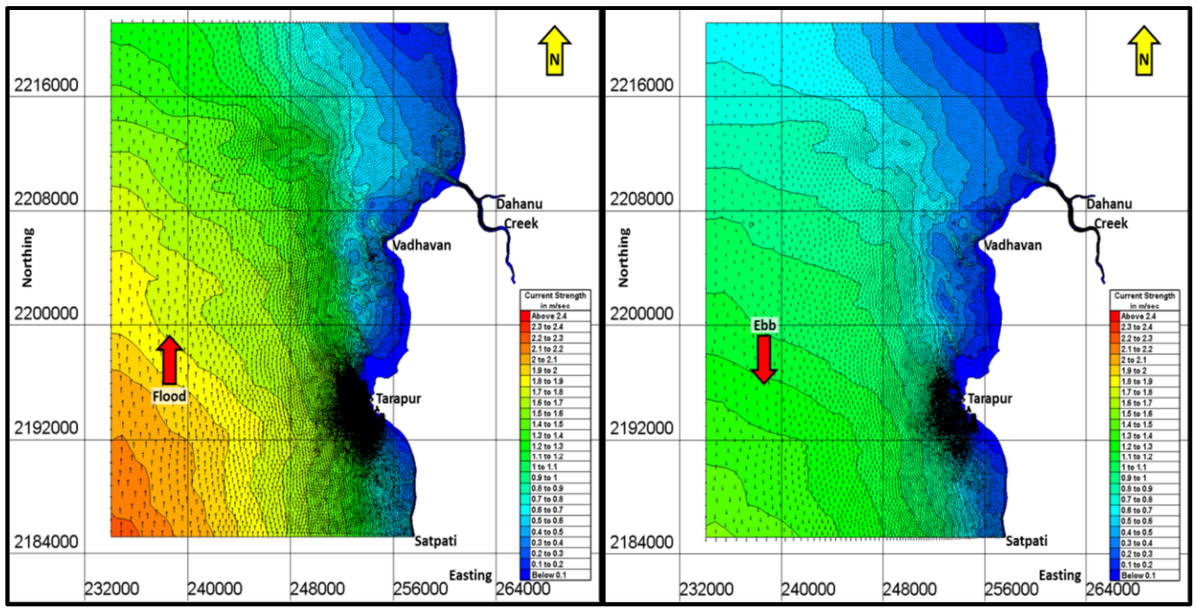


FIG.10: Flow Patterns Observed during Flood / Ebb Tide for Existing Bathymetry Condition

Note- The oceanographic data (January 2017) provided by M/s JNP is for Non-Monsoon Season only. Thus, this report describes the hydrodynamic studies carried out and its findings to assess the impact of proposed port at Vadhavan on hydrodynamics and siltation at TAPS by using data of Non-monsoon season only.

Further to this, the latest velocity data collected for thermal studies (24th -25th January 2018) is utilised to validate the model near TAPS area by considering the similar lag adopted for the studies used for calibration. The plots of comparison of current strength & direction in model and that at site (Location 'C' as given in FIG.7) for this data are presented in FIG. 11 (A) & 11 (B) respectively.

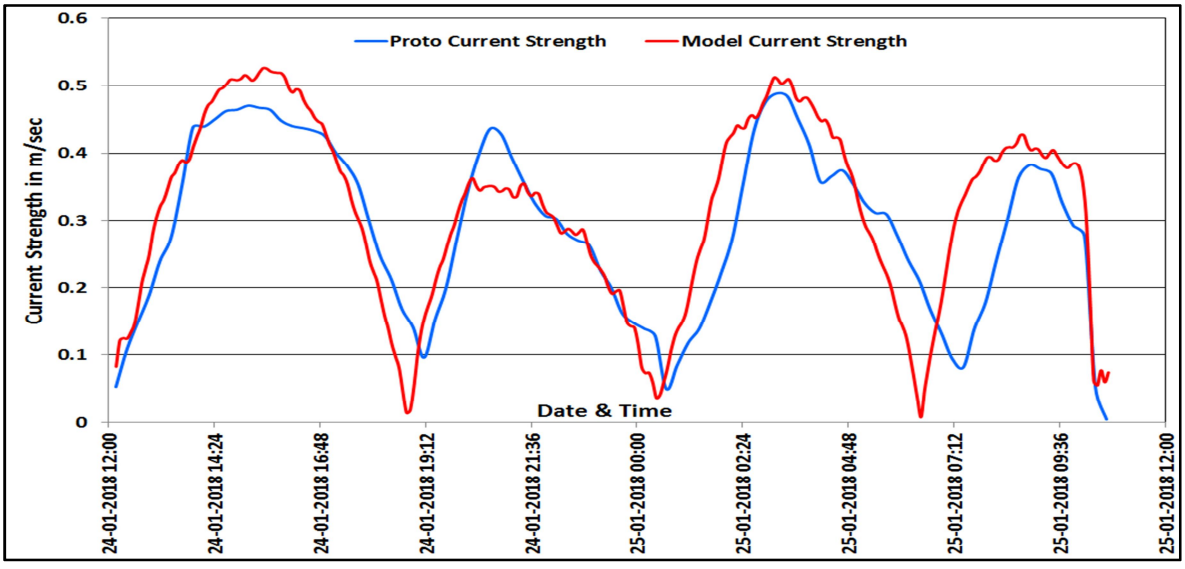


FIG.11(A): Measured Current Strength Near TAPS (24/01/2018 – 25/01/2018)

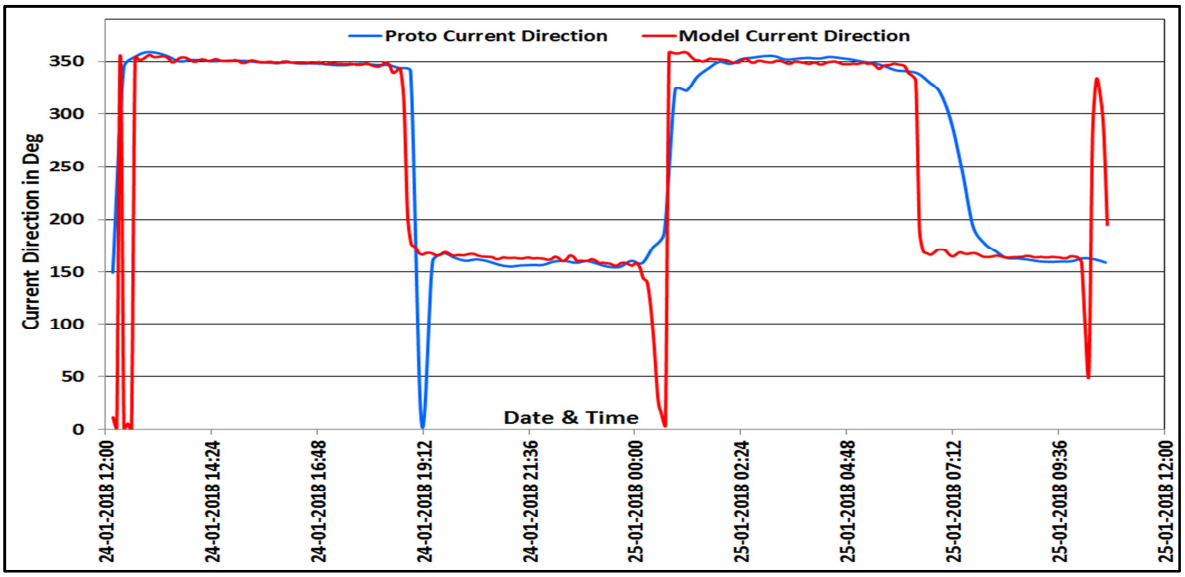


FIG.11(B): Measured Current Direction Near TAPS (24/01/2018 – 25/01/2018)

It can be inferred from above figures that model is well calibrated for Vadhavan area as well as validated for TAPS area. As such it is used to assess the impact of proposed development of port at Vadhavan on TAPS.

4. MODEL STUDIES TO ASSESS IMPACT OF PORT AT VADHAVAN ON TAPS

The hydrodynamic studies to finalise the layout of proposed port at Vadhavan were carried out using well calibrated hydrodynamic model for the various layouts submitted by JNP and the final layout was evolved by CWPRS after studying the various alignments of breakwater as well as shapes of reclamation. The layout recommended by CWPRS (TR No. 5583 of March 2018) is given in FIG.12. This layout is used to assess its impact on TAPS.

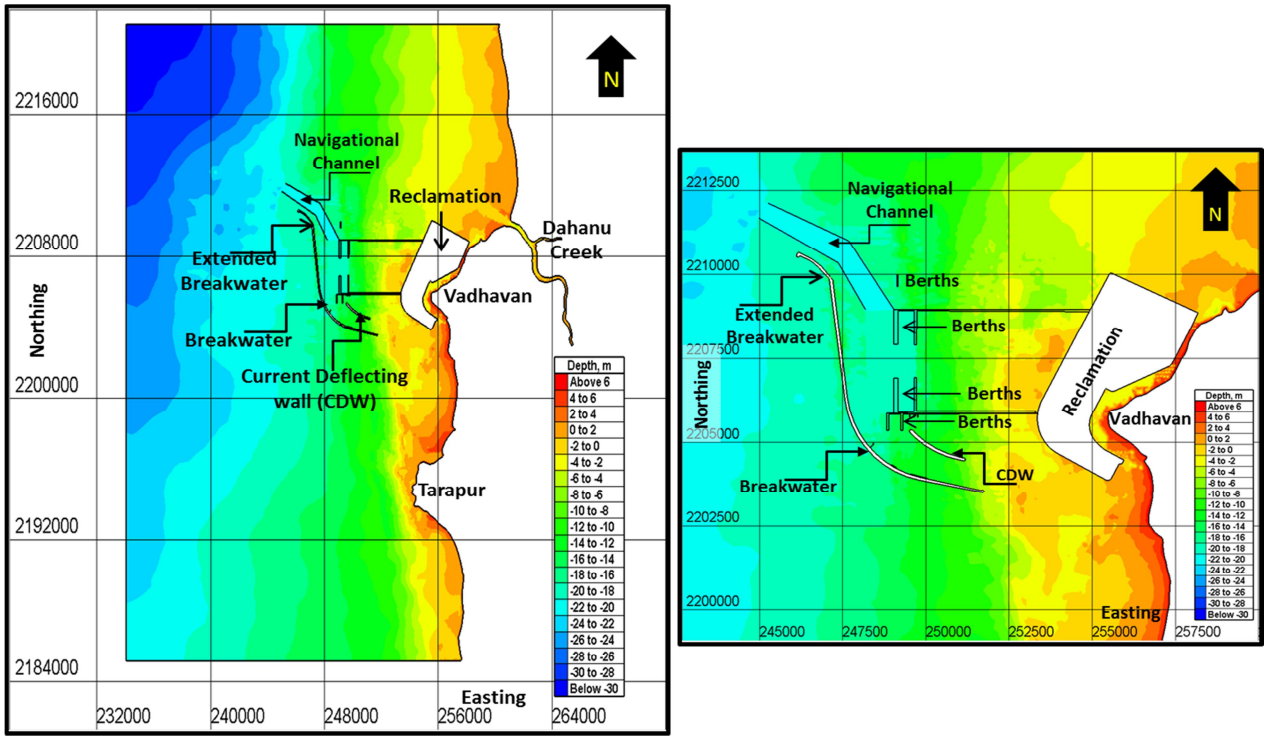


FIG. 12: Recommended Layout of Proposed Port at Vadhavan

The hydrodynamic studies to assess the flow conditions in and around TAPS, intake/ northern outfall channel of TAPS-1&2 and intake/outfall of 3&4 as well as in forebays and pumpbays are carried out and are described in the following paragraph.

4.1 Hydrodynamic Studies to assess flow field near TAPS – Existing Condition

The well calibrated hydrodynamic model for the non-monsoon data (Year 2017) is used to study in detail the flow conditions in and around TAPS area wherein the pump and outfall discharges provided by JNP for both TAPS-1&2 and 3&4 were also simulated. The finite element mesh is used to discretise various areas of intakes/outfalls, forebays, pumpbays etc. of TAPS by generating the fine mesh in these areas. The zoomed portion of finite element mesh adopted for TAPS- 1&2 and 3&4 is shown in Fig. 13 (A) and 13 (B) respectively.

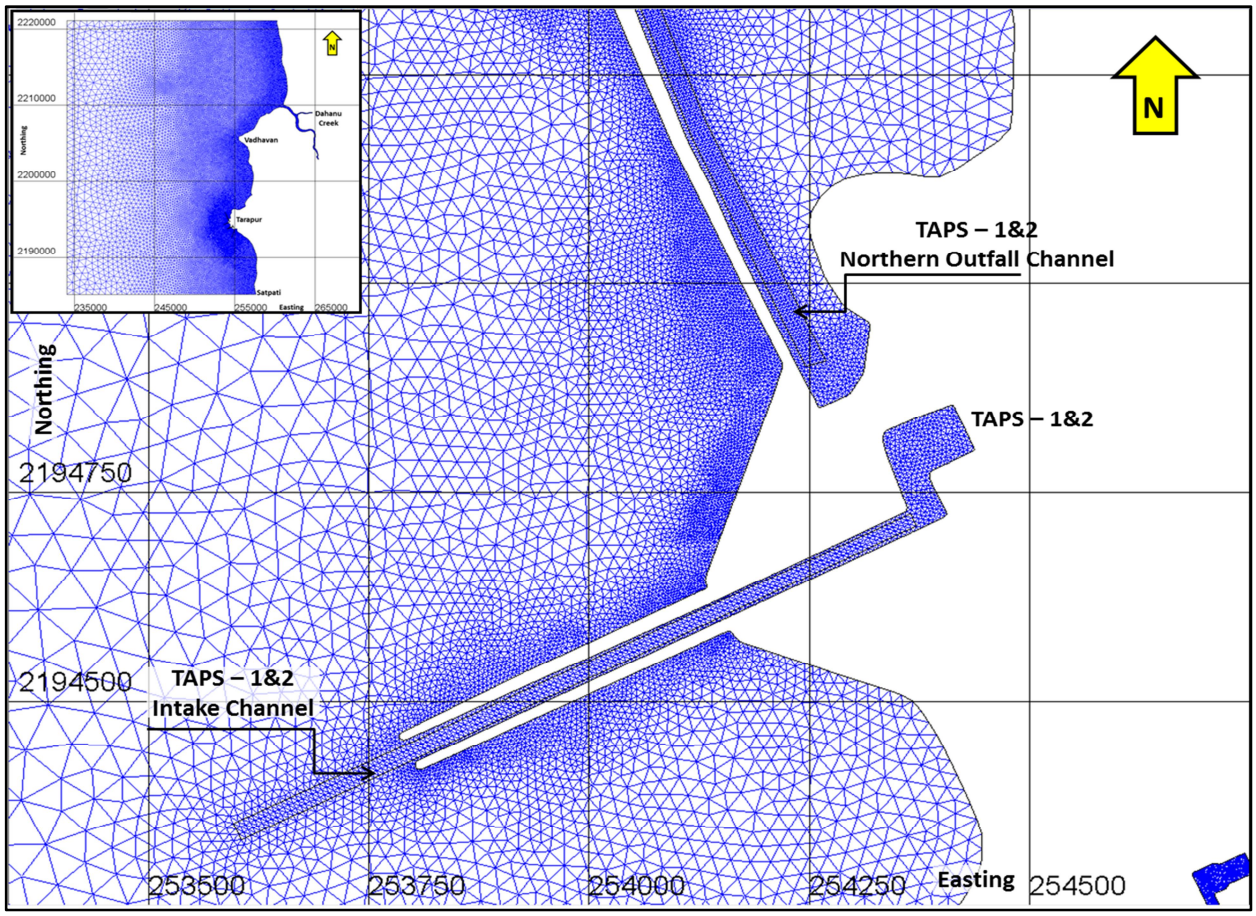


FIG. 13(A): Zoomed Portion of Finite Element Mesh for TAPS-1&2

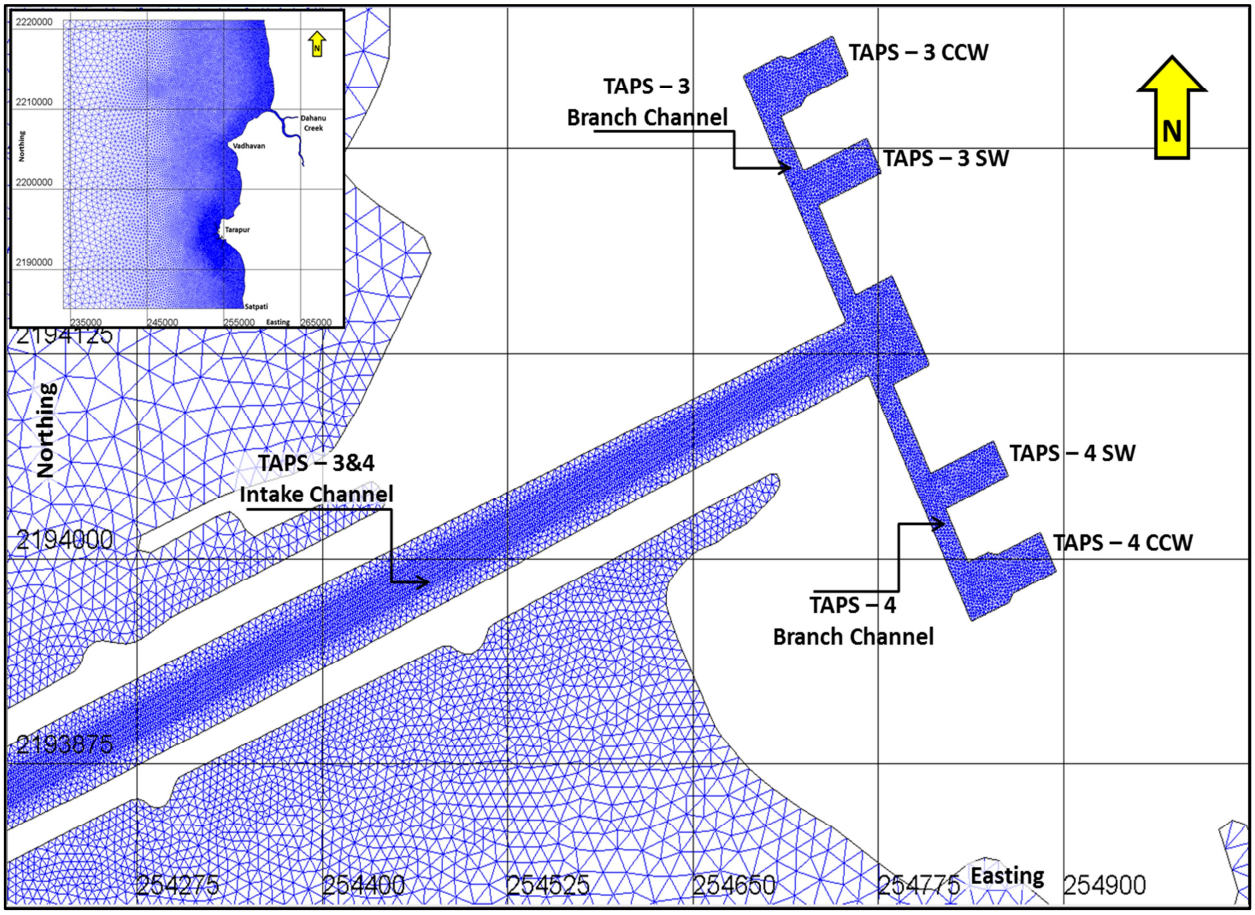


FIG. 13(B): Zoomed Portion of Finite Element Mesh for TAPS-3&4

The bathymetry/bed levels in this area are reproduced by interpolating the levels over the finite element mesh nodes and are shown in FIG. 14.

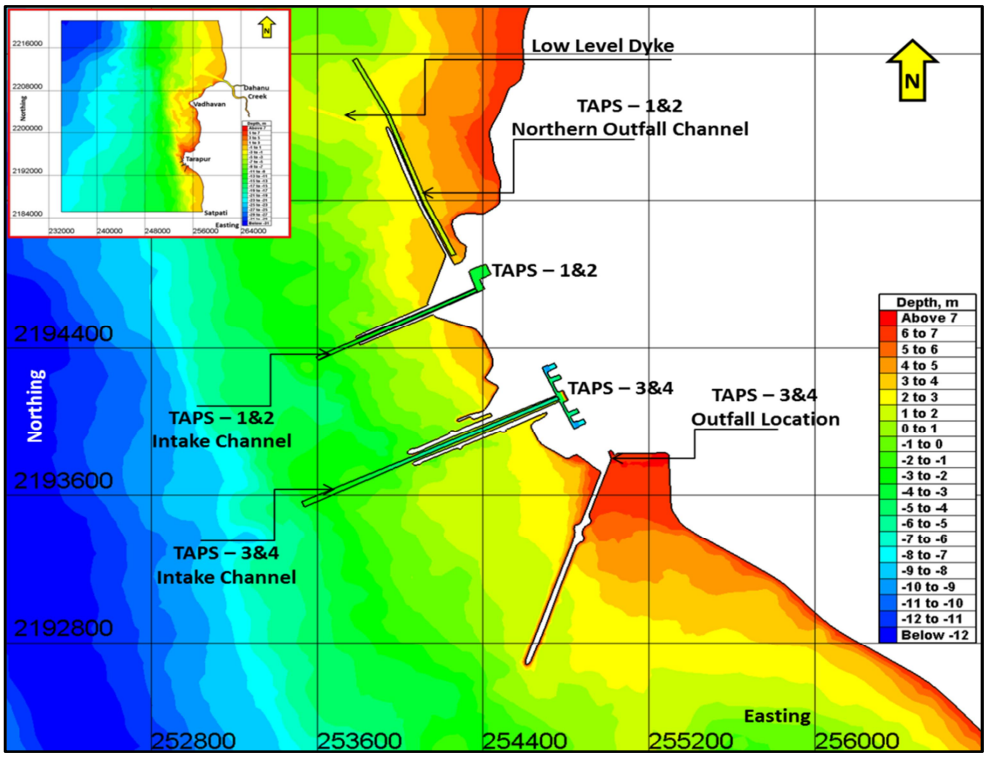


FIG. 14: Bathymetry near TAPS for Existing Condition

The hydrodynamic flow patterns observed in model near TAPS-1&2 is shown in FIG. 15(A) & 15(B), while that near TAPS-3&4 in FIG.15(C) & 15(D) during flood and ebb phase of the tide respectively.

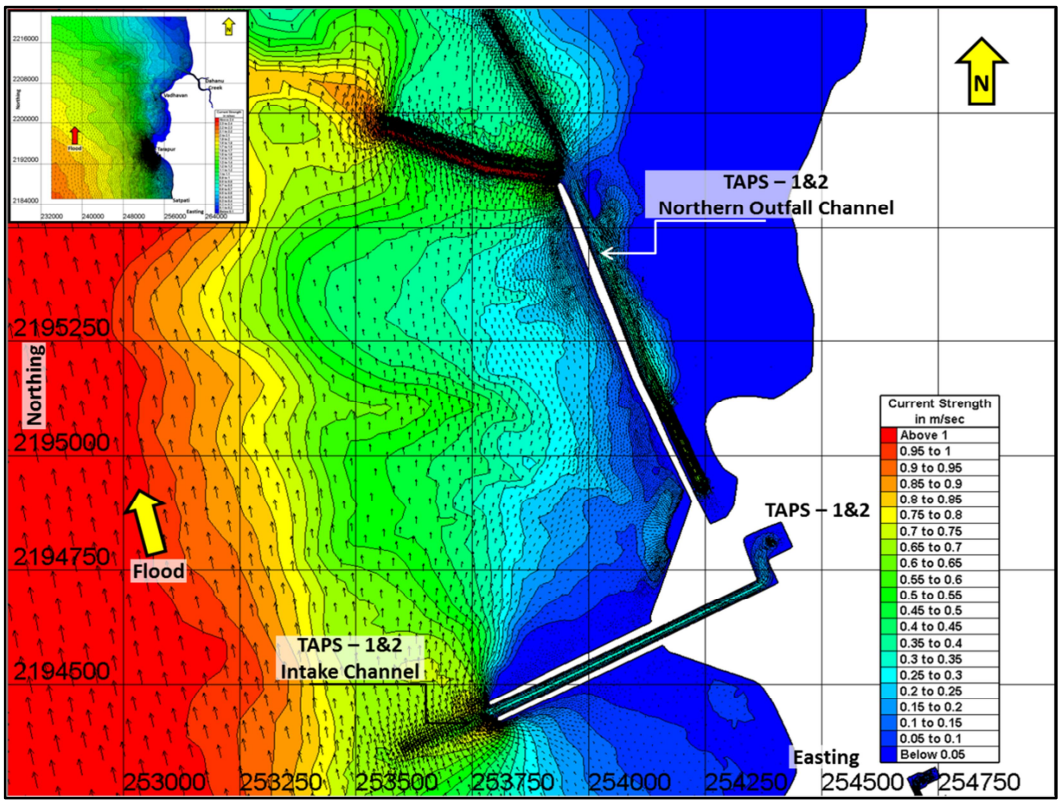


FIG. 15(A): Flow Patterns observed during Flood Tide near TAPS-1&2- Existing Condition

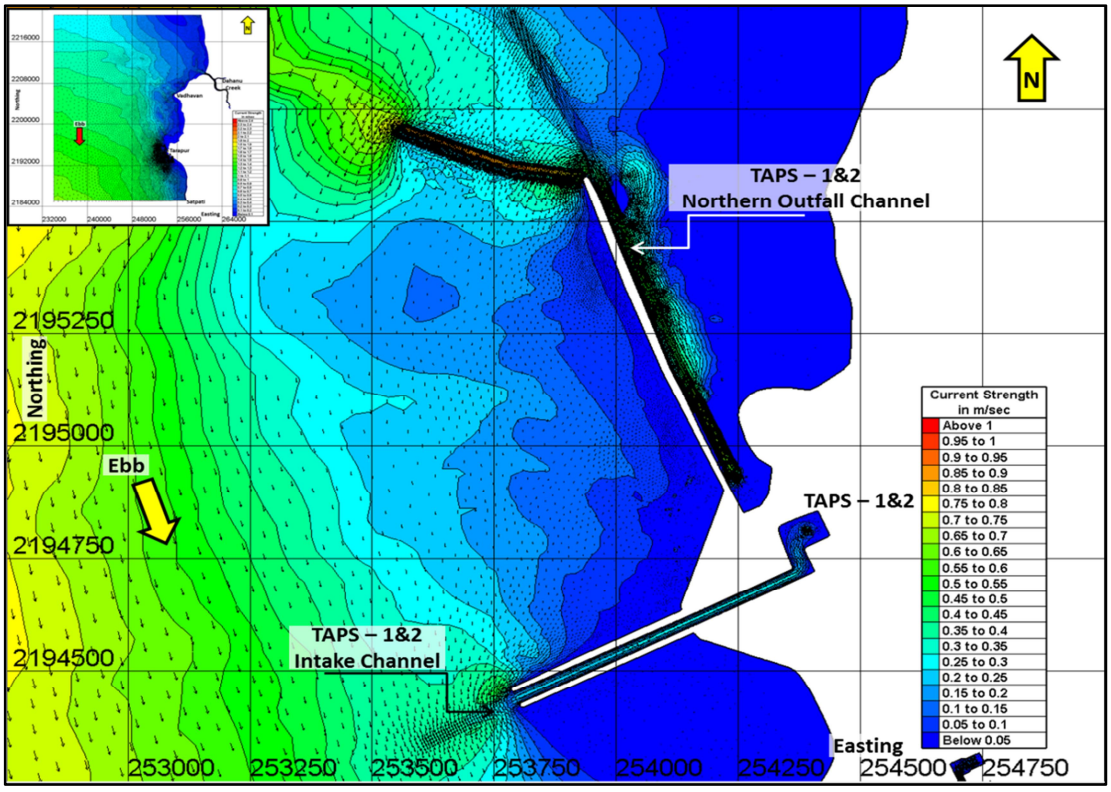


FIG. 15(B): Flow Patterns observed during Ebb Tide near TAPS-1&2- Existing Condition

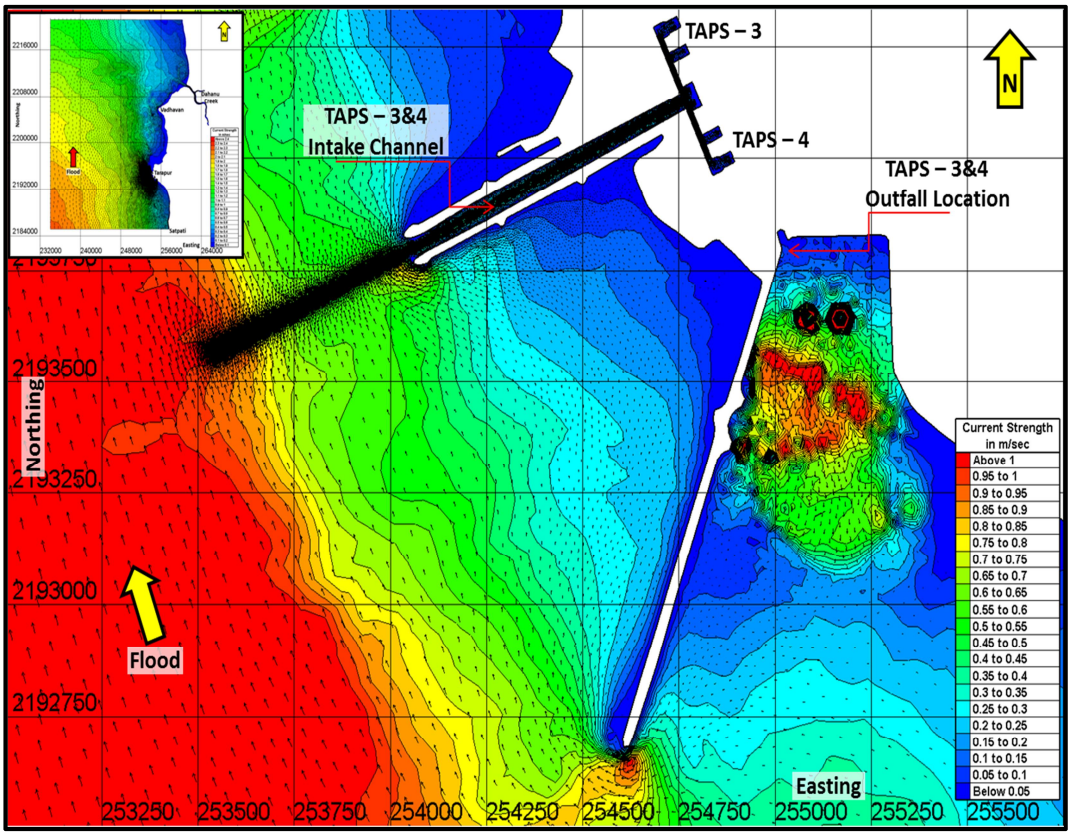


FIG. 15(C): Flow Patterns observed during Flood Tide near TAPS-3&4- Existing Condition

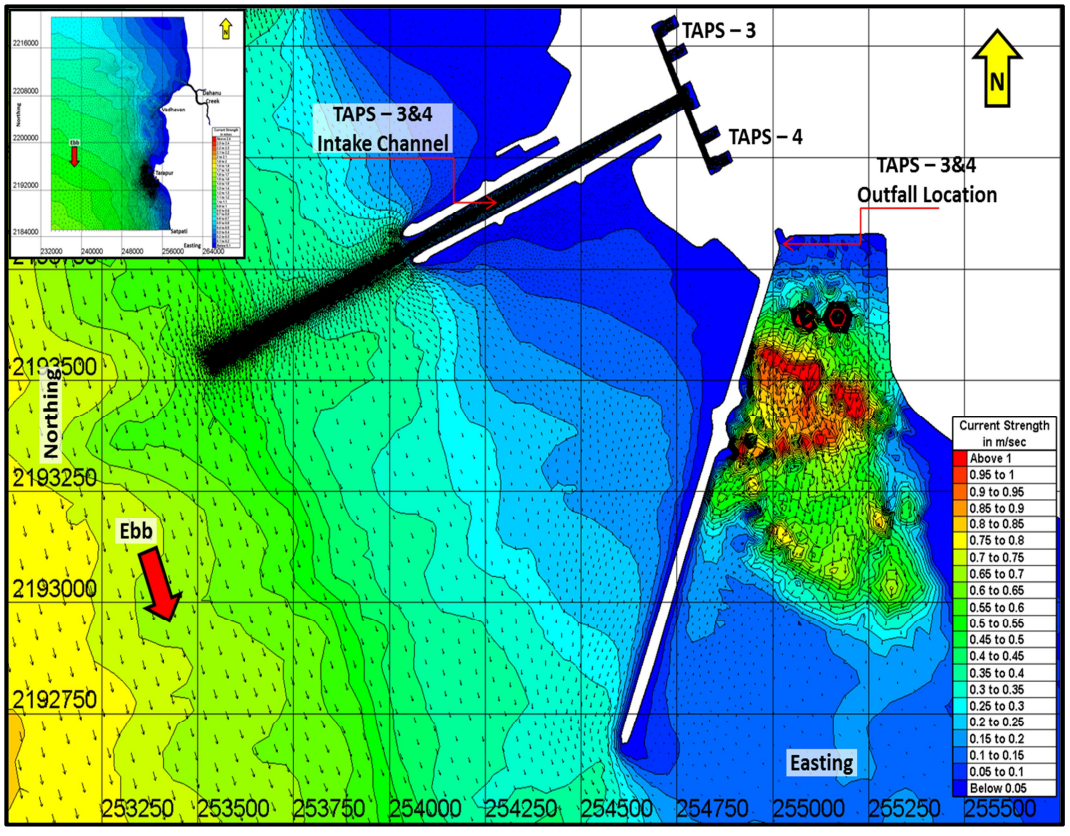


FIG. 15 (D): Flow Patterns observed during Ebb Tide near TAPS-3&4- Existing Condition

The data on current strength at various locations is extracted from model and these locations (near TAPS area-Intake & Outfall Channels) are shown in FIG. 16(A), while locations in forebays/pumpbays are shown in FIG. 16(B).

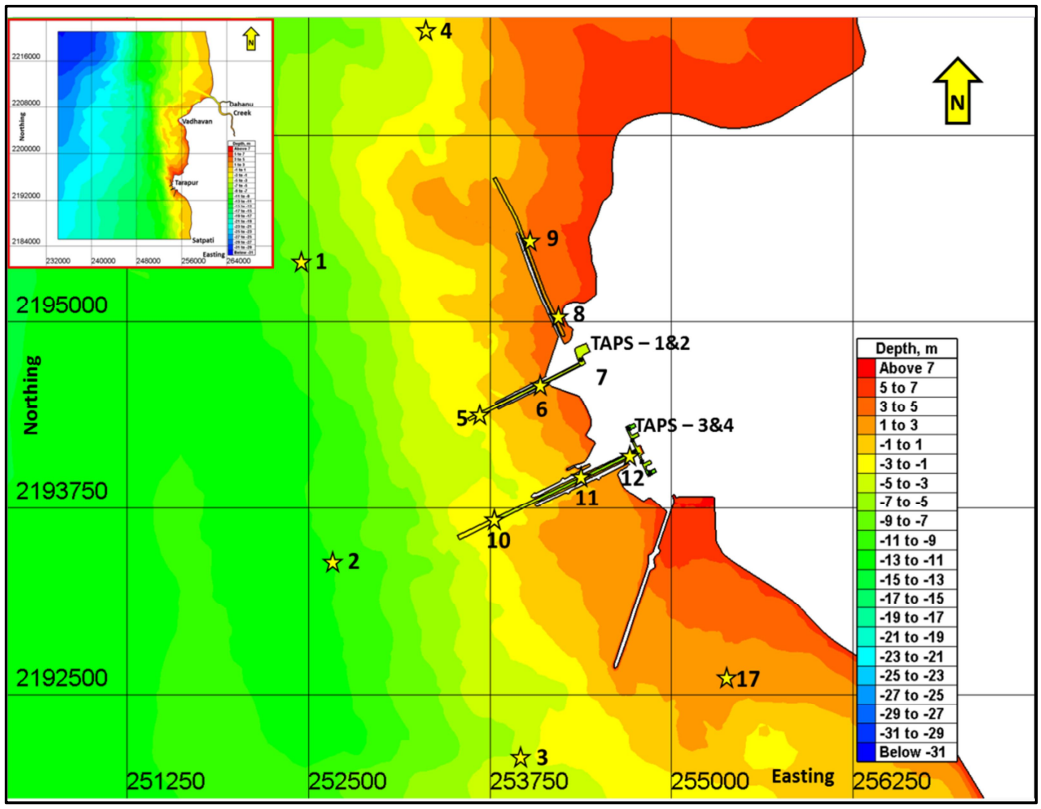


FIG. 16 (A): Locations of Current Data near TAPS Area

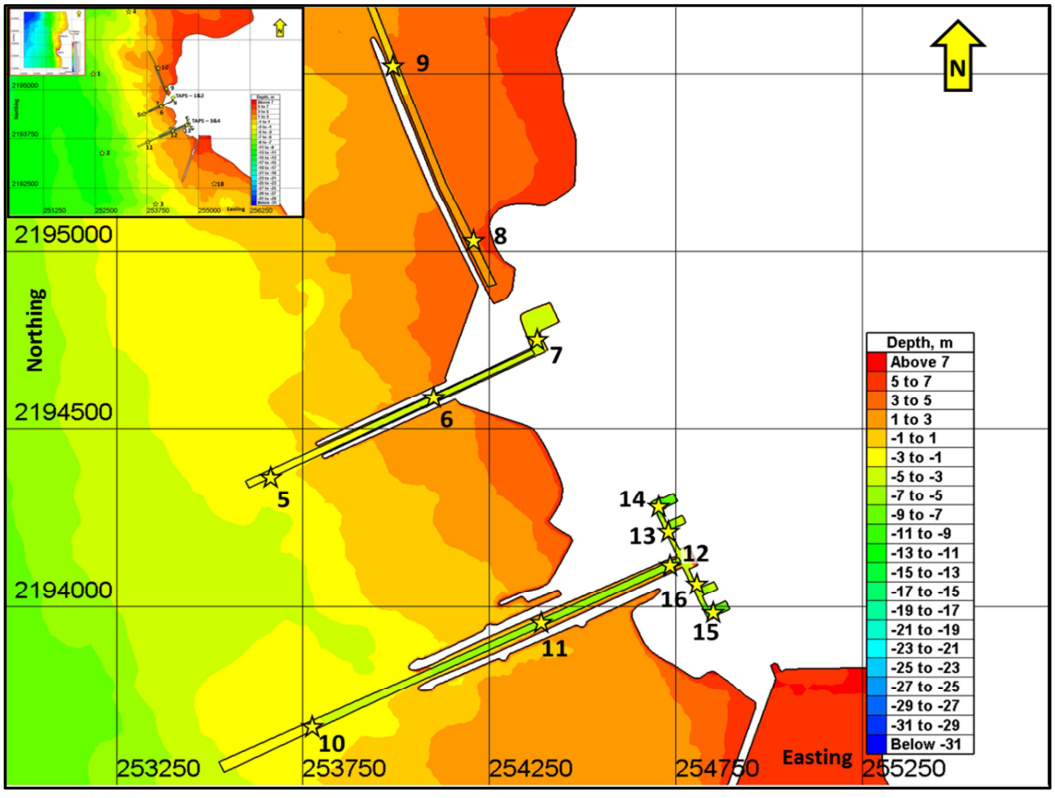


FIG. 16(B): Locations of Current Data in Forebays / Pumpbays of TAPS

The average current strengths observed in model at above locations are given in Table-I.

TABLE-I
Current Strengths at Various Locations near TAPS (Existing Condition)

	Locations Near TAPS																
Point number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Ave.Current strength,m/s for Existing Condition	0.633	0.610	0.493	0.247	0.281	0.338	0.218	0.765	0.697	0.230	0.422	0.495	0.776	0.117	0.108	0.777	0.172

Similarly, in order to assess the impact of proposed port at Vadhavan, the model is modified by incorporating the final layout of port at Vadhavan. The hydrodynamic studies were carried out for the modified scenario and are described in detail in the following paragraph.

4.2 Hydrodynamic Studies to assess flow field near TAPS – Final Port Layout

The hydrodynamic model modified by incorporating the final layout of port at Vadhavan is used to assess the likely changes in the flow-field (current, water depths) for the tidal hydrodynamic conditions prevailing during non-monsoon season (Year 2017). For the studies under consideration, the discharges of pump intakes and outfalls for both TAPS-1&2 and 3&4 as considered for existing condition were again simulated. The bathymetry/bed levels in this area after incorporation of recommended layout of port at Vadhavan is shown in FIG.17.

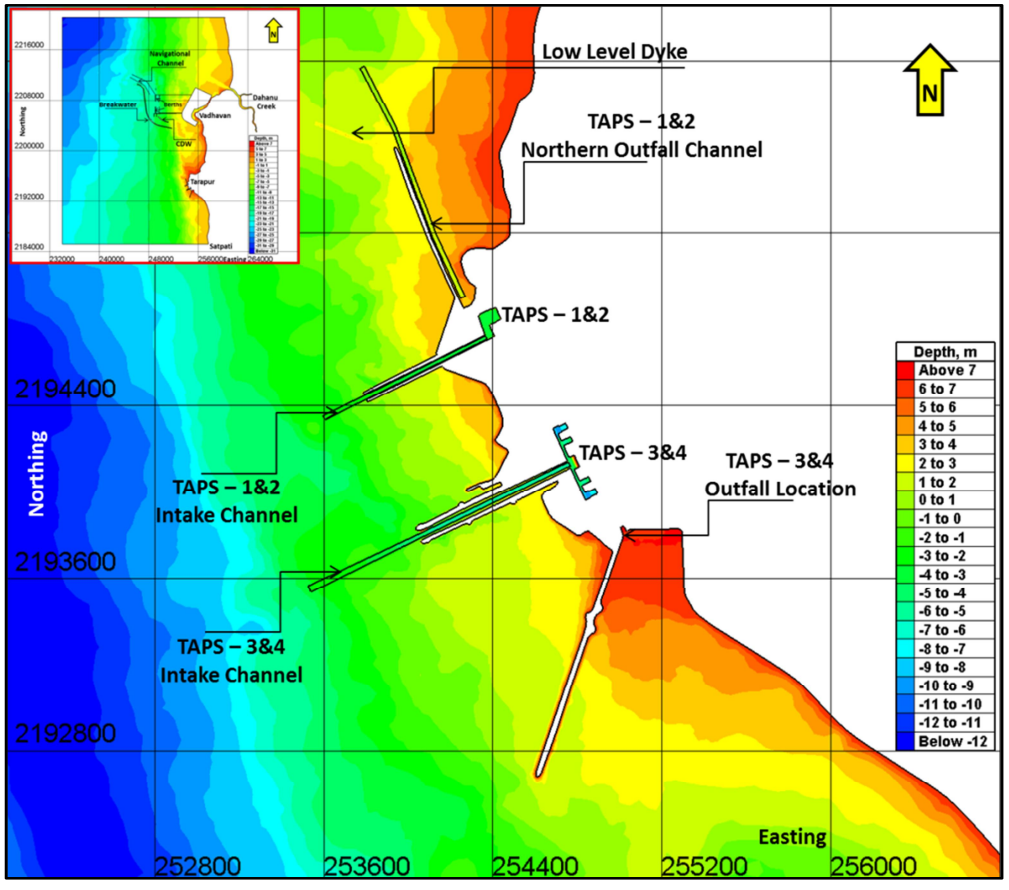


FIG. 17: Bathymetry near TAPS for Final Port Layout

The flow field observed in model near TAPS-1&2 is shown in FIG. 18(A) & 18(B), while in FIG.18(C) & 18(D) for TAPS-3&4 during flood and ebb phase of the tide respectively.

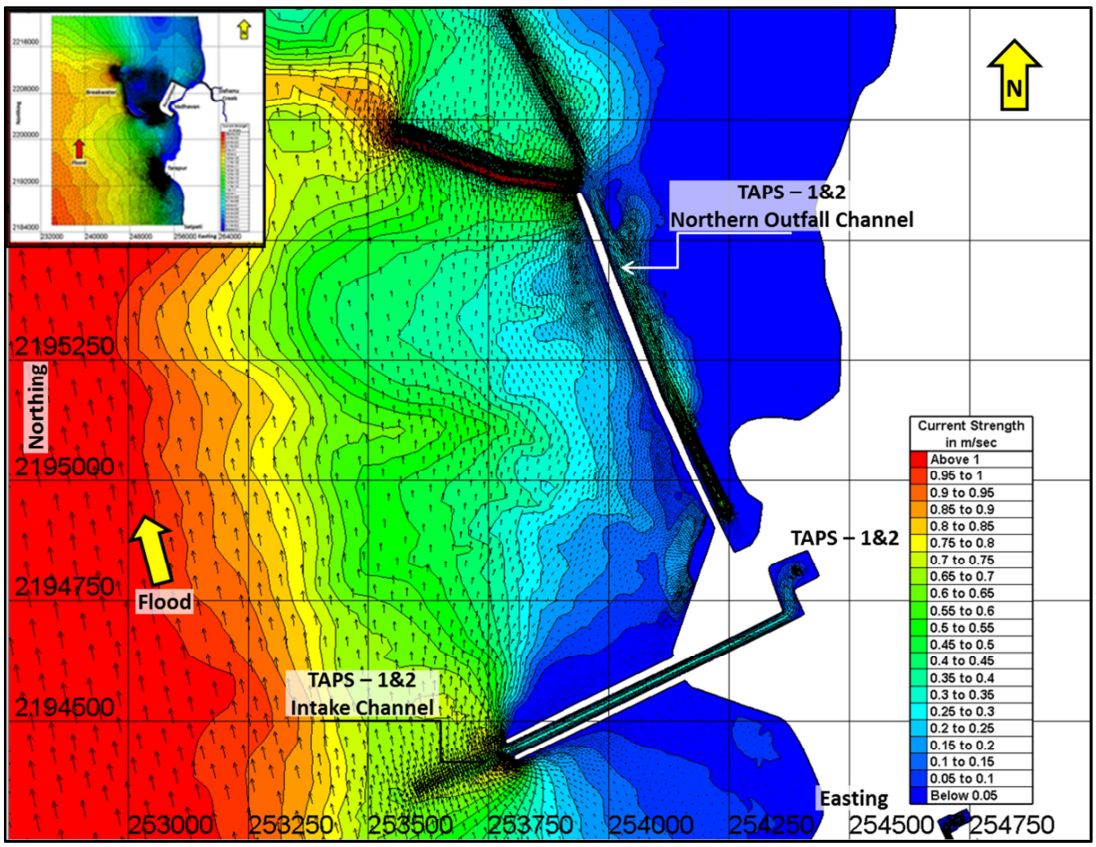


FIG. 18(A): Flow Patterns observed during Flood Tide near TAPS-1&2 -Final Port Layout

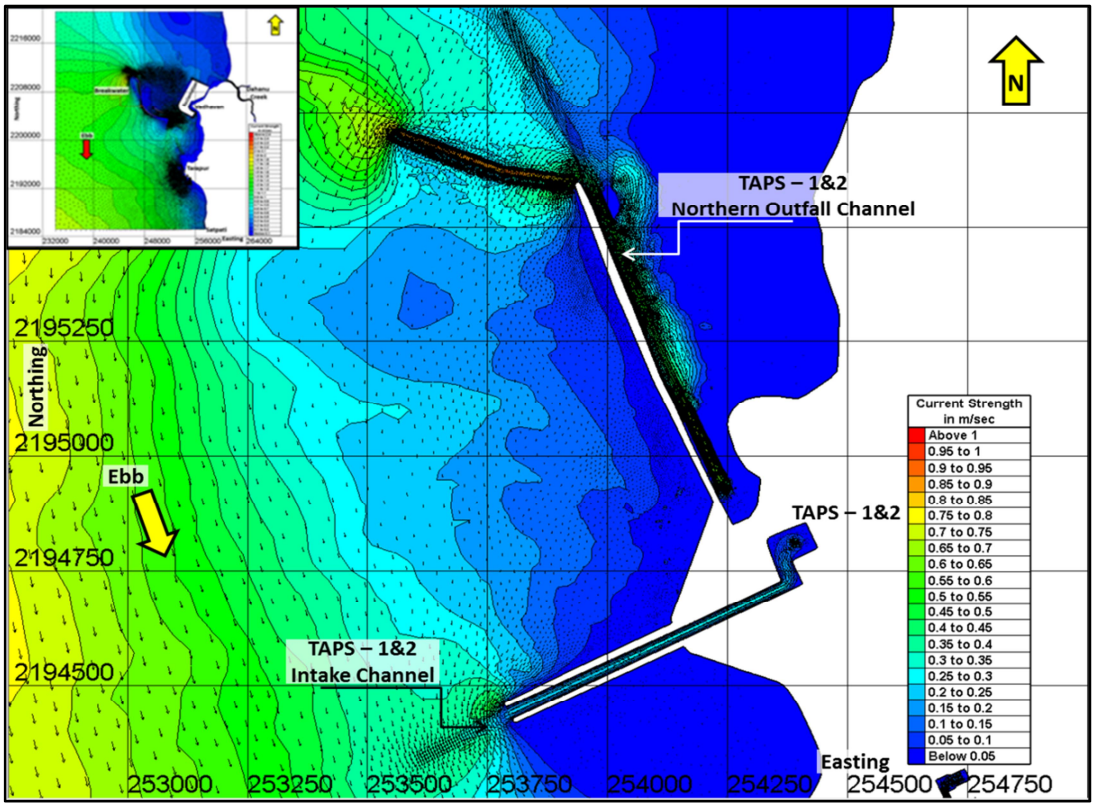


FIG. 18(B): Flow Patterns observed during Ebb Tide near TAPS-1&2 -Final Port Layout

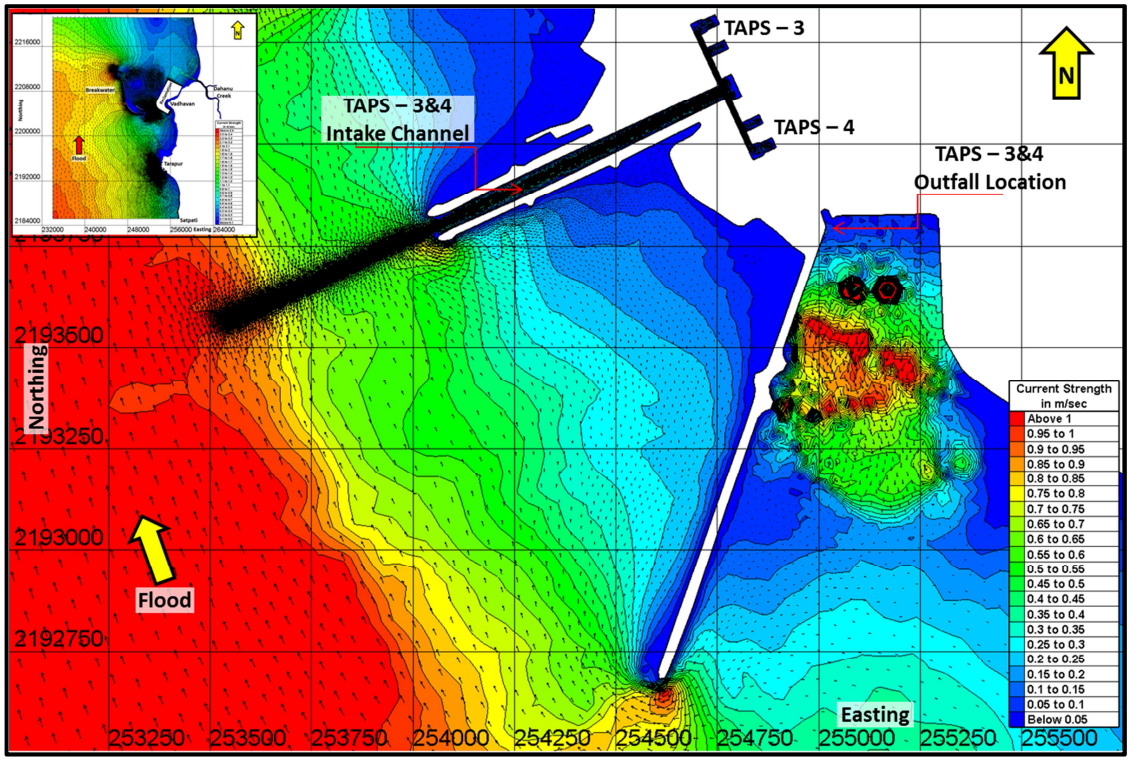


FIG. 18(C): Flow Patterns observed during Flood Tide near TAPS-3&4 -Final Port Layout

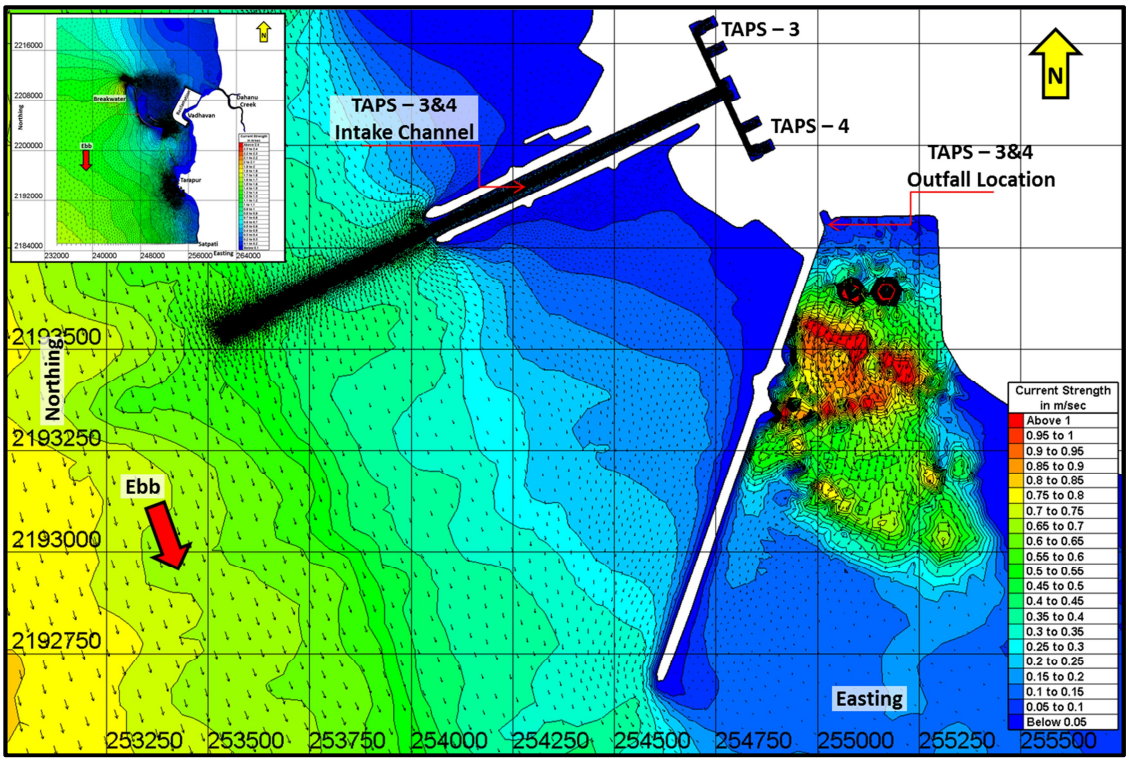


FIG. 18(D): Flow Patterns observed during Ebb Tide near TAPS-3&4 -Final Port Layout

The locations where the current strength observed in model near TAPS area-Intake & outfall channels for final port layout condition are similar to those for existing condition as shown in FIG. 16(A), while for forebays/pumpbays are shown in FIG.16 (B). The current strengths obtained from model at these locations are given in Table-II.

TABLE-II
Current Strengths at Various Locations near TAPS (Final Port Layout)

	Locations Near TAPS																
Point number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Ave.Current strength,m/s for Proposed Layout	0.579	0.560	0.451	0.221	0.259	0.331	0.215	0.757	0.696	0.212	0.420	0.494	0.777	0.115	0.109	0.788	0.168

4.3 Assessment of impact on hydrodynamics due to proposed port at Vadhavan

The studies carried out for the simulation of tidal hydrodynamic condition including reproduction of discharges at Pump intake/ northern outfall for TAPS-1&2 and Pump intake/ outfall of 3&4 for the existing condition as well as with final port layout of Vadhavan were used for assessment of impact of proposed port on TAPS from tidal hydrodynamic consideration. Based on above studies, the impact of proposed port at Vadhavan on TAPS is assessed by comparing the current strengths and water depths at various locations in and around TAPS area. The plots for comparison of the current strengths at typical few locations given in FIG. 16(A) & 16(B) (in intakes, outfalls and forebays/pumpbays etc.) in and around TAPS are shown in FIG. 19 to 26.

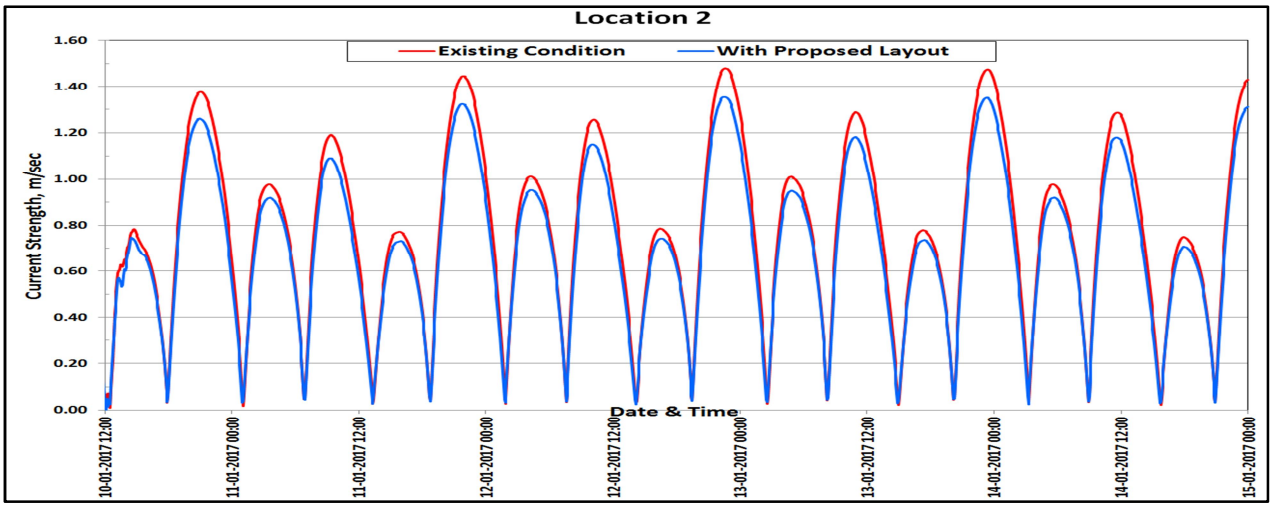


FIG. 19: Comparison of Current Strength at Location 2

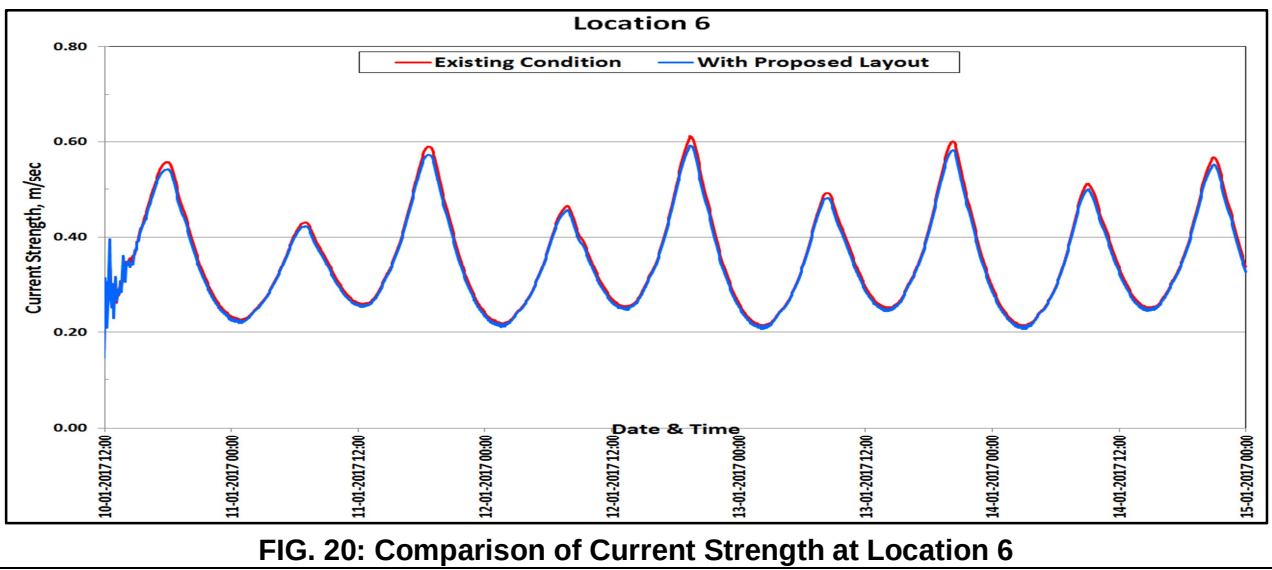


FIG. 20: Comparison of Current Strength at Location 6

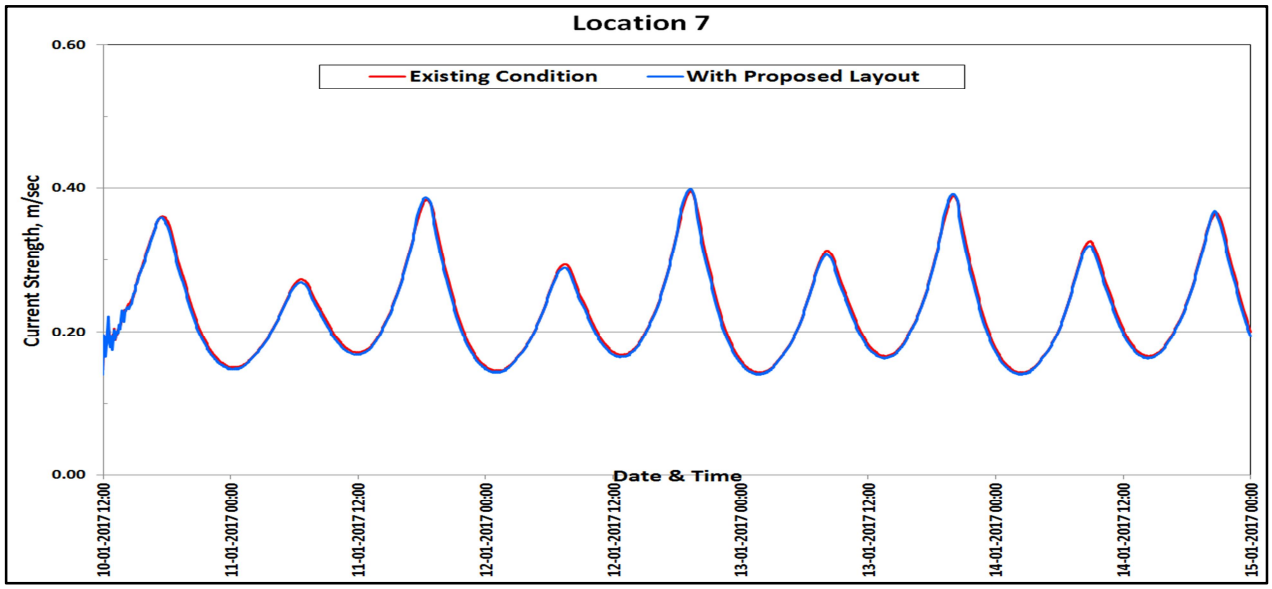


FIG. 21: Comparison of Current Strength at Location 7

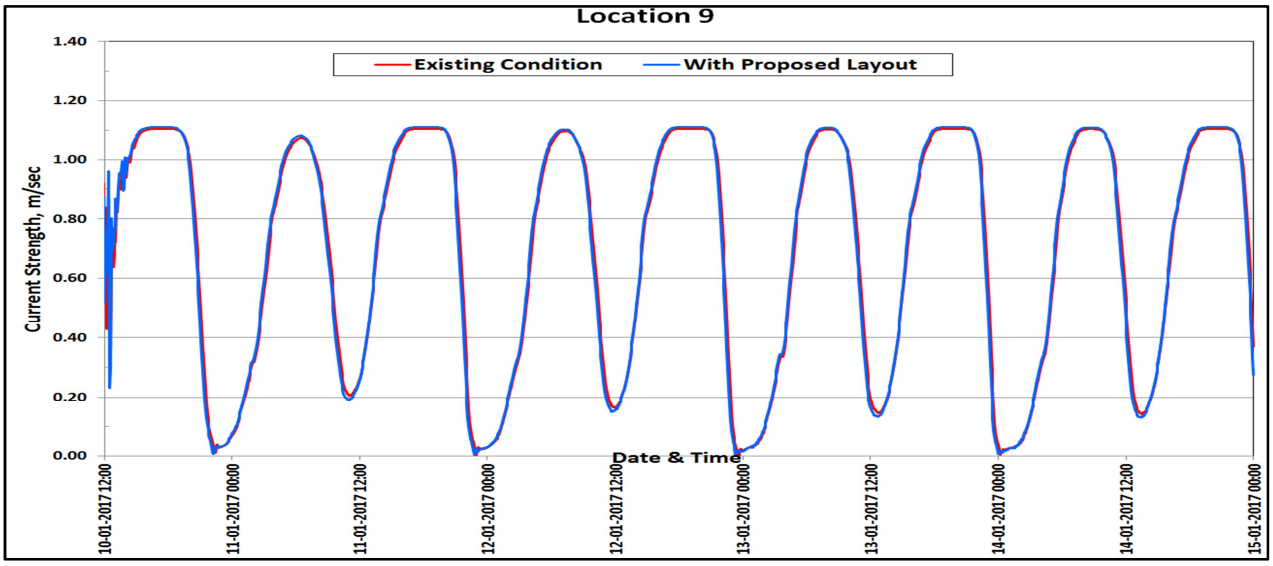


FIG. 22: Comparison of Current Strength at Location 9

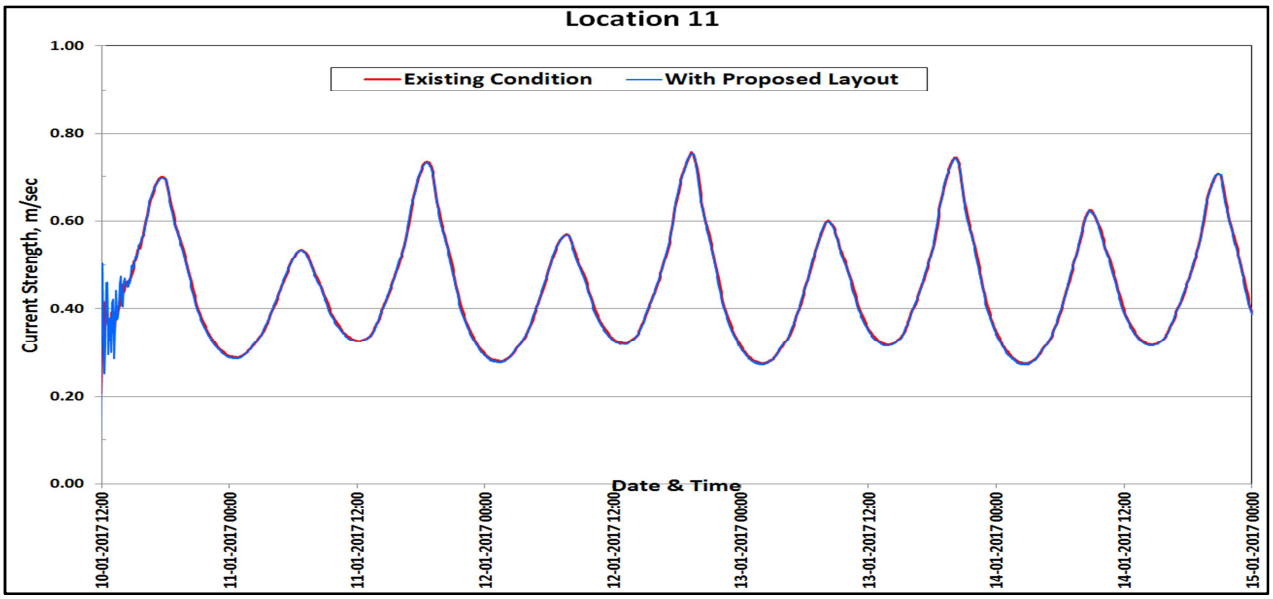


FIG. 23: Comparison of Current Strength at Location 11

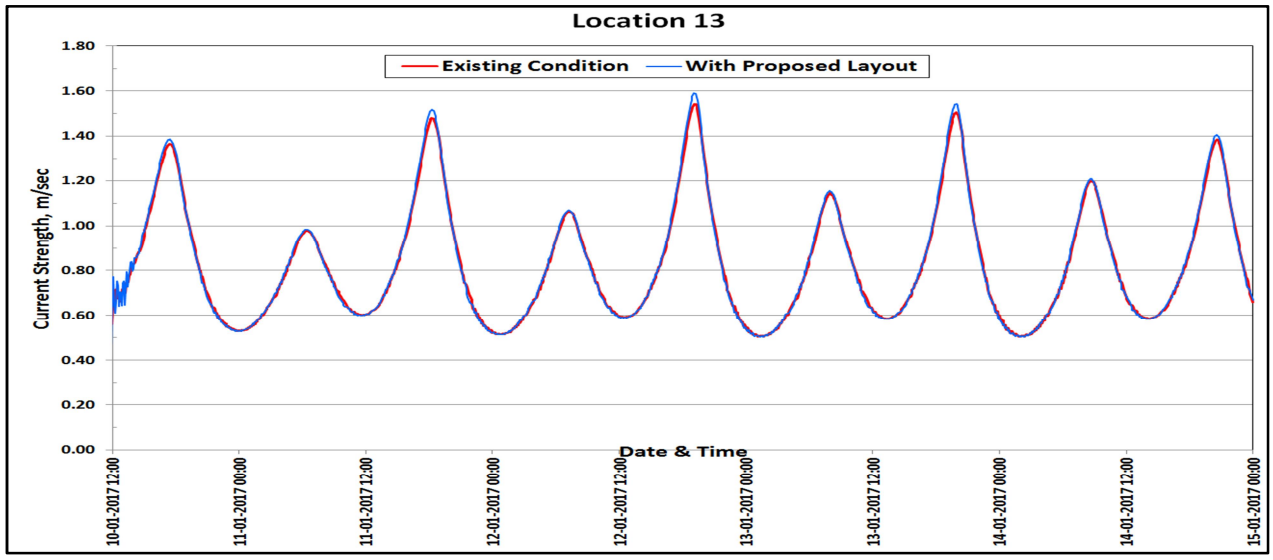


FIG. 24: Comparison of Current Strength at Location 13

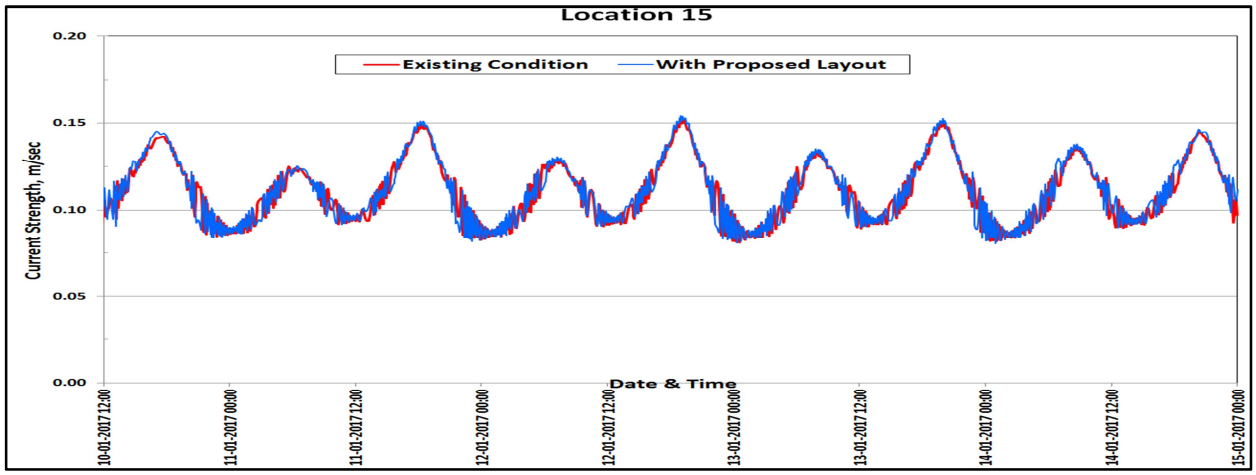


FIG. 25: Comparison of Current Strength at Location 15

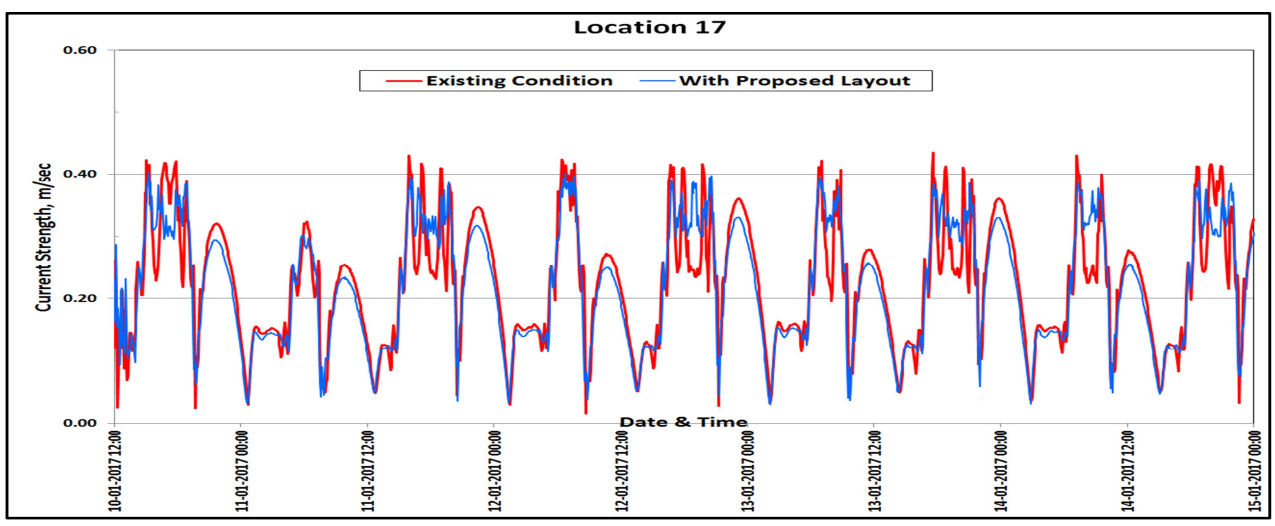


FIG. 26: Comparison of Current Strength at Location 17

The comparison of average current strengths measured at various locations (1-17) in and around TAPS for existing condition as well as with proposed port layout and its variation in percentage is given in Table-III.

TABLE-III
Comparison of Current Strengths at Various Locations near TAPS

Point number	Average Current Strength,m/s		Percentage Variation in Current Strength
	Existing	Proposed Layout	
1	0.633	0.579	-9%
2	0.610	0.560	-8%
3	0.493	0.451	-9%
4	0.247	0.221	-11%
5	0.281	0.259	-8%
6	0.338	0.331	-2%
7	0.218	0.215	-2%
8	0.765	0.757	-1%
9	0.697	0.696	0%
10	0.230	0.212	-8%
11	0.422	0.420	0%
12	0.495	0.494	0%
13	0.776	0.777	0%
14	0.117	0.115	-2%
15	0.108	0.109	1%
16	0.777	0.788	1%
17	0.172	0.168	-2%

It is observed from above table that, due to the development of proposed port at Vadhavan there will be reduction in the current strength by about 9% on the seaward side of intake channels of TAPS (in relatively deeper part of sea, Point No. 1, 2, 3), while it is about 11% on north side of northern outfall channel of TAPS-1&2 (Point No. 4) being nearer to Vadhavan port and about 2% on southern side of outfall channel of TAPS-3&4 (Point No. 17) being far away from Vadhavan port. However, in the guided portion of intake channels, forebays as well as outfalls of TAPS-1&2 and 3&4, there will be insignificant impact on current strength (<2%).

The water depths extracted from the model at various locations such as forebays of TAPS-1&2 and 3&4 (Point No. 7,14 &15) are compared for with and without proposed port at Vadhavan and are shown in FIG. 27-29 respectively.

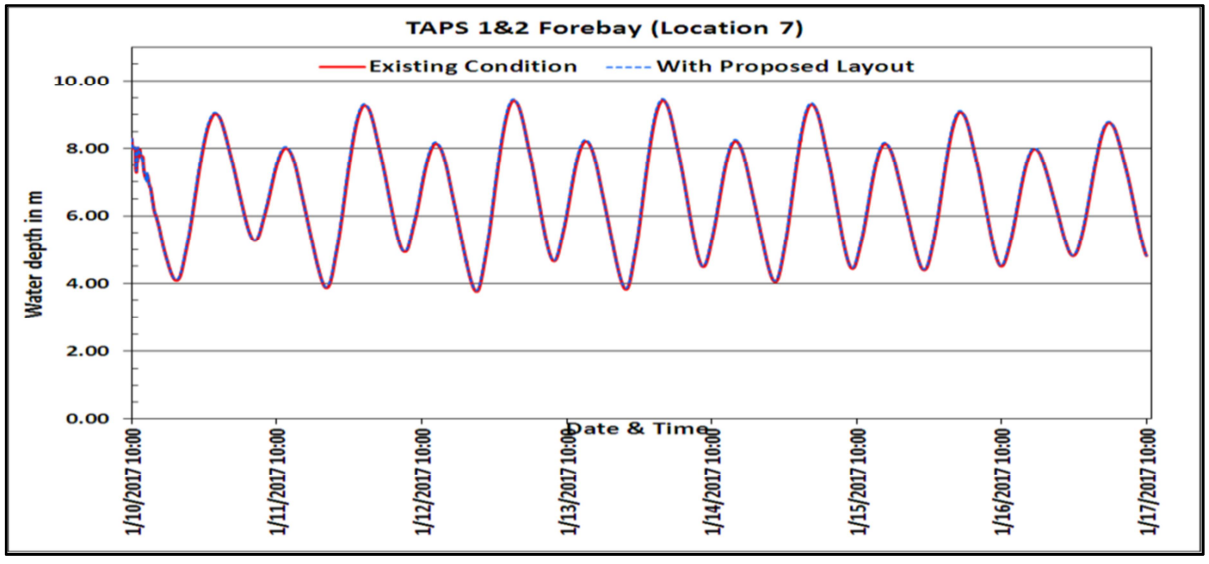


FIG. 27: Comparison of water depths at Location 7

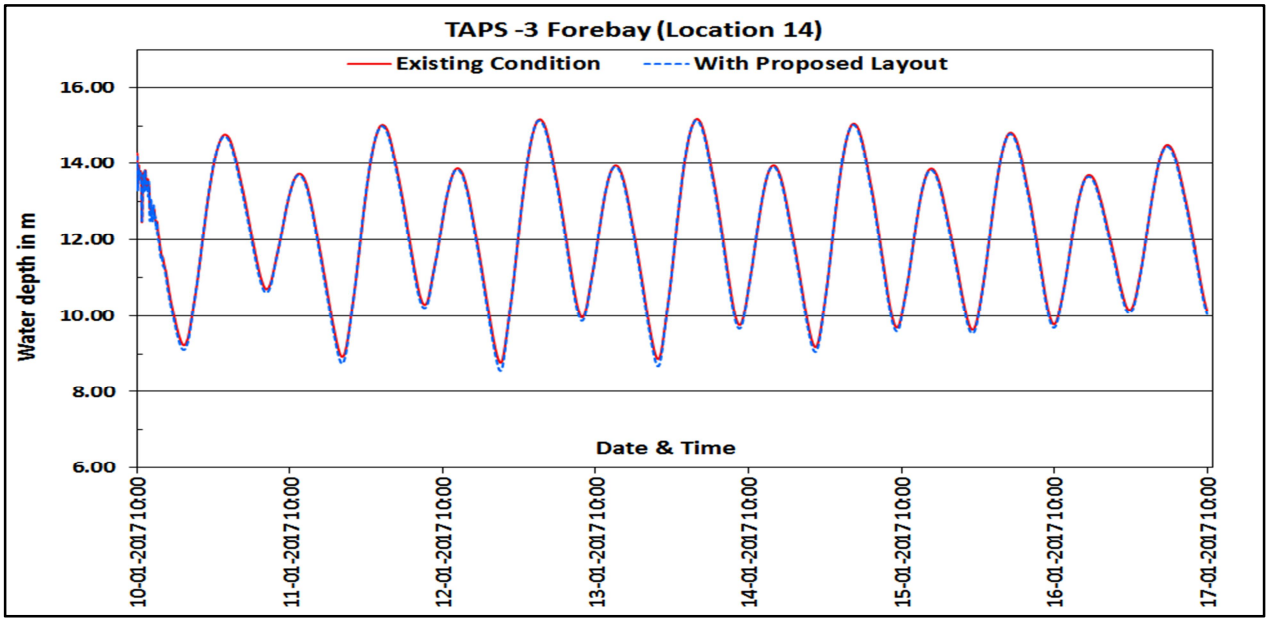


FIG. 28: Comparison of water depths at Location 14

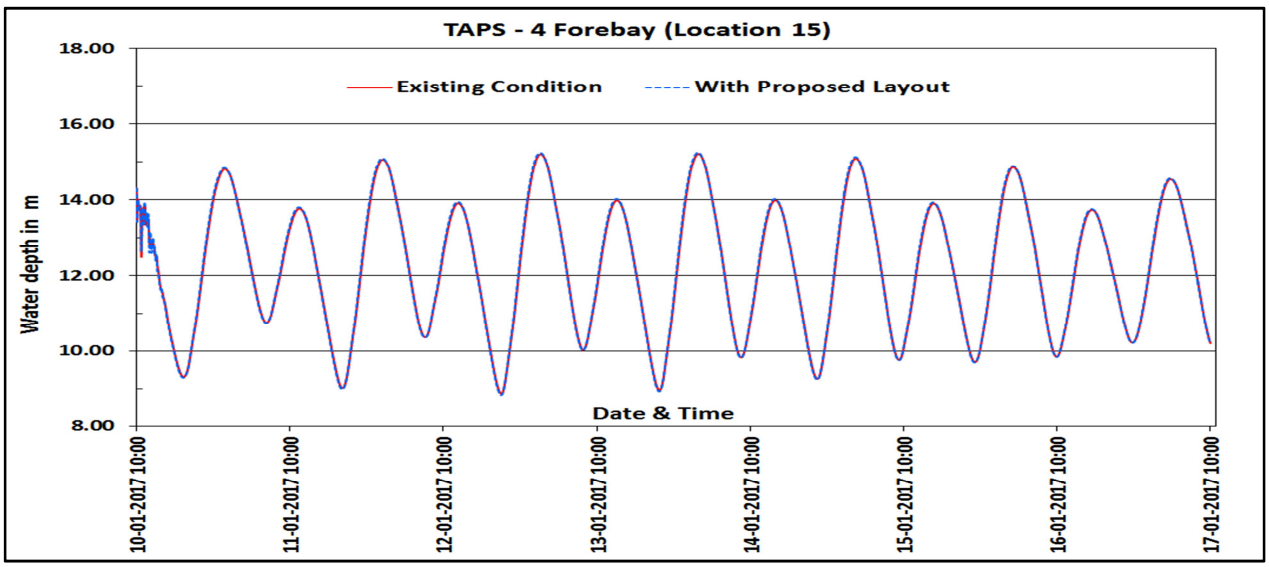


FIG. 29: Comparison of water depths at Location 15

It is observed from above figures that, there will be negligible variation (<1%) in water depths in forebays, pumpbays of TAPS-1&2 and 3&4 due to proposed port layout as compared with that of existing condition (without port layout).

5. STUDIES TO ASSESS IMPACT OF PORT AT VADHAVAN ON SILTATION AT TAPS

The assessment of the impact of proposed development of port at Vadhavan on siltation at TAPS is carried out using the information on suspended sediment concentration (Non-monsoon Season only) provided by JNP vide letter dated 23.01.2018. The details of field data collected for SSC as well as bed samples are reported in CWPRS TR No. 5583 of March 2018. The plot of variation of suspended sediment concentration (SSC) in mg/lit along with respective tide at Dahanu is shown in FIG. 30.

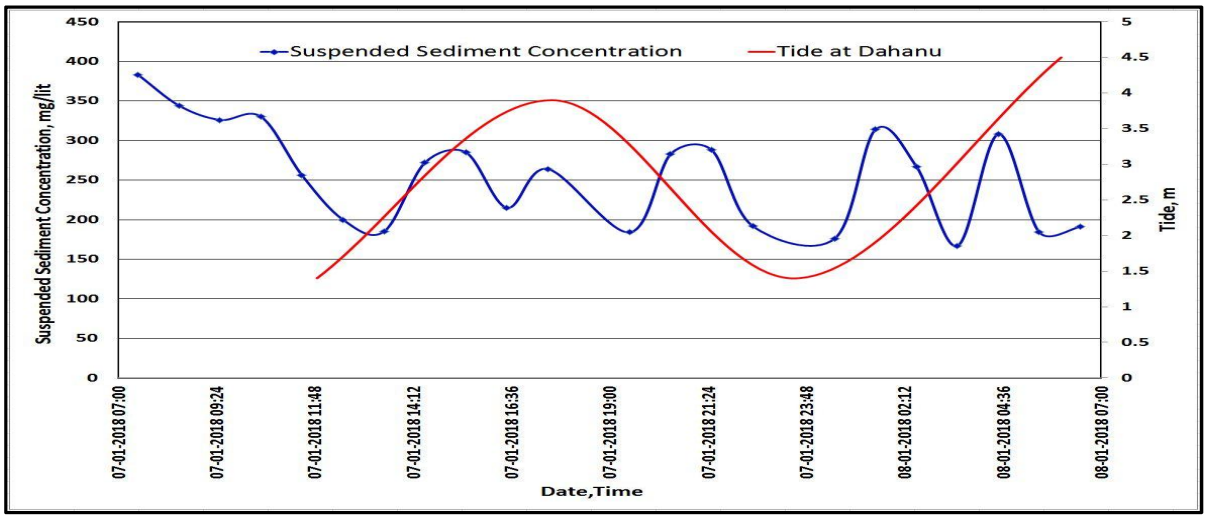


FIG. 30: Plot of Suspended Sediment Concentration (SSC) and Tide at Dahanu

The plot indicates that the SSC varies from 380 mg/lit to 170 mg/lit, wherein the concentration is higher during mid-tide level, while it reduces as the flow reaches to high water during flood tide and low waters during ebb tide. The grain size analysis of suspended sediments carried out reveal that the suspended sediments contain 68% of silt and 26% of clay and as such the sediment is classified as clayey silt having grain size D_{50} as 0.008 mm. The data collected on bed samples reveal that the bed material is also clayey silt with D_{50} varies between 0.005 mm and 0.015 mm. This indicates that the material in suspension and that at bed is having similar characteristics that the material is of cohesive nature. Further to this, it can also be inferred that the deposition of the material at bed is due to settlement of the material in suspension. This information is of significance to decide the type of sediment transport formulation to be used to estimate the likely rate of deposition/siltation.

CWPRS Officials along with JNPT official visited TAPS-1&2 and 3&4 on 25-26th October 2018 to discuss about siltation in intake/outfall channels as well as forebays/pumpbays area of TAPS-1&2 and 3&4. The information about silt getting accumulated at intakes/outfalls, forebays, pumpbays etc. was provided by JNP for TAPS-1&2 and 3&4 vide email dated 30th November 2018 (TAPS letter No. TAPS 3&4/TSS/2018/S/121 dated 30.11.2018) and described in paragraph 2.5 of this report.

5.1 Siltation Studies for TAPS-1&2 and 3&4 – Existing Condition

The data forwarded by JNP about TAPS mentioned that the de-silting of intake channel up to pump bay of TAPS-1&2 was carried out every year, while for TAPS-3&4 the de-silting is being carried out for pump bays once in two years. The TAPS officials during discussions in October 2018 informed that de-silting of northern outfall channel of TAPS-1&2 and outfall at 3&4 is not carried out and as such it is considered that the flow velocities in these areas are sufficient enough to flush the sediments or the sediment getting deposited is practically negligible which do not require de-silting.

The quantity of silt deposited in the areas where de-silting is carried out is presented in Table-IV.

TABLE-IV
Present Rate of Deposition of Silt at TAPS

Area	Duration (Years)	Deposition of Silt (Cum)
Intake channel up to traveling screen of TAPS-1&2	1 Year	362
Pump bays of TAPS-3&4 (Each unit)	2 Years	1100

The above mentioned information about silt getting accumulated was utilized to calibrate the silt model at prescribed locations of TAPS area given in Table-IV and is described in following paragraph.

Calibration of Silt Model

The calibration of silt model for present rate of siltation at TAPS-1&2 and 3&4 was carried out by considering various parameters responsible for siltation. The hydrodynamic conditions determined during non-monsoon season were considered for the same. The well calibrated hydrodynamic model for simulating tidal phenomenon is used to couple it with sediment module "SISYPHE" of TELEMAC suite. The suspended sediment concentration (SSC) in the nearby area of TAPS happens to be between 380 mg/lit to 170 mg/lit during non-monsoon season for the period for which data collection was carried out. The parameters such as grain size of bed material and suspended sediments, SSC, settling velocity of suspended sediment, salinity, temperature, current strength etc. from field data which contribute to the process of siltation were considered for the model studies under consideration in association with the information CWPRS had for the nearby area of TAPS on sediment characteristics during the year. The material being of cohesive in nature, the erosional and depositional behaviour of sediment in the area under consideration is estimated based on Krone (1962) and Parthenaides (1962) formulation, which is adopted in Telemac software. The calibration of siltation is carried out at TAPS-1&2 and 3&4 areas and is shown in FIG. 31 & 32 respectively.

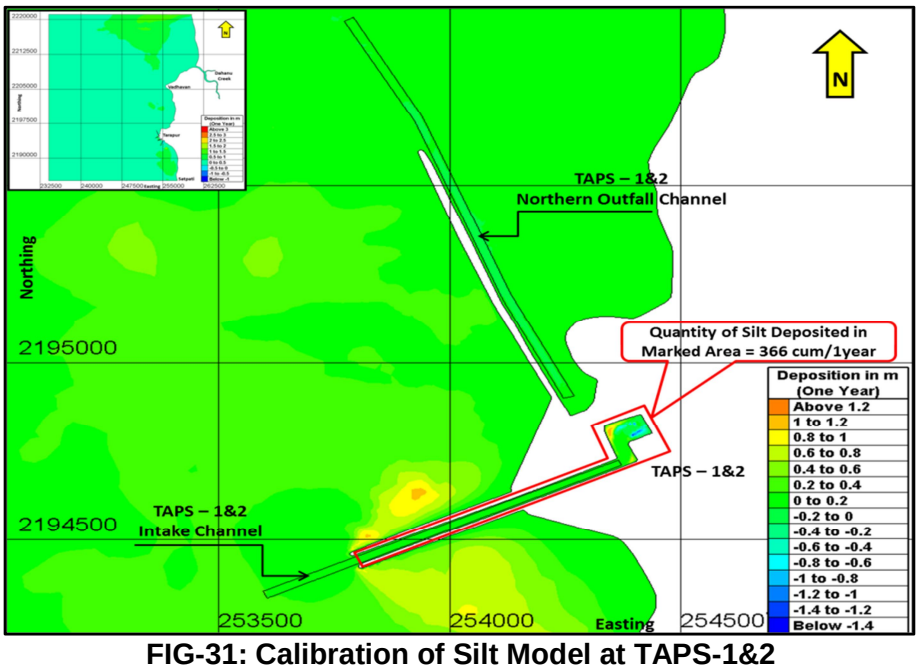


FIG-31: Calibration of Silt Model at TAPS-1&2

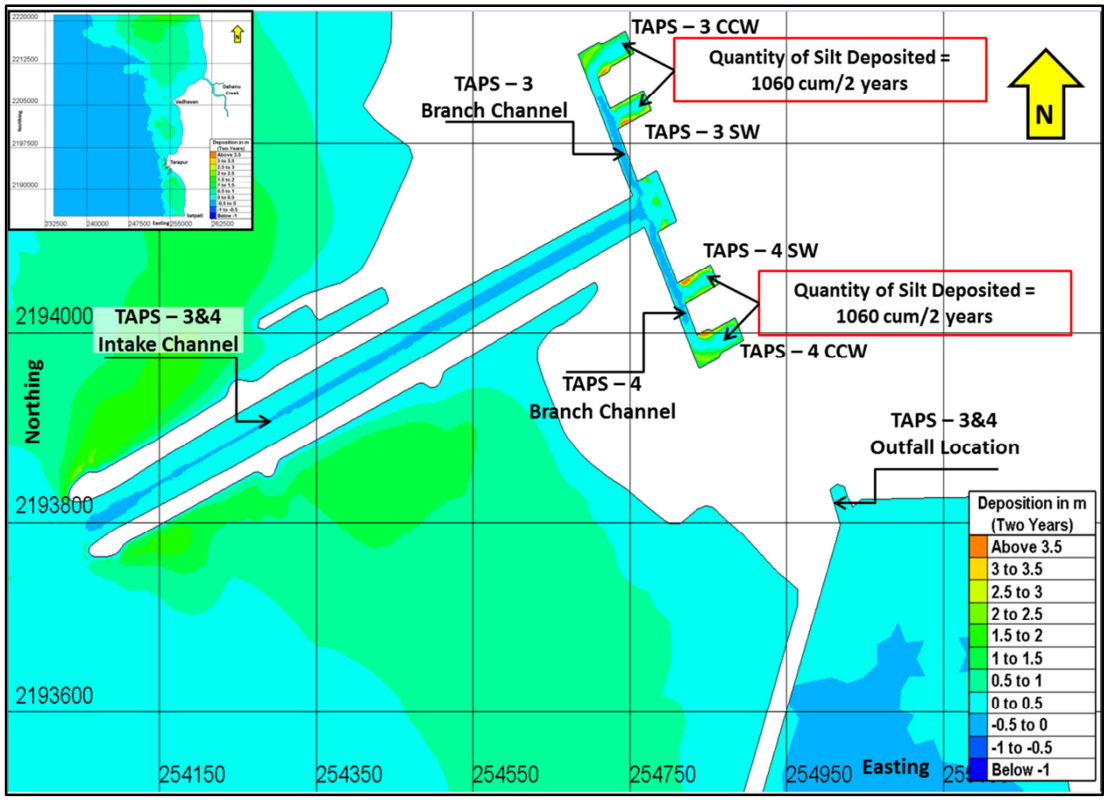


FIG-32: Calibration of Silt Model at TAPS-3&4

The comparison of quantity of silt deposited at prescribed areas of TAPS-1&2 and 3&4 (provided by TAPS) and that estimated from model is given in Table-V.

TABLE-V
Comparison of Quantum of Silt Deposited in Prototype and Model for TAPS

Area considered for calibration	Quantum of silt deposition in cum	
	PROTYPE	MODEL
Intake channel up to pump bay of TAPS-1&2	362 (for 12 months)	366 (for 12 months)
Pump bays of TAPS-3&4 (Each Unit)	1100 (for 24 months)	1060 (for 24 months)

It is inferred from above table that the silt module is reasonably well calibrated for quantity of silt deposited at prescribed area of TAPS-1&2 and 3&4.

5.2 Siltation at TAPS-1&2 and 3&4 – Final Port Layout Condition

The parameters used for calibration of silt model were also adopted to estimate the likely rate of siltation at TAPS-1&2 and TAPS-3&4 for the case of domain which includes final port layout (CWPRS TR No. 5583 of March 2018). The pattern of likely rate of siltation/deposition over the prescribed area of TAPS-1&2 as well as TAPS-3&4 are shown in FIG. 33 (A) & 33(B) respectively.

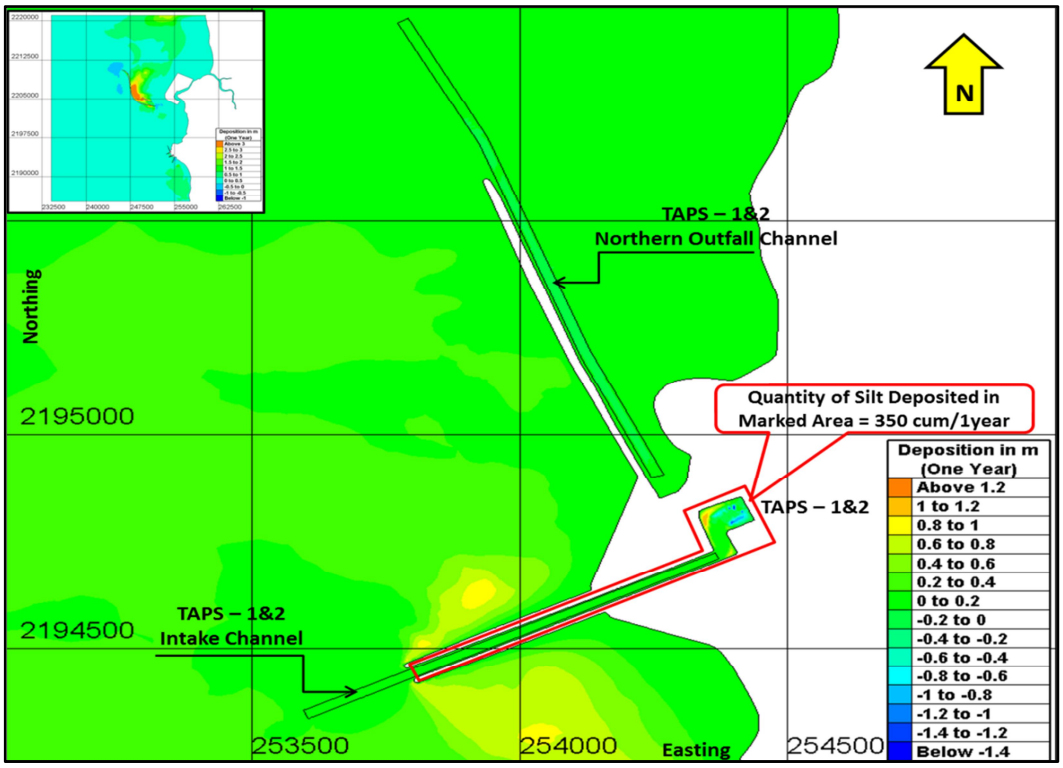


FIG. 33(A): Zoomed Portion of Silt Deposition for TAPS-1&2 - Final Port Layout

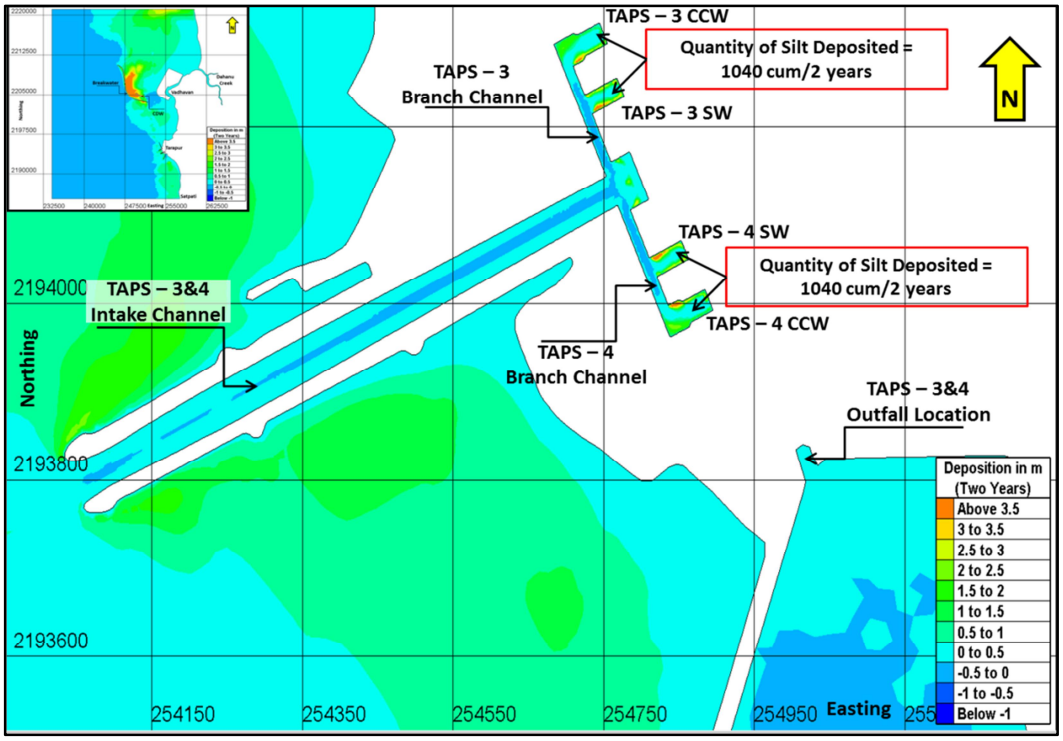


FIG. 33(B): Zoomed Portion of Silt Deposition for TAPS-3&4 - Final Port Layout

The studies to estimate the likely quantum of silt deposition in intake channel up to traveling screens of TAPS-1&2 and pump bays of TAPS-3&4 reveal that, the quantity of silt deposited will be about 350 cum for period of one year for TAPS-1&2; while it will be about 1040 cum per unit for the period of two years for TAPS-3&4. This comparison of likely quantum of silt deposition at TAPS-1&2 and 3&4 obtained from model for existing and with final port layout condition is given in Table-VI.

TABLE-VI
Comparison of Estimated Quantum of Silt Deposition Obtained from Model for Existing & Final Port Layout Conditions

Area considered	Quantum of silt deposition in cum	
	Existing Condition	Final Port Layout Condition
Intake channel up to pump bay of TAPS-1&2	366 / yr	350 / yr
Pump-bays of TAPS-3&4 for Each unit	1060 / 2yrs	1040 / 2yrs
Northern Outfall Channel of TAPS-1&2 (Guided Portion)	2.0 / yr	2.0 / yr
Outfall of TAPS-3&4 (Down-flow side of Weir)	175 / yr	55 / yr

This reveals that there will not be increase in siltation in intake/outfall and pump bays of TAPS-1&2 and 3&4 due to development of proposed port at Vadhavan. In view of no de-siltation being carried out by TAPS in outfalls of TAPS-1&2 and 3&4, the siltation rates in outfalls are determined from model studies only. These values indicate practically no siltation over an area of TAPS-1&2 northern outfall channel and down-flow side of TAPS-3&4 outfall weir (up to 4 m contour w.r.t. CD) i.e. over area of about 20 ha. Thus at the outfall weir of TAPS-3&4, average depth of deposition per year is practically insignificant. The results obtained from model studies for intake channel, forebays and branch channel of TAPS-3&4 also shows a similar trend of reduction in quantum of siltation as that of prescribed areas considered for calibration of silt model. Thus there will not be adverse impact (increase in siltation) on TAPS intakes/outfalls due to development of proposed port at Vadhavan.

Note- The tidal hydrodynamic and siltation studies were carried out considering uninterrupted pumping from pumpbays with prescribed rate of pumping along with prescribed outfall discharges as provided by TAPS for units 1&2 and 3&4 as well as the de-silting is carried out every year in TAPS-1&2 and once in two years in each unit of TAPS-3&4..

6. CONCLUSIONS

1) The oceanographic data collected during January-February 2017 (Non-Monsoon Season) at the proposed port location at Vadhavan on various parameters such as tide, current, bed samples etc. indicate that the tides are semi-diurnal in nature with diurnal inequality and the maximum tidal range is about 5.87 m during spring tide, while it is 2.1 m during neap tide. As such the Vadhavan-Tarapur area is in macro tidal region. The information on current strength measured at mid-depth reveal that the maximum strength of the current is about 1.25 m/s during spring tide, while it is about 0.66 m/s during neap tide. The current direction w.r.t. north varies from 3º – 23º during flood tide, while it is about 204º – 215º during ebb tide. The suspended sediment concentration varies from 380 mg/lit to 170 mg/lit and contains 68% of silt and 26% of clay and as such the sediment is classified as clayey silt having grain size D_{50} as 0.008 mm. The analysis of the bed samples collected indicate that the material is Clayey Silt with average value of D_{50} as 0.011 mm.

2) The mathematical model developed for Vadhavan area indicates that for the existing bathymetry condition, the tide measured at the mouth of Dahanu creek and observed in model compares well and is 95% in agreement. Similarly, current strength & direction are also in good agreement with that observed at site. Thus mathematical model is reasonably well calibrated for the prevailing hydrodynamic flow conditions for the tide and current data provided by M/s JNP for non-monsoon season for the year 2017.The model is also validated for current data (24^{th} -25^{th} January 2018) collected by CWPRS for thermal mapping studies and is also in good agreement with field data measured in front of TAPS.
3) The hydrodynamic studies carried out reveal that, due to the development of proposed port at Vadhavan there will be reduction in the current strength by about 9% on the seaward side of intake channels of TAPS (in relatively deeper part of the sea). The reduction in the current strength by about 11% is observed on north side of northern outfall channel of TAPS-1&2 as this area is nearer to Vadhavan port, while by about 2% on southern side of outfall channel of TAPS-3&4, since it is far away from Vadhavan port. On the other hand, in the guided portion of intake channels, forebays as well as outfalls of TAPS-1&2 and 3&4 there will be insignificant impact on current strength (<2%).
4) The water depths at forebays, pumpbays of TAPS-1&2 and 3&4 are compared for with and without Vadhavan port layout and it reveal that, there is negligible variation (<1%) in water depths. As such, it can be concluded that there will not be any significant impact on TAPS due to proposed port development at Vadhavan from tidal hydrodynamic considerations.
5) The variation in current strength as well as water depth in intake channels of TAPS-1&2 and TAPS-3&4 is less than 2%, thus there will be insignificant variation in the volume of water available at pump bays compared to existing volume of water. Hence, it will not hamper the uninterrupted supply of desired volume of water to pumps which are operating at existing daily discharge rates for TAPS-1&2 and TAPS-3&4.
6) The likely quantity of silt deposition in intake channel up to traveling screens of TAPS-1&2 and pump bays of TAPS-3&4 observed in the model compares well with the quantity of silt deposited at site. These quantities of deposition are considered equivalent to the quantity removed from these areas at site during de-silting. Hence, it is revealed that the silt model is reasonably well calibrated for quantity of silt accumulated in areas of TAPS-1&2 and TAPS-3&4.
7) The quantity of silt deposition in intake channel up to traveling screens of TAPS-1&2 for existing condition is about 362 cum as observed at site, while about 366 cum is observed in the model for the period of one year. The likely quantum of silt deposition due to the development of proposed port at Vadhavan will be about 350 cum for the period of one year. Similarly, for TAPS-3&4 the quantity of silt deposition in pump bays for existing condition is about 1100 cum per unit as observed at site for the period of two years, while it is about 1060 cum as observed in the model. The likely quantum of silt deposition due to the development

of proposed port at Vadhavan will be about 1040 cum per unit for the period of two years as observed in the model.

8) The estimation of accumulation of silt due to the development of proposed port at Vadhavan indicates that there will not be increase in siltation in intake/outfall channels, forebays as well as pumpbays of TAPS for prescribed pumping rate at intakes as well as outfall discharges. Hence it can be concluded that there will not be any adverse impact of proposed port development at Vadhavan on siltation at intake/outfall channels, forebays as well as pumpbays of TAPS-1&2 and TAPS-3&4.

REFERENCES

1) CWPRS Technical Report titled “Mathematical model studies for assessment of wave tranquility for the development of proposed port at Vadhavan, Maharashtra” bearing No. 5558 of January 2018

2) CWPRS Technical Report titled “Mathematical model studies for hydrodynamics for hydrodynamics & siltation for the development of proposed port at Vadhavan for M/s JNPT” bearing No. 5583 of March 2018.

3) CWPRS Technical Report titled “Field data collection at Tarapur for the proposed development of port at Vadhavan, Maharashtra” bearing No. 5615 of August 2018

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