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MATHEMATICAL MODELING APPROACH FOR ASSESSMENT OF MAINTENANCE DREDGING IN A PORT

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Abstract: In recent years, increasing attention has been paid to development within the port sector. One of the aspects of the sustainable development when it comes to coastal region is also intrusion in marine and coastal areas which often involve sediment dredging and disposal operations both ambient forcing and human activities. The increasing attention paid to this wide topic is also exacerbated by the exploitation of the coastal zone for National economic, touristic and social reasons. Indeed, estuarine, coastal, and harbor areas often undergo operations that temporarily increase sediment transport, e.g., for beach nourishment, for maintaining safe navigation depth in approach channels, and to remove contaminated sediment primarily to support their use. For example, to counteract erosion processes that degrade beach quality often, beach maintenance is required. To nourish beaches sand has to be dredged and moved. Moreover, harbor areas and navigation channels require maintenance dredging to allow the regular circulation of the vessels. The quantity of sediments to be dredged can vary in relation to the various purposes, e.g., to maintain or improve the navigation depth of ports and harbors, for creating or improving facilities, for beach nourishment and open-water disposal or morphological reconstruction in transitional areas. Common modeling approaches involves hydrodynamic and transport models suitable to quantify and to compare the transport processes of the different sediment. On the other hand, technical and scientific literature highlights the lack of a whole and comprehensive methodology driving the selection of appropriate modeling tools and of accuracy levels needed for a reliable assessment of the induced sediments handling operations. It has to be stressed that past studies found that results rarely focus on long-term effects of sediments dispersion, within either seasonal or annual they are focused on short-term scenarios usually related to either one or few tidal cycles or extreme events. This paper proposes a mathematical modeling approach intended to estimate the maintenance dredging in a port.

***IndexTerms* - hydrodynamics, sedimentation, dredging.**

I. INTRODUCTION

With revolution in the civilization the human started to travel from one place to another, with change in time also began transport of the goods. Transport and travel were not just limited to the land surface transport but also through River waterways and via sea within the country and beyond. The advent in sea transport and the feasibility of ease of transport as well as trade the settlements came into being near to the coastlines. As so many ways of transport system and trade flourished through the sea transport which paved way for development of ports and harbours. Further for the navigational channels and approach channels this trade necessity gave rise to the clearing the bed material or to deepen the navigational channels for better and smooth travel for the vessels which is nothing but the Dredging in approach channel. It is understood that the dredging goes way back as there have been some evidence available as use of dredging dating back in 4000 BC during the construction of pyramids as the Nile River was channelled in to seven arms with wharfs built to facilitate the vessels. With problem of siltation and the understanding to ensure the safe voyages there was due consideration given to tackle the sedimentation by the means of safe navigational channels with the help of dredging, but due to lack of equipment to facilitate the removal of sediment, the humans started manual digging up of the mud by hand which was not that efficient and was only limited to shallow waterways. But as the intensity in travel via sea and frequency of trade increased, dredging became necessary to invent better ways to dredge.

With the progressive development over the years the Indian maritime industry has grown into an indigenous massive sector contributing towards Indian economy. Almost, 95 % of the nation's trade by volume and 70 % in terms of value is moved through ocean. The two important factors that play to the advantage of the Indian shipping industry is the vast coastline of over 7,500 km and the other one being the geographical location which placed strategically on the major trading routes.

The Dredging in approach channel in the country is majorly handled by the Dredging corporation of India (DCI). DCI nearly covers more than 60 % of the dredging in the India. The Ministry of Shipping (MOS) has laid down essential guidelines for carrying out the dredging activities.

The problem of the sediment transport is of dynamic in nature and so in due process sedimentation makes estimation of the dredging quantities a tricky affair. There are various methods on which the coastal engineers rely upon for estimating the dredging quantities. The popular ones being comparison of the bathymetric charts of pre and post dredging activity. The other methods include the triangulation of area and calculating the volume by Simpson's rule. Help of GIS maps is also taken to identify the possible pattern of sedimentation and identifying the possible sights of dredging.

Lars Mikkelsen ET. Al (1980) described the significant of capital and maintenance dredging quantity in the approach channel and should be calculated accurately. Considering the fact this study is undertaken to

- Calculate the dredging quantity by finding the area of elements from the hydrodynamic study.
- Determine the maintenance dredging by depth of deposition from the sediment transport.
- Acquire the volume of dredging by using area and depth of deposition.

This particular method aims to reduce the tedious calculations and provide a reliable estimation within a less span of time. This method is elaborated further in this paper.

II.METHODOLOGY

The main objective of this project is to provide a comprehensive approach to quantify the maintenance dredging for port operation. This Section help to understand the general methodology adopted to carry out this project work with focus on the various tools/modules used for simulating the site-specific conditions to give flow patterns and sedimentation patterns along with the data used.

The Project was categorized in three different sections as mentioned in scope of project, and these three sections uses three tools or approaches as given below:

- Hydrodynamics (HD): MIKE 21 HD FM
- Sediment Transport (ST): MIKE 21 ST
- Dredging

2.1 Hydrodynamics (HD)

MIKE 21 Flow Model – HD is a modelling system for 2-D free surface flows based on flexible mesh approach. The simulation of hydraulic and environmental phenomena in lakes, estuaries, bays, coastal areas and seas is possible using MIKE 21. It may be applied wherever layered deposition can be neglected. The simulation of water level variations and flows in response to a variety of forcing functions in lakes, estuaries and coastal regions is facilitated by hydrodynamic module. The effects and facilities include:

- Bottom shear stress
- Wind shear stress
- Barometric pressure gradients
- Coriolis force
- Momentum dispersion
- Evaporation
- Flooding and drying
- Wave radiation stresses

MIKE 21 HD is a non-linear model and as such one of the most advanced and comprehensive hydrodynamic models available. It simulates in the time domain, the propagation of flows and takes the effects of the tidal variations and wave driven currents into account. The interaction between waves and tides is also taken in to account. The HD module is based on the numerical solution of the two-dimensional shallow water, depth averaged Reynolds averaged Navier-Stokes equations. The spatial discretization of the equation is performed using a cell-centered finite volume method. The spatial domain is discretized by subdivision of the continuum into non-overlapping elements. In the horizontal plane, an unstructured grid is used comprising of triangles or quadrilateral elements. An approximate Riemann solver is used for computation of the convective fluxes, which makes it possible to handle discontinuous solutions. An explicit scheme is used for time integration. (MIKE21 HD Manuals, 2014)

2.2 Sediment Transport (ST)

MIKE21 Flow Model – ST describes erosion, transport and deposition of sand under the action of currents and waves or pure current. It is specifically suited for application to coastal engineering problems for studying sediment transport studies of non-cohesive sediments. The hydrodynamic basis of ST module is calculated using the HD module of MIKE21 Flow Model FM. The sand transport calculations are carried out using a mean horizontal velocity component.

The ST module can calculate sediment transport rates using two different model types:

- Pure current
- Combined wave and current

The sediment transport is calculated in two modes: Bed load and Suspended load for pure current model, the bed load and suspended load are calculated separately whereas for combined wave and current actions, the total load is calculated. For the pure current model, the formulations available in the model are:

- Engelund and Hansen (total load)
- Van Rijn (bed load + suspended load)
- Engelund and Fredsøe (bed load + suspended load)
- Meyer-Peter and Muller (bed load)

In the model with combined waves and currents, sediment transport tables need to be generated for the general spectrum of wave field. These are then used in the calculations to find transport rates using linear interpolation. Currently only one fraction of sediment input is allowed in both cases. There is also a provision for including the effects of morphological changes on the hydrodynamics of the area which in turn affect the sediment transport pattern. (MIKE21 ST Manuals, 2014)

2.3 Dredging

Dredging is a procedure of removal of sediments and debris from the bottom of water bodies (river, estuaries, sea, etc.) using special devices known as "dredgers" for enabling the safe navigation of vessels. Dredge is the name of the device used for excavation and scraping of the sea bed. To put is simply, a ship equipped with excavation tool which is capable of weeding off depositions such as sand, gravel, sediments, etc. from the seabed is referred as dredger ship or more generally a dredger. Dredgers are of great importance, as they serve the purpose of ensuring the necessary safe bottom clearance for the smooth navigation. The excavation is carried out in either shallow or fresh waters with the aim to gather up the sediments located in the bottom to dispose-off at another place for various purposes such as

- For smooth navigation of vessels for commercial purposes.
- For Beach nourishment as part of replenishing the sand on public beaches which might have undergone severe coastal erosion
- For mining of various resources and materials such as Gold or Coal etc.
- Removal of contaminants from the sea bed.
- Reclamation of areas damaged by oil spills or natural calamities
- Development of new harbours and enhancing the existing port capacities.

2.3.3 Scope of Dredging

The scope for dredging in India is vast. Opportunities for this segment are available within the development and maintenance of existing major ports, building new ports, offshore resource exploration, in upcoming national waterways (NWs) and demand from the navy. During 2012-17, the demand for capital and maintenance dredging is estimated to be about 63 million cubic meters (mcm) and 530 mcm respectively. An estimated demand of about 100 mcm at minor ports during the identical period provides additional opportunity for dredging. Moreover, the modal shift of cargo towards inland and coastal waterways offers bright prospects for sustainable economic prosperity within the segment. The government's Make in India initiative has attracted plenty of interest likewise, given the massive scope within the dredger building industry. The dredging industry in India is gradually studying, with a positive demand forecast for the segment. The government's new Foreign national trading policy, 2015-2020 provides incentives under two schemes – the Merchandise Exports from India Scheme and also the Service Export from India Scheme – to encourage the export of manufactured goods and services from India collectively of the companies listed under these schemes, the maritime industry can claim a gift of 5 per cent free on-board shipment or exchange realized by way of leasing assets, undertaking foreign projects or selling ships and equipment manufactured in India. Under these two schemes, businesses can acquire a privileged status (star rating) and have trade transactions facilitated so as to scale back transaction costs and time. The ports individually collect and send the demand for dredging to the Ministry of Shipping (MoS). Further, proposals for the fitting of latest ports are approved by the central or state governments. The MoS analyses the demand for dredging and therefore the proposals for developing new ports so allocates funds in phases during each yr. However, the targeted dredging level achieved has fallen significantly below the projected demand. this can be often attributed to delays or failures at the project implementation stage, financial and environmental constraints, lack of engineering studies to assess the quantum and kind of dredging requirements, and meagre response from bidders to undertake the work.

2.3.4 Current Dredging Demand in India

India has a vast coastline of over 7,500 km along the east and west coasts. It has 13 major ports in the public sector, 10 in the private sector and 187 minor ports under various maritime boards and state governments. The demand drivers for dredging are the requirement for deeper draught at ports, construction of new ports, land reclamation, emerging trends like deployment of ultra-mega-size vessels, consistent maintenance and capital dredging at existing ports, inland transport and water linking projects, trenching works for laying pipelines in offshore projects, promotion of tourism, and beach nourishment. Dredging Corporation of India (DCI) controls about 60 per cent of the maintenance dredging market in India. DCI and Mercator Limited have a large fleet of trailer suction hopper dredgers (TSHDs) as well as other dredgers, while Van Oord India and International Seaport Dredging Private Limited operate with one TSHD each in India. European companies bring their dredgers into the country on a project requirement basis. While 593 mcm of dredging is being projected for 2016-17 alone, there is a huge backlog of capital dredging requirement projected under the Twelfth Plan (2012-17) that did not materialize due to various reasons, and is now anticipated to be taken up in the near future. This will further increase the demand for capital dredging and once this is completed, maintenance dredging volumes will also increase. During 2017-18 and 2018-19, dredging (maintenance and capital) of about 159.36 million cum was carried out across major ports of which, the capital dredging accounted for about 20%. The below table gives approximate siltation at various ports in India. It is foreseen that Major Ports shall deepen and widen their navigational channel to attract deep draft vessels and the forecast indicate, net dredging quantity may be approximately 4 billion cu m (1.6 billion cu m capital and 2.4 billion cu m maintenance) to be dredged in next 10 years.

III. CONVENTIONAL VS PROPOSED APPROACH

Clearly the mathematical model has many and varied applications in hydraulic and coastal engineering and by its use it is possible to make great advances in field investigations, design and constructions. The mathematical model should not be merely as a replacement of physical model rather these two types of modelling are complementary to each other. The possibilities of making serious errors are much greater in the mathematical approach and consequently much more care is required. For many applications of modelling and especially those involving wind stresses, salinity variations, effects of the Coriolis acceleration, changing reflection conditions and such influences the physical model is not a viable option and mathematical model in such cases proves to be advantageous. The main focus to undertake this study is to throw light towards a less tedious approach than that of the conventional approaches to compute the dredging quantities. Among the conventional methods a few have been listed below:

•Morphological Difference Method:

In this widely used method the dredging quantity is computed by observing the morphological changes in a particular place at a fixed time interval. For general understanding let us consider a basin area in port whose dredging is to be computed the bathymetry survey for that basin area is done prior to the maintenance dredging, the survey for the same area is repeated after a specific time period after the dredging operation for an identical period of time and the difference in the bathymetry survey provides the morphological changes in the time being. The difference of the two bathymetry surveys when multiplied by the area of port basin gives us the dredging quantity in that basin over that period of time.

•Simpsons Rule:

In this method there is "Simpsons 1/3rd Rule" and "Simpsons 3/8th Rule" the volume of sediment is calculated by dividing the desired are into 'n' number of sections and then computing the volume of all the sections and taking the summation of the volumes of section which gives average depth of deposition or erosion in that area. Generally, these methods are fairly accurate but the computations are tedious and lengthy and may take long time.

•Trapezoidal Rule:

For estimation of the dredge area and volume, the trapezoidal section of the channel is considered. The simplest form of integration is the trapezoidal rule. In this rule, we simply divide the length of the channel into a number of equally spaced sections, with each section resembling a trapezoid. We can see that this approximation of a section as a trapezoid is feasible only when the section length is small, i.e., we have to divide the length into many sections to be able to use the trapezoid approximation.

The mathematical model approach suggested in this study will help to bring accuracy in volume calculations and may prove to give better results while computing the dredging quantities in less amount of time. In this study attempts have been made to use cell centric volume method by using element area derived from the flexible mesh generated to create bathymetry as an input for the hydrodynamic setup. The hydrodynamic result gives us the areas of triangulated mesh over the desired location. The hydrodynamic model is then used to setup the sediment transport model from which we get the aggradations and degradation taking place in the desired location. The amount of sedimentation or erosion when multiplied with this element area will give us the net deposition for that area.

IV. MATHEMATICAL MODEL STUDY FOR MAINTENANCE DREDGING

4.1 2-D Computational Model for Hydrodynamic Studies

MIKE 21 HD FM was used to carry out the hydrodynamics studies, as explained briefly in the methodology about the MIKE 21 HD module, this module helps to predict the flow patterns and the current velocities in the model area caused due to action of various forces such as tides, wind and waves. In this model we simulate the flow conditions for the different phases of tide in order to find out the current velocities and the flow patterns respectively. An area of 17 km x 21.5 km was considered as a model domain. The area covers part of Dahej Port, and covers the entire area consisting of the various Jetties located in the Dahej Port region as shown in Figure 01. The area of interest mainly lies with the Jetties of LNG Petronet mainly North and South Jetties. The model area has been discretized into triangular coarse and fine mesh using Mesh Generator tool from MIKE Zero toolbox as shown in Figure 02. The bathymetry for the existing condition was taken from the CMAP (DHI) and the local bathymetries near jetties was taken from the bathymetric surveys and superimposed on the bathymetry from CMAP.

The flexible mesh approach in MIKE 21 HD FM facilitates the generation of fine mesh with small triangular elements for the areas of interest. The total numbers of 4280 elements are used in the mesh with 2348 nodes. The Courant–Friedrichs–Lewy (CFL) number for the model solution was 0.8 which is also the recommended value. The model was setup for the existing condition for the model domain with four open boundaries required to be defined. The flow simulations were carried out by providing observed tide with a tidal range of 9.7 m as the input boundary at Southern side and tide with appropriate phase lag at the Northern boundary. As the flow is almost parallel to the contours along the western boundary no cross flow was considered and the Western boundary was defined as a zero-flux boundary. The open boundary on the East side is that of the River Narmada and a discharge of 1000 cumecs was considered from the river boundary. The simulation was carried out for 15 days for a period between 21/02/2018 to 08/03/2018 as the field observed current for C1 & C2 location was available during the same period. The simulation results in the flow pattern and current velocities which were recorded every 30 minutes. The plots representing the flow conditions and current velocities during various phases of tides are shown in Figure 03(A)-03(B).

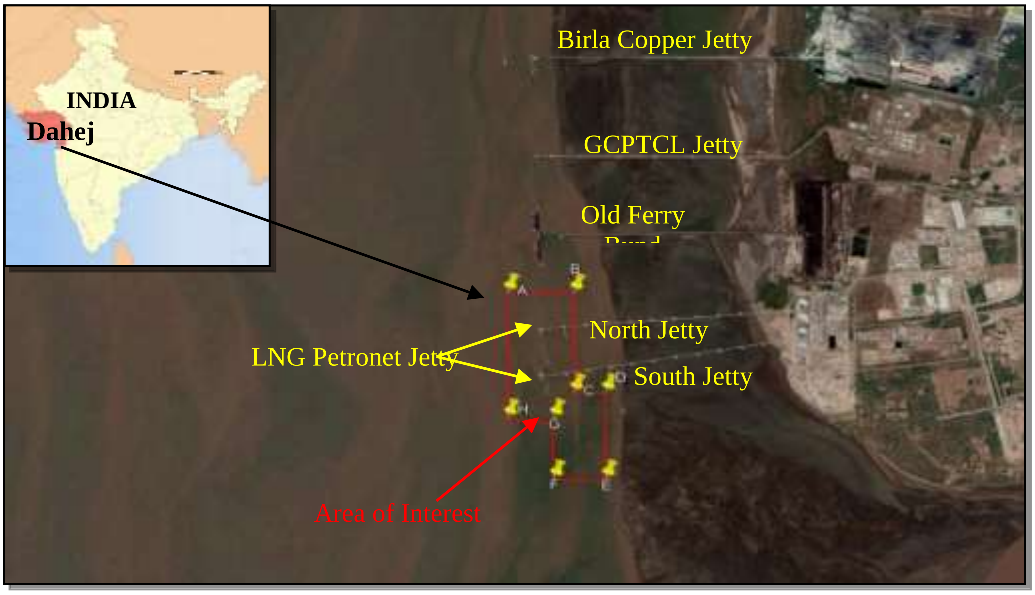


Figure 01: Location Map

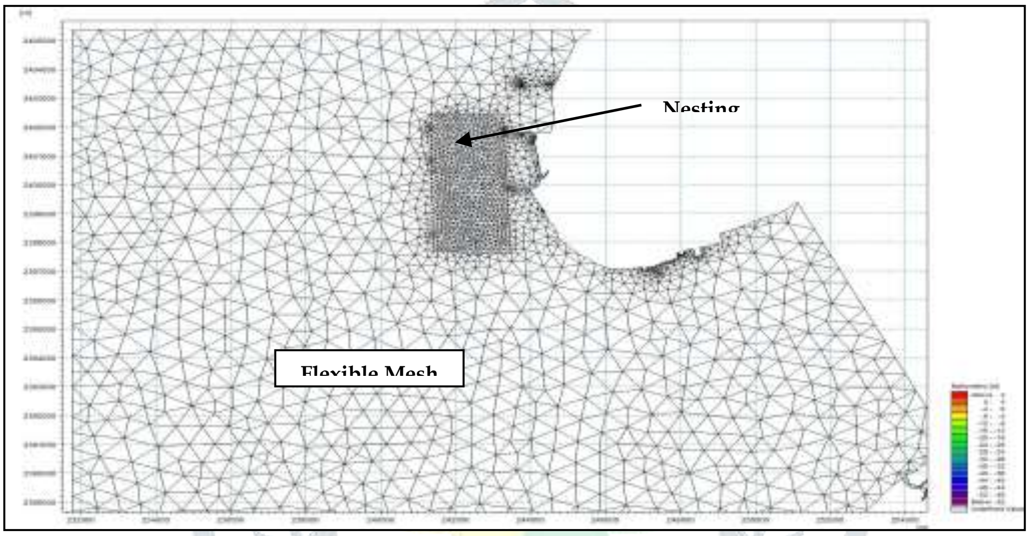
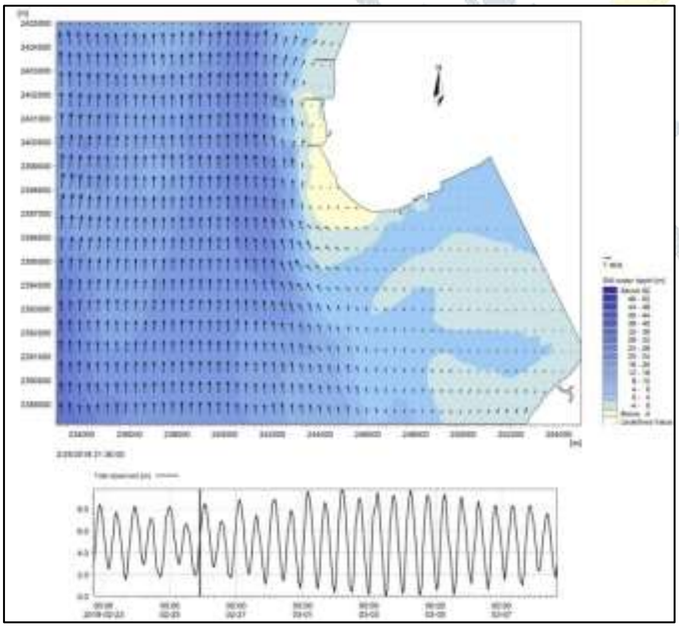


Figure 02: Computational Model



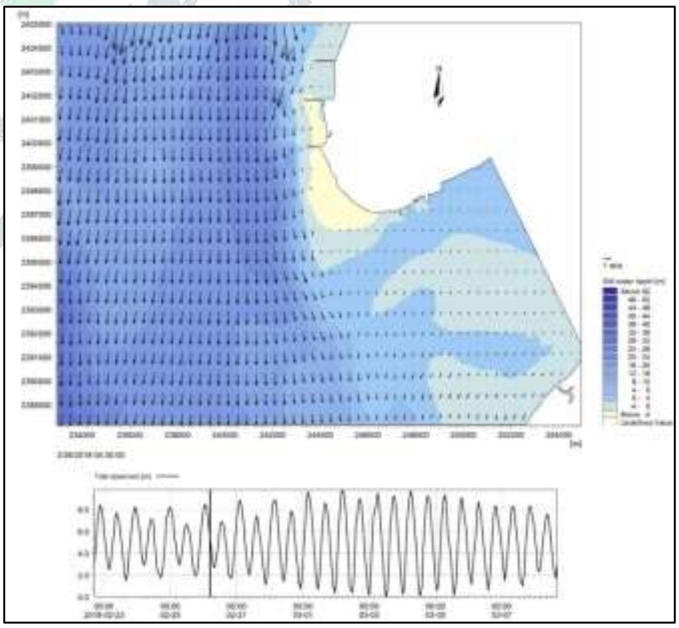


Figure 03(A): Typical Flow Field During Peak Flood (Existing)

Figure 03(B): Typical Flow Field During Peak Ebb (Existing)

From the flow simulations it was observed that there is no cross circulation near the jetty area and the current varies from 0.05 to 2.3 m/s during spring tide and it varies from 0.06 m/s to 1.6m/s during neap tide.

4.1.1 2-D Calibration of Model

The model is calibrated by comparing the computed current with the site observed current. In this case the site observed current is available for C1 & C2 locations. The model extracted current for C1 and C2 location for the same time duration is compared with the observed current and is shown in Figure 04, it is observed that the computed current matches well with the observed current. In general, a 70-80 % similar current comparison is considered to be satisfactory for a model calibration. In This case it is observed that the computed current is more than 80% match, thus the model is said to be calibrated.

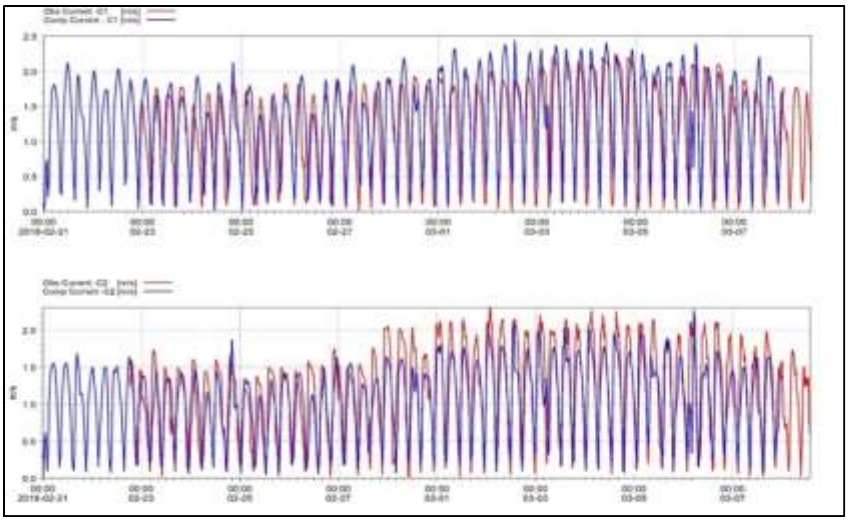


Figure 04: Comparison of Currents (Observed Vs Computed)

Overall, from the hydrodynamic model it is observed that there is no cross flow and the flow direction is almost parallel to the contours along the western boundary. Along with the flow simulation and current velocities the other important model output in this case is the element area. The element areas are also computed from the HD model. These element areas form the integral part in attempt to calculate the maintenance dredging near the jetties. Using these element areas, we can accurately get the area of both the nesting area as well as area of interest as shown in Figure 05 (A-B). The derived element area for the area of interest has been given in Table No. 01 below. It is observed that the total element area for the area of interest is the summation of all the element area falling under the area of interest which happens to be 12,99,938.39 m^2.

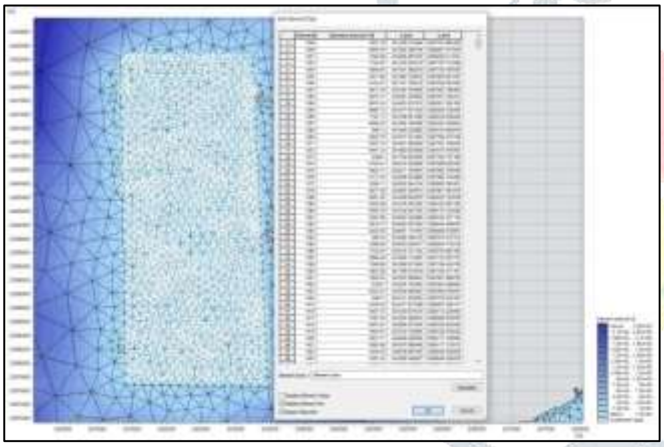


Figure 05(A): Element Area for the Nesting Area

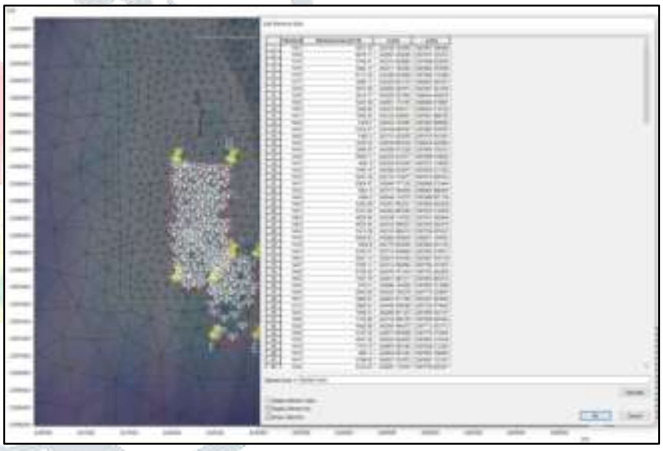


Figure 05(B): Element Area for the Area of Interest

Table No. 01: Element Area for Area of Interest

Element No	Element Area m^2	x	y	Element No	Element Area m^2	x	y
1357	4913.16	242160.1641	2397997.786	1565	6629.35	242755.1865	2397689.9
1358	6075.71	242097.4396	2397973.163	1568	16806.6	242468.6013	2397576.132
1374	5740.41	242274.0269	2397996.62	1575	7276.12	242946.4877	2397726.716
1375	4922.17	242211.194	2397962.168	1576	7057.29	242884.9485	2397690.575
1376	6117.45	242396.525	2397988.135	1579	7570.02	242712.1362	2397617.165
1377	3599.11	242502.8441	2398005.593	1582	22900	242487.5719	2397476.88
1378	5977.28	242085.3977	2397907.491	1588	11534.6	242887.7527	2397594.64
1392	2619.73	242582.0279	2398044.499	1590	22087.2	242775.4707	2397556.918
1393	5224.58	242661.1192	2398090.619	1592	18964	242597.2952	2397409.309
1395	3298.85	242553.9365	2398004.717	1597	26652.4	242727.8206	2397447.296
1396	7330.24	242016.1011	2397870.662	1598	24117.8	242567.0135	2397262.179
1401	7893.83	242335.5999	2397961.89	1602	32944.5	242817.5144	2397318.15
1402	5339.7	242204.1039	2397904.097	1603	36696	242697.7777	2397192.528
1403	5032.47	242459.4666	2397960.88	1609	4314.02	242608.7693	2398125.576

1404	5497.3	242141.0321	2397874.043	1610	6797.48	242592.5274	2398185.07
1422	3436.52	242639.987	2398039.426	1611	3316.81	242563.8777	2398087.555
1424	3956.83	242589.5732	2397964.726	1612	5077.61	242526.5629	2398193.392
1430	5658.71	242323.2794	2397896.48	1613	4066.79	242510.2378	2398094.301
1431	4681.9	242254.6162	2397873.14	1614	6234.53	242482.3033	2398241.185
1432	7546.15	242488.454	2397904.217	1615	3537.32	242477.2956	2398052.121
1451	6264.57	242849.7773	2398086.512	1616	4025.84	242489.1649	2398140.643
1452	6621.8	242777.3849	2398064.09	1617	6268.91	242371.7366	2398340.596
1454	4560.2	242649.1184	2397989.627	1618	5435.78	242416.6178	2398210.736
1456	6383.69	242567.4682	2397908.94	1619	4837.06	242412.768	2398049.402
1461	6741.64	242364.9633	2397843.311	1620	4400.36	242428.1336	2398149.612
1463	9872.25	242443.4658	2397842.482	1621	5761.45	242326.7065	2398395.731
1478	6508.93	242895.6288	2398031.194	1623	5324.13	242341.6357	2398285.526
1479	8252.9	242775.9341	2397984.643	1624	5501.25	242361.6701	2398228.453
1481	9105.51	242712.047	2397952.018	1625	6205.53	242384.679	2398100.55
1483	6021.13	242614.0704	2397867.545	1626	4144.04	242269.9918	2398382.447
1488	6729.05	242479.7015	2397783.083	1627	3441.59	242228.3636	2398412.161
1502	7847.79	242851.9653	2397963.064	1629	4238.17	242274.9287	2398284.287
1504	6753.3	242699.1041	2397885.722	1630	6254.19	242295.5125	2398182.593
1506	5642.04	242555.7593	2397774.521	1631	8950.45	242307.0055	2398115.814
1507	5808.27	242607.9173	2397807.264	1632	3718.23	242248.3149	2398326.074
1512	5868.91	242446.3566	2397722.575	1633	2998.53	242180.9654	2398378.045
1524	7989.31	242886.8473	2397906.455	1637	5860.13	242245.577	2398220.179
1526	7154.62	242734.8681	2397829.225	1638	7598.95	242257.4769	2398066.978
1528	4582.68	242565.4951	2397713.504	1639	3676.57	242192.6925	2398328.844
1529	5187.24	242677.6637	2397779.734	1640	4209.72	242133.8586	2398401.808
1532	4971.22	242504.321	2397684.31	1649	8460.93	242097.3754	2398510.295
1543	7770.15	242867.8582	2397838.313	1650	7288.45	242180.1124	2398218.78
1545	8851.2	242804.8532	2397805.8	1651	6463.42	242182.7166	2398066.775
1547	5799.63	242627.1079	2397687.133	1652	5213.03	242153.8416	2398285.658
1548	6124.24	242687.1184	2397720.62	1653	5881.43	242081.4914	2398368.397
1551	7570.02	242539.8133	2397619.2	1667	8693.14	242019.6124	2398477.294
1560	6119.89	242940.2611	2397794.243	1668	6858.98	242134.9165	2398171.071
1561	6969.09	242815.7168	2397725.589	1669	6672.13	242137.1139	2398105.488
1564	7570.02	242625.9747	2397618.182	1670	7601.66	242017.0319	2398398.161
Element No	**Element Area m^2**	**x**	**y**	**Element No**	**Element Area m^2**	**x**	**y**
1671	5919.45	242089.7474	2398301.448	3153	7885.8	242608.7885	2398975.587
1686	6345.89	242052.8428	2398187.56	3155	5678.77	242424.9029	2398891.21
1687	5395.17	242062.2984	2398077.651	3156	9193.91	242530.1286	2398965.676
1689	7846.79	242033.9444	2398251.059	3157	5634.92	242356.9418	2398795.529
1706	6632.71	242045.1766	2398014.315	3158	6037.65	242295.876	2398694.908
1709	6606.84	242014.7047	2398128.879	3159	4634.58	242413.5761	2398824.018
3071	4455.72	242038.7418	2399174.12	3160	5406.67	242213.223	2398467.774
3083	5706.81	242092.0502	2399149.462	3161	6994.43	242241.3054	2398583.371
3085	5342.08	242036.8528	2399047.157	3165	7131.07	242496.6245	2398902.59
3088	5906.21	242145.8495	2399188.375	3166	5808.95	242300.2016	2398628.443
3093	5706.88	242093.4199	2399081.746	3167	5498.19	242353.6627	2398731.105
3095	4665.43	242032.9136	2398986.395	3168	5025.98	242467.237	2398790.451
3098	5893.22	242205.7798	2399161.752	3169	7189.74	242255.8243	2398514.079
3103	7147.61	242154.675	2399046.769	3173	6491.18	242523.7713	2398834.487

3105	5141.55	242081.0353	2398947.399	3174	5474.95	242362.235	2398605.245
3108	7123.2	242213.2356	2399087.861	3175	4576.97	242407.4482	2398702.392
3110	4980.36	242314.3296	2399182.666	3176	4889.1	242464.3882	2398733.249
3112	7458.37	242146.2296	2398973.185	3177	4885.17	242321.7223	2398502.716
3113	6305.59	242053.7084	2398878.702	3179	9815.76	242593.4381	2398807.221
3117	7154.05	242279.2352	2399066.455	3180	4475.39	242369.2368	2398548.81
3119	5683.82	242329.4422	2399120.478	3181	4532.33	242411.6948	2398642.997
3120	5333.48	242433.6826	2399162.336	3182	6969.83	242517.1358	2398682.367
3121	7876.24	242198.7421	2398926.47	3183	4895	242350.2857	2398449.902
3122	9473.35	242096.8904	2398822.207	3185	11259.8	242589.6513	2398712.302
3123	7687.74	242001.3814	2398637.809	3186	4428.15	242424.8068	2398524.774
3124	7957.39	242071.6515	2398751.537	3187	6293.47	242482.9089	2398623.883
3125	5910.62	242627.4577	2399167.541	3188	4534.71	242415.0529	2398464.999
3128	5958.51	242299.0145	2399004.84	3191	7426.01	242489.0189	2398562.095
3129	5667.58	242496.5222	2399159.303	3192	6103.73	242460.2478	2398425.621
3130	5807.13	242394.0575	2399108.37	3195	6932.11	242540.1086	2398524.583
3131	6192.76	242265.5198	2398944.322	3196	5304.27	242521.0914	2398447.883
3132	8112.37	242176.7297	2398844.189	3197	7044.28	242440.5107	2398355.389
3133	5468.55	242070.434	2398629.176	3199	7303.92	242608.6261	2398528.47
3134	5509.05	242112.1648	2398695.292	3200	6340.46	242578.2048	2398409.2
3135	6343.98	242598.0663	2399103.385	3201	8477.57	242496.6941	2398305.56
3138	5970.85	242373.0566	2398990.573	3203	6109.73	242634.4912	2398450.279
3139	6312.41	242529.2034	2399099.549	3205	8251.06	242573.5446	2398337.109
3140	7243.27	242417.8926	2399040.08	3208	6451.49	242629.5711	2398300.225
3141	5081.02	242313.0479	2398895.519	3210	6207.34	242636.2625	2398229.02
3142	7747.49	242233.3425	2398799.004		**1299938.39**	**TOTAL AREA m^2**	
3143	7144.11	242113.3194	2398577.712				
3144	6281.96	242174.626	2398684.472				
3145	6481.83	242637.7216	2399048.04				
3147	5665	242378.4334	2398925.757				
3148	7686.32	242490.1988	2399034.293				
3149	6141.98	242302.883	2398832.483				
3150	7488.09	242229.6146	2398725.854				
3151	5251.59	242147.1621	2398464.573				
3152	6063.65	242181.9912	2398608.454				

4.2 Sediment Transport Model for Existing Condition

The HD model form the basic input for sediment transport studies. The sediment transport studies were carried out by using MIKE 21 ST. The same model setup that of HD was used to simulate the sediment pattern in the Dahej Port. The simulation of sediment transport in the vicinity of the port area will provide insight into the accretion and erosion patterns in the area of interest and will help us to arrive at the quantities require to be dredged for maintenance purposes. The Figure 06 (A) shows the sediment pattern in the existing condition and Figure 06 (B) shows the sediment pattern in the area of interest and accretion and erosion in the area of interest. The Table No.02 shows the total bed thickness change in the area of interest and also the average accretion/erosion in the area of interest.

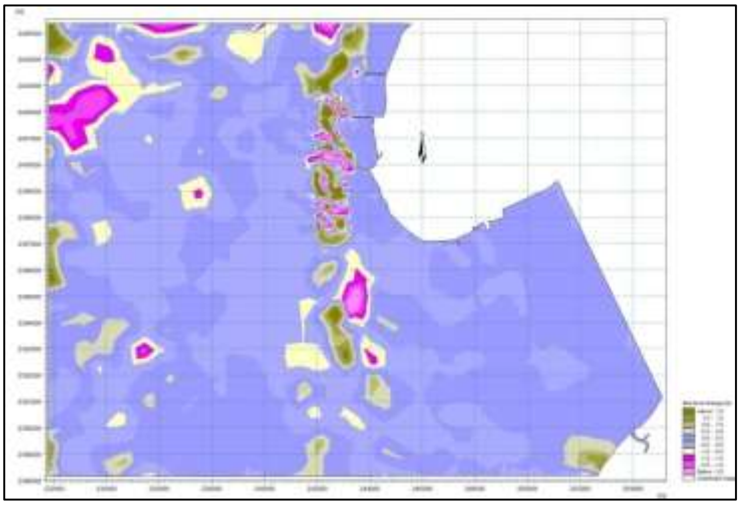


Figure 06(A): Sediment Pattern in Existing Condition

Figure 06(B): Deposition/ Erosion in the Area of Interest

Table No. 02:Total Bed Thickness Change in Area of Interest

Element No	Bed level change	x	y	Element No	Bed level change	x	y
1357	0.542646	242160.1641	2397997.786	1565	-0.418041	242755.1865	2397689.9
1358	-3.05214	242097.4396	2397973.163	1568	-0.788752	242468.6013	2397576.132
1374	2.71998	242274.0269	2397996.62	1575	2.22152	242946.4877	2397726.716
1375	0.219707	242211.194	2397962.168	1576	3.84374	242884.9485	2397690.575
1376	0.102096	242396.525	2397988.135	1579	3.64044	242712.1362	2397617.165
1377	-0.617487	242502.8441	2398005.593	1582	-0.208179	242487.5719	2397476.88
1378	0.656135	242085.3977	2397907.491	1588	1.22629	242887.7527	2397594.64
1392	0.670423	242582.0279	2398044.499	1590	-2.37734	242775.4707	2397556.918
1393	0.237645	242661.1192	2398090.619	1592	-0.46064	242597.2952	2397409.309
1395	2.89521	242553.9365	2398004.717	1597	2.09226	242727.8206	2397447.296
1396	0.616573	242016.1011	2397870.662	1598	4.09986	242567.0135	2397262.179
1401	0.281267	242335.5999	2397961.89	1602	-5.14236	242817.5144	2397318.15
1402	2.63502	242204.1039	2397904.097	1603	4.41468	242697.7777	2397192.528
1403	-1.15463	242459.4666	2397960.88	1609	-0.646968	242608.7693	2398125.576
1404	-0.539955	242141.0321	2397874.043	1610	-0.695182	242592.5274	2398185.07
1422	0.494529	242639.987	2398039.426	1611	0.445433	242563.8777	2398087.555
1424	-0.518787	242589.5732	2397964.726	1612	-5.54934	242526.5629	2398193.392
1430	6.73175	242323.2794	2397896.48	1613	-0.739815	242510.2378	2398094.301
1431	3.96155	242254.6162	2397873.14	1614	-2.82926	242482.3033	2398241.185
1432	0.00617437	242488.454	2397904.217	1615	0.0967079	242477.2956	2398052.121
1451	-0.307408	242849.7773	2398086.512	1616	-2.5467	242489.1649	2398140.643
1452	-0.843617	242777.3849	2398064.09	1617	1.68037	242371.7366	2398340.596
1454	3.24772	242649.1184	2397989.627	1618	-1.15783	242416.6178	2398210.736
1456	1.20659	242567.4682	2397908.94	1619	-3.19375	242412.768	2398049.402
1461	-5.90736	242364.9633	2397843.311	1620	-1.50031	242428.1336	2398149.612
1463	-0.616373	242443.4658	2397842.482	1621	8.25685	242326.7065	2398395.731
1478	-1.42498	242895.6288	2398031.194	1623	2.0629	242341.6357	2398285.526
1479	2.4684	242775.9341	2397984.643	1624	-1.04143	242361.6701	2398228.453
1481	0.733213	242712.047	2397952.018	1625	0.235694	242384.679	2398100.55
1483	0.368303	242614.0704	2397867.545	1626	-0.589999	242269.9918	2398382.447
1488	-1.59764	242479.7015	2397783.083	1627	-5.49894	242228.3636	2398412.161
1502	1.34312	242851.9653	2397963.064	1629	5.17058	242274.9287	2398284.287
1504	0.932718	242699.1041	2397885.722	1630	-1.38207	242295.5125	2398182.593
1506	0.0584815	242555.7593	2397774.521	1631	-1.01944	242307.0055	2398115.814

1507	-0.479949	242607.9173	2397807.264	1632	1.23956	242248.3149	2398326.074
1512	1.8275	242446.3566	2397722.575	1633	-5.55797	242180.9654	2398378.045
1524	0.709816	242886.8473	2397906.455	1637	1.0167	242245.577	2398220.179
1526	-1.14024	242734.8681	2397829.225	1638	1.74594	242257.4769	2398066.978
1528	0.191506	242565.4951	2397713.504	1639	-4.12013	242192.6925	2398328.844
1529	2.36583	242677.6637	2397779.734	1640	-7.21916	242133.8586	2398401.808
1532	-4.35298	242504.321	2397684.31	1649	-2.28901	242097.3754	2398510.295
1543	2.36619	242867.8582	2397838.313	1650	-2.56188	242180.1124	2398218.78
1545	2.98118	242804.8532	2397805.8	1651	-2.71755	242182.7166	2398066.775
1547	0.648194	242627.1079	2397687.133	1652	-2.25434	242153.8416	2398285.658
1548	0.416322	242687.1184	2397720.62	1653	-2.80958	242081.4914	2398368.397
1551	-5.41054	242539.8133	2397619.2	1667	-6.86075	242019.6124	2398477.294
1560	3.58038	242940.2611	2397794.243	1668	-0.97378	242134.9165	2398171.071
1561	2.25232	242815.7168	2397725.589	1669	-2.74627	242137.1139	2398105.488
1564	1.76263	242625.9747	2397618.182	1670	-3.8269	242017.0319	2398398.161

Element No	Bed level Change	x	y	Element No	Bed level Change	x	y
1671	0.740227	242089.7474	2398301.448	3153	2.73248	242608.7885	2398975.587
1686	-1.51226	242052.8428	2398187.56	3155	1.54576	242424.9029	2398891.21
1687	-1.75548	242062.2984	2398077.651	3156	0.6145	242530.1286	2398965.676
1689	5.54358	242033.9444	2398251.059	3157	0.493437	242356.9418	2398795.529
1706	-2.65796	242045.1766	2398014.315	3158	-3.32071	242295.876	2398694.908
1709	-0.43608	242014.7047	2398128.879	3159	-1.20053	242413.5761	2398824.018
3071	4.72736	242038.7418	2399174.12	3160	2.76759	242213.223	2398467.774
3083	1.2287	242092.0502	2399149.462	3161	1.54699	242241.3054	2398583.371
3085	1.2646	242036.8528	2399047.157	3165	-2.21537	242496.6245	2398902.59
3088	-0.642778	242145.8495	2399188.375	3166	-5.68631	242300.2016	2398628.443
3093	4.85885	242093.4199	2399081.746	3167	-2.22171	242353.6627	2398731.105
3095	2.61704	242032.9136	2398986.395	3168	-1.66429	242467.237	2398790.451
3098	-0.0425366	242205.7798	2399161.752	3169	3.10627	242255.8243	2398514.079
3103	-0.0393893	242154.675	2399046.769	3173	2.39535	242523.7713	2398834.487
3105	2.10122	242081.0353	2398947.399	3174	-4.45905	242362.235	2398605.245
3108	0.0530678	242213.2356	2399087.861	3175	-6.73615	242407.4482	2398702.392
3110	-4.80819	242314.3296	2399182.666	3176	4.24015	242464.3882	2398733.249
3112	3.94732	242146.2296	2398973.185	3177	-0.239632	242321.7223	2398502.716
3113	6.00845	242053.7084	2398878.702	3179	2.30031	242593.4381	2398807.221
3117	-0.779063	242279.2352	2399066.455	3180	-0.201071	242369.2368	2398548.81
3119	-5.81106	242329.4422	2399120.478	3181	-2.4416	242411.6948	2398642.997
3120	8.16634	242433.6826	2399162.336	3182	2.48328	242517.1358	2398682.367
3121	-2.36989	242198.7421	2398926.47	3183	1.16529	242350.2857	2398449.902
3122	-1.75409	242096.8904	2398822.207	3185	2.84317	242589.6513	2398712.302
3123	-2.3052	242001.3814	2398637.809	3186	0.283585	242424.8068	2398524.774
3124	-0.651205	242071.6515	2398751.537	3187	0.552336	242482.9089	2398623.883
3125	0.220552	242627.4577	2399167.541	3188	1.97457	242415.0529	2398464.999
3128	0.630504	242299.0145	2399004.84	3191	2.75855	242489.0189	2398562.095
3129	2.54511	242496.5222	2399159.303	3192	2.8949	242460.2478	2398425.621
3130	0.780145	242394.0575	2399108.37	3195	-2.4881	242540.1086	2398524.583
3131	4.12936	242265.5198	2398944.322	3196	1.57517	242521.0914	2398447.883

3132	7.7792	242176.7297	2398844.189	3197	4.8365	242440.5107	2398355.389
3133	0.617199	242070.434	2398629.176	3199	0.209477	242608.6261	2398528.47
3134	-1.21227	242112.1648	2398695.292	3200	-2.41046	242578.2048	2398409.2
3135	0.686338	242598.0663	2399103.385	3201	-1.1993	242496.6941	2398305.56
3138	-2.30728	242373.0566	2398990.573	3203	-2.73626	242634.4912	2398450.279
3139	2.71799	242529.2034	2399099.549	3205	0.0686416	242573.5446	2398337.109
3140	-0.827119	242417.8926	2399040.08	3208	-5.36636	242629.5711	2398300.225
3141	0.00500038	242313.0479	2398895.519	3210	-6.21298	242636.2625	2398229.02
3142	-1.78104	242233.3425	2398799.004		**25.24**	TOTAL BED THICKNESS CHANGE (m)	
3143	1.20038	242113.3194	2398577.712		**0.135**	AVERAGE DEPTH OF DEPOSITION (m)	
3144	0.81677	242174.626	2398684.472				
3145	2.81776	242637.7216	2399048.04				
3147	2.05763	242378.4334	2398925.757				
3148	4.75973	242490.1988	2399034.293				
3149	7.88896	242302.883	2398832.483				
3150	1.56443	242229.6146	2398725.854				
3151	-5.73745	242147.1621	2398464.573				
3152	1.57143	242181.9912	2398608.454				

4.3 Maintenance Dredging Quantity

By cell centric volume method using the element area derived from the result of hydrodynamic study gives us the areas of triangulated mesh over the area of interest. The sediment transport model is then setup using the hydrodynamic model results, from which we get the aggradation and degradation taking place in the area of interest. Now to arrive at the maintenance dredging quantity we have multiply the element area of area of interest with the average amount of sedimentation or erosion computed from the sediment transport studies. The quantity of the maintenance dredging is thus computed as given below:

The total element area = **1299938.39 m^2**

The average depth of deposition over the area of interest = 0.135 m

Thus, the net deposition in the area of interest = 1299938.39 x 0.135

= 0.17 Mm^3

The Maintenance Dredging quantity computed using the mathematical model approach gives us 0.17 Mm^3 quantity over a period of one month in the area of interest.

V. RESULTS & DISCUSSIONS

Studies were conducted using MIKE 21 (HD) and sediment transport models to investigate the changes in the flow field and hydraulic regime, along with sedimentation pattern. The following are the observations from the studies:

1. From hydrodynamic studies with existing conditions, it is noticed that flow direction is almost parallel to the contours along the western boundary and the cross flow is not significant in the area.
2. The current varies from 0.05 to 2.3 m/s during spring tide and it varies from 0.06 m/s to 1.6 m/s during neap tide.
3. From sedimentation studies it is observed that the current reduces significantly between Adani (Old Ferry Bund) Jetty and North Jetty which make the area susceptible to sedimentation. The sediment deposition needs to be tackled by periodic maintenance dredging to maintain proper draft for smooth navigation of vessels.
4. The dredging quantity based on the mathematical model study approach is computed as 0.17 Mm^3 over a period of one month.

VI. CONCLUSION

A Two-Dimensional mathematical model MIKE21 HD and ST was used to study the hydrodynamics and sedimentation in the vicinity of the jetty area in order to compute the dredging quantity in a port. Sincere efforts were taken in order to provide a new approach towards computation of dredging quantity in lieu of the conventional approaches in order to save the time and to arrive at much reliable quantities.

The project study was divided into three parts as Hydrodynamic studies, Sedimentation studies and computation of Dredging quantity. The results of study shows that the quantities arrived with the mathematical model approach are in the order of 0.17 Mm^3 over a period of one month. For any port operations to be efficient it is recommended to undertake the maintenance dredging work in order to maintain the sufficient navigable depths, and to arrive at the reliable dredging quantities it is recommended to use such advanced tools and methods which are not only cost effective in long run but also time saving. Further scope of this method can be explored by comparing the results with the conventional methods provided the availability of data etc.

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REFERENCES

[1] Lars Mikkelsen, Preben Mortensen and Torben Sorensen "Sedimentation in Dredged Navigation Channels" (17th International Conference on Coastal Engineering, March 23-28, 1980)

[2] Frank Engelund and Jorgen Fredsoe "A Sediment Transport Model for Straight Alluvial Channels",(Nordic Hydrology, 7, 1976, 293-306)

[3] MIKE 21 HD and ST Manual 2014, By DHI

[4] Dredging Guidelines for Major Ports, Government of India, Ministry of Ports, Shipping and Waterways 2021. www.shipmin.gov.in

[5] http://dredge-india.nic.in/ Dredging Corporation of India Website.