

Modelling of Sedimentation Pattern along South West Coast of India – A Case Study

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ABSTRACT: Coastal morphodynamics of any site is dependent on many factors such as environmental conditions, sediment properties, human interference and their complex interaction. The human interferences due to infrastructure development may lead to several problems such as Coastal accretion and erosion, choking of tidal inlets, formation of sand bar, changes in the flow regime etc. To avoid excessive or unwanted morphodynamics changes at a desired location, proper understanding of area before any infrastructure development to be taken up is very essential. Honnavar location in Karnataka was selected to study the coastal dynamics and sediment transport based on the data available at Central Water & Power Research Station (CWPRS), Pune. To study coastal dynamic features MIKE 21 HD (Hydrodynamic Module) and for sediment transport MIKE 21 MT (Mud Transport Module) was used. Calibration of model was done with field data to improve the accuracy of dynamic properties and to assess the sediment transport pattern. The studies were carried for both monsoon and non monsoon season. The model was calibrated for non monsoon season. Sedimentation studies indicated that during non-monsoon season deposition was taking place in the river mouth due to low discharge from the rivers and formation of sand bars was noticed. During monsoon rivers carry more suspended sediments and those sediments will be discharged into the sea. Due to high discharge from the rivers in monsoon period the deposition was not taking place near the river mouth and it was distributing along the coast. Further, it is planned to provide a hypothetical harbour layout and test it for the changes in the flow conditions and sedimentation pattern so as to ascertain the trend of sedimentation in this region.

KEYWORDS: Coastal Morphodynamics, Coastal Erosion, Hydrodynamics, Mud Transport

I. INTRODUCTION

An attempt has been made to study the sedimentation pattern along the Karnataka coast and presented in this paper. Karnataka is situated on the south western side of the Deccan peninsular of India. It is located approximately between 11.5 North and 18.5 North Latitudes and 74 East and 78.5 East longitude comprising of Deccan Plateau, the Western Ghats Mountain Range and the Coastal Plains. The coastal region is known as karavali Karnataka and it starts from western ghats in the west and extends till the edge of the Karnataka plateau in the east. The coastal region of Karnataka includes rivers emptying into Arabian sea, creeks, waterfalls etc. the Karnataka coastal region can be divided into western ghats and the plains. The coastal belt has an average width of 50 km to 80 km and covers a distance of around 270 km north to south. The common type of soil seen in the coastal Karnataka region is coastal laterite soil and coastal alluvial soil.

The coastal dynamic features have been numerically modeled using the tool MIKE 21 HD (Hydrodynamic Module) [5] and for sediment transport MIKE 21 MT (Mud Transport Module) [6]. Calibration of model was done with field data to improve the accuracy of dynamic properties and to assess the sediment transport pattern. This study is part of our research work of assessment of sedimentation pattern along West coast of India.

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Mathematical model studies for examining wave tranquillity with OUTRAY model indicates the different predominant wave directions and wave heights. [1] Mathematical model studies for simulation of hydrodynamics and sedimentation in and around the port using MIKE 21 HD and MIKE 21 MT shows the changes in hydrodynamic conditions and formation of tidal circulation due to proposed developments. The results of tidal hydrodynamic simulation and wave hydrodynamic simulation are the basic input to the sediment transport model. Sediment transport model predicts the probable zone of siltation and erosion in and around the port area. [2]

II. STUDY AREA

Honnavar site was considered for the model studies as the data was available at CWPRS and it seems to be a typical site for sedimentation studies due to its unique features like inlet with good discharge from rivers. Honnavar is a port town in Uttara Kannada district of Karnataka, India (Figure 1). Honnavar is around 70 Km south of Karvar. The town is the headquarters of Honnavar Taluk. The Konkan Railway line passes through Honnavar, and its longest bridge is 2.065 km in length across the Sharavati River. The National Highway (NH-17) connecting Mangalore to Mumbai also passes through Honnavar. Honnavar along with other port cities of Karnataka such as Bhatkal, and Mangalore has a very long history. The principal export from Honnavar was black pepper during ancient period. During the European domination of the Indian Ocean trade the Portuguese and the English built warehouses at the port. Basavaraj Durga Island is located around 3 Km from Sharavathi Bay in the Arabian Sea. The coastline of Honnavar has an inlet with sand bars at the mouth. Sharavathi is the major river draining into the Arabian Sea. Owing to the importance of this coastal town, sediment movement characteristics of Sharavathi Bay and the field observed data available at CWPRS this location was selected for our study.



Fig. 1. Location map of study area Honnavar in Karnataka

III. METHODOLOGY

The Mathematical models MIKE21 HD and MIKE21 MT were used for simulation of hydrodynamics and sedimentation in and around Honnavar in Karnataka. The hydrodynamic model studies include simulation of flow field with the existing conditions for both monsoon and non-monsoon seasons. The field data available with CWPRS data bank was used for calibration and simulation of the model. The results of the tidal hydrodynamic simulation and wave hydrodynamic simulation are the basic input to the sediment transport model. The sediment transport model simulates siltation in and around the river inlet at Honnavar considering tidal currents. These studies predict the probable zone of siltation and erosion in and around the river mouth. It is also possible to estimate the likely annual maintenance dredging after the proposed deepening of the channel and construction of the outer breakwaters if any in future.

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IV. DATA ANALYSIS

The data required for the model studies are mainly bathymetry, tidal levels, wave conditions, wind, currents and sediment data. C-MAP data was used for preparation of bathymetry. The data was collected during 1-12 January 2017 for a site specific study near Honnavar. Field studies report entitled “Oceanographic Investigations at Haldipur, Karnataka, West Coast of India” was provided by CWPRS which comprises of data of tide, currents, wave period and suspended sediments concentration at Honnavar.

V. BATHYMETRY DATA

The offshore data on depths were taken from the C-MAP and was used for preparation of bathymetry for computational model. The depth contours near the Sharavathi Bay i.e, study area was taken from the CWPRS bathymetry data was incorporated in the computational model which show that they are generally parallel to the shore with gradual slope up to the model limit of 20m contour. The 4m depth contour was close to the shore. Throughout the stretch the contour slope was gradual with 2m interval contours. Two rivers were discharging into the sea at Honnavar area with a gentle slope of 2 to 4m. The bathymetry as shown in Figure 2 specifies that the three open boundaries, one closed boundary with two rivers discharging into the sea and the island was included in the bathymetry. Three locations were used to compute the currents to compare with field observed currents. All these information were used for setting up the computational model.

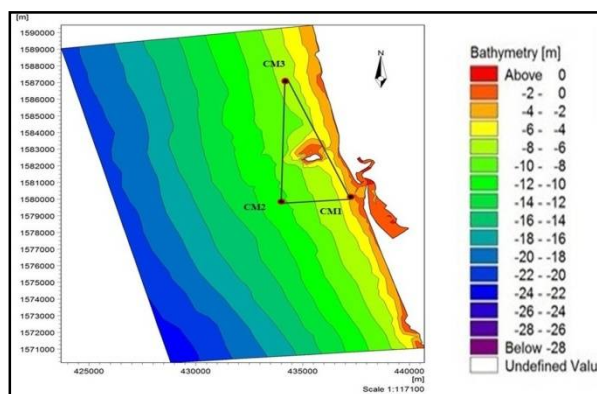


Fig. 2. Bathymetry with existing condition showing field observation points

VI. TIDE DATA

The Kumta tide has been given in the South and North boundary with appropriate phase lag. This tide data was extracted from the C-MAP data and time series file was created to apply as boundary conditions like Kumta tide (Figure 3). The tidal range near Kumta in general was of the order of 2.2 m during spring and 1.4 m during neap tide. Tidal observations were done at Honnavar Jetty during 1-12 January 2017 at an interval of one hour was available at CWPRS. The data analysis indicated that the observed tidal range was 1.8m during High tide and about 1.2m during Low tide and the same was considered initially for comparison and further it was extrapolated to longer duration. Tidal levels at Honnavar are given below.

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Mean Higher High Water (MHHW)	+1.8m
Mean Lower High Water (MLHW)	+1.5m
Mean Sea Level	+1.2m
Mean Higher Low Water (MHLW)	+1.0m
Mean Lower Low Water (MLLW)	+0.4m

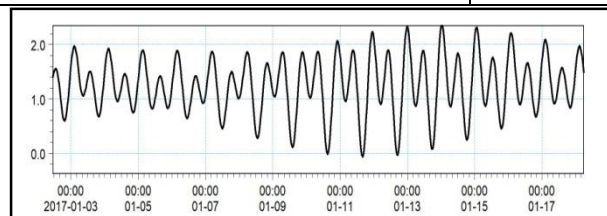


Fig. 3. Kumta tide for Non-monsoon season

VII. CURRENT OBSERVATIONS

Currents observed at three locations (Figure 4) one in the river mouth and the other two in the offshore covering spring and neap tide for a duration of two weeks during 1-17 January 2017 was available. The analysis of the data indicated that there is a reversal of flow during flood and ebb phase and the average currents at C1 location near the river mouth varied from 0.05 to 0.25 m/s. At C2 location in the offshore the average currents were of the order of 0.05 m/s with a peak value of about 0.35 m/s. Similarly at C3 location north of Basavaraj island the average currents were of the order of 0.05 m/s with a peak value of about 0.27 m/s.

Table 2: Locations of field observed currents.

DATUM:WGS-84, CM-75, Zone-43				
ID	Easting	Northing	LATITUDE	LONGITUDE
CM-1	436885	1580784	14° 17'53.4628"N	74° 24' 53.2746"E
CM-2	434100	1580800	14° 17' 53.7498"N	74° 23' 20.3159"E
CM-3	433497	1583548	14° 19' 23.1395"N	74° 22' 59.3442"E

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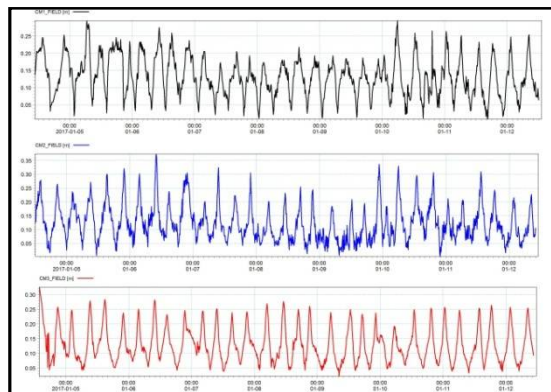


Fig. 4. Observed field current data in time series

VIII. SEDIMENTS

CWPRS provided the required sediment data, the average sedimentation concentrations was 150 mg/l. The data report indicated that total 120 samples were analyzed and the suspended sediment concentration varied from 15mg/l to 195mg/l during different phases of tide and water depth. The silt and clay content in the pre monsoon period is generally greater than 80% and the overall average silt and clay content is about 84%. The average D_{50} value of the sediments at site was considered as 0.40 mm for simulation. Due to presence of more clay and silt contents, here we adopted Mud Transport module instead of Sand Transport Module in MIKE 21.

IX. SETTING UP OF MATHEMATICAL MODEL

Setting up of the model is actually another way of saying transforming real world events and data into a format, which can be understood by the numerical model. Model set up consists of selection of model domain, data processing, generation of bathymetry, consideration of initial/boundary conditions and wind input. Using the prepared data and bathymetry initial model was established.

X. SIMULATION OF FLOW CONDITIONS

Hydrodynamic studies include simulation of the flow field during the Non-monsoon season. Further the studies were carried out to assess changes in the hydrodynamic condition and formation of tidal circulations in monsoon season as well. Initially, Non-monsoon season was considered for the studies. The model region considered for hydrodynamic flow simulation extends for about 20km along the shore line and for about 10km cross-shore covering about 20m depth contour as shown in Figure 2. It could be seen that there are three open boundaries where flow conditions are required to be given. The flow simulations were carried out for a spring and neap tidal conditions with a tidal range of 2.03m. The Kumta tidal was provided as input along the northern and southern open boundaries with appropriate lag. The discharge from the nearby rivers was also considered during setting up of the model. The simulations were carried out with different model calibrating parameters like Eddy viscosity, bed resistance- Manning's coefficient and discharge, until the computed value nearly matches with the field observation values and thus the model was calibrated as shown in Figure 5. The currents simulated were observed to be changing the direction indicating reversal of flow. Generally, for non-monsoon season the tidal velocity is varying between 0-0.2 m/s along the shore line for low water and high water conditions, similarly it is varying from 0.2-0.5 m/s current velocity for peak flooding and peak ebbing conditions for entire model area.

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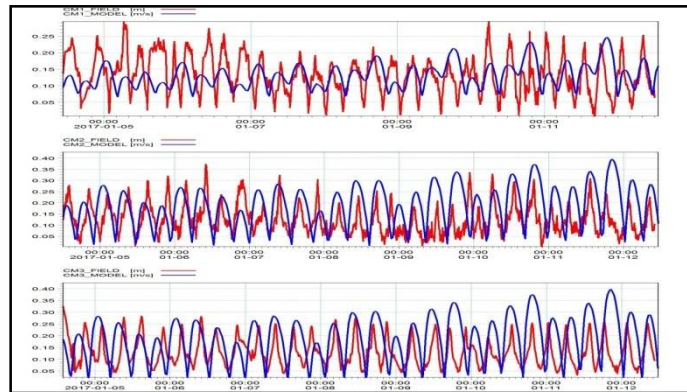


Fig. 5. Calibration of currents (Comparing the computed V/s field observed currents)

At river mouth the tidal velocity is varying from 0.20 -0.40 m/s for low water and peak flooding conditions, similarly current velocity is varying from 0.1-0.5 m/s for high water and peak ebbing conditions. A typical flow field during low water and peak flood is shown in Figure 6.

For Monsoon season, the tidal velocity is varying from 0.10-0.30 m/s for high water and low water conditions, similarly varying from 0.20-0.50 m/s for peak flooding and ebbing flow conditions for entire model area. At the river mouth the tidal current velocity is varying from 0.30-0.8 m/s for all high water, low water, peak flooding and ebbing conditions. By analysis of all the flow conditions, variation in current velocity can be observed for different seasons. Once the model is set for flow conditions it can be used for simulation of sedimentation.

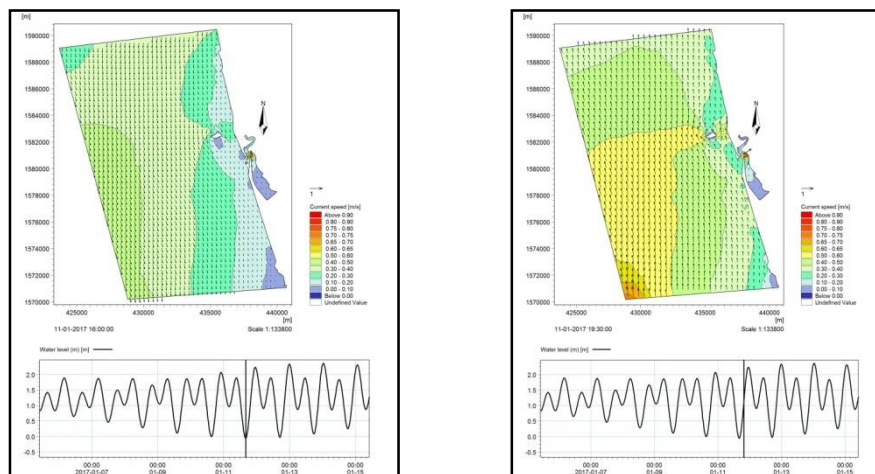


Fig. 6. A typical flow field during low water and peak flood

XI. SEDIMENTATION STUDIES

The hydrodynamic information namely water levels and velocities are obtained in the model region by the hydrodynamic model considering various flow conditions. Using this information as input, the sediment transport model computes deposition and erosion pattern in the model region. The sediment transport model is based on 2-dimensional depth averaged sediment transport equations of conservation of mass of sediment. Considering the tide and

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wave conditions at the site the hydrodynamic and sediment transport models were operated for a period of two months for both non-monsoon and monsoon seasons covering both spring and neap tidal conditions, using available data. The average sedimentation concentration was 150 mg/l at the river boundary and at the tidal boundaries in the offshore a uniform value of 50 mg/l was considered. The model were operated for different tidal and wave conditions and the general trend/ pattern of sediment transport, depth of deposition of sediment were simulated to identify the areas of potential siltation in and around the Sharavathi river mouth near Honnavar.

The sedimentation during different phases of the tides was observed. Siltation pattern after the simulation period for monsoon and non-monsoon seasons is shown in Figure 7. It could be seen that the zone of deposition is near to the shore and to some extent in rivers. For non-monsoon season the average deposition is about 0.15m and the highest deposition is 0.24m on southern side of island. In non-monsoon season the deposition was taking place in the river mouth region due to low discharge from the rivers and formation of sand bars is observed.

During Monsoon season the average deposition is about 0.3m in the shadow region of Basavaraj Island and around 0.2 m on the northern side of the island. During monsoon rivers carry more suspended sediments and those sediments will be discharged into the sea. Due to high discharge from the rivers in monsoon period the deposition was not taking place near the river mouth and it was distributing along the coast.

By comparing both non-monsoon and monsoon season sediment transport plots it could be seen the trend of erosion, deposition and sediment movement pattern can be observed at the Sharavathi river inlet.

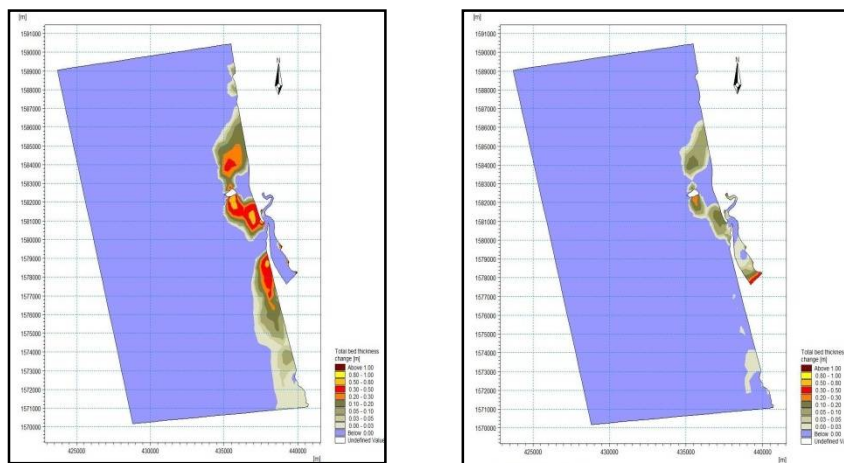


Fig. 7. Siltation pattern for monsoon and non-monsoon seasons

XII. CONCLUSION

Generally, for non-monsoon season the tidal velocity is varying between 0-0.2 m/s along the shore line for low water and high water conditions, similarly it is varying from 0.2-0.5 m/s current velocity for peak flooding and peak ebbing conditions for entire model area. At river mouth the tidal velocity is varying from 0.20 -0.40 m/s for low water and peak flooding conditions, similarly current velocity is varying from 0.1-0.5 m/s for high water and peak ebbing conditions. For Monsoon season, the tidal velocity is varying from 0.10-0.30 m/s for high water and low water conditions, similarly varying from 0.20-0.50 m/s for peak flooding and ebbing flow conditions for entire model area. At the river mouth the tidal current velocity is varying from 0.30-0.8 m/s for all high water, low water, peak flooding and ebbing conditions.

Sedimentation studies indicated that during non-monsoon season the average deposition is about 0.15m and the highest deposition is 0.24m on southern side of island. It was also observed that the deposition was taking place in the river mouth region due to low discharge from the rivers and formation of sand bars is noticed.

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