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Impact of Breakwater on Estuary Mouth Stabilization from Sedimentation perspective

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ABSTRACT**: Beypore estuarine system is formed at the confluence of the third largest west flowing river, the Chaliyar in Kerala which is the chosen study area. This paper presents the impact evaluation of an estuary mouth stabilization with parallel breakwater and attempts to assess whether sedimentation stabilization indeed have beneficial effects on port operation throughout the year. The analysis relies on the field observed data, which comprises extensive data on bathymetry, tide, tidal currents, wave and discharge. Depth averaged 2D Finite volume model is run with the above-mentioned data. 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 seasons. The model was calibrated for non-monsoon season. Results indicate that the breakwaters are effective in arresting the continental shelf sediment from entering the estuary and keeping the mouth open for most part of the year which helps in smooth movement of vessels in and out of the estuary.

***KEYWORDS:** Estuary, Mouth Stabilization, Breakwater, Sediment Transport Pattern, Monsoon*

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I. INTRODUCTION

Beypore is the ancient port town located in the Kozhikode district in the state of Kerala, India (Fig 1). Beypore is 180 km North of Cochin and 391 km away from Trivandrum. It is an estuarine port, where Beypore river discharges into the Arabian Sea. Beypore port is the second biggest port in Kerala after Cochin and currently handles about 100,000 tones of cargo and 7500 passengers per annum. The nearest ports are Kochi and Mangalore. Beypore port is one of the oldest ports in Kerala from where trading was done to the Middle East. Now the port has a depth of about 8 meters alongside wharf and approach channel. The main problem faced by the coastal infrastructure is sedimentation and this may be attributed to the discharge from upstream side, sediments from the continental shelf and dredging disposal [6] and [8]. During past couple of decades back N.Anilkumar et al (2001) had studied the seasonal dynamics of Beypore estuary and had estimated the annual sediment in-put and the net sediment transported towards the sea were of the order of 8.8 x 10^4 and 5.7 x 10^4 tons per/year respectively so that the annual entrapment of sediment was 3.1 x 10^4 tons per/year [7]. The study indicated that the Beypore estuary is dynamic in nature. In this study an attempt has been made to assess the hydrodynamic flow conditions and sedimentation aspects with the existing parallel breakwaters at the inlet and without the breakwaters using numerical models to understand the sedimentation pattern.

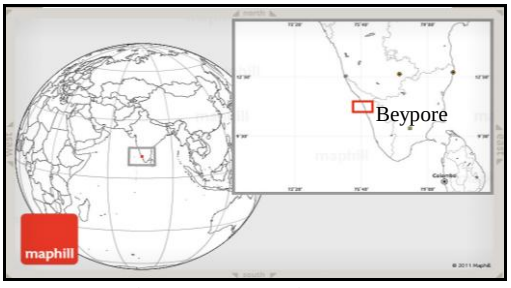

Figure 1: Location Map

II. SCOPE OF STUDIES

In this paper an attempt has been made to study the tidal hydrodynamics and sedimentation aspects of the Beypore estuary with existing breakwater and without breakwater. The study was carried for both monsoon and non monsoon condition with appropriate discharge and field measured data. The model was calibrated for non monsoon condition and the calibrated model was used for further studies.

III. METHODOLOGY

The Mathematical models MIKE21 HD and MIKE21 ST were used for simulation of hydrodynamics and sedimentation in and around Beypore in Kerala. 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 Central Water & Power Research Station (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 Beypore 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.

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. Field studies data was available with CWPRS data bank [1] and [2]. The data was collected during May and September 2017 in and around Beypore Estuary. The location of field data collection is shown in Fig 2.

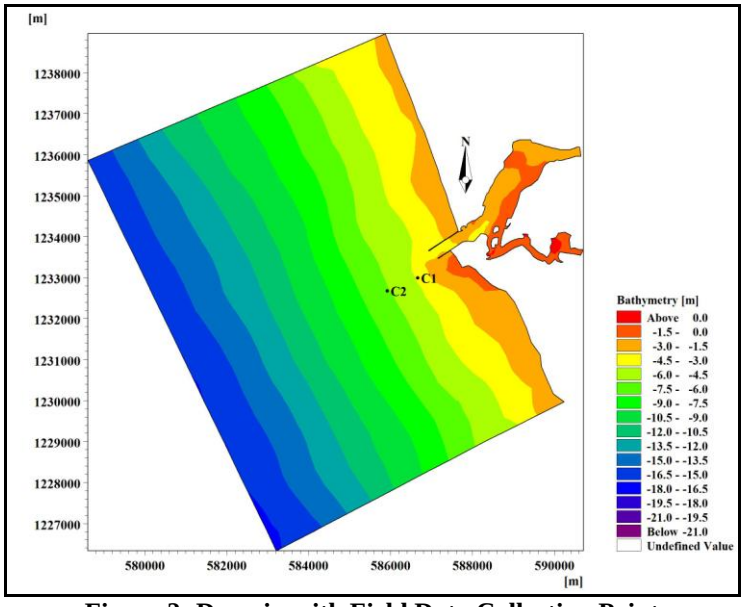

Figure 2: Domain with Field Data Collection Point

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4.1 Bathymetry

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 Beypore Estuary, study area was taken from the CWPRS data was incorporated in the computational model which show that they are generally parallel to the shore with gradual slope. The 3.5 m depth contour was close to the shore. Throughout the stretch the contour slope was gradual with 2m interval contours. The Chaliyar River discharging into the Arabian sea at Beypore area is considered. The computational bathymetry of 7 km by 9.5 km was discretized into triangular mesh with 1,00,000 nodes and the maximum element area of 2,00,000 m^2 is shown in Fig.3. There are three open (water) boundaries, one land boundary with two rivers discharging into the sea is shown in the bathymetry. Two locations were used to compute the currents and compare with field observed currents. All of this information was used for setting up the computational model.

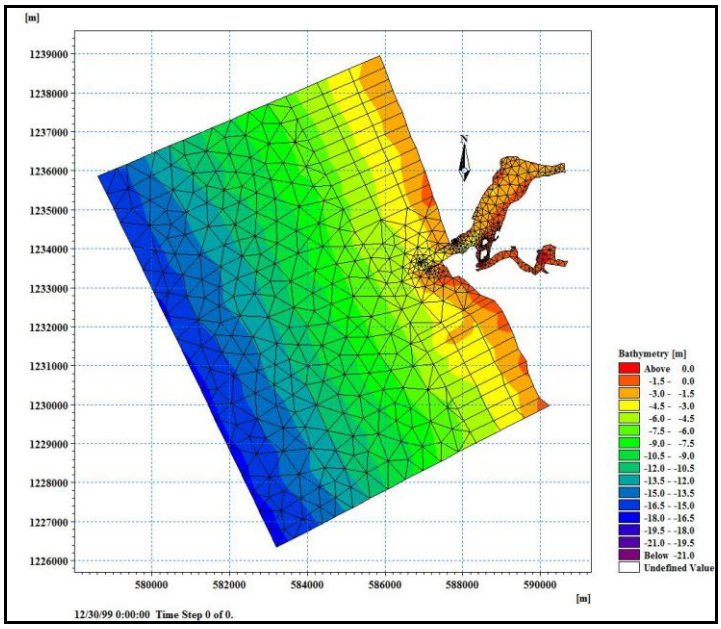

Figure 3: Beypore bathymetry with mesh

4.2 Tide

The existing site is near to Beypore tidal station and Beypore tide with appropriate phase lag has been used for the model simulation. The tide at Beypore was mixed semidiurnal tide with unequal tidal range of 1.4 m. The tide used in the model studies is shown in the Fig. 4.

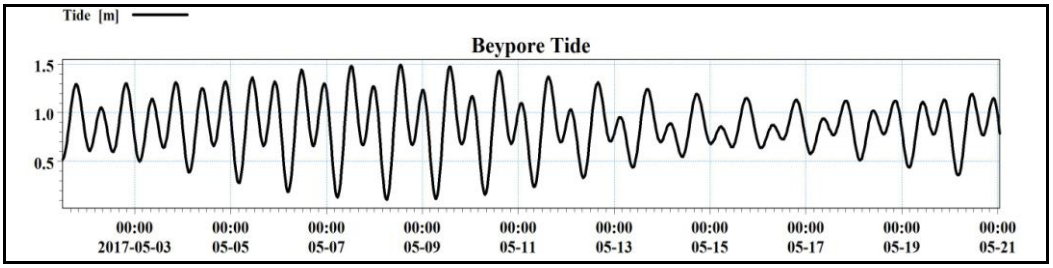

Figure 4: Beypore tide for Non-monsoon season

4.3 Current

Currents observed at two locations one in the river mouth and the other in the offshore covering spring and neap tide for a duration of two weeks during 01-21 May 2017 was available at CWPRS data bank. The analysis of the data indicated that there is a unidirectional flow and the average currents at C1 location near the river mouth varied from 0.2 to 0.54 m/s. At C2 location in the offshore the average current were of the order of 0.1 m/s with a peak value of about 0.8 m/s and is shown in Fig. 5.

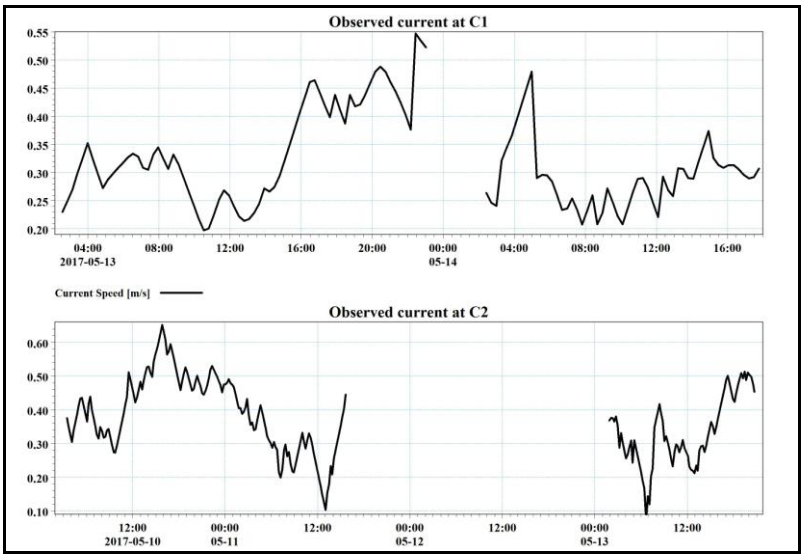

Figure 5: Observed Current at C1 and C2

4.4 Sediment data

CWPRS provided the required sediment data, the average sedimentation concentrations were 141 mg/l in May and 113 mg/l in September 2017. The data were analyzed and are tabulated below (Table .1) during different phases of tide and water depth. The sea bed material mostly consists of silty loam with the percentage of clay is 10- 15%, that of silt is 40- 50% and the rest being fine sand. The material along the beach and inside river consists of coarse sand with no silt or clay. From the bed material analysis, it is clear that during non-monsoon (May), coarse sediment varying from 0.015 mm- 1.20 mm are present in the river portion, whereas finer sediment of 0.007- 0.016 mm are found in sea. During first week of September continuous ebbing in the Chaliyar river was observed thereby indicating sufficient discharge, finer sediments were found both in the river and sea. The average D50 value of the sediments at site was considered as 0.115 mm for simulation. Due to presence of coarse and fine sand, here we adopted Sand Transport module instead of Mud Transport Module in MIKE 21.

Table 1. **Details of Sediment Data Analysis**

Location	May (mg/l)	September (mg/l)
Feroke Bridge	0.020- 0.090	0.004-0.036
Mouth	0.040- 0.149	0.012- 0.079
At 1.5 km from Mouth	0.071-0.159	0.008- 0.059
At 2.25 km from Mouth	0.033-0.167	0.017- 0.065
At 4.25 km from Mouth	0.046- 0.640	0.011- 0.835

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V. 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.

5.1 Simulation of Model with Breakwater

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 9.5 km along the shore line and for about 7 km cross-shore covering about 16 m depth contour was considered. 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 1.4 m. The Beypore tide was provided as input along the northern and southern open boundaries with appropriate lag. The discharge from the Chaliyar river was considered during setting up of the model. The model studies 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 is shown in Fig 6 and it could be seen that the observed and computed currents match reasonably well. The simulations were carried with different tides and discharges. The typical flow pattern for the existing conditions in the model domain during

peak flooding non monsoon and monsoon season is shown in Fig. 7. The flow fields obtained by the model in the existing conditions during different phases of the tide over the entire model area was analyzed for both non-monsoon and monsoon seasons. Generally, for non-monsoon season the tidal current is varying between 0.12-0.38 m/s along the shore line for low water and high water conditions, similarly it is varying from 0.16-0.71 m/s current velocity for peak flooding and peak ebbing conditions in the inlet mouth between the breakwaters.

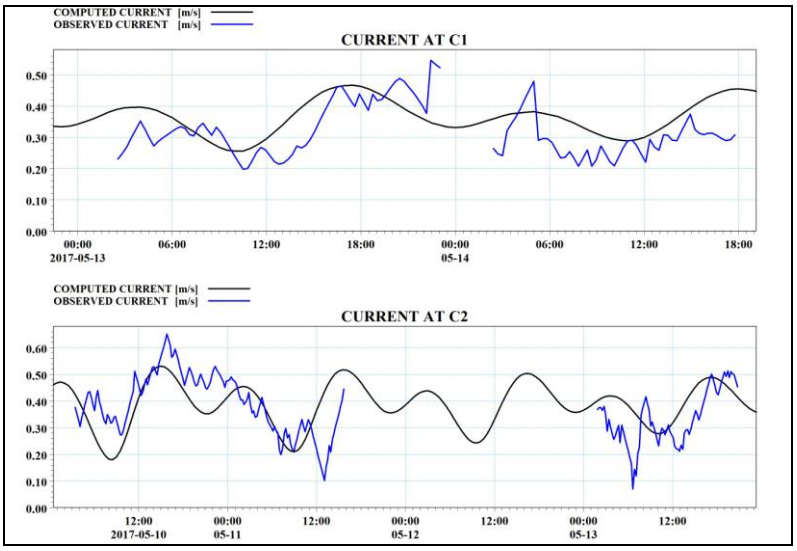
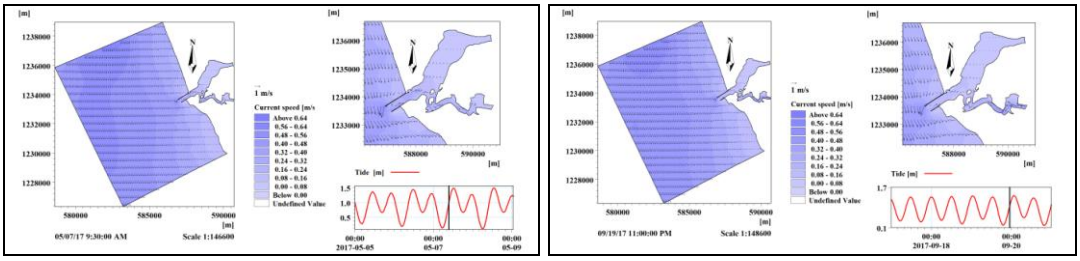


Figure 6: Calibration of currents (Comparing the computed V/s field observed currents)

Similarly model for Monsoon season were simulated as well. At river mouth the tidal current is varying from 0.14-0.38 m/s during low water and peak flooding conditions, similarly it varies from 0.16-0.82 m/s for high water and peak ebbing at inlet mouth between the breakwaters.

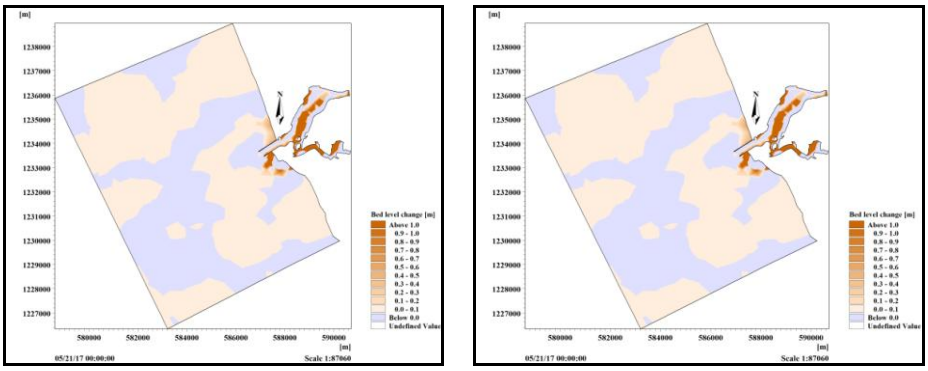


Non Monsoon **Monsoon**

Figure 7: Flow Field during Peak Flooding in Existing Condition

5.2 Sedimentation Studies with Breakwater

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 wave conditions at the site the hydrodynamic and sediment transport models were operated for both non-monsoon and monsoon seasons covering both spring and neap tidal conditions. The model was 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 Beypore Estuary mouth near Kozhikode, Kerala. 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 Fig 8. 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 Chaliyar River inlet including the south of southern breakwater.

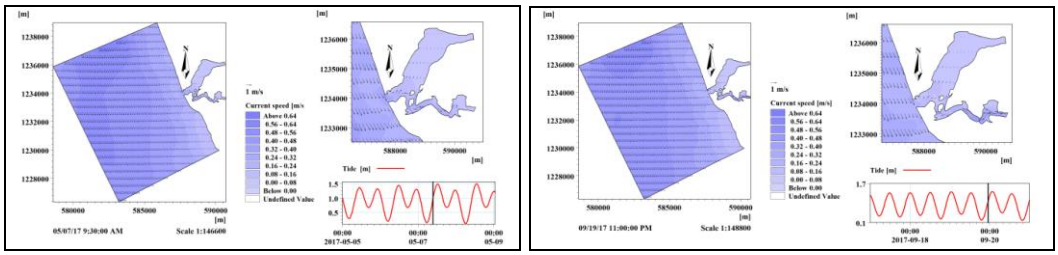


Non-Monsoon **Monsoon**

Figure 8: Siltation pattern for and seasons

5.3 Simulation of Model without Breakwater

To know the impact of breakwater on the coast, model studies were carried out by removing the breakwater and it was observed that during non-monsoon season the tidal velocity is varying between 0.14-0.26 m/s along the shore line for low water and high water conditions, similarly it is varying from 0.12-0.29 m/s current velocity for peak flooding and peak ebbing conditions for entire model area.



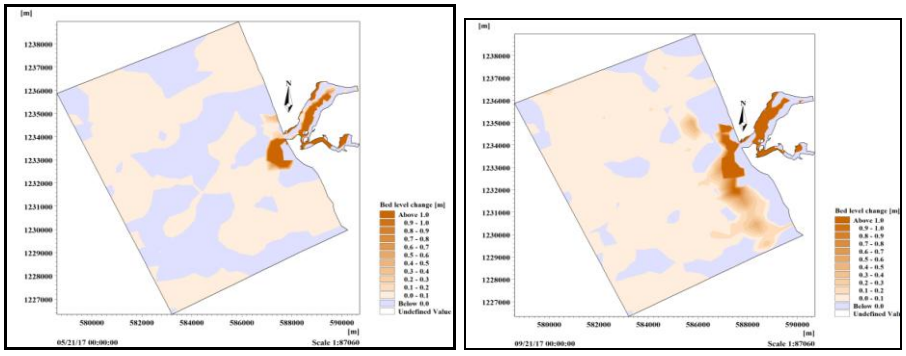
Non Monsoon **Monsoon**

Figure 9: Flow Field during Peak Flooding Without Breakwater

A typical flow field during peak flooding without breakwater for both Non-monsoon and Monsoon is shown in Fig.9. Similarly model for Monsoon season were simulated as well. At river mouth the tidal velocity is varying from 0.14 -0.24 m/s for low water and peak flooding conditions, similarly current velocity is varying from 0.16-0.48 m/s for high water and peak ebbing conditions.

5.4 Sedimentation Studies without Breakwater

The model was 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 Beypore Estuary mouth without breakwater near Kozhikode, Kerala. The sedimentation during different phases of the tides was observed. Siltation pattern after the simulation for monsoon and non-monsoon seasons is shown in Fig 10. 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 Chaliyar River inlet including the south and north of mouth.



Non- Monsoon **Monsoon**

Figure 10: Sedimentation Pattern Existing Condition

VI. CONCLUSION

The numerical model studies for hydrodynamics and sedimentation were carried out for the natural existing conditions and without the existing breakwaters at Beypore inlet in Kerala using mathematical models like MIKE 21 HD and MIKE 21 ST were used for simulation of hydrodynamics and sedimentation studies.

The currents simulated with existing parallel breakwaters were observed to be changing the direction indicating reversal of flow. Generally, for non-monsoon season the tidal current is varying between 0.12-0.32 m/s along the shore line for low water and high water conditions, similarly it is varying from 0.16-0.71 m/s for peak flooding and peak ebbing conditions in the inlet mouth between the breakwaters. During monsoon it was observed that at river mouth the tidal current is varying from 0.14-0.38 m/s during low water and peak flooding conditions, similarly it varies from 0.14-0.82 m/s for high water and peak ebbing at inlet mouth between the breakwaters.

It was observed that in general, the flow is unidirectional in the Beypore region mostly towards south during both monsoon and non-monsoon season and the tidal flow found to change direction post monsoon and pre-monsoon. During Non-Monsoon the continental shelf sediments are carried into the estuary and are found to deposit in the estuary due to weak ebb currents but in the monsoon the ebb currents are strong due to the continuous discharge from the Chaliyar River because of this the continental sediments are washed off along with the upstream sediment. Monsoon discharge of the river carries huge quantity of sediment with it and it gets deposited in the branch river, in front of mouth and on the Southside of the coast, in order to keep mouth open throughout the year breakwater is necessary as it stream lines the flow and as a consequence reduces chocking of the river mouth with sediments.

ACKNOWLEDGEMENT

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