



Chapter 10

A 2D Hydrodynamic Model Study in Brahmaputra River for Implementation of Bank Protection Work at Nimatighat

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Abstract. The morphological characteristics in a natural channel are widely affected by its sediment transport capacity. There are various possible reasons which may imbalance the sediment supply and transport rates and alters the flow dynamics in the channel. River Brahmaputra is associated with the problems of bank erosion, deposition of sediments, rapid bed aggradations, and drainage congestions and flooding from decades. Channel dredging is a possible method that can be implemented in the vulnerable reaches to remove the accumulated sediments and provide sufficient flow depth in the channel for navigation as well as for the safe passage of flood waves. Dredging in the channel improves the bed slope, increases the flow area and results in quick disposal of water during the high flow period. In this work, river hydraulics near the eroded bank is evaluated using a two-dimensional hydrodynamic model by considering three possible dredging widths in the channel along with a series of permeable spurs. The suitable alternative out of the proposed methods is selected based upon the computed parameters.

Keywords: Dredging · Permeable spurs · Two dimensional hydrodynamic model

1 Introduction

A river is an integrated system of water and sediments carried along with it. Any alterations in the atmospheric and terrestrial systems of a watershed are integrated and manifested in the river system. As the river flows, the dynamics of the exchange between its water and sediment load along with the geology and the hydrology of the landscape creates a complex network of processes, resulting in a given physical form of the river system. River morphodynamics is a consequence of channel dimensions, gradients and channel adjustment by an erosion deposition process [1]. The alluvial rivers are characterized by the sediment transported from its bed and bank. Most of the alluvial rivers in

India like Ganga and Brahmaputra show erratic behaviour both during the lean period and flow period. The planform of these alluvial rivers are constantly changing and are extremely dynamic character. Equilibrium can be at best a statistical phenomenon since there must be local erosion and deposition as flow changes [2]. River channel behaviour often needs to be studied for its natural state and responses to human activities.

High silt carrying capacity and gradient variations of the Brahmaputra River causes aggradations and degradations at different locations. To prevent bank erosion in Majuli, four numbers of spurs are constructed to deflect the flow from the bank promoting the silting in the neighbouring areas. The main channel is getting contracted near the Nimatighat in the presence of a large sandbar. During monsoon, 30,000–50,000 cumec of water passes through the contracted portion causing heavy erosion near the bank. It is the interest of the stake holders to carry out a river training work in that stretch to reduce the soil and property loss. Before implementing any possible river training measures in field, a numerical or field model study is essential for the decision-making process. Proper representation of the braided stretch and bed-level variations is difficult to model in field scale, and therefore, a 2D hydrodynamic model is a good alternative for flow prediction. Hydrodynamic models are helpful in quick simulation with different flow scenarios. In this study, BRAHMA-2D model is used for simulation. This model is developed by IIT-Guwahati in collaboration with Brahmaputra Board. The basic objective of this simulation is to apply the 2D hydrodynamic model in a highly braided stream to quantify the velocity distributions near the eroded bank and to adopt the best alternative out of a single measure or from a couple of measures. Three possible dredging widths and a series of permeable spur are considered in the simulation. Morphological changes are not taken into account because the current version of BRAHMA-2D model solves the two-dimensional shallow water equation, and the sediment transport simulation is not yet incorporated.

2 Governing Equations and Numerical Scheme

Two-dimensional depth averaged shallow water equation by neglecting the viscous and Coriolis effect can be expressed in matrix form as follows [3]

$$\frac{dU}{dt} + \frac{dF}{dx} + \frac{dG}{dy} = S \tag{1}$$

where,

$$U = \begin{Bmatrix} \eta \\ q_x \\ q_y \end{Bmatrix} F = \begin{Bmatrix} q_x \\ q_x^2/h \\ q_x q_y/h \end{Bmatrix} G = \begin{Bmatrix} q_y \\ q_x q_y/h \\ q_y^2/h \end{Bmatrix} S = \begin{Bmatrix} 0 \\ -gh \frac{d\eta}{dx} - s_{fx} \\ -gh \frac{d\eta}{dy} - s_{fy} \end{Bmatrix}$$

where η is the water surface elevation (m), q_x and q_y discharge/width in x and y direction, $\frac{d\eta}{dx}$ and $\frac{d\eta}{dy}$ are the water surface slopes in x and y direction, s_{fx} and s_{fy} are the friction slopes

in x and y direction, respectively. After transforming the equations in boundary-fitted system [4]

$$\frac{\partial}{\partial t}[J\eta] + \frac{\partial}{\partial \xi}[JhU] + \frac{\partial}{\partial \eta}[JhV] = 0 \quad (2)$$

$$\frac{\partial}{\partial t}[Jhu] + \frac{\partial}{\partial \xi}[J\{huU\}] + \frac{\partial}{\partial \eta}[J\{huV\}] = -Jgh\left(\frac{d\eta}{dx} - s_{fx}\right) \quad (3)$$

$$\frac{\partial}{\partial t}[Jhv] + \frac{\partial}{\partial \xi}[J\{hUv\}] + \frac{\partial}{\partial \eta}[J\{hVv\}] = -Jgh\left(\frac{d\eta}{dy} - s_{fy}\right) \quad (4)$$

where,

$$U = \left(\frac{\partial \xi}{\partial x}u + \frac{\partial \xi}{\partial y}v\right) \text{ and } V = \left(\frac{\partial \eta}{\partial x}u + \frac{\partial \eta}{\partial y}v\right), J = \begin{vmatrix} \frac{\partial x}{\partial \xi} & \frac{\partial x}{\partial \eta} \\ \frac{\partial y}{\partial \xi} & \frac{\partial y}{\partial \eta} \end{vmatrix} = \begin{vmatrix} \frac{\partial x}{\partial \xi} & \frac{\partial y}{\partial \xi} \\ \frac{\partial x}{\partial \eta} & \frac{\partial y}{\partial \eta} \end{vmatrix}$$

A second-order accurate explicit Mc-Cormack predictor–corrector scheme is used for the solution of the unsteady flow equations. A splitting algorithm is employed for the solution in which the two-dimensional equations are divided into four one-dimensional equations, and each 1D equations are solved successively. Variables determined in the predictor part are used during the corrector part. The non-physical oscillations near the steep regions need to be smoothed by some specific numerical treatment, otherwise this oscillation propagates in the solution leading to the failure of the model. Addition of coefficient of artificial viscosity in the solution is one technique to suppress these dispersions, but it requires a trial and error process to select the proper amount of diffusion [5]. TVD scheme is a method that can be used to add the right amount of dissipation subsequently at the sharp region. The benefit of the TVD model is that in this scheme, the proper amount of weightage to be added at the steep regions is decided algebraically, and it is also free of adjustable parameters. Five points total variation diminishing scheme is used in this model [6]. Stability of the model is ensured by CFL condition.

3 Study Area of the Proposed Dredging for Modelling Exercise

Majuli, the nerve-centre of the Neo-Vaishnavite culture, is situated between 26° 45' N–27° 12' N latitude and 93° 39' E–94° 35' E longitude. Map of the study area is shown in Fig. 1a. It is seen from Fig. 1b that due to the presence of series of spurs at the upstream of the reach deflect the flow towards the south bank. Since the river channel is contracting from 1.30 km upstream to 730 m downstream, and when the flow takes place through this contracted curvature part with high velocity, it causes erosion near the bank. Flow area near the affected bank can be increased by dredging some portion of the sandbar and diverting some amount of water through the dredged channel. A combination of permeable spurs at the upstream of the dredged channel is another alternative that can be implemented. Prior to the implementation, feasibility of the proposed suggestions for channel improvement is studied by employing the mathematical model.

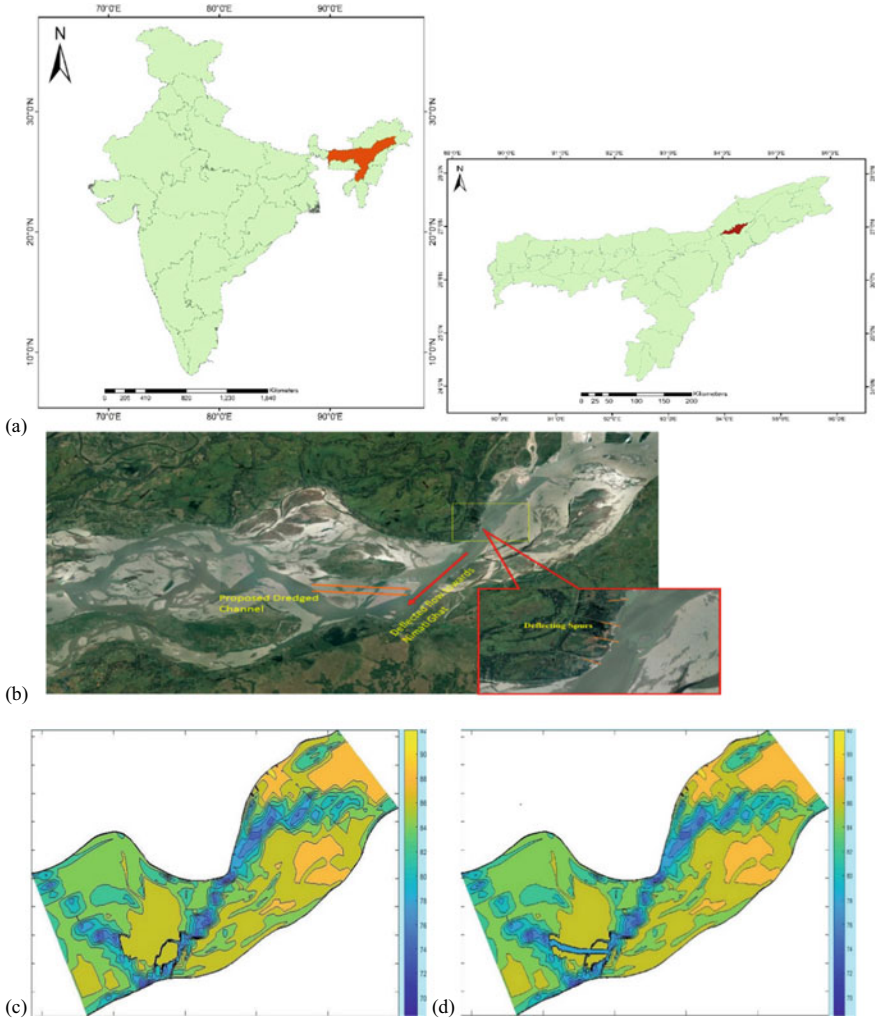


Fig. 1 **a** Map of the study area. **b** Detailing of the modelled area. **c** Bed elevation after the proposed dredging. **d** Bed-level elevation at present

4 Boundary Condition in the Model

In hydrodynamic simulations, accuracy of the computed outputs is governed by the boundary conditions, especially at the upstream and downstream location. The model simulations with incorrect datasets increase the uncertainty in the model and thus the decision-making processes. Data scarcity is a big issue in model simulation. Hydrodynamic models with wrong boundary conditions leads to an inferior solution. In this model, a stage-discharge curve for different return period is prepared from the frequency analysis of the hydrological datasets of 20 years collected from different sources (Fig. 2).

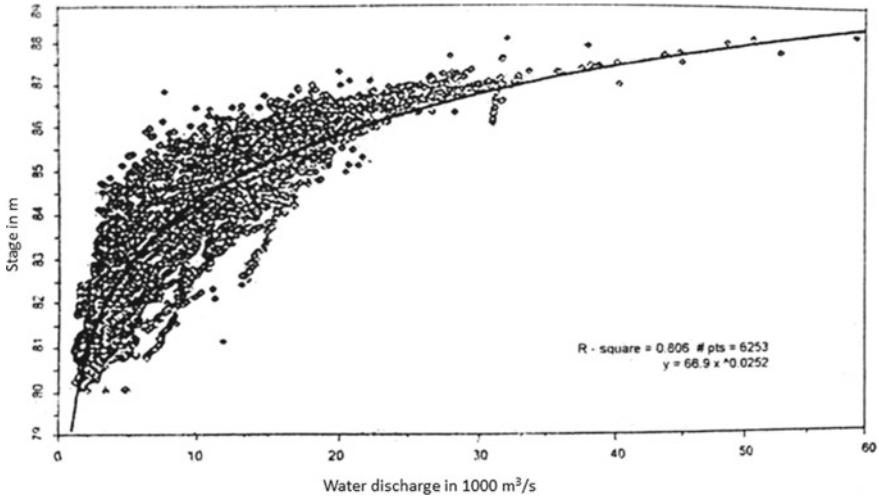


Fig. 2 Rating curve near Majuli. Courtesy: Brahmaputra Board

5 Result and Discussion

First Case: Dredging of the Sandbar with Three Different Width

In the first case, model is simulated by considering the three different dredging widths in the channel. Width in probable dredged locations is considered as 150, 300, and 450 m.

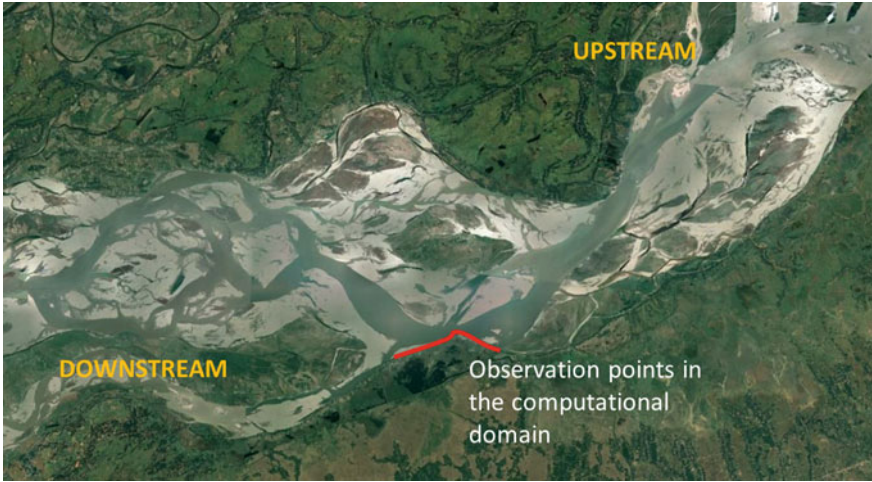
Current speed near the banks and along the centreline the dredged channel is plotted in Fig. 3b, c. From this simulation, it is observed that out of the three possible dredging conditions considered here, channel having dredged width 450 m considerably reduces the near bank velocity and increases the current speed within the channel as compared to the others.

Second Case: Dredging of the Sandbar with Porcupine Screen

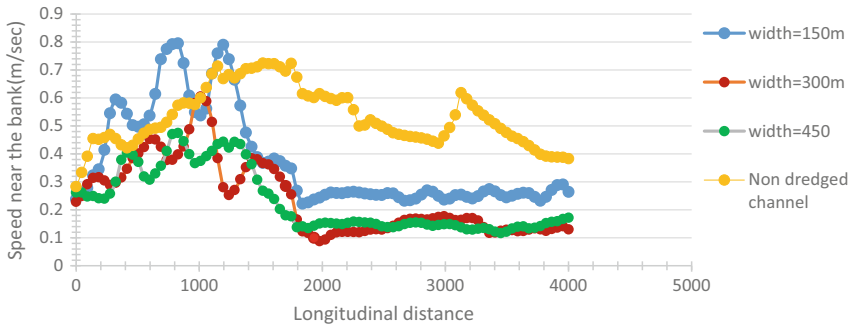
From the above simulation, it is found that with 450 m dredging width, there is a considerable reduction in velocity profile. In the second simulation, a series of porcupine screen is installed from the upstream of the dredged channel and extended up to the affected portion of the bank. Figure 4a shows the locations for installation of the porcupine screens.

In the hydrodynamic model, porcupine screens are simulated as permeable spurs. Permeable spurs are used to reduce the velocity and promote siltation but not to deflect the flow. In simulation, roughness values at those points are increased to modify the momentum fluxes. Velocity profiles are plotted near the bank.

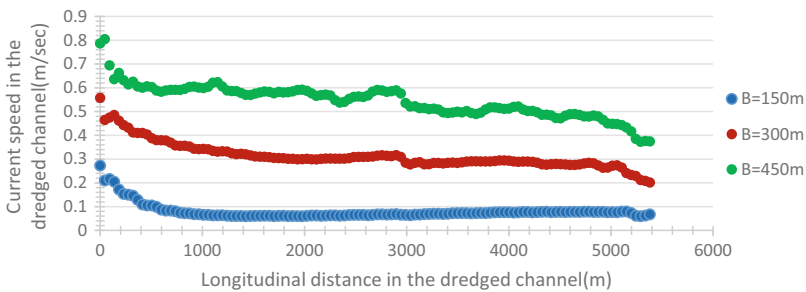
From Fig. 4b, by comparing the computed outputs under two scenarios, it is seen that there is not any significant reduction in current speed near the bank after installing the porcupine screens at the upstream along with the 450 m dredging.



(a) Flow parameter observation points near the south bank



(b) Water speed near the south bank at different dredging width

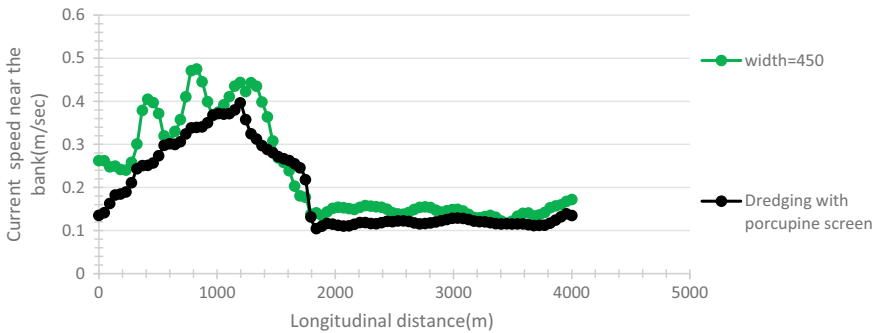


(c) Water speed in the dredged channel at different dredging width

Fig. 3 a Flow parameter observation points near the south bank. **b** Water speed near the south bank at different dredging width. **c** Water speed in the dredged channel at different dredging width



(a) Proposed location for RCC porcupine screen installation



(b) Current speed near the bank with series of RCC porcupine screens

Fig. 4 **a** Proposed location for RCC porcupine screen installation. **b** Current speed near the bank with series of RCC porcupine screens

6 Conclusions

A 2D hydrodynamic modelling study is carried out by using BRAHMA2D model in the Brahmaputra River for a reach length of 35 km near Nimatighat to find out best possible measures for bank protection. Two possible alternatives are used in the simulation. In the first case, mid sand bar is dredged with three possible widths and computed velocity profiles are compared. In the second case, a series of RCC porcupines are installed at the upstream of the dredged channel. From the simulation, it is observed that the 450 m dredged channel considerably reduces the velocity near the bank; however, no significant changes is noticed in flow speed after the installation of the porcupine screens. It is necessary to carry out a morpho-hydrodynamic and cost–benefit analysis before implementing these methods in the field.

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