STUDY ON HYDRODYNAMIC RESPONSE OF GORAI RIVER TO DREDGING USING DELFT 3D

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ABSTRACT
Owing to the reduction of upstream water flow after construction of Farakka Barrage on the Ganges River, huge amount of sediment loads are settling down on Gorai river bed, hindering the safe passage of flow. For such sediment dominated rivers, dredging operations can be undertaken with a view to increase the river conveyance. The objective of this study is to investigate the hydrodynamic response of Gorai river to dredging using Delft 3D. A 25 km reach of the Gorai River, subdivided into 5 monitoring points for the year 2010 was selected for the model simulation. Simulated hydrodynamic parameters were compared before and after dredging to assess the functionality of dredged bathymetry. Results reveal that hydrodynamic performance, specifically, flow augmentation for the dredged condition is 9.632% with velocity increase of 9.82% and water level decrease of 14.98%. Thus the dredging strategy can be defined as an efficient one in facilitating the hydrodynamic response of the river. These results suggest that the dredging strategy can be defined as an efficient one in understanding the hydrodynamic response of the river and will help the river regulation authority to undertake appropriate future developments projects for the river restoration.

Keywords: Gorai; hydrodynamic; Delft3D; flow augmentation

INTRODUCTION

The pride of Bangladesh is its rivers, one of the largest networks in the world with a total number of about 700 rivers including tributaries, which have a total length of about 24,140 km. The country is a part of three major river systems of South Asia, namely, the Ganges-Padma, the Brahmaputra-Jamuna and the Meghna. From the time immemorial, rivers have played a significant role in forming the life line for our country, which recently is facing problems due to natural and anthropogenic reasons. In general, diversion of river flow in the upstream, salinity intrusion, excessive sedimentation causing navigability disturbance and flooding are the major problems relating to rivers in our country (FAP-24).Due to increasing withdrawal of the Ganges River in its upstream inside India, its distributaries inside Bangladesh are slowly facing death for not receiving their winter flow. The Ichhamoti is dead, the Baral and the Chandana are dying, the Mathabhanga rarely gets flow during flood months, and the Gorai also gets dried up at its off-take during winter (M. Inamul Haque, 2015).Gorai River is the major distributary of the Ganges River in the right bank and a main source of freshwater within the Bengal Delta area (Addams, 1919). With a total length of about 200 km Gorai has a catchment area of 15160 km² and is located between 21° 30’ N to 24° 0’ N latitude and 89° 0’ E to 90° 0’ E longitude (Bangladesh er Nod Nodi,2010) covering south western region of Bangladesh. The river takes off from the Ganges at Talbaria, north of Kushtia town and 19 km downstream from the Hardinge bridge and discharges into the Bay of Bengal through the Madhumati and Baleswar Rivers (Islam and Gnauck, 2011). Due to implementation of the Farakka Barrage in 1975, the dry season flows in Ganges River started to decline subsequently which results in reduction of flow through the Gorai River and deposition started ensuing in the off-take. As a result, two types of environmental impacts have been created in the Gorai catchment area (BWDB, 2010). The sediment particles are settling down on the river bed rapidly, which is one of the major problems of Gorai River morphology. On the other hand the saline sea water is pushed up in the upstream area due to capillary upward movement. As the Gorai is the main lifeline of South-western part of Bangladesh dredging efforts can be taken to de-silt its off-take to keep the flow coming from the Ganges River(M.Inamul Haque, 2015). In this study, realizing the importance of rivers in Bangladesh in general and understanding the predicament of river Gorai in particular, efforts have been ensued to address the hydrodynamic analysis of the river Gorai with respect to dredging as a part of solution of sediment problems and flow augmentation. Hydrodynamic parameters including discharge, velocity and water level were compared before and after dredging and portrayed in the graphs and charts.

Effects of Dredging on river hydrodynamics

Dredging operations involve the removal of bed material and associated vegetation from a river channel with an objective of increasing the river channel capacity and its ability to convey water (Andries J. et.al, 2015).The exact ramifications of river dredging upon river hydrology and geomorphology will be a function of the river topology, sediment characteristics, the dredging technique employed, existing floodplain connectivity and antecedent environmental conditions. Channels which have been deepened by dredging silt-up more frequently as they return to their pre-dredged state(Judy England and Lydia Burgess-Gamble, 2013). Dredging can reduce water levels at some locations but this depends on local conditions and is therefore case specific. Local reductions in water levels automatically mean a reduction in flood risk. Dredging would automatically prevent out of bank flow from occurring(Judy England and Lydia Burgess-Gamble, Environment Agency, 2013). Dredging activity is combined with a greater fine sediment load to cause bed armoring and dredging causes increase in the discharge and velocity decreasing in the water level (Trevor Bond, 2013). If a dredged channel is also straightened, the water velocity is increased significantly, due to increased slope and the loss of energy dissipation at bends. Faster water causes much more damage during floods.(Southern Tier Central Regional Planning & Development Board,2013).

Study Area

The study area covers about 25 km reach of the Gorai River flowing from 10km downstream from the Ganges-Gorai off-take within the kushtia district to the 5 km upstream of the Kamarkhali transit within the Kamarkhali upazilla. Figure 1 shows the Google map of the study area.

Fig. 1: Map showing the study area

METHODOLOGY

Methodology of the study covers data collection, setting up of a model of 25 km river reach of the upper Gorai and performing analysis for two simulation period; dry and flood period and two settings; pre and post dredging conditions. Cross section data for the year 2009-2010, time series discharge data at the Gorai Railway Bridge (SW-99), Water level data at Kamarkhali (SW-101) and Kamarkhali transit (SW-101.5) have been collected from Bangladesh Water Development Board (BWDB) and Water Resources planning organizations for the model setup. Physics-based nonlinear morpho-dynamic model Delft3D of version 3.28.50.01 was used as a modeling tool. Hydrodynamic parameters such as discharge, velocity and water level were compared before and after dredging and portrayed in graphs and charts. A25 km long river reach with an average width of 800 m; started from 6 km downstream from the Ganges-Gorai off-take was discretized by 720*36(m*n) cells. The average dimension of each grid cell was approximately 40m*40m.After developing the study area with good quality grids, processed cross section data were imported and has been interpolated and diffused to obtain a spatially varying depth file. Figure 2 shows the grid and depth of the study reach. Bathymetry data was collected during the monsoon period of the year 2010 measured with respect to the PWD datum.120 cross sections at approximately 200 m interval have been used for the setup of the initial bathymetry of the model. Figure 3shows the initial defines the monitoring points which have been used for observing simulated velocities, discharge and water level.

Calibration and Verification of the Model

Calibration and verification of a numerical model requires two independent data sets, one of which is used to calibrate the model and the other to validate the results. Calibration of the model has been done simulating the model from 1st of June, 2010 to 31st of August, 2010 and verified for the time ranging from 1st of September to 30th of November. Computed water surface elevations have been compared with the observed water surface elevations at Kamarkhali station (SW-101). Roughness and eddy viscosity are the parameters that have been used to play to obtain an adequate match with the observed field conditions. Manning's roughness coefficient has been adjusted after several trial of the model during calibration to an average value of n = 0.025, The value of eddy viscosity has been considered as 10.0 m2/s. The model was validated at the Kamarkhali for the period 1st of September to 30th of November that shows a good agreement with the observed data.

Selection of Dredge Section

Proposed dredged section is a trapezoidal one (GRRP, 2000). In this study a dredging section of 200 m base width having side slopes of 1:20 and 13 m deep from the side banks has been used to understand the dredging response on the river hydrodynamics. Figure 2 shows the comparative plot of the river bed.

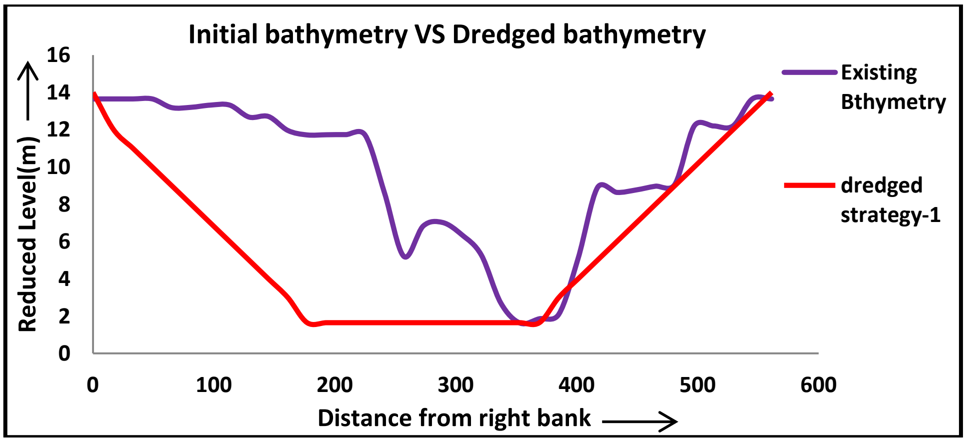

Fig. 2: Initial bathymetry Vs dredged Bathymetry

RESULTS AND DISCUSSIONS

Analysis on Dredging Response:

Simulated depth averaged velocities at 5 different monitoring points are plotted to visualize the changing pattern and the length wise difference in magnitude. The peak velocity ranges from 0.7 m/s-0.9 m/s during the flood period and the value ranges from 0.1m/s-0.25 m/s during the period of lean flow. Trough and peak magnitudes of the velocities show that change in velocity along the reach varies from 4%-7%. Flow velocity along the study reach decreases due to the changing fluvial processes but the percentage change is not so significant due to small length of the study area. A dredging strategy remarkably alters the bathymetry. It induces a change in flow velocity. As the river bed deepens by dredging, it provides a more smooth passage for the flow. Seasonal variation in the flow volume also causes a change in the velocity time to time.

Figure 2(a), (b) show the comparison of depth average velocity of the study reach of the river for the two conditions of pre and post dredging strategy during the wet seasons. It can be visualized that during both the wet and dry season for the year 2010 there is a higher velocity of flow in the main channels and flood plains in case of dredged bathymetry. The velocity in the main channel is obviously greater than the velocity in the side channels. During the wet season flow velocity throughout the study reach varies from 0.3 m/s-0.9 m/s in case of original depth profile whereas the range of velocity increases to 0.4 m/s-1.1 m/s in dredged bathymetry. During the lean period flow velocity falls within the range of 0.06 m/s-0.16 m/s that increases to 0.30 m/s to 0.65m/s in dredged bathymetry.

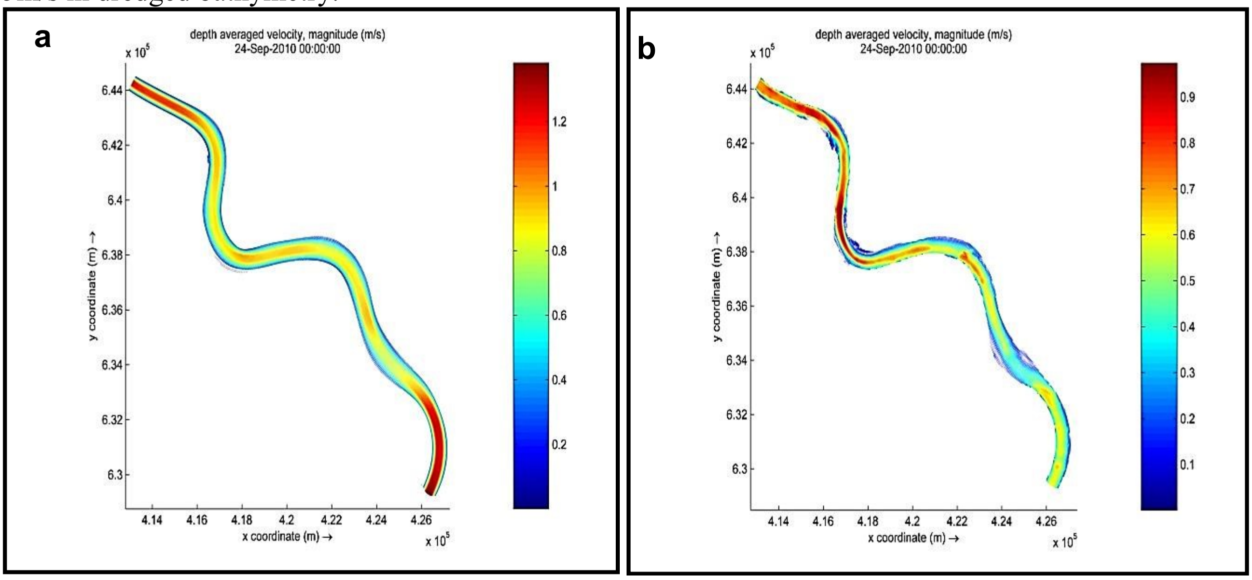

Fig. 2: Simulated depth average velocity during wet season (a) Pre-dredging; (b)Post dredging

Simulated discharges at 5 different monitoring points named are plotted to visualize the changing pattern and the length wise difference in magnitude of discharge. Simulated discharge during the flood period ranges from 2800 m3/s to 4200 m3/s. Trough and peak magnitudes of the discharge show that change in discharge along the reach varies from 12%-17% with maximum discharge at the 1st monitoring point and minimum at 5th monitoring point. To compare the pre and post dredging work, average of the discharges of 5 monitoring points is taken as the mean discharge in case of pre-dredging work. As the flow velocity increases due to dredging, it induces an increase in discharge along the study reach that augments both the dry and wet season flow. Simulated water levels at 5 different monitoring points were plotted to visualize the changing pattern and the length wise difference in magnitude. Water depth increases along the reach as the flow velocity and discharge decreases along the reach. But the simulated water levels showed a decreasing pattern along the reach as the bed level lowers along the bathymetry at an average slope due to land topography. During dry period simulated water level varies from 2 m to 3.5 m and the level rises to 8m to 9.5 m during flood period. As dredging result in narrowing and deepening of the channel, the still water level drops. The series of figures below show the effect of dredging on the water surface elevation of the study reach of the river Gorai in both dry and wet seasons. It can be visualized that during both the wet and dry season for the year 2010 there is a lower water depth in the main channel in case of dredged bathymetry comparing with the original depth profile. Due to dredging, channel navigability increases contributing more water flow through the main channel, thus the water level drops in both the main channel and flood plains.

Discussion and Results:

The percentage variation of average monthly velocity, discharge and water level for the dredging scenario comparing with the original bathymetry can be tabulated as follows (Table 1) for better visualization. Positive percentage indicates percentage increase in corresponding parameter and negative percentage depicts the percentage decrease of the corresponding parameter.

Table 1 Response of Gorai river to dredging

Months	**Velocity (%)**	**Discharge (%)**	**Water level (%)**
Jan	8.67	6.24	-11.37
Feb	11.03	6.04	-11.77
Mar	10.19	6.44	-13.30
Apr	9.17	6.89	-13.23
May	9.84	8.38	-14.98
Jun	9.59	8.61	-14.17
Jul	9.37	9.81	-14.76
Aug	9.17	10.73	-15.21
Sep	13.39	10.63	-15.78
Oct	7.56	6.55	-14.08
Nov	4.25	6.40	-13.68
Dec	6.56	6.25	-13.38

From the analysis it has been found that for dry period velocity increase was obtained as 8.312%, corresponding percentage increase during wet season are 9.816%.For dry period discharge increase was obtained as 6.403%, corresponding percentage increase during wet season are 9.632%.For dry period water level decrease were obtained as 11.57%, corresponding percentage during wet season are 14.93%.

CONCLUSION, RECOMMENDATIONS AND STUDY LIMITATIONS

The models presented in the study are by far believed to be the most realistic simulation in terms of hydrodynamics. In the present study a deep insight on the effect of backfilling rate has not been considered. The percentage increase in flow discharge is not satisfactory enough to revive the Gorai River, thus dredging cannot be adopted as a permanent solution for the restoration. Moreover dredging has some negative Impacts. The process of dredging can damage ecology by directly affecting its physical habitat, disrupting riverine processes and reduced connectivity with the floodplain. Furthermore as in most of the real cases the spoil dumping areas are within the catchment area, a portion of the deposited sediment from the disposal sites returns to the dredged channel which may affect the sediment transport rate, cumulative erosion and cumulative deposition of the dredged channel. To avoid the difficulties in estimating the exact volume of the spoil deposition in the dredged channel, it is not incorporated in this study. Future study can be performed by counting the fact. For further extension, dredging section with any other dimensions and alignments can be considered to produce variable results.

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