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CHANGES OF SEDIMENT DISCHARGE ON THE PASUR RIVER USING FUTURE CLIMATE CHANGE SCENARIO

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ABSTRACT: The principal rivers of Bangladesh in the south-west region are Gorai, Pasur-Sibsa, Chitra,Bhola, Sonatola, Bishkhali Rivers. These rivers, connected with the Bay of Bengal through a specific land formation, are known as estuary. The Pasur-Sibsa is one of the estuaries of Bangladesh that has prominent importance due to its geographic location and ecological setting. The second largest sea port of Bangladesh Mongla is approximately 132 km upstream of the Bay of Bengal. For the proper functioning of the Mongla port, adequate navigability of the Pasur River is a prerequisite. Discharges, salinity, sediment flow of the Pasur River have a profound impact on the livelihood of the people of the Pasur dependent area. This main purpose of this study is to understand the future hydro-morphological scenario of this river for better water management and development. In this context, a one-dimensional hydraulic model, HEC-RAS has been setup over the Pasur river basin. It has been found that the sediment deposition increases with the decrease of flow in the river system which may affect the navigability of the river system. Considering future climate change scenario, it has been found that future sediment discharge will be increased.

Keywords: c*limate, HEC-RAS, navigability, sediment*

1. Introduction

Growing concerns about climate change are considered as an important dimension for environmental planning. Increase in rainfall intensity is projected to be one of the notable consequences of climate change and possibly results in the anticipated acceleration of hydrological cycles (Shaw et al., 2005; Hirabayashi et al., 2008; Mailhot and Duchesne, 2010). Applications of 1D mathematical models were reported as early as in the 1960s (Chang, 1982: Lin, 1981). In the past few decades, 2D and 3D mathematical models for sediment transportation have been developed to predict river regime and riverbed deformation due to engineering projects (Li, 1989) .The development of sediment transport mathematical models has been receiving more and more recognition, because they can be applied to assess the process of river bed evolution (Dewals, 2010).The movement of sediment shows profound significance to river. The process of sediment transport and deposition can change the topography of the river bed (Chen, 2012).The sediment deposition is a key factor to limit the river development and management (Wellmeyer, 2005). Southwestern regions of Bangladesh are bounded by The Ganges and the Lower Meghna in the east and by the Indian Border in the west and by the Bay of Bengal in the south. The coastal region of Bangladesh and the rivers in this

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region shows a continuing process of siltation progressing generally from NW to SE. In this study, a 1D sediment model has been developed in the Pasur river. On the basis of the theories of overseas and domestic experts, the theoretical and applied researches of one-dimensional (1D) models are very mature, and the reliability and accuracy are good (Simpson, 2006).The main objectives of this study are:

a) To study on the siltation rate of the river Pasur, Mongla and Sibsa River system.

b) Estimate the rate of change of sediment discharge due to climate change

2. Study Background

2.1. Tidal characteristics of Pasur Sibsa

The Sibsa has earlier tide than the Pasur. Tides are semi-diurnal. The approximate tidal range is between 1.5m and 3.0 m. Tidal stations at Hiron Point, Joymonirgoal and Mongla are maintained for observation and record of daily tide. During monsoon the Hinterland Rivers are in spate and current may attain strength up to $3ms^{-1}$ (BIWTA, 2012).

2.2. Hydrologic Characteristics

Mongla port consists of shore based facilities and a sheltered anchorage in the Pasur river. The banks of the river have continuous belt of mangrove forest of Sundarbans with small creeks at places throughout the passage from 5.75 miles south of Hiron Point upto the Mongla Harbor area. The weather in the port area is tropical with minimum temperature is 8^0 C and humidity of 50%. During summer maximum temperature rises to 40^0 C and humidity is 95%. Southwesterly monsoon from June to August causes rainfall of average 200cm (Womera, 2006).

2.3. Morphological Characteristics

The dominant bed material can be classified as fine sand. There is no distinct variation in the bottom sediment over the area. (min D50=.098 mm max D50 =.126mm mean D50=.11mm), although it is strongly suspected that coarser material would be encountered over the shoals, due to sorting action of the waves that will break in these areas. The variance of the bottom grading is surprisingly small (typical D85/D15=2.6) which implies very little cohesive material is settling out of suspension in the main channel on over the outer bar..Consequently, the tidal currents along must be sufficient to maintain the cohesive material in suspension and transport it out of the Pasur entrance and over the outer bar, where it will be deposited in deeper water (Khan, 1995)The dominant suspended material can be classified as medium silt, D50=.015mm. The majority of the suspended load is therefore classified as wash load which will have a little effect on the morphology and the sedimentation characteristics of the area.

The key observations from the sample analysis are:

a) The bed material along the main flow areas of the bigger rivers is fine sand. Closer to the banks it is often mainly silt.
b) The suspended solid fine materials does not contribute significantly to erosion/sedimentation processes in the main flow regions of the bigger rivers including the navigation channel of Mongla port.
c) The transport of bed materials is significantly smaller than the transport of fines. It contributes to the total transport of sediment by to approximately one-third.

3. Data Collection

MPA carried a hydrographic survey along the Pasur River Channel from Sabur Beacon to Hiron Point at sections of Mongla Nullah and at sections in Sibsa River during the period of 2002-2003. These data include bank to bank width during the high tide and depth below chart datum (CD). These data has been collected from WARPO and reproduced and used in the software. Discharge and sediment data has been collected from CEGIS. The suspended sediment samples were collected in each vertical at Surface, 0.2, 0.4, 0.6, 0.8 and Bottom (1m above the bed) of the total depth. Determination of total suspended sediment concentration and separation of fine and coarse sediment in suspended was done by filtration method. The filtration method was somewhat faster for samples of small concentrations. Usually Millipore filter papers are used in case of water samples with rather low content of sediments. This is due to the fact that the pores of the filters are of the dimension 0.45 µm. The concentration samples are separated by an elutriator into grain size fractions above and below 0.05 mm.

4. Methodology

4.1. Mathematical model description

HEC-RAS is a well known and very widely adopted open source 1D model. It is developed by Hydrologic Engineering Centre, US army crops of engineers. The model is originally developed for 1D open channel hydrodynamic analysis. It is assumed that transport of wash load is supply-limited and that wash load sediment will pass through a stream reach, without interacting with the bed and being deposited to drive aggradations. The movement of bed material load is assumed to be transport-limited so that scour or fill will occur if the local transport capacity is either greater than or less than the supply from upstream. HEC-RAS uses St. Venant Equations (Equation 1,2, 3 and 4) in the form of continuity to describe flow movement and equilibrium equations for sediment transport modeling. The flow is also solved using the Preissmann four-point scheme, with elaborate considerations of complex cross-sectional geometry.

St.Venant Equation:

The continuity equation:

$$v\frac{\delta A}{\delta x} + A\frac{\delta v}{\delta x} + b\frac{\delta h}{\delta t} = 0\dots\dots\dots (1)$$

The dynamic or momentum equation:

$$g\frac{\delta h}{\delta x} + v\frac{\delta v}{\delta x} + \frac{\delta v}{\delta t} = g(i - j)\dots\dots\dots (2)$$

Mass conservation for water:

$$b\frac{\delta \eta}{\delta t} + \frac{\delta Q}{\delta x} = q\dots\dots\dots (3)$$

Momentum conservation for water:

$$\frac{\delta Q}{\delta t}+\frac{\delta}{\delta x}\left(\frac{Q2}{A}\right)=-gA\frac{\delta\eta}{\delta x}-\frac{\tau}{\rho}P\ldots\ldots\ldots(4)$$

Here, A=the cross-sectional area of the section of the section, h=depth of water flow at the section, v=mean velocity at the cross-section, Q=discharge at the section, t= time, g=gravitational acceleration, b=local surface width, ρ=fluid density, q=flow per unit width, τ= boundary shear stress

4.1.1. Steps of mathematical modeling

Two steps are involved in HEC-RAS modeling:

Hydrodynamic modeling: Geometric data consists of connectivity information of the stream system, cross sectional data and hydraulic structure data. In this study, geometric model is developed by

a. The PASUR-SIBSA river system is drawn schematically from U/S of Mongla port to Hiron Point.

b. Two reaches are considered. These are Upper Reach, Lower reach.

c. Cross sectional data (112 cross-sections for Pasur, 6 cross-sections for MonglaNullah). Cross sections' numbers are ordered within a reach from D/S to U/S In a particular cross-section data:

d. Contraction or expansion co-efficient (0.1 for contraction and 0.3 for expansion) .Mannings' n (.021 ~ .026)

e. At U/S of Pasur near Mongla (Station No Pasur 112) flow hydrographs are used as boundary conditions as input data.

b.At D/S of Pasur near Sea mouth Stage Hydrograph (Station No Pasur 1) are used as boundary conditions as input data.

Morphological Modeling (sediment modeling):

HEC-RAS sediment routing routines the sediment continuity equation named as Exner Equation (Equation 5). It is computed for each control volume for each mixing step.

$$(1-\lambda_p)B\frac{\partial\eta}{\delta t} = -\frac{\partial Qx}{\delta x}\ldots\ldots\ldots(5)$$

Here, B=channel width, η=channel elevation, λp=active layer porosity, t=time, x=distance, Qx= transport sediment load

Sediment Transport Potential: Sediment transport potential is the measure of how much material of particular grain class a hydrodynamic can transport. Transport potential is computed with one of a number of sediment-transport equations are based on the value of d_{50} and d_{90} (grain size).

This value, computed separately for each grain class regardless of their prevalence in the bed, is called the sediment potential. The sediment transport potential used for the study is Acker and White (1973). Acker and white is a total load function that is developed from flume data for relatively uniform gradations ranging from sand to fine gravels. Hydrodynamics were selected to cover a range of bed configurations including ripples, dunes and plane bed conditions. Suspended sediment is a function o shear velocity while bed load is a function of shear stress.

Equilibrium Depth: Equilibrium depth is the defined smallest depth at which all particle sizes in the bed surface mixture will resist erosion for given hydraulic forces imposed on the bed. It is the maximum potential scour depth. It is based on a relationship between hydraulic energy, bed roughness and sediment transport intensity. Equilibrium depth is computed by combining Manning's Equation (Equation 6) for flow velocity, Stickler's Equation (Equation 7) for given roughness and Einstein's Transport intensity Equation (Equation 8). Transport capacity is the total, single representative transport for the actual system gradation. The stratification weight is the sum of the grain depth of each grain size.

Manning's Equation:

$$V=\frac{1.49}{n}(\sqrt[3]{R^2})(\sqrt{S_f})\dots\dots\dots (6)$$

Stickler's Equation:

$$n= \frac{\sqrt[6]{d}}{29.3}\dots\dots\dots (7)$$

Einstein's Transport intensity Equation:

$$\Psi= \frac{(\rho s-\rho w)}{\rho w}\frac{d}{DSf}\dots\dots\dots (8)$$

Here, V= velocity, R= hydraulic radius, S_f =friction slope, n=Manning's n value, d=representative particle size, ρ_s= grain density, ρ_w= water density, D= depth

Followings are the different steps of morphological modeling:

a. Initial conditions and transport parameters:

I. Ackers-white Transport Function used for the study

II. Exner 5 sorting method used for the study

III. Van Rijn fall velocity method used for the study:

IV. Bed gradation curve: Two bed gradations are individually defined for Pasur and Sibsa River

V. Maximum depth of scour: 5m for each section (assumed)

b. Boundary conditions: HEC-RAS model has three boundary conditions for has option for three boundary conditions. These are:

I. Rating Curve II. Sediment load series III. Equilibrium load

In this study, boundary conditions for sediment modeling, used for the Pasur and Mongla nala are:

Mongla nala (Reach: Mongla nala, River Station: 6): Sediment load series

Pasur River (Reach: Upper, River Station: 140): Sediment load series

Estimation of future sediment discharge: Yu et al. (2010) summarize the changes in temperature and precipitation changes predicted by 16 global circulation models for three emission scenarios for the fourth assessment report of the IPCC. The median warming predictions for Bangladesh across the models by the 2050s is 1.55^{0}C.Simulations of the future transboundary inflows of the three major rivers (Ganges, Brahmaputra, and Meghna) indicate increased basin precipitation will result in increased inflows into Bangladesh over the monsoon period. The Pasur river is in hydrodynamic connections with The Ganges. The increase in discharge in The Pasur will be similar to The Ganges basin. The average change in discharge(%) in Ganges is given in Table 1.

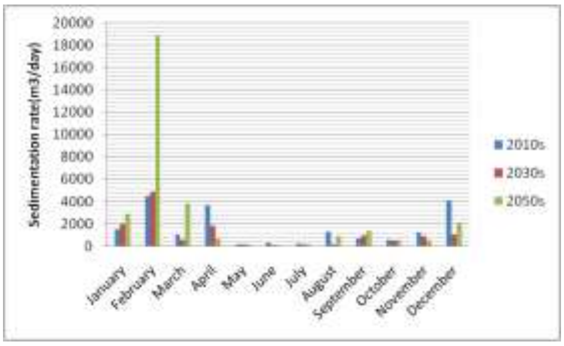
Table 1: Estimated average increase(%) in discharge in Ganges

Month	2030s	2050s
May	9.3	11.8
June	11.9	16.7
July	13.5	15
August	8.8	12
September	7.3	12.5

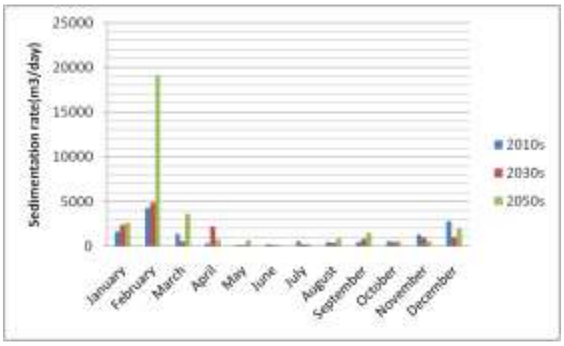
Based on this flow discharge increment, the future sediment discharge(m^3/day) has been found out from the mathematical model developed over the region.

4. Results:

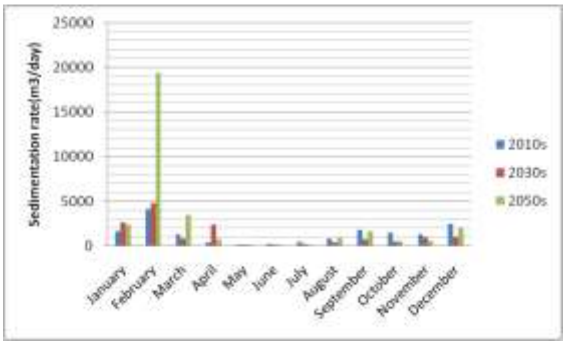
The rate of sediment discharge for 2010s, 2030s and 2050s for five selected cross-section of Pasur river (80, 82,84 and 86) are given below in a bar chart form. These five cross-sections are comprised of 8000 km reach length of the river. Mongla port, the second largest sea port of Bangladesh located within this reaches length. Geographic position of Mongla Port is: Latitude: 22^{0}38’ Longitude: 89^{0}35.57’.



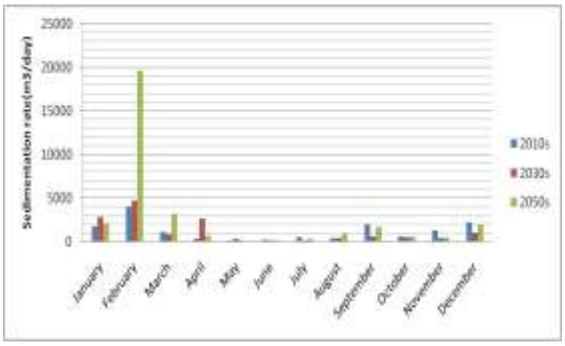
Cross section 80



Cross section 82



Cross section 84



Cross section 86

Figure 1: Sedimentation rate comparison between 2010s, 2030s and 2050s

The above figure shows that, the sediment transport rate exhibits a seasonal pattern. Sedimentation rate is maximum in February. In pre-monsoon season, the flow velocity remains small, that is the reason of high sedimentation rate. The upper reservoirs play an important role to block the role and make the rate of deposition reduce, so the trend of deposition becomes slow as time goes on. The simulation results show that the scope of deposition in the middle reach has the relatively large change. Due to climate shifting, the flow pattern may change. Simultaneously, the type and sedimentation rate changes are occurring. By incorporating the temperature change, humidity change and air velocity change phenomena in the model, a far better result can be obtained.

5. Conclusion:

The present study finds that, future sediment flow will increase if all other conditions remain constant. This may cause severe navigability problem of Pasur River. Dredging and width contraction of river are two possible solutions of the navigability problem. Dredging is done almost every year in the pasur channel. Attempts should be made to make the channel stable. A Study on conserving the ecological balance of this river system considering the climate change context is recommended.

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