CHANGES OF HYDRO-MORPHOLOGY OF SHITALAKHYA RIVER AND EFFECT OF PROPOSED BRIDGE USING HEC-RAS 1D MODEL

S. A. Saki* & M. M. Miah

Department of Water Resources Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh
**Corresponding Author: saki.afzal@gmail.com*

ABSTRACT

Knowledge on hydro-morphologic behaviour of a river is for essential design of bridges and hydraulic structures; flood control; planning, maintaining and controlling reservoir, training and stabilization of rivers. The purpose of the study is to analyse hydrological and morphological characteristics of the river and predict the scour and afflux caused by a proposed bridge using HEC-RAS 1D model. For this purpose several morphological and hydrological parameters were analysed from the collected satellite images, cross sectional data, water level data and discharge data. For proposed bridge, a model was set up in HEC-RAS 1D, calibrated and validated**.** Scour and afflux were computed using the collected bridge data. Negligible amount of erosion and deposition occurred in the study reach and some shifting in thalweg were observed. No significant shifting in river banks occurred during the study period (1981 to 2011). A decreasing trend was observed in maximum water level and maximum annual discharge. So navigability of the river is being threatened greatly. The scour and afflux were found within limit indicating the viability of bridge construction.

Keywords: Hydro-morphology; afflux, scour; thalweg movement, HEC-RAS 1D

INTRODUCTION

Shitalakhya, one of the main circulating rivers of Dhaka city, has ample importance in navigation, industrial purpose and economy of Bangladesh. The parent river of Shitalakhya is Old Brahmaputra. The river getting its flow through Banar River and then flows down via Ghorashal, Narayanganj and Madanganj. Finally it discharges into the river Dhalweswari, opposite to Munshiganj town. The River is used for navigational purpose, fishing, farming, industrial use and water supply. The lowering of water level and decrease of discharge has hampered the navigability of the river. The river is used for transboundary carrying goods along with navigational purposes. The river is one of the sources of municipal water of Dhaka city. Several parameters govern the hydrologic and morphologic characteristics of the river. Previous studies reported reduction of flow depth and degradation of water quality (IWM 2006; Hossain et al.; 2014; Rouf et al., 2013; Shaikh, 2006). There are two bridges on this river. There is a plan of constructing 3rd Shitalakhya Bridge on the river and the present study focuses on the changes in hydro-morphology of the river throughout the study period and the effect of bridge in terms of afflux and scour.

CURRENT HYDRO-MORPHOLOGICAL CONDITION OF SHITALAKHYA

The Shitalakhya River is running in a soil bed with a high resistance to erosion. Firstly, the river velocity seldom reaches the value sufficiently high enough to erode this bank. Secondly, the structures along the banks, function more or less as fixation points for the river current. The original river banks are resistant to scouring, as they consist of ferruginous laterite clay. However; recent deposits are subjected to continuous erosion and deposition. This is because runoff as well as tidal influences have sufficient high velocity to erode and deposit the river bed materials.

METHODOLOGY

Data Collection

For hydrological and morphological analysis cross section data of different years for stations L-1 to L-19, discharge data for several years (1990-2010) at Demra station (BWDB station No. 179) and water level data at Lakhpur (BWDB station No. 177) and Demra (BWDB station No. 178) for 1981 to 2010 were collected from Bangladesh Water Development Board (BWDB). Data pertaining to the proposed bridge were collected from Roads and Highways Department (RHD). The satellite (LANDSAT) images were collected and analyzed for determining the shift of bank line. The satellite images of 1975, 2000 and 2015 were collected for this purpose.

ANALYSIS OF DATA

Morphological Data Analysis

The morphological analysis was carried out using the obtained cross sectional data, satellite images, and historical maps. Cross-section at different stations (L1 to L19) were plotted and superimposed in Microsoft Office Excel for years 1981, 1992, 2001 and 2009. The variation in cross section was determined in terms of cross sectional area, top width and maximum depth at different stations. The analyses were done for the year 1981, 1992, 2001 and 2009. Satellite images collected from CEGIS, were superimposed in ArcGIS to analyse bank line shift.

Hydrological Data Analysis

Analysis of water level and discharge data was carried out to ascertain the hydrological condition of the Shitalakhya River. The maximum water level and the maximum discharge for different years were plotted in Microsoft Office Excel to show the variation with time. The maximum and minimum discharge and water level of a river are important for the design of a structure. So Design High Water (DHW) and Design Low Water (DLW) were determined using Gumbel's distribution method.

Model Setup

The river bank and centre line was generated by HEC-GeoRAS. Collected cross section data and geometric data were assigned in HEC-RAS. The model was initially run for unsteady flow. For this, flow hydrograph was used as upstream boundary condition and stage hydrograph was used as downstream boundary condition**.** The model was calibrated [Fig. 1] using daily water level of year 2009 at Lakhpur station.

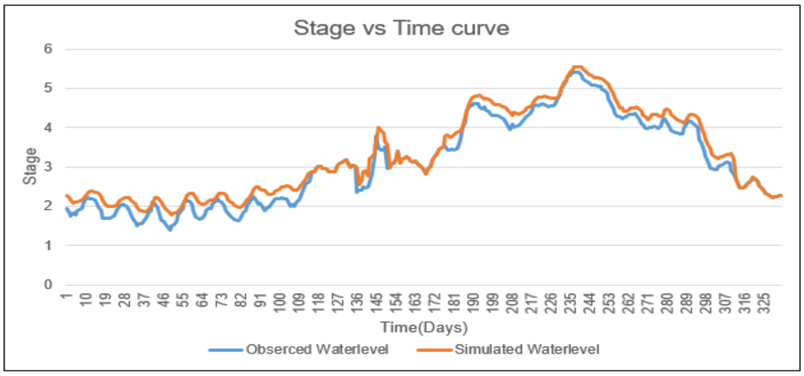


Fig. 1: Calibration Curve of Unsteady Model for the Shitalakhya River

Calibrated 'n' value was found to be 0.018. The model was validated [Fig. 2] for year 2014 for same station and Manning's 'n' value of 0.018. The ratio of the root mean square error to the standard deviation of measured data (RSR) and Nash-Sutcliffe efficiency (NSE) value showed in table 1.

Table 1: Model Performance Analysis

	RSR	NSE
Calibration	0.258	0.716
Validation	0.506	0.835

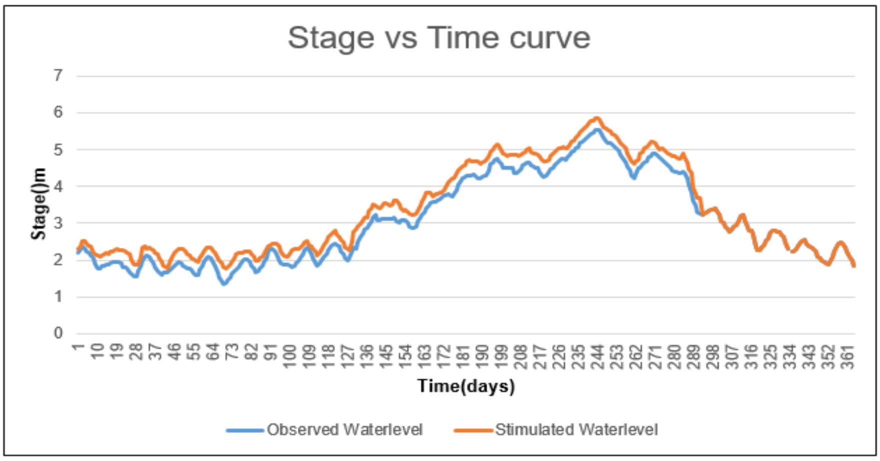
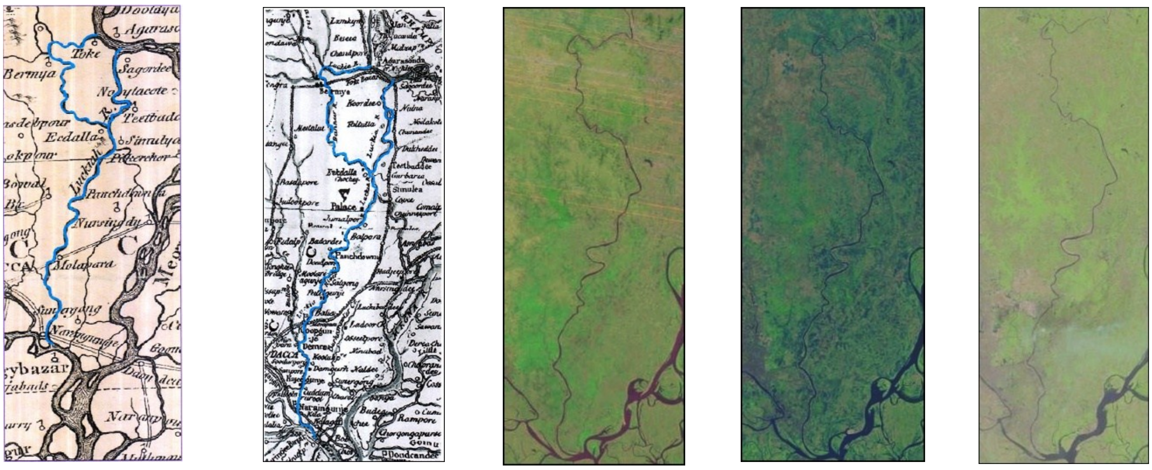


Fig. 2: Validation Curve of Unsteady Model for the Shitalakhya River

Calibration and validation indicated good performance of model. The collected bridge data such as geometric data, pier and abutment details were used as input. The model was run under steady condition for this purpose. Pier scour, contraction scour and abutment scour were obtained as output.

RESULTS AND DISCUSSIONS

Results of the analysis reveal that both the banks were stable and did not change much during the study period [Fig. 3].



1776 **1840** **1975** **2000** **2015**

Fig. 3: Maps of Different Years Showing the Changes in Plan Form of the Shitalakhya River

The variation of top width, cross sectional area and maximum depth for these stations are given in table 2.

Table 2: Changes in area, top width and maximum depth of the river

Year	Area (m^2)	Top Width (m)	Maximum Depth(m)
Station L-1			
Year 1981	1333.63	121.23	13.15
Year 1992	1482.18	105.31	13.69
Year 2001	1128.41	152.35	14.23
Year 2009	1607.41	155.74	14.83
Station L-7			
Year 1981	1958.1	150.47	16.64
Year 1992	2195.23	159.86	13.49
Year 2001	1811.46	177.04	13.22
Year 2009	2401.09	177.87	13.44

The cross sectional area reduced marginally during 1981 to 2001 at the upper reach stations (L-1 to L-10) but increased [Fig. 4] in the downstream stations (L-11 to L-19). Almost all the stations showed an increasing trend of cross-sectional area from 2001 to 2009.Similar trend was observed for top width and maximum depth.

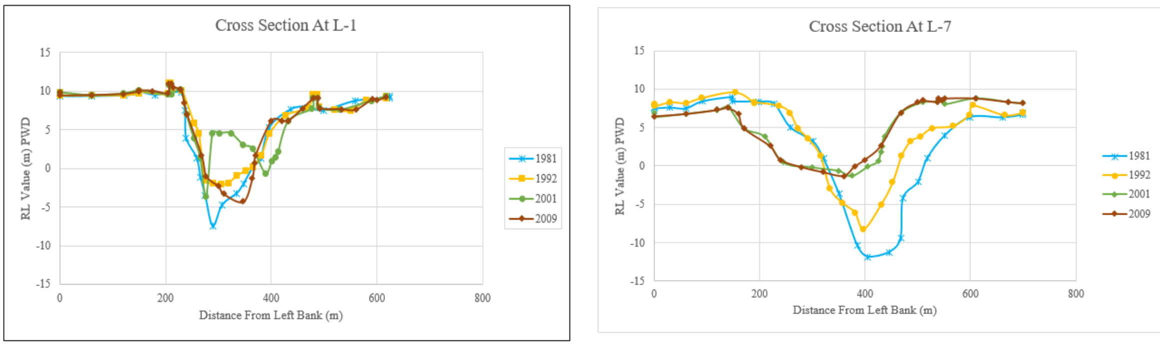


Fig. 4: Changes in Cross-Section for different years at L-1 and L-7

The thalweg movement was very insignificant during 1981 to 1992. But during the period of 1992 to 2009 the thalweg movement occurred significantly due to erosion and deposition which is shown in [Fig. 5(a)] and [Fig. 5(b)]

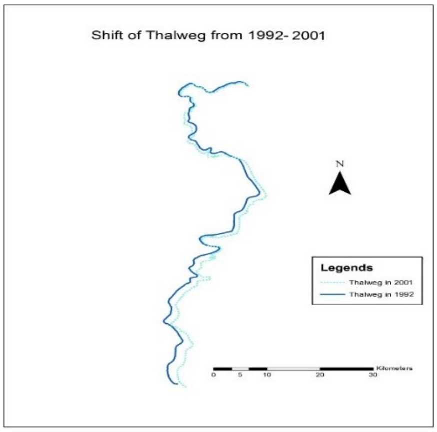


Fig. 5(a): Plan View of Shitalakhya River showing Thalweg Movement from 1992 to 2001

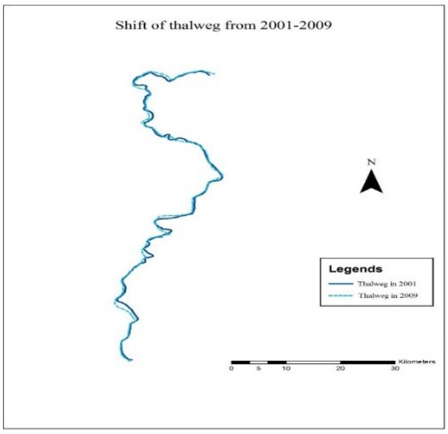


Fig. 5(b): Plan View of Shitalakhya River showing Thalweg Movement from 2001 to 2009

The hydrological data as showed in [Fig. 6(a)] reveal that water level remained almost same from 1981 to 2012. The average value of water level was found to be 4.8m PWD. There was some variation due to natural calamities like floods, surges, etc. But the water level showed a decreasing trend after 2004 may be due to low prevailing discharge. The design high water was found to be 10.24m PWD for station 177 and 7.5m PWD for station 179 for 100 years return period. On the other hand the low water of 0.96m PWD for station 177 and 0.82m PWD for station 179 for 100 year return period. There was a declining trend in the maximum annual discharge of the river [Fig. 6(b)]. The annual peak discharge reduced from 1850 m^3/s to 1550 m^3/s during the last decade. The design discharge for Demra station was found to be 3288 m^3/s for 100 years return period and the dominant discharge was found to be 1436.67 m^3/s. The decrease in discharge might occur due to siltation in the river. Proper dredging work should be done in the river bed for the survival of Shitalakhya River.

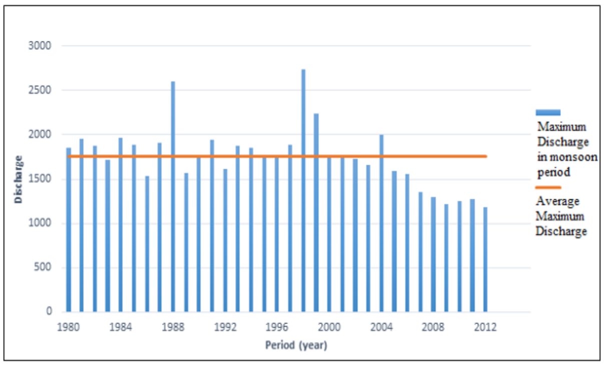


Fig. 6(a): Changes in Maximum water level in Different Years

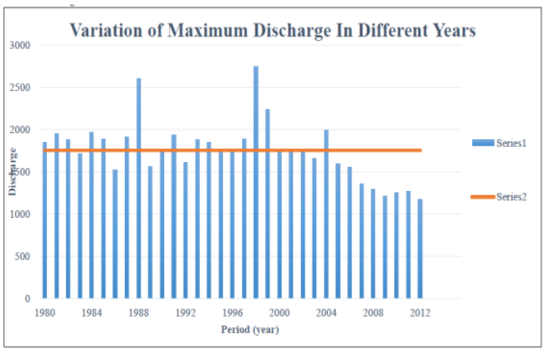


Fig. 6(b): Changes in Maximum Discharge in Different Years for monsoon period

The effect of proposed bridge was predicted in terms of afflux and scour. The afflux was determined and the value was found to be 0.3m which remained within the allowable limit. The pier scour is found to be 3.6m, the abutment scour is 0.3m for left channel and 0.3m for the right channel. The contraction scour depth is 0.7m for left bank, 1.3m for main channel and 0.6m for right channel. Scour due to contraction, pier and abutment is shown in the [Fig. 7].

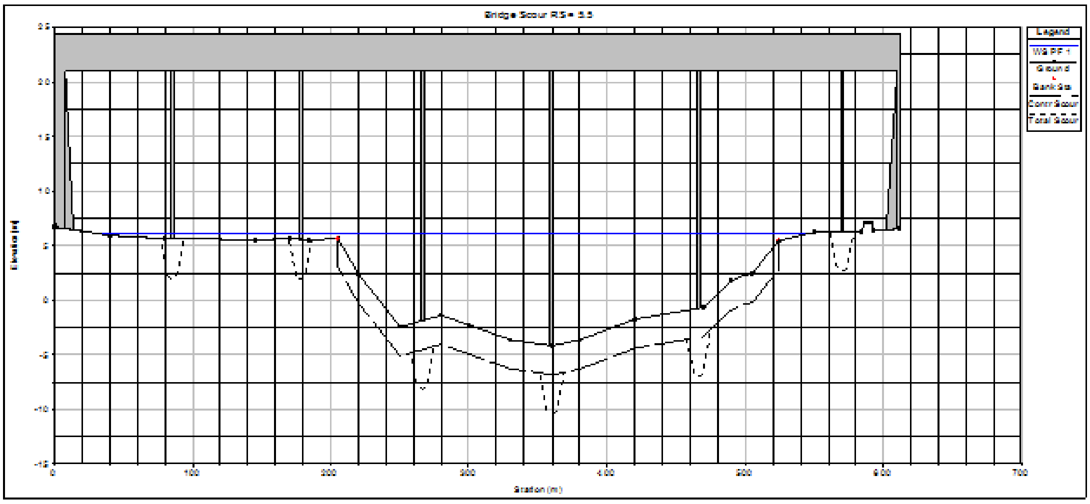


Fig. 7: Combined Effect of Contraction, Pier and Abutment Scour

REFERENCES

Hossain, S; Rahman, M; Nusrat, F; Rahman, R and Anisha, N.F. 2014. *Effects of Climate Change on River Morphology of Bangladesh and A Morphological Assessment of Shitalakhya River*. Journal of River Research Institute (RRI), pp 1-13.

Institute of Water Modeling (IWM). 2006. *Feasibility and Mathematical Model Study of Approaching and Investigating Strategy for Rehabilitating The Buriganga-Turag- Shitalakhya River System and Augmentation of Dry Season Flow in the Buriganga River*. Final Report.

Rouf, T and Miah, MM. 2013. *A Comprehensive Study on Hydro-Morphology and Water Quality of Shitalakhya River* proceeding of the International Conference on Climate Change Impact and Adaptation (I3CIA-2013), pp 985- 993.

Shaikh, MKI. 2006. *A Study on Some Geometric Parameters of Shitalakhya RIver*. B.Sc. Engineering Thesis, Department of Water Resources Engineering, Bangladesh University of Engineering and Technology, Dhaka.