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HYDROLOGICAL ANALYSIS AND HYDRAULIC ASSESSMENT OF THE EXISTING PAGLA-JAGANNATHPUR-AUSHKANDI ROAD AND ROAD STRUCTURES USING MIKE 21C MODEL

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Abstract

River Research Institute (RRI) has carried out a mathematical model study to assess the adequacy of the existing Pagla-Jagannathpur-Aushkandi road and associated road structures (bridges and culverts) and to devise appropriate hydrological and hydraulic design parameters of the same together with river training works where necessary. The study is based on extensive field survey data that include cross-sections of rivers and drainage routes, topographic data, road alignment data, soil characteristics, road structure data etc. The secondary data used in the study include historical hydrological data of rivers, time series satellite images etc. A two-dimensional mathematical model has been developed covering the entire stretch of the road (29 km). The initial bathymetry of the model is formed with topographic data and cross-section data of the rivers and drainage routes that cross the road. The model boundary conditions corresponding to different return period discharges have been determined by flood frequency analysis. At some upstream boundaries where measured discharge data are not available, slope area method is used to calculate discharges corresponding to different return period floods (20 year, 50 year and 100 year). The study results show that the existing Pagla-Jagannathpur-Raniganj-Aushkandi Road alignment except at some bridge approaches is found to be suitable route under likely hydrological and hydraulic conditions. The existing top level of the road is below the design formation level in most parts of the road. The design formation level of the road is 9.75 and 9.70 mPWD at Debor Point and Raniganj respectively. At some locations the existing road runs almost parallel to and very close to the rivers. The road structures at these locations may draw substantial flow during flood condition and some of the same have already damaged due to not taking this fact into account during design. Also there is potential for occurrence of parallel flow along the approach embankments of these structures. Protective measures should be undertaken along the East side slope of the approach embankments on both sides of the bridge over the Naljur river (from chainage 23.135 km to chainage 23.264 km) and the needed extent of protective measures is 90m and 50m towards Jaganathpur and Raniganj respectively extending from the bridge abutments. New PC girder bridges may be considered at the structure locations where approach is damaged fully or partially due to flood.

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Introduction

Sunumganj district is located in the Northeast region of Bangladesh. Dhakshin Sunamganj and Jagannathpur are two upazillas under Sunamganj district. These upazillas are naturally resourceful with rice and fish cultivation. At present, there is a road communication between these upazillas and rest of the country. But the existing road faces some problems from Debor point to Ranigonj. The study area is shown in Figure 1.

There are some instances of road pavement settlement, partial damage or complete washing out of approach road, collapse of bridges due to undermining of foundation, damage of road embankment side slope, damage of approach road embankment slope protection works and damage of culverts due to scour. Also it is needed to connect these Upazillas with national road network. Under such circumstances, it is essential to improve the Pagla-Jagannathpur-Raniganj-Aushkandi road. If this road is improved to the status of regional highway, it will be easier to transport agricultural products from Dhakshin Sunamganj and Jagannathpur to other parts of the country, and people of this region will get transport facilities throughout the year.

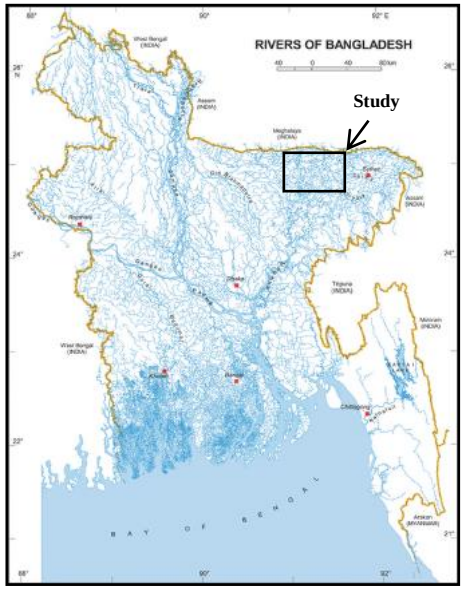

Figure 1. Location of study area

It will connect Jagannathpur Upazilla headquarter to the district town and rest of the country. It will also shorten the distance between capital city of Dhaka and Sunamganj district by 51km. Schools, madrasas and small cottage industries will be benefited. As a result, socio-economic condition of the people will

improve. The main purpose of this project is to establish a direct and shorter roadway connection for Sunamganj with Dhaka, port city Chittagong and Eastern part of Bangladesh. This road will reduce traffic congestion in Sylhet city corporation area and improve overall land transport facilities of Sunamganj district along with traffic safety (RHD, Request for Proposal 2014). Road embankment along the haors creates obstruction to natural flow of water and is subjected to wave actions (BUET 2008). Also bridges often constrict the flow area under the bridge and the bridge piers enhance this constriction resulting in increase of speed, acceleration of scouring process, backwatering of stage etc. Mathematical modelling is state-of-the-art technology applicable in planning, design and improvement stages of the road embankment and road structures to ensure safe and economic design of the same. The technology can also be applied for devising suitable mitigation measures to counteract any negative impact of the road project.

The MIKE 21C tool is suited for river and floodplain hydro-morphological studies and includes modules to describe flow hydrodynamics, sediment transport, alluvial resistance, scour and deposition, bank erosion and planform changes. The modules can run interactively, incorporating feedback from variations in the alluvial resistance, bed topography and bankline geometry to the flow hydro-dynamics and sediment transport (DHI 2006).

Methodology

A field survey campaign has been carried out to collect field data necessary for model development and hydro-morphological study. Field survey includes road alignment survey from Debor Point to Raniganj, road structure survey, bathymetric survey, velocity measurement and soil sample collection. Data collected through field survey are road levels, road cross-sections, location and dimension of existing road embankment slope protection works, location and dimension of existing road structures, pier diameter, bed level near the structure, river and khal cross-sections, velocity through the road structure, soil sample from the road etc.

The pre-monsoon 2014 bathymetric survey data and DEM data have been used to form the initial bathymetry of the model. A two-dimensional model has been developed which covers around 29 km stretch of the road from Debor Point to Raniganj. A curvilinear computational grid has been generated to study different aspects of the road project within the stipulated time. The grid for hydrodynamic simulation of the model has a dimension of 100×1600. It means the length and width of the study reach are represented in the model with 100 and 1600 grid points respectively. The grid is generated incorporating an expanse of floodplain on both sides of the road.

The initial bathymetry is prepared based on the pre-monsoon 2014 bathymetric survey data collected under this study and DEM data. After completion of the bathymetric survey the data are processed. The initial bathymetry is then prepared using standard MIKE 21C bathymetry preparation module. The initial bathymetry corresponding to the generated grid is shown in Figure 2.

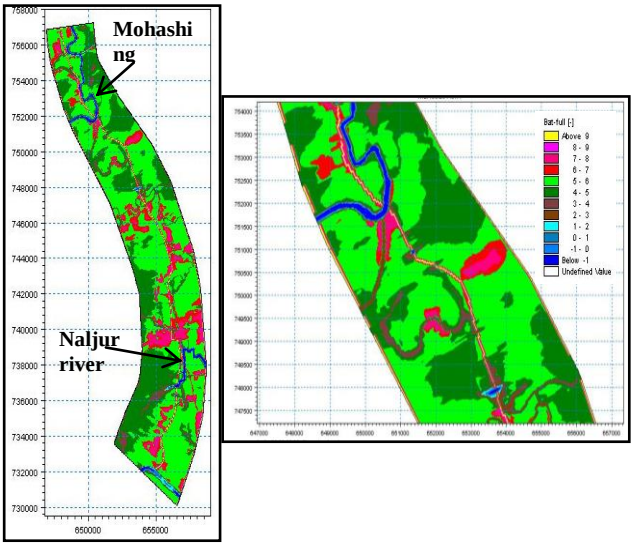

Figure 2. Initial bathymetry of the model (MIKE 21C)

There is no water level and discharge gauge station within the model domain to compare the model results with measured ones. However, it appears that the model has reproduced flow pattern in the study area for different return period discharges with reasonable accuracy.

Results and discussion

Hydraulic analysis of the road and road structures has been conducted by use of the developed two-dimensional mathematical model. Since the road and the road structures are already in place the model runs have been conducted with three different return period discharges (20 year, 50 year and 100 year) to assess the hydrodynamic response of the structures in terms of discharge and velocity through the structures, water level at and along the structures, flood depths around the structures, afflux etc. The analysis is made to assess the performance of the structures under design and extreme discharge conditions. The results of the analysis are described below:

Velocity fields

The velocity fields at and around the road and road structures for different return period discharges have been furnished in Figure 3. It is noticeable that for all return period discharges, the velocity over the floodplain is very low (< 0.2 m/s). Relatively high velocity is observed along the course of the Mohashing and the Naljur rivers. The simulated maximum velocity through the existing road structures is determined for 50 year and 100 year return period discharges (RRI 2014).

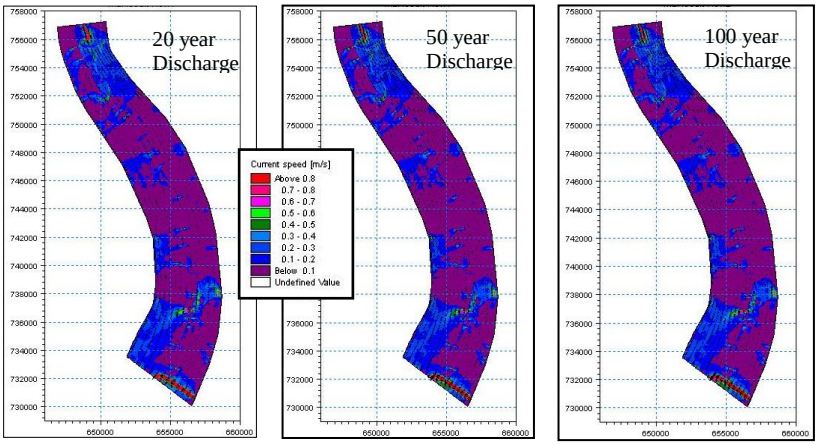

Figure 3. Velocity fields for different return period discharges at and around the Existing Pagla-Jagannathpur-Raniganj road (MIKE 21C)

The road structures should be designed for 50-year discharge. Therefore, magnitude of flow through each structure corresponding to this (50 year) discharge has been extracted from the model simulation results. It is observed that very high velocity occurs through the structures that have already experienced full or partial damage.

Water levels along the road

The two-dimensional plots of the water levels at and around the road for different return period discharges appear in Figure 4. It is evident from Figure 4 that the afflux caused by the road and road structures is not high and varies from 3cm to 7cm for different return period discharges. It is noticeable from Figure 4 that there is not much variation in the water levels along the road from Debor Point to Raniganj. There is a mild water level slope from Debor Point to Raniganj with relatively higher water level at Debor Point. In the floodplain slight local variations in the water level are noticeable. The overall water level slope in the floodplain is From North-East to South-West (RRI 2014).

Flood depths

The road runs through the low-lying and haor areas. These areas go under water during flood season. There are scattered villages and bazaars connected by unmetalled roads with the road under study. The source of inundation water is principally the overbank spillage of Kalni-Kushiyara, Surma, Mohashing and Naljur rivers. Flood depths at and around the road for different return period discharges are shown in Figure 5.

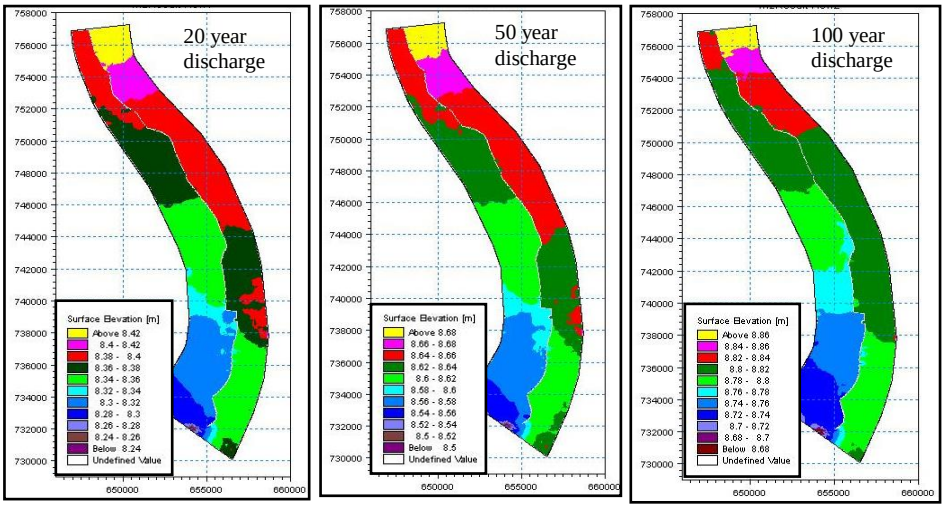

Figure 4. Simulated two-dimensional plots of water level at and around the Pagla Jagannathpur-Raniganj road for different return period discharges

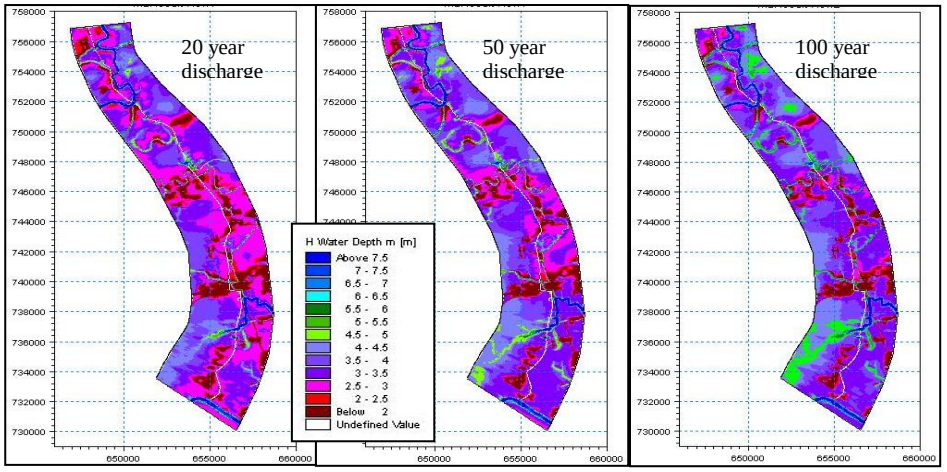

Figure 5. Simulated two-dimensional plots of water depth at and around the Pagla-Jagannathpur-Raniganj road for different return period discharges

Slope protection works

During extreme flood the low areas around the road experiences average flood depth more than 3 m with low flow velocity. Along the existing road there are a number of road structures (culverts and bridges) to allow for safe passage of floodwater. The structures have been constructed over the drainage routes that cross the road. No hydro-morphological study has been conducted to decide about hydrologic and hydraulic design parameters of these structures. As a result there is occurrence of parallel flow along the approach embankment at some structure locations. The slope of the road embankment should be protected against likely damage by parallel flow current at these locations. On the other hand, there is potential for road embankment slope damage due to wave actions at some locations. Therefore, appropriate measures should be taken against such slope damage. The vulnerable locations of the road embankment slope damage have been identified under the framework of this study. The hydrologic and hydraulic design parameters of the slope protection works have been furnished (RRI 2014). The identified locations where slope protection works will be needed are shown in Figure 6.

Figure 6. Identified locations for road embankment slope protection works (Source: Google earth 2014)

Hydrological and hydraulic design of road and road structures

For the design of road and road structures the following design data are used:

Formation level of the road	: 9.70 to 9.75 mPWD
Standard High Water Level (Markuli)	: 9.75 mPWD
Standard Low Water Level (Markuli)	: 1.60 mPWD
Velocity	: 0.5-2.50 m/s
D_{50} of silt	: 0.08 mm

For the design of slope protection works the following design data are used:

Design flood level	: 8.61to 8.66 mPWD
Velocity	: 0.8 m/s
D_{50} of silt	: 0.08 mm
Depth of flow	: 3 to 4 m
Wind speed	: 30 m/s
Fetch length	: 4 km
Wind duration	: 2 hours
Wave height	: 1.35 m
Wave period	: 3.5 sec
Wave runup	: 1.08 m

Navigational clearances

The rivers and khals in the study area do not fall under any classified navigational route by BIWTA. No minimum vertical and horizontal clearance is specified either by BIWTA or RHD. In determining appropriate navigational clearance local requirements for the passage of fishing boats, market boats, coal or stone barges etc. should be taken into account. Navigational status of different rivers and khals that crosses the road is taken by discussing the local people.

Conclusion and recommendations

The following conclusions and recommendations have been drawn based on study results.

- The existing Pagla-Jagannathpur-Raniganj-Aushkandi Road alignment except at some bridge approaches is found to be suitable route under likely hydrological and hydraulic conditions. The afflux caused by the road and road structures is not high and varies from 3 cm to 7 cm for different return period discharges.

- At some locations the existing road runs almost parallel to and very close to the rivers. The road structures at these locations may draw substantial flow during flood condition. Also there is potential for

occurrence of parallel flow along the approach embankments of these structures. Approach road slope protection measures should be undertaken there.

- The road embankment may come under wave action at some locations. The wave runup is 1.08 m. The model simulated flow velocity through the different existing structures varies from 0.5 m/s to 2.5 m/s. The highest velocity is observed at Jagannathpur regulator. The actual velocity through this regulator could be well above 3.0 m/s for flood discharges because the regulator could not be reproduced in the model to its actual dimension.

- Road embankment slope protection works should be undertaken against occurrence of parallel flow along the road embankment and wave action.

- The existing navigation clearance for the P.C girder bridge over the Mohashing river is found to be 2.45 mPWD. The observed minimum bed level under the bridge is found to be about -10.42 mPWD. In this case, CC blocks/geo-bags should be kept ready for emergency dumping, if necessary.

- The approach road slope of the bridge over the Mohashing river at Jagannathpur end should be protected against parallel current and wave action. The required length of the protective measure is 200m on both sides of the road.

- A 52m long bridge with two spans may be considered at Chainage 18.176km in place of the existing culvert. The design flood level and height of the bridge are 8.63 mPWD and 9.87 mPWD respectively. The deck level of the bridge is 11.97 bmPWD. The Design scour level around the pier is suggested to be -1.0 mPWD. The bottom level of the pile foundation should be set well below this level.

- The extended part (Bailey bridges at both ends) of the P.C Girder Bridge at Vomvomi (Chainage at 7.064 km) will have to be closed by compacted earth filling. In order to safe passage of flow through the existing bridge, both sides protective works in the form of retaining wall will have to be constructed. The gaps between the existing road and abutment wall along with proposed retaining wall will have to be developed as a road embankment at both sides by compacted earth filling. Since the velocity has been increased 1.3 times with permanent bridge opening that may develop more scour at and around the bridge sub-structure. To overcome this situation the existing bed level (-7.04

mPWD) will have to be filled by dredged soil up to G.L. Then the protective works should be placed according to the design furnished.

- The existing length of the bridge over the Naljur river (from chainage 23.135 km to chainage 23.264 km) is shorter than the effective width of waterway according to the Lacey's formula (177 m). 20 year and 50 year return period flood level at the bridge location is 8.35 mPWD and 8.61 mPWD respectively. The observed minimum bed level along the centre line of the bridge is found to be -7.7 mPWD. The required height of the bridge is 10.35 mPWD. The deck level at the centre of the bridge is 12.45 mPWD.

- Protective measures should be undertaken along the east side slope of the approach embankments on both sides of the bridge over the Naljur river (from chainage 23.135 km to chainage 23.264 km). The needed extent of protective measures is 90m and 50m towards Jaganathpur and Raniganj respectively extending from the bridge abutments.

- The likely magnitude of discharge through the bridges and culverts in the south of the bridge over the Naljur river under design flood condition is substantially high compared to the existing opening of these structures. The bridges are also narrow in width. These structures should be replaced by PC girder bridges with adequate opening to accommodate for the likely design flood discharge.

- The existing damaged approach culvert at Chainage 18+176 km may be replaced by PC girder bridges. New PC girder bridges may be considered at the structure locations where approach is damaged fully or partially due to flood. The suggested hydrologic and hydraulic design parameters may be considered for construction of these bridges.

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