Tech. J. River Res. Inst. 13(1): 76-86, 2016 (October), ISSN: 1606-9277

NUMERICAL MODELLING USING MIKE21C FOR THE PROPOSED BRIDGE ON KALNI RIVER UNDER HABIGANJ ROAD DIVISION

A.K.M. Ashrafuzzaman[1], Md. Abul Ala Moududi[1], Swapan Kumar Das[2], Mohammad Mehedi Hasan[3], Md. Alauddin Hossain[1] and Pintu Kanungoe[4]

Abstract

River Research Institute (RRI) has conducted a mathematical model study to determine the suitable location of proposed bridge along with alignment of approach road and to provide the hydraulic and hydrological design parameters of the same including river training works. The study is based on the historical hydrological data, time series satellite images, recent bathymetry, bankline and sediment data. The collected data have been analysed using appropriate methods to derive information about present physical conditions of the river, past and future trends in morphological development and necessary inputs for development of MIKE 21C model. The model is developed covering a river stretch of 15km including the likely bridge location. The study results show that the proposed bridge over the Kalni river should be located in the straight reach at Sullah Ghat. The length of the bridge is 340 m. The left end and right end co-ordinate of the bridge is 627988E, 718823.5N and 627827E, 719123N respectively. Six spans of the bridge may be considered with two spans of equal length (60 m) in the middle. The rest four spans (two in the left side and two in the right side) are of 55m each. The design discharge for the bridge and bridge substructure is 3468 m^3/s and 3667 m^3/s respectively. The design water level for the bridge and bridge substructure is 8.89 mPWD and 9.08 mPWD respectively. The wave runup is 1.41 m considering road embankment slope of 1:2. The bridge deck level at centreline of the bridge is 23.75 mPWD. The design scour level at the abutment is -4.13 mPWD. The bottom level of the bridge girder should be kept at 20.75 mPWD. The bottom level of pile foundation for the abutment should be placed well below this level. The design scour level for the bridge pier is suggested to be -14.35 mPWD. The bottom level of the pile foundation should be set well below this level. The thalweg profile in the vicinity of the proposed bridge shows the potential for large bed degradation at the meander bends in the upstream of the bridge location. The minimum bed level at the bridge location is -3.24 mPWD whereas the minimum bed level at these bend locations is as low as -24.57 mPWD. The approach road formation level at access road is 10.3 mPWD.

[1]Principal Scientific Officer, RRI, Faridpur-7800, Bangladesh, e-mail: ashrafuzzaman_89@ymail.com
[2]Director (In-charge), Geotechnical Research Directorate, RRI, Faridpur-7800, Bangladesh
[3]Scientific Officer, RRI, Faridpur-7800, Bangladesh
[4]Chief Scientific Officer, RRI, Faridpur-7800, Bangladesh

Introduction

Sunamganj and Habiganj districts are located in the North-East region of Bangladesh. Ajmiriganj and Sulla are two remote upazillas under Habiganj and Sunamganj districts respectively that are situated in haor area. Sunamganj-Madanpur-Derai and Habiganj-Baniachong are already constructed part of Roads and Highways Department (RHD) road network. Madanpur-Derai-Sullah (Derai-Sullah part) road and Baniachong-Ajmiriganj road are two ongoing Annual Development Programme (ADP) projects of Government of Bangladesh (GoB).

Now, the complementary road communication between Sullah and Ajmiriganj is imperative in order to have a fast and easy road communication with the capital city Dhaka and other parts of the country via Habiganj for the people of Sullah as well as Sunamganj district. In order to connect Sunamganj and Habiganj districts and to enhance the communication facilities, Road Division, RHD, Habiganj has planned and taken initiatives to construct a roadway bridge over the Kalni river.

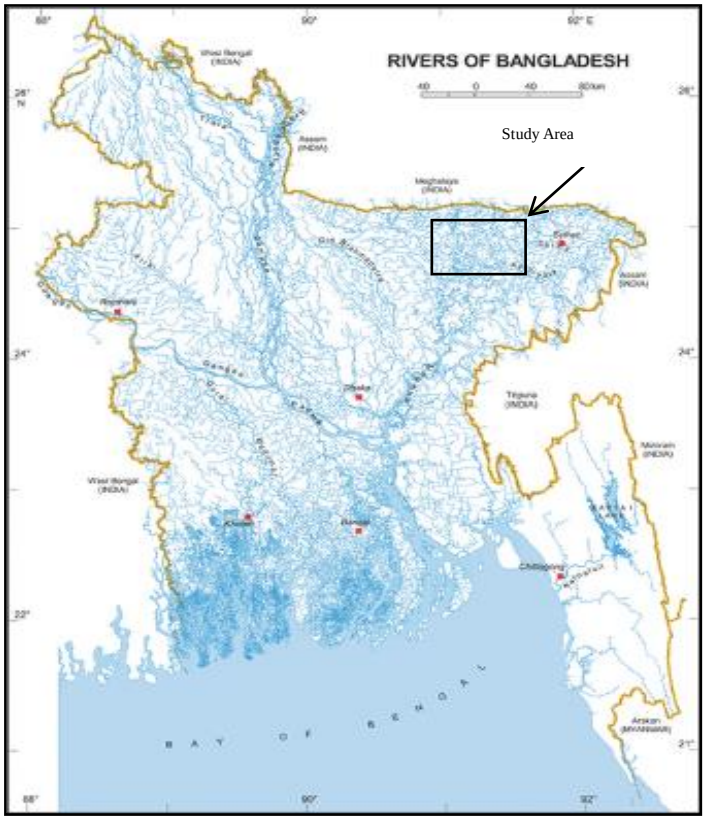

Figure 1. Location of study area (Source: Google images 2015)

The project area (Figure 1) is hydrologically affected by the influence of the Meghalaya Foothills and Shillong Plateau on the north of India. The proposed bridge site is located in the Kalni river catchments having overland flow, interflow and base flow of varying degrees. As such, there are several reasons why it is important to consider likely hydrological, hydraulic and morphological impacts when planning to construct a bridge or any water resources development intervention in this area or over a river.

Rivers of this region are very dynamic in nature and are changing and evolving. Periodic human interference from past to present can initiate major adjustments to the river system. Failure to recognize these ongoing changes may lead to implementation of inappropriate projects that operate poorly in future.

Moreover, river dynamics and channel changes or shifting can impose a degree of uncertainty in planning future water resources developments. In view of the above mentioned facts a number of hydrological and morphological aspects related to the proposed bridge seem to be crucial for investigation. In this connection, a comprehensive study is needed using mathematical modelling technology to address all the relevant aspects of the bridge project and suggest appropriate measures to be taken to ensure its overall sustainability. On the other hand, since the proposed road and bridge will be constructed in a low lying area that goes regularly under water the project may change the existing hydrologic regime substantially if not properly planned and designed (RHD, Request for Proposal 2012).

Methodology

In order to conduct the study necessary hydrological data of the Kalni river, satellite image of the study area and other relevant information have been collected. A field survey campaign has been conducted to collect the recent bathymetric data of the river, nearby road alignment data etc. Sub-soil investigations have also been conducted at four locations at and around the proposed bridge. In order to conduct EIA and EMP study environmental data from the project area and relevant agencies have been collected.

The collected data have been processed and analysed to the extent of gaining understanding of the present physical conditions of the river at the bridge location and environmental conditions in the project area and also deriving information to use as model inputs. A two-dimensional model covering an extent of about 15 km of the Kalni river has been developed using modelling software MIKE 21C. The initial bathymetry of the model is formed by use of the recently surveyed bathymetric data. The initial bathymetry of the model is shown in Figure 2.

Necessary hydrological, hydrographic and sediment data have been collected through a field survey campaign. Historical hydrological data of the rivers concerned and satellite images of the study area have been collected from Water Resources Planning Organization (WARPO), Dhaka and Centre for Environmental and Geographic Information Services (CEGIS), Dhaka respectively. The collected data have been processed and analysed to the extent of deriving necessary inputs for the MIKE 21C model that has been developed for hydraulic analysis of bridge and approach road and also for obtaining other information relevant to the bridge project. The model has been calibrated for monsoon 2005 hydrological data. The calibrated model is then applied for different scenarios simulations in base and with bridge conditions.

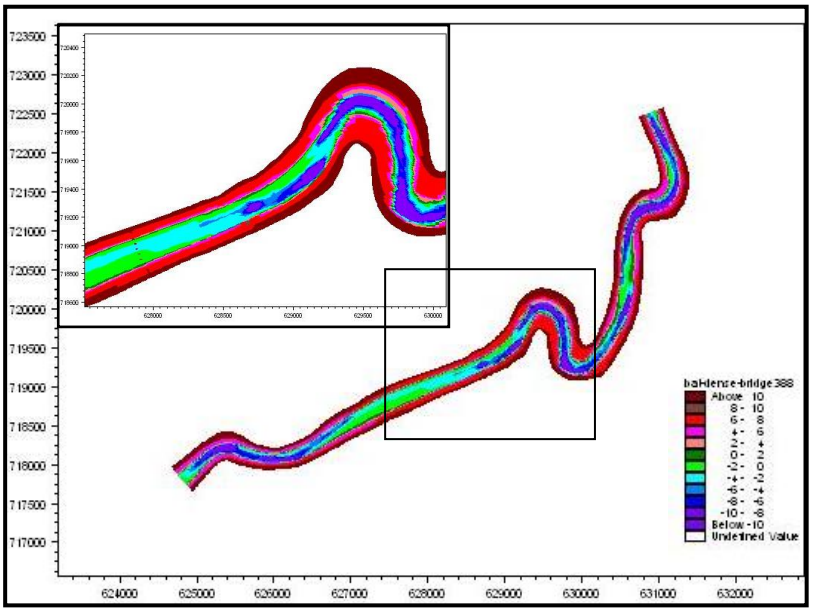

Figure 2. Initial bathymetry of the model (MIKE 21C)

Results and discussion

Suitable reach for bridge location

It appears from the analysis of collected hydrological and hydrometric data of the river and also satellite image of the study area that the straight reach near the Pirijpur Ghat and Sullah Ghat is almost stable in terms of lateral migration and bed degradation. The favourable river stretch for siting of the bridge is shown in Figure 3. Four alternative bridge locations have been selected in this reach for hydrodynamic and morphological assessments to decide about suitable bridge location. The bend in the downstream of the straight reach is still mild and has

potential for future development. On the other hand, two consecutive meander bends in the immediate upstream of the Pirijpur Ghat are sharp and increasing in meander ratio slowly due to resistance offered by the cohesive bank materials. The river at these bend locations is unstable and yet to achieve its dynamic equilibrium. Since the disturbances caused by the river instabilities at the upstream bend locations may travel downstream, the bridge location should be safely away from these bends.

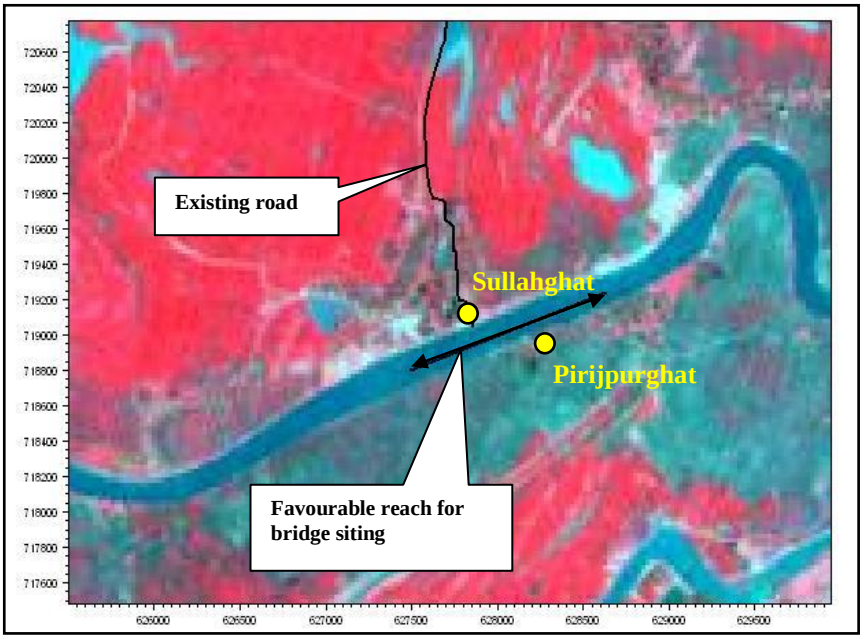

Figure 3. Favourable river stretch for siting of the bridge (Source: Satellite image 2014, CEGIS)

Proposed bridge alignment and velocity field

The hydrodynamic simulations of different return period discharges show similar velocity distribution pattern along the cross-sections with maximum velocity being almost in the middle of the river. After taking into account different relevant issues, the bridge location is selected at Sullah Ghat. The alignment of the bridge is shown in Figure 4. The design discharge for the bridge has been estimated as 3468 m^3/s from flood frequency analysis and based on the design discharge and other relevant issues in view; appropriate length (340 m) for the bridge has been determined. The model simulations with different return period discharges have been conducted with bridge in place to see the effects of bridge constriction on existing hydraulics at and around the bridge. It is found from the simulation results that the bridge causes local increase in velocity around the bridge piers but has negligible effects on the water level upstream compared to the base condition. It means that with the

selected bridge opening the free passage of flood flow will not be hampered. The velocity field in the vicinity of the bridge for 100-year discharge and with bridge in place is shown in Figure 5. The bridge is introduced in the model as accurately as possible as per decision as to number of spans, pier width etc.

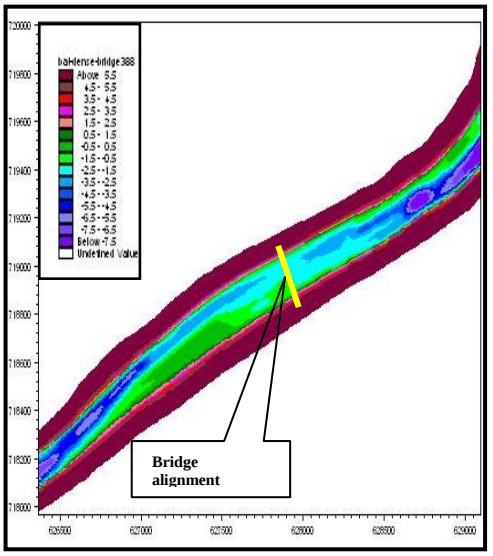

Figure 4. Proposed alignment of the bridge over the Kalni river at SullahGhat (MIKE 21C)

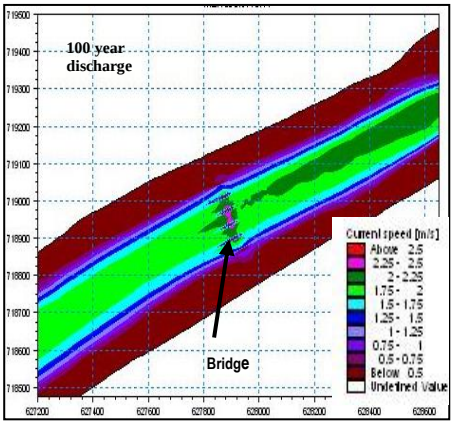

Figure 5. Velocity field at and around the bridge for 100 year discharge (MIKE 21C)

Hydrological and hydraulic design of bridge and approach road

The hydrological and hydraulic design parameters of the bridge and approach road obtained from the study are given below:

Design discharge for bridge substructure (100 yr. return period)	: 3667 m^3/s
Discharge for bridge and approach road (50 yr. return period)	: 3468 m^3/s
Design flood level for bridge substructure (100 yr. return period)	: 9.08 mPWD
Design flood level for bridge (50 yr. return period)	: 8.89 mPWD
Standard Low Water Level	: 1.11 mPWD
Standard High Water Level	: 8.55 mPWD
D_{50} of silt	: 0.08 mm
Significant wave height	: 1.25 m
Wave period	: 4s
Wave runup	: 1.41 m
Formation level of approach road (Sub grade level)	: 10.3 mPWD
Bottom level of the bridge girder	: 20.75 mPWD
Deck level at centreline of the bridge	: 23.75 mPWD
Design scour level for abutment	: -4.13 mPWD
Design scour level for pier	: -14.35 mPWD

Velocity information at and in the vicinity of the Bridge

Velocity information at and in the vicinity of the bridge location in base and with bridge conditions is shown respectively in Table 1 and Table 2 below.

Table 1. Velocity information at bridge location in base condition

Return Period (year)	Discharge (m^3/s)	Maximum velocity (m/s)	Cross-sectional mean velocity (m/s)
25	3259	1.87	1.17
50	3468	1.95	1.22
100	3667	2.05	1.23

Table 2. Velocity information with bridge in place and for 100-year discharge

Location	Maximum velocity (m/s)	Near bank velocity (m/s)
Along left bank in the immediate upstream and downstream of the bridge	-	1.2 to 1.5
Near left abutment	0.80	-
Near right abutment	0.50	-
Along right bank in the immediate upstream and downstream of the bridge	-	1.1 to 1.5
At the second pier from the left	2.20	-
At the third pier from the left	2.40	-
At the fourth pier from the left	2.44	-

Bridge height and span arrangements

According to Bangladesh Inland Water Transport Authority (BIWTA) navigational route classification the proposed bridge area falls under Class II navigational routes (Zakiganj-Fenchuganj-Ajmiriganj-Dilalpur transit route). It means minimum vertical clearance should be 12.20 m with reference to Standard High Water Level (SHWL). The SHWL is found to be 8.55 mPWD. The bottom level of the bridge girder in this case is the summation of Standard High Water Level and minimum vertical clearance as specified by BIWTA. The bottom level of girder is thus 20.75 mPWD. The minimum horizontal clearance for Class II navigation route is 76.22 m. The selected bridge length is 340 m. It can be seen that the total bridge length is divided into 6 (six) spans with two

spans of equal length (60 m) in the middle. The rest four spans (two in the left side and two in the right side) are of 55 m each.

Need for river training works

At the proposed bridge location and immediately upstream and downstream of it, the river is flowing almost in straight alignment. However, upstream of this straight reach there are two consecutive sharp bends. These bends do migrate slowly due to resistance offered by the cohesive bank materials against bank erosion. From local people's experience and interview and mathematical model run it seems that the bank erosion in this reach is very negligible. The minimum bed level at the proposed bridge location is -3.24 mPWD. However, large bed degradation is observed at the upstream bend locations. The minimum recorded bed level there is as low as -24.57 mPWD. As per subsoil investigation report the composition of left bank soil is silty clay and clayey silt and the bank is very less erodible. So, it may be opined that since the banks of the Kalni river at the bridge site is stable, there may not be any bank protection works and guide bund required at present to guide the flow.

Alignment and road structures along the link road

The appropriate alignment of the link road connecting the proposed bridge over the Kalni river with existing Baniachong-Ajmiriganj road has been determined considering relevant issues.

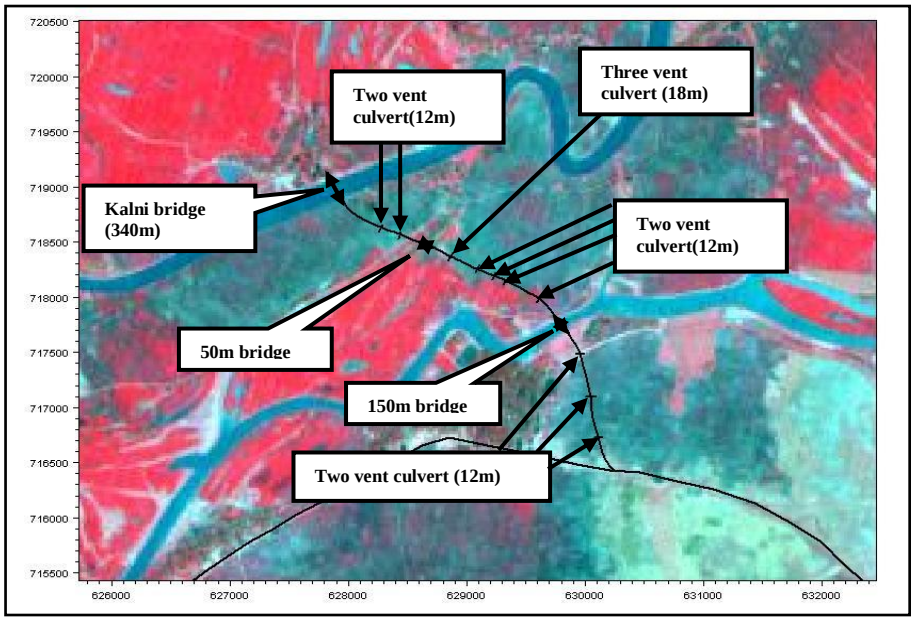

Figure 6. Positions of bridges and culverts along the link road (Source: Satellite image, 2014 CEGIS)

The link road lies on an active floodplain of the Kalni river. In order to ensure safe passage of floodwater during an extreme event, road structures at different positions along this road have been proposed. The type, position and length of the road structures are shown in Figure 6. It can be seen from Figure 6 that one 150 m long bridge, one 50 m long bridge, nine two vent (12 m) culverts and one three vent (18 m) culvert will be needed at different locations along the link road (access road).

Approach road slope protection works

The abutments and slopes of the approach embankments should be protected from erosion caused by parallel current and wave action. The approach road is 320 m long.

Conclusions

The following conclusions have been drawn based on study results:

- The proposed bridge over the Kalni river should be located in the straight reach at Sullahghat.
- In the study reach the river flows through Surma-Kushiyara floodplain and Meghna estuarine floodplain physiographic units. The soils of these regions consist mainly of loam and clay and thereby, are resistant to bank erosion. Bank erosion does occur there but at a slow pace.
- Analysis of satellite images and recent cross-section data and model results show that there is no lateral stability problem at the proposed bridge location. There are defined banks, well grown trees and human settlements on both sides of the river at the proposed bridge location. It is unlikely that the bridge could be outflanked during its design life.
- The outer bank of the mild bend downstream of the proposed bridge location may develop further slowly.
- The thalweg profile in the vicinity of the proposed bridge shows the potential for large bed degradation at the meander bends in the upstream of the bridge location. The minimum bed level at the bridge location is -3.24 mPWD whereas the minimum bed levels at these bend locations is as low as -24.57 mPWD.

- Due to unique planform of the meander bends in the immediate upstream of bridge, complex flow occurs there and the disturbance travels downstream of the bend. The river is yet to reach its dynamic equilibrium at these bends locations.

- The length of the bridge is 340m. Left end co-ordinate of the bridge is 627988E, 718823.5N and right end co-ordinates of the same is 627827E, 719123N.

- The design discharge for the bridge and bridge substructure is 3468 m^3/s and 3667 m^3/s respectively. The design water level for the bridge and bridge substructure is 8.89 mPWD and 9.08 mPWD respectively.

- The standard high water level is 8.55 mPWD. The wave runup is 1.41m considering road embankment slope of 1:2. The approach road formation level at access road is 10.3 mPWD. The bottom level of the bridge girder should be kept at 20.75 mPWD. The bridge deck level at centreline of the bridge is 23.75 mPWD.

- Six spans of the bridge may be considered with two spans of equal length (60 m) in the middle. The rest four spans (two in the left side and two in the right side) are of 55 m each;

- The design scour level at the abutment is -4.13 mPWD. The bottom level of pile foundation for the abutment should be placed well below this level. The design scour level for the bridge pier is suggested to be -14.35 mPWD. The bottom level of the pile foundation should be set well below this level.

- The meander bend upstream of the proposed bridge may undergo both lateral and down valley migration at a slow pace and it may influence the flow pattern in the downstream straight reach. The evolution of the outer banks at the consecutive sharp bends in the immediate upstream of the straight reach should be monitored closely.

- There is no immediate threat of lateral bank migration at the proposed bridge location. The abutments and slopes of the approach embankment should be protected against current and wave action. The length of the left approach embankment is 320 m.

- The suitable alignment of the link road connecting the bridge and the existing Baniachong-Ajmiriganj road has been furnished. The length of this link road is 3650 m. Total volume of earthwork for approach road on both sides of the bridge is 106700 m^3.

- There should be road structures along the link road to allow for smooth drainage during flood season. In order to allow for safe passage of flood water during an extreme event (1 in 100 year) one 150 m long bridge, one 50m long bridge, nine two vent (12 m) culverts and one three vent (18 m) culvert will be needed at suggested positions.

References

BUET and IWM 2008. Manual on Hydrologic and Hydraulic Design of Bridges. Jointly Prepared by Bangladesh University of Engineering & Technology (BUET) and Institute of Water Modeling, Mohakhali, Dhaka, Bangladesh.

BWDB 1995. Standard Design Criteria, Office of the Chief Engineer, Design, Bangladesh Water Development Board (BWDB), Ministry of Water Resources, Government of the Peoples Republic of Bangladesh, Dhaka.

DHI Water and Environment 2006. MIKE 21C, River Hydrodynamics and Morphology, User Guide, DHI-Institute of Water & Environment, Copenhegen, Denmark

Garde R.J., Subramanya K., Nambudripad K.D. 1961. Study of Scour around Spur-dikes, J. Hydrau. Divi. Proceedings of ASCE. 87(HY 6): p-23-37

RHD 2012. Request for Proposal for Hydrological and Morphological Study using mathematical model and EIA & EMP for the Bridge on Kalni River and approach road at proposed Sunamgonj-Madanpur-Derai-Sullah-Azmirigonj-Habigonj Regional Highway (Sullah-Jalshuka part) under Road Division.

RRI 2013. Hydrological and Morphological Study using mathematical model and EIA & EMP for the Bridge on Kalni River and approach road at proposed Sunamgonj-Madanpur-Derai-Sullah-Azmirigonj-Habigonj Regional Highway (Sullah-Jalshuka part) under Road Division, Inception Report.

RRI 2014. Hydrological and Morphological Study using mathematical model and EIA & EMP for the Bridge on Kalni River and approach road at proposedSunamgonj-Madanpur-Derai-Sullah-Azmirigonj-Habigonj Regional Highway (Sullah-Jalshuka part) under Road Division, Final Report.

Satellite image 2014. Center for Environmental and Geographic Information Services (CEGIS), Gulshan, Dhaka.

Van Rijn C. 1984. Sediment Transport, Part-III Bed Forms and Alluvial Roughness, ASCE J. Hydrau. Engg. 110(12): pp-1733-1754.