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Ahydro-Morphological Analysis for Selecting a Suitable Bridge Site on the Kushiara River at Golapgonj Upazila in Sylhet District

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I. Introduction

The overall purpose of the study was to conduct detailed hydro-morphological analysis for the bridge site for determining suitable bridge location. The scope of work included direct observation through field visit to the bridge site and the river reach, public opinion for bridge site selection, collection of information from the local people regarding hydro-morphological behavior of the river and their views about different bridge locations. Collection of relevant secondary data. Carrying hydrologic and morphological analysis that would help, together with local people's opinion and existing road communication system. The appropriate selection of the bridge site.

The study followed an integrated, interdisciplinary approach in investigating different aspects associated with the proposed construction of the bridge. An important component of the study was field observation and gathering information from the local people (through participatory approaches) on their perceptions of the necessity of the bridge. The hydro-morphological behavior of the river, socio-economic use of the river, and the suitable location for constructing the bridge. This field component was then integrated with an in-depth Hydrological and morphological investigation of the Kushiara River in the vicinity of the proposed bridge location.

1.1 Aim of the Study

To analyze hydro-morphologically for selecting a suitable bridge site on the Kushiara River at GolapgonjUpazila, Sylhet.

1.2 Objectives of the Study

The objectives of the study are to conduct detailed hydrological-morphological study which includes;

- To conduct detailed hydro-morphological study on the Kushiara river.
- To identify the hydro-morphological impact on socio-economic status due to proposed Road Bridge
- To determine elevation and terrain analysis of the study area.
- To analyze the hydrological aspect like flow direction,flow accumulation, basin and streams Links.

1.3Background of the Study

The background of the research study is enumerated below:

- Bangladesh is a land of rivers where number of bridges are constructed over it.
- Bangladesh is a delta with an extensive river network extending throughout the country.
- Any intervention in this very complex river system and floodplain can disturb the existing natural setting as well as social dynamics.
- River communication in the country is being disrupted due to unplanned construction of hundreds of bridges, culverts on rivers and canals.
- Due to unplanned and inappropriate site selection of road bridge, there are adverse environmental impact in the surrounding areas.
- It largely creates huge socio economic impact in entire area.
- Proper site selection and navigability are the first priority while constructing any bridge.

Figure: Picture of poor bridge side

1.4 Scope of Work

The scope of work of this study is Limited to the following:

- To make a comparative analysis between past and present water flow of the study area using historical images.
- To generate Digital Elevation Model (DEM), Contour, Land use map, Geo-morphological map using hydrological tools of ArcGIS from Google Earth Pro images.
- To prepare 3-Dimentional map of the study area from SRTM image for better analysis.
- To identify the nature of the river and water flow of river.
- To identify a suitable location of the proposed bridge.
- To determine alignment of approach road of the proposed bridge.
- In carrying out hydro-morphological and navigational study river features.
- To collect and analyze Satellite images and finding the river corridor.
- To determine formation level of approach road at proposed bridge abutment and access roads.

1.5 Approach and Methodology

1.5.1 Integrated and Interdisciplinary Approach

Bangladesh is a delta with an extensive river network extending throughout the country. Any intervention in this very complex river system and floodplain can disturb the existing natural setting as well as social dynamics. Solution to an existing problem is often multi-dimensional in nature, including technical, social, economic, environmental, institutional and often political dimensions, all of which interact with each other.

1.5.2 Methodology

An important component of the study was field observation and gathering information from the local people through participatory approaches. The key information obtained were people's perceptions of the necessity of the bridge, the hydro-morphological behavior of the river, socio-economic use of the river, and the most suitable location for constructing the bridge.

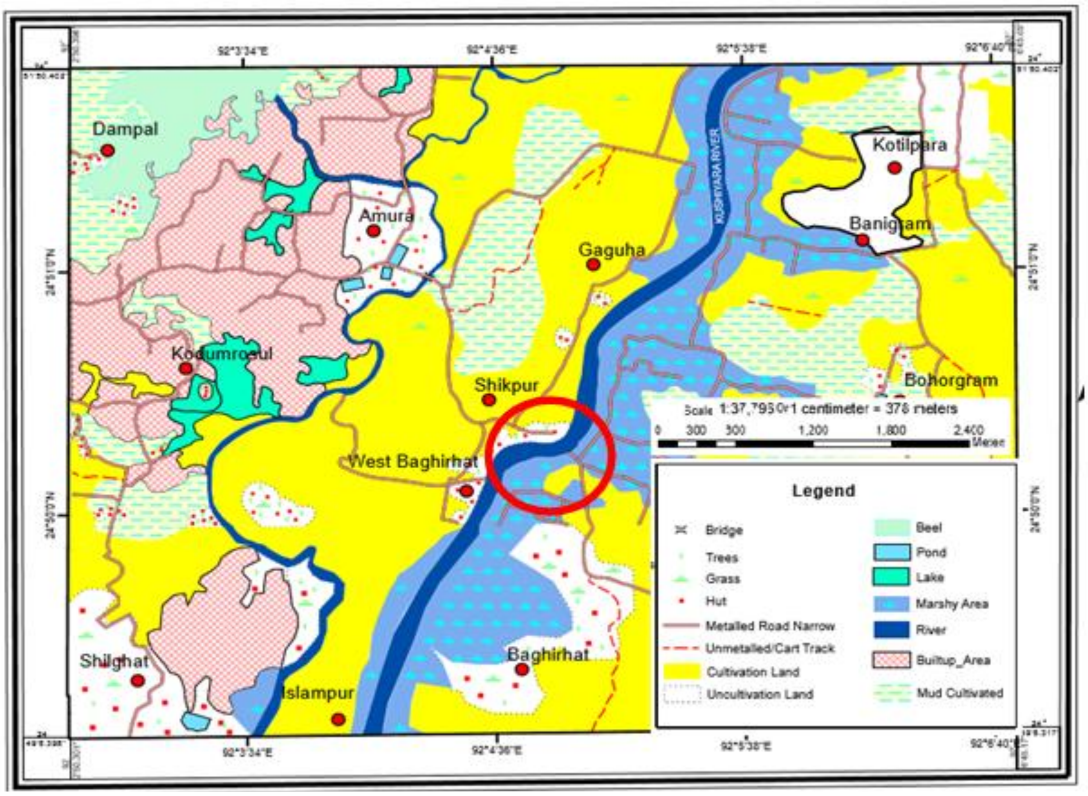


Figure: Land Use Map of the Study Area

The hydro-morphological analysis started with the estimation of design discharge and water level. The hydro-morphological model outputs were used in analyzing the stability of the river reach. Historical bank line shifting of the river was estimated using satellite images. Data collection:

- Data has been collected from Google Earth Pro.
- Data has been collected from SRTM Satellite Image.
- Historical Images has been used for analysis of River Flow channel for last 10 years.
- DEM and Contour Map has been prepared to identify the nature of terrain.

❑ Procedure:

- Hydrological tools of ArcGIS have been used to determine flow direction, flow accumulation, basin and stream links.
- Land usemap has been prepared for better analysis and determine water gap.
- Soil region and earthquake zone map have analyzed for better analysis.
- 3-Dimensional map has been created for better assessment and determining probable bridge location.

❑ Analysis and Interpretation:

- GIS based suitability analysis and map preparation has been done.
- Data interpretation has been carried out using GIS tools.
- Best probable bridge site has been selected by hydro-morphological analysis.

The location of the bridge finally selectedconsidering the findings of the hydro-rphologicalres for scour were also suggested.

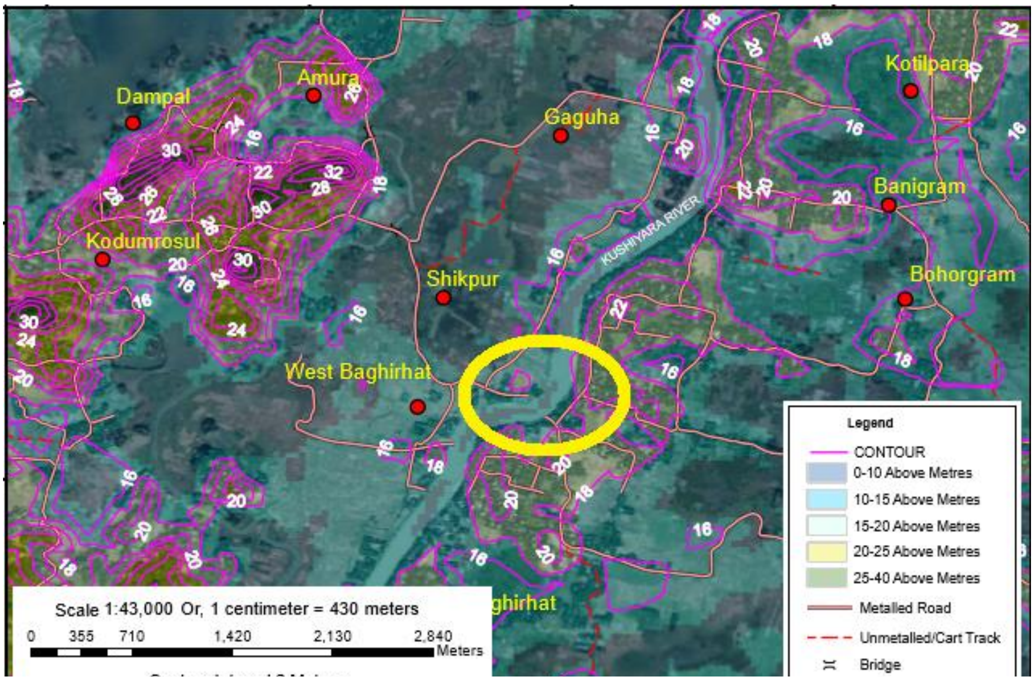


Figure: Contour map of the study area.

1.6 Structure of the Report

Chapter Two presents a description of the study area, including socio-economic setting, climate, land use characteristics, river system and morphology, hydrological characteristics and the infrastructures and communication network in the vicinity of the proposed bridge location. Chapter Three summarizes data collection procedure and types of data collected. Chapter Four provides a detailed description of hydro-morphological analysis and the finding of the analysis, including design discharge and water level, key hydraulic parameters at the bridge site, and the results for bank erosion based on satellite image analysis. Selection of the appropriate bridge location is presented in Chapter Five, with a clear depiction of the site selection process in the context of different criteria. In Chapter Six, expected outcome of the project has been discussed. Finally, Chapter Seven presents the conclusion and recommendation of the study, including a summary of the key findings and the bridge design parameter.

II. Study Area

2.1 Location

The proposed bridge, as mentioned in section 1.1, would be constructed over Kushiara River at GolapganjUpazila in the district of Sylhet. The proposed study site is located on Kushiara River at Sikhpur village and Bohorgram village at Golapganjupazila of Sylhet district which belongs to North-East region of Bangladesh. The proposed Golapganj Bridge will be 280-meter-long and will connect Bianibazar road with Golapganj-Amura road which is separated by Kushiara River. The river flow path has changed in course of time the river was flowing by the side of Bhorgram bazar but now the river is flowing through the middle of the mouza. The bridge will be constructed at Shikpurkheyaghat – Bhorgramkheyaghat. There is some cultivable land beside the river bank of ShikpurKheyaghat side but the opposite side includes some cultivable and some private land. River erosion is medium on opposite side of Shikpurkheyaghat.

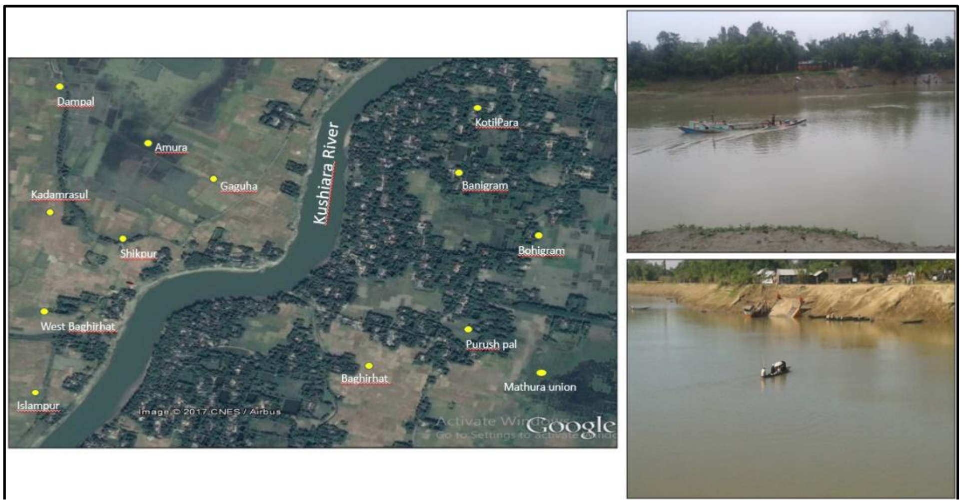
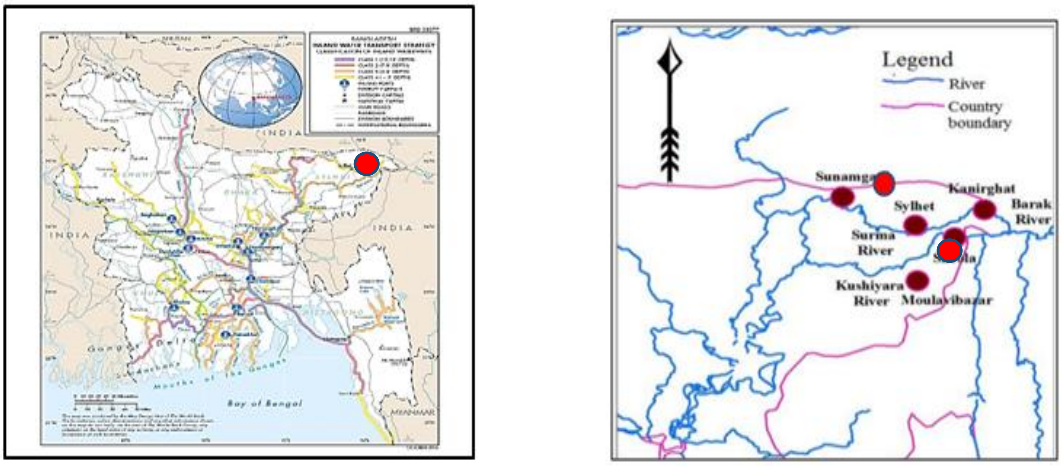


Figure: General Area pf GolapgonjUpazilla, Sylhet (Study Area)



Legend: Study Area
Figure: Location of Study Area in Bangladesh Map

2.2 Socio-Economic Setting

GolapganjUpazila (sylhet district) area 278.34 sq km, located in between 24°41' and 24°55' north latitudes and in between 91°55' and 92°06' east longitudes. It is bounded by sylhetsadar, jaintiapur and kanaighat upazilas on the north, fenchuganj and barlekha upazilas on the south, beanibazar and Barlekhaupazilas on the east, Sylhet Sadar and DAKSHIN SURMA upazilas on the west.Population Total 263953; male 132175, female 131764; Muslim 252167, Hindu 11725, Buddhist 21, and others 40. Indigenous communities such as manipuri and tripura belong to this upazila. Water bodies Main rivers: Surma, Kushiyara, Sonai; SingariBeel, BaghaBeel, FatamatiBeel. Main sources of income are Agriculture which is 34.03%. Other non-agricultural laborer is 6.03%, industry is 0.94%, commerce is 14.64%, transport and communication 4.01%, service 6.16%, construction 2.88%, religious service 0.58%, rent and remittance 18.34% and others 12.37%. Ownership of agricultural land Landowner 42.76%, landless 57.24%; agricultural landowner: urban 27.98% and rural 43.91%. Main crops are Paddy, chilli, pumpkin, arum,' barbati.Extinct or nearly extinct crops of this area are Mustard, sesame, linseed.Main fruits Jackfruit, mango, litchi, banana, latkon, guava, lemon, shaddock, betel nut, coconut. Fisheries, dairies and poultries: Dairy 40, poultry 70.Communication facilities Pucca road 300 km, semi-pucca road 200 km, mud road 500 km; waterway 20 nautical miles. Culvert 300, bridge 84. Extinct or nearly extinct traditional transports are Palanquin, bullock cart.

Figure: Kushiara River (Gopalganj) reach under study with location of bridge

Noted manufactories LP gas plant. The number of Natural resources Gas field is 4. Cottage industries Ice cream factory, bakery. Hats and bazars are 30, fair 1, Golabganj, Dhaka Dakshin, Bhadeshwar and Mokam bazars; Chaitra Samkranti Mela is notable. Main exports Natural gas, barbati, and pumpkin, chili.All the wards and unions of the upazila are under rural electrification net-work. However, 46.20% of the dwelling households have access to electricity.Sources of drinking water Tube-well 83.01%, tap 2.03%, pond 8.43% and others 6.49%. The presence of intolerable level of arsenic has been detected 10.003% in shallow tube-well water of the upazila.

2.3 Physical Settings

The description of physical settings of the study area includes the climatic conditions, agro ecological settings, geology and soil types, hydrological system and river morphology, current status of water resources systems and existing communication network, etc.

2.3.1 Climate

There is significant rainfall in most months of the year. The short dry season has little effect on the overall climate. This location is classified as Am by Köppen and Geiger. The average annual temperature is 24.8 °C in Golapgong. The rainfall here averages 3768 mm. In the month of June the rainfall is maximum. Maximum rainfall measured is 752 mm during the month of June. Maximum temperature raises upto 28.3°C during the month of August.

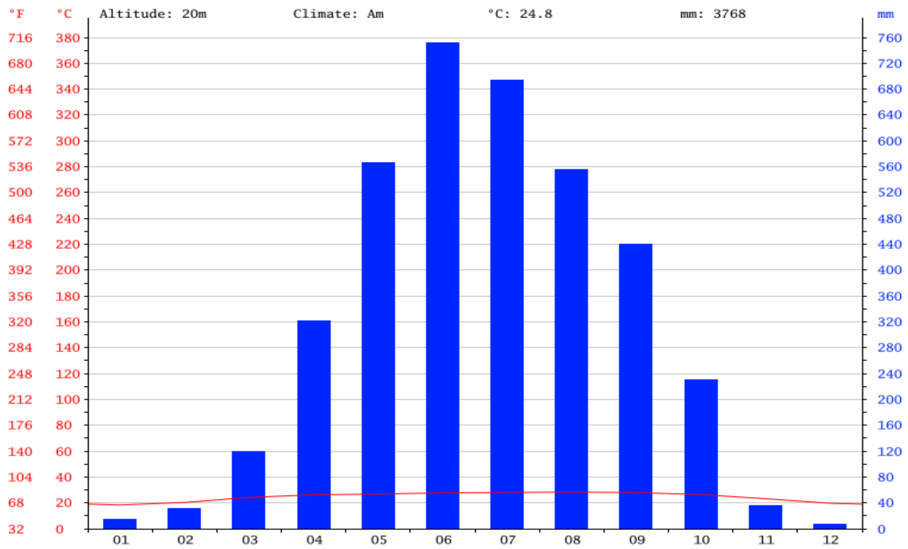


Figure: Variation of monthly temperature and rainfall in Golapganj, Golapganj (BMD station nearest to the site)

2.3.2 Agro-ecological system

The present study location at Golapganj is under rural setup. The Eastern Shurma-Kushiara floodplain and Northern-Eastern Hills occupies the relatively higher parts of the Surma-Kushiyara floodplain formed on sediments of the rivers draining into the Meghna catchment area from the hills. This area is occupied by grey, heavy silty clay loams on the ridges and clays in the basins. Organic matter content of the soil is moderate. Soil reaction ranges from strongly acidic to neutral.

2.3.3 Geology and seismology

The bridge site falls within the soil region classified as the 'Non-Calcareous and Calcareous Brown Floodplain soils. Non-calcareous Brown Floodplain soils Occur largely on the Old Himalayan Piedmont Plain, mostly on the ridges. Calcareous Brown Floodplain soils have cambic B-horizon that is predominantly oxidized, containing lime in the profiles. They comprise pale brown to olive brown, friable, loamy and clay soils occurring on the upper parts of ridges on the Ganges river floodplain and on the river bank of the Ganges tidal floodplain.On the basis of earthquake epicenters and morphotectonic characteristics. Bangladesh is divided into three seismic zones, namely zone-I, zone-II and zone-III.

2.3.4 River Network and Morphology

The Kushiyara River is a distributary river in Bangladesh and Assam, India. It forms on the India–Bangladesh border as a branch of the Barak River, when the Barak separates into the Kushiyara and Surma. The waters of the Kushiyara thus originate in the state of Nagaland in India and pick up tributaries from Manipur, Mizoram and Assam.It flows between the towns of Zakigonj, Sylhet, and Karīmganj, Assam and after the village of Panjipuri enters entirely into the BeanibazarUpazila of Bangladesh.

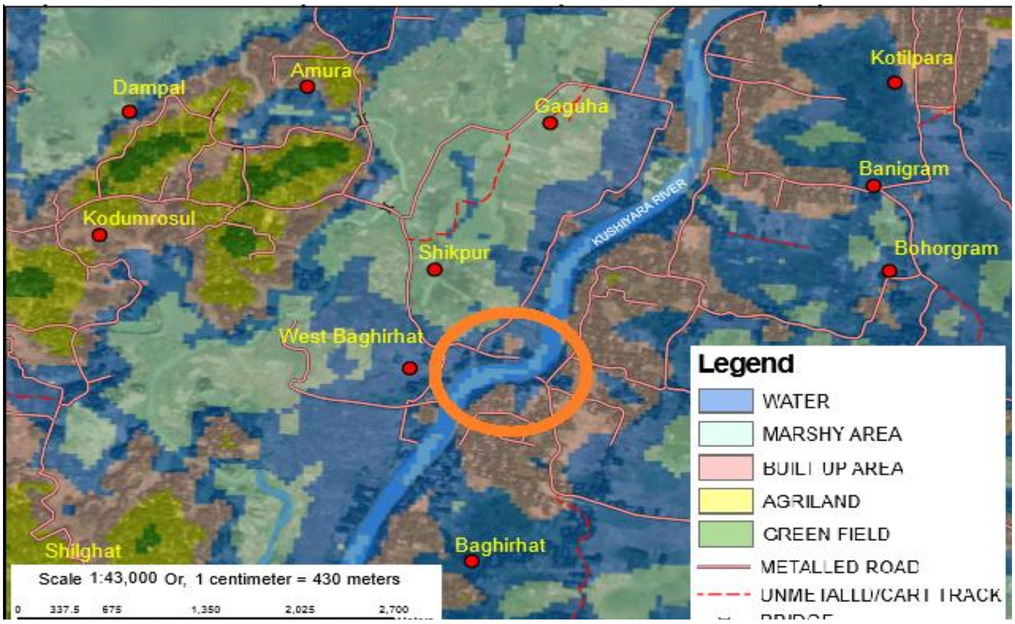


Figure: Geo-morphological Map of the Study Area

2.3.5 Hydrologic Characteristics

Water level fluctuation of a year for Golapganj. Fluctuation of water level from year to year is considerable. The graph below shows the water level hydrograph at stations for the 2016 hydrological year. Maximum water level was found in between month of August and September for both of the study area. Water level arose approximately 10.54 m.

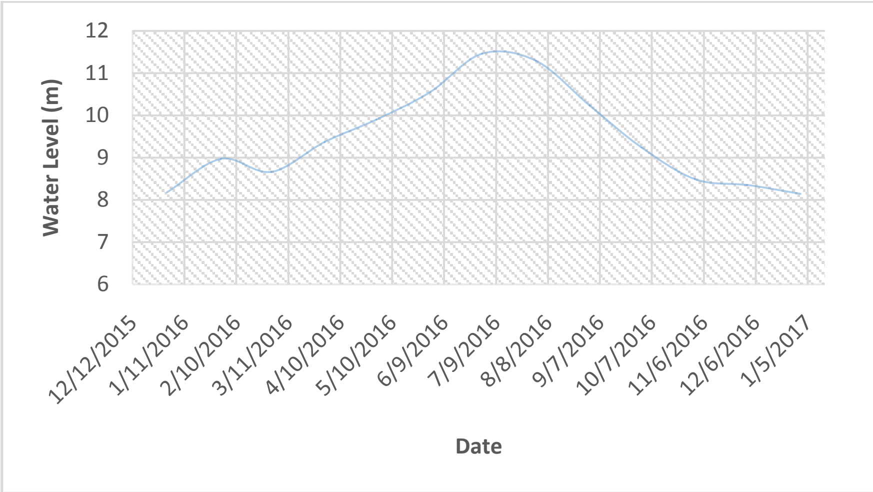


Figure: Water level hydrographs at Islampur, Sylhet (SW: 332) for 2016 hydrological year.

2.3.6 Communication Networks

The proposed Bridge site of Golapganj is in Bohorgram Mouza of 5 no.Budhbari Bazar Union and shickpur Mouza of Amura Union of GolapganjUpazila in Sylhet district. The bridge will be located at Shickpurferryghat. This ferryghat is connected with Golapganj-Sylhet Road by a bituminous road which is around 10 ft wide. This site is around 7 Km away from Golapganj town. The opposite side is connected with Bianibazar by 10 ft wide carpeted road.

2.4 Tentative Bridge Location

Before proceeding to model study, we need to identify preliminary alternative locations of the proposed bridge. Analyzing the river network of this area and based on the site visit, the I selected three alternative locations for the proposed bridge. The alternative locations are figured out in. Alternative A is located about 100 meters upstream of existing ghat,Alternative C is in between the existing road of both sides and Alternative B is about 200 meters downstream of existing Ghat.

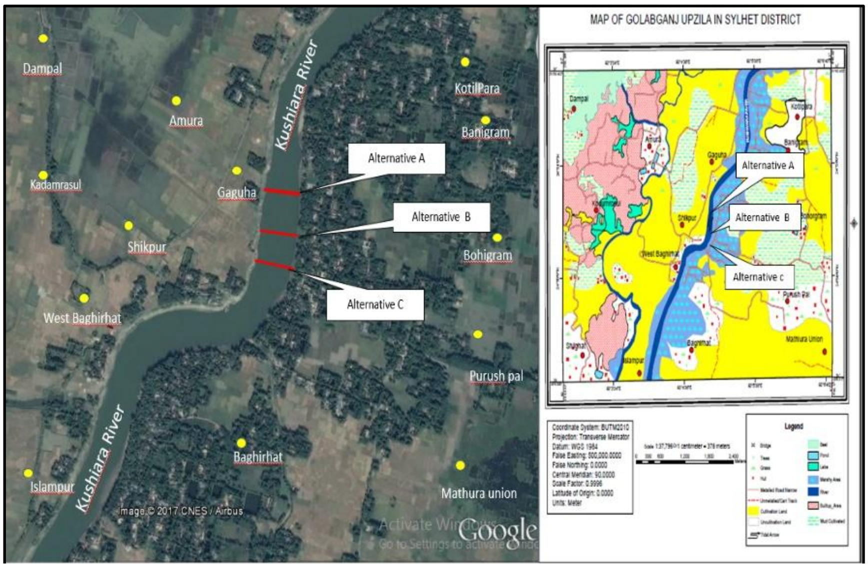


Figure: Tentative Bridge Location at Kushiara River, Golapganj

III. Data Collection

3.1 General

As discussed in Chapter One, the study followed an interdisciplinary approach. An important component of the study was field observation and gathering information from the local people through participatory approaches. The technical analysis, i.e. analysis of hydro-morphology and estimation ofdifferent parameters associated withthe proposed bridge required a wide range of data, including river bathymetry, topography, river discharge and water level, riversediment size distribution, satellite images, etc.

3.2Field Data Collection

Several visits were made to the study site by the me in the study area. Information from the local people was gathered mostly through individual interview and group discussion. The useful information that were obtained from the interviews and discussion were people's perceptions of the necessity of the bridge (what is the present status and if and how the proposed bridge will benefit them), the hydro-morphological behavior of the river (flooding patterns, bank erosion, historical shifting of river bank lines), socio-economic use of the river (e.g. Types of vessels plied in the river and types of products transported), and the suitable location for constructing the bridge.

3.3 Topographic and Bathymetric Data

Field surveys were carried out to collect up-to-date bathymetric, bank line and topographic data covering a reach of about 1.0 km. The aim of this task was to produce digital topographic and hydrographic maps which would be utilized for the hydro-morphological study. The scope of the work included establishing geographic reference and bench mark at both banks of the bridge site; preparing maps of physical features and land topography at a block of 300 m by 300 m at both banks at the bridge site, taking spot levels at 10m~20m grid interval for plain land and at smaller intervals in undulated areas, recording site information on water level, High Flood Level, type of traffic and navigation, etc., and preparing bathymetric map and cross-sectional drawings. All these topographic and bathymetric data were used to estimate cross-sections at different locations along the study reach of the KushiaraRivers. The topographic and bathymetric survey works were sub-contracted to global survey.

IV. Hydro-Morphological Analysis

4.1 General

This Chapter presents the details of the hydro-morphological analysis conducted for the study. Design discharge and water level were estimated through frequency analysis of available data and picking the particular values corresponding to the chosen return period. A number of hydraulic parameters, including flow area, flood level, hydraulic depth, and velocity were estimated for various conditions. Such information was useful for subsequent morphological analysis and for deriving bridge design parameters. Moreover, the stability of the selected river reach in terms of bank line shifting was also analyzed using satellite images.

4.2 Hydrologic Analysis

The hydrologic analysis in this section focuses on estimation of design water level and discharge. The analysis involves mostly the frequency analysis with different probability distributions functions for the selected design return period. The historical data on annual peak water level and discharge are used for the purpose. The design return period is selected based on the size and importance of the proposed bridge.

4.2.1 Estimation of design discharge and water level

The proposed bridge is located in Kushiara River. But the length of the available data is inadequate (1981 -1982, and 1996-2002) for carrying out frequency analysis. Hence the data of the next nearest gage station at Golapganj which is 13 km upstream from the proposed bridge site have been taken in to account. The gage station, maintained by Bangladesh Water Development Board (BWDB), measures both water level and discharge. It can be noted that the historical record of annual maximum water level and discharge data are broken and some of the data are missing. In such case, it is justifiable to estimate the missing data by correlation with a nearby station; otherwise it is preferable to consolidate the recorded sequences as if they formed a continuous record (Niell, 1973). The frequency analysis of the highest flood event BWDB observed time series data (1984-2017) of the nearby gauging station **(SW: 332)** on Islampur was carried out by Log Pearson Type III method. There are lot of method to predict highest flood level like Gumble, Log Pearson type III etc. As Log Pearson type III gives the best result for Bangladesh it has been chosen.

- The 1 in 50 years water level data is **12.54 m PWD** for Gauge station **(SW: 332)**.
- The 1 in 50 year's water level data is **11.46 m PWD** for bridge site as design water level.
- The hydrodynamic model generated a maximum discharge of **784.02m3/s.**
- The design discharge was estimated using hydrodynamic model as discussed in this chapter.
- Then the height flood level data obtain through analysis of the people's perception were compared with the data generated from the frequency analysis is **SW: 332**.

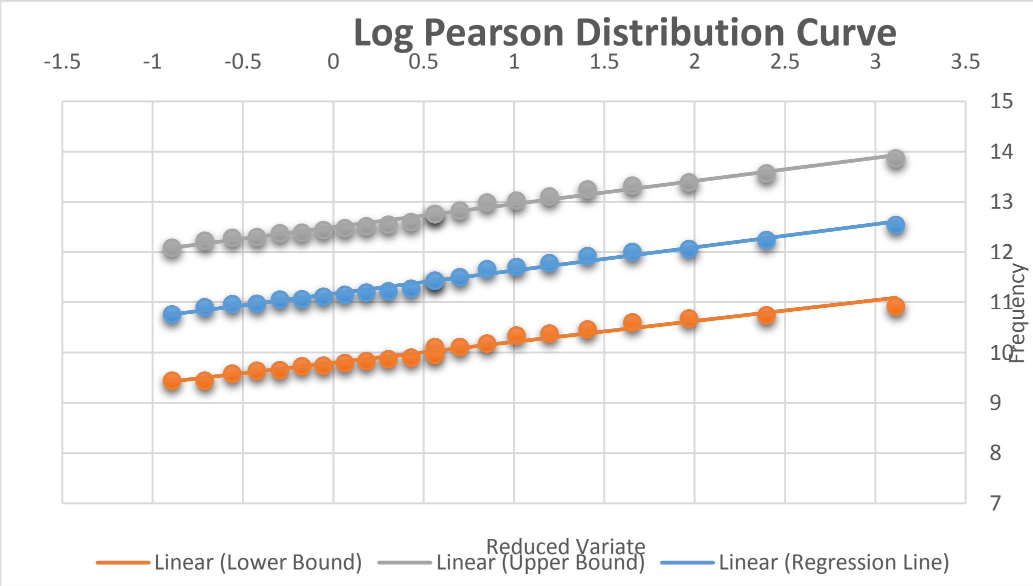


Figure: Annual Maximum Water Level with 90% Confidence Limit

Year	Annual maximum water level, m PWD	Year	Annual maximum water level, m PWD
1970	12.244	1981	11.274
1971	11.704	1982	10.974
1972	11.064	1983	11.434
1973	11.504	1984	11.664
1974	11.924	1985	11.194
1975	11.224	1986	10.764
1976	11.154	1987	12.004
1977	11.434	1988	12.544
1978	11.054	1989	10.964
1979	11.114	1990	10.904
1980	11.784	1991	12.064

Table: Annual maximum Water Level of BWDB Gauge Station SW: 332 at Islampur, Sylhet

PDF	Return period			
	2.33	20	50	100
Normal	11.574	13.754	14.354	14.764
LN2	11.544	13.894	14.564	15.024
LN3	13.634	17.204	19.634	21.924
LP3	11.984	12.544	12.544	12.554
EV1	11.304	14.074	15.154	15.964

Table: Values of Probability Distribution Function of different Return Period for BWDB Gauge Station SW: 332.

4.2.2Estimation of Standard High-Water Level

The height for the proposed bridge on the Kushiara River has been determined based on the standard high-Water Level (SHWL) at the bridge site. SHWL is known as overhead clearance datum that water level will seldom exceed. This water level has been calculated using water level exceedance curve by using the following NEDECO Formula.

SHWL=FML 5%

Where,

SHWL=Standard High-Water Level

FML= Fortnightly Mean Water Levels with 5% exceedance (20-year return period)

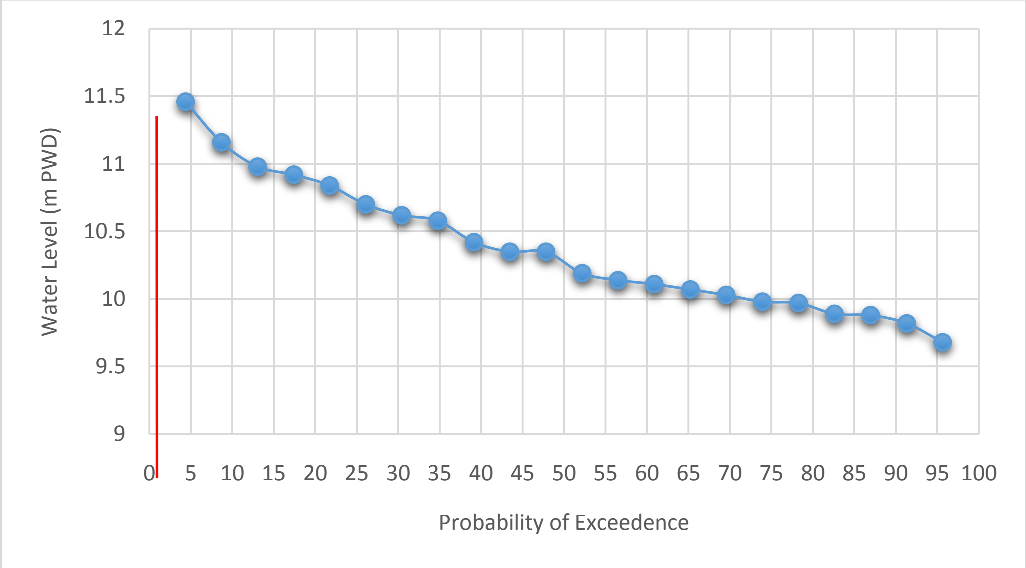


Figure: SHWL Calculation by Probability of Exceedance Curve

4.3 Impact of climate change on design water level and discharge

In the backdrop of climate change, it is important to assess whether the anticipated climate change will have any impacts on design water level and discharge. This stems from the present common understanding that the effect of climate change would be to increase the sea level rise and monsoon rainfall which in turn are likely to have an impact on design water level and discharge, respectively. The impact of climate change on design water level and discharge is discussed below.

(a) Design water level

According to the Fourth Assessment Report (AR4) of LPCC. The average rate of sea level rise was 0.18 ± 0.0005 m/yr from 1961 to 2003. The thick dark line is a three-year moving average of the instrumental records. The recent annually averaged satellite altimetry data are shown in red (Douglas, 1997).

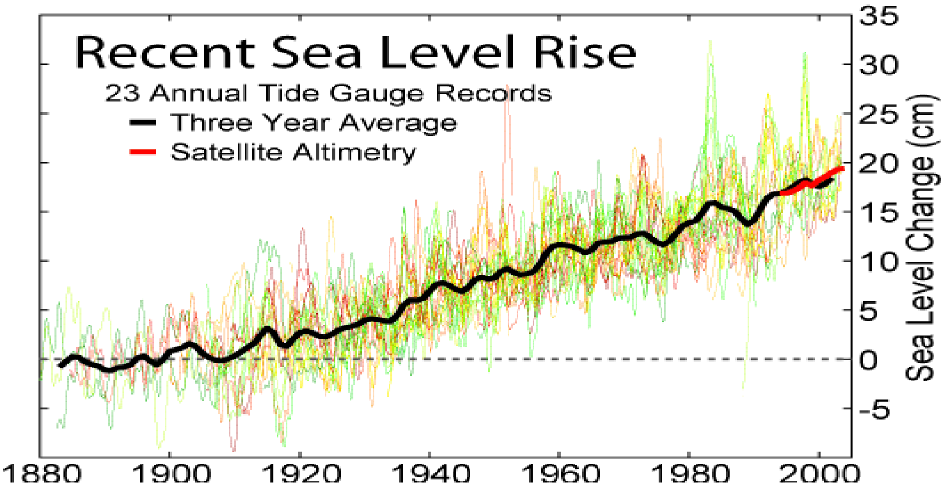


Figure: Rise of sea level based on 23 tidal gauge records and satellite altimetry

Using last 22 years historical tidal data, trends of rise of sea level are 4.0 mm/year at Hiron Point, 6.0 mm/year at Char Changa and 7.8 mm/year at Cox's Bazar. Hence the mean sea level rise over the Bangladesh coast as around 4mm/year or 0.4m/100 years.

Tidal Station	Region	Latitude (N)	Longitude(E)	Datum (m)	Trend (mm/year)
Hiron Point	Western	21°48'	89°28'	3 784	4
Char Changa	Central	22°08'	91°06'	4996	6
Cox's Bazar	Eastern	21°26'	91 °59'	2.60	7.8

Table: Trend of sea level rise in three coastal stations (MoEF, 2005)

Based on the predictions of various global climate models data, sea level has been projected for different climate change emission scenarios known as SRES scenarios. According to AR4 report, sea level is projected to rise between the present (1980-1999) and the end of this century (2090-2099) under the SRES B1 scenario by 0.18 to 0.38 m, B2 by 0.20 to 0.54 m, A1B by 0.21 to 0.48 m, A1T by 0.20 to 0.45 m, A2 by 0.23 to 0.51 m, and A1F1 by 0.26 to 0.59 m. During 2090 to 2099 under A1B, the central estimate of the rate of rise is 0.38 m/yr. For an average model, the scenario spread in sea level rise is only 0.002m by the middle of the century, and by the end of the century it is 0.15m.

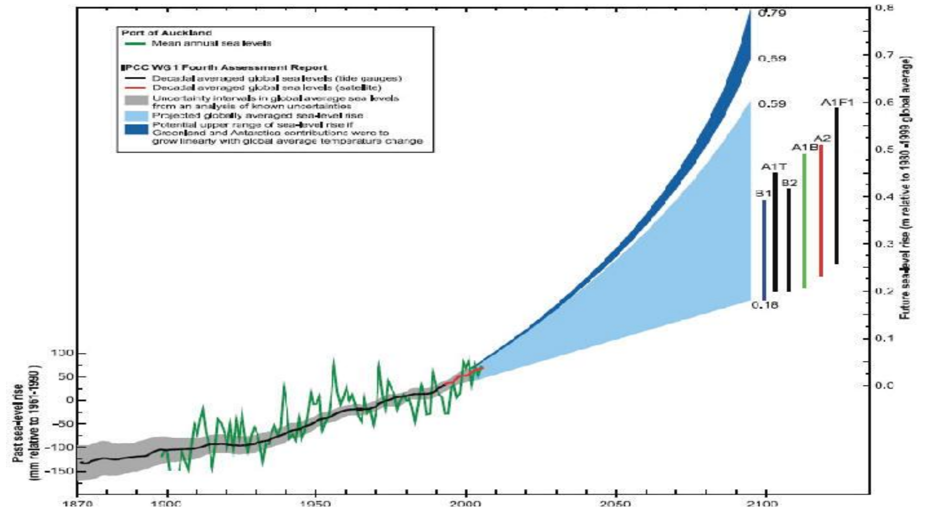


Figure: Predicted Sea Level rise (IPCC, 2001)

According to the IPCC, mean rise of sea level based on the SRES AIB scenarios will be 0.35m (range 0.2lm - 0.48m) at 2090-2099 relative to baseline years 1980-1999. Hence, mean change of seal level in the next 20 years will be 0.007m. Given the uncertainties in the projection of the sea level rise and the fact that the proposed bridge location is far away from the coast line, the effect of sea level rise due to climate change on design water level is not considered in subsequent analysis.

4.4 Hydraulic Parameters of Bridge Location

A widely used one-dimensional hydraulic model HEC-RAS, developed by U.S. Army Corps of Engineers (2005), was used to derive a number of hydraulic parameters at the bridge location for without and with bridge conditions.The HEC-RAS system can be used for both steady flow water surface profile computation and unsteady flow simulation. The system can handle a full network of channels, a dendritic system, or a single river reach. The effects of various obstructions such as bridges, culverts, weirs, embankments and structures in the flood plain may be considered in the computations. For steady flow analysis, the solution of the one-dimensional energy equation by standard step method (Sturm, 2001) is used as the basic computational procedure. This is an iterative procedure using secant method of solution (Ortega and Poole, 1981). The flow in natural and Man-made channels is estimated by the use of the one-dimensional Manning Equation. Energy losses are evaluated by friction and contraction/expansion (coefficient multiplied by the change in velocity head). Where the water surface profile is rapidly varied, the momentum equation is utilized. The HEC-RAS steady flow module has options to run either with upstream or downstream boundary conditions depending on the flow regime (US Army Corps of Engineers, 2005). For sub-critical flow the downstream boundary condition in terms of any of (1) water surface elevations, (2) critical depth, (3) normal depth, and (4) rating curve is to be defined. For gradually varied unsteady flow simulation, the HEC-RAS solves the complete hydrodynamic mass conservation and momentum conservation equations (popularly known as the St Venant Equations) with an implicit finite difference method generating a system of linearized algebraic equations. The solution algorithm uses the Preissmann type scheme (Cunge et al., 1980). The options for hydraulic calculations at cross-sections, bridges, culverts and other hydraulic structures that were developed for the steady flow component are also incorporated into the unsteady flow module.

4.5.1 Model set-up

In the present study for computation of design hydraulic parameters, the HEC-RAS with option for a steady flow analysis was considered adequate. It was run as a single reach model as there was no tributary and distributary of the KushiaraRiver at Golapganjin the vicinity of the bridge location. For the present study, the third type of boundary condition, which is normal depth as mentioned above, was selected. This is calculated by the model itself using the Manning's equation. This needs the energy slope to be specified by the users. In absence of energy slope in the present analysis and given that there would be insignificant difference between the hydraulic gradient and energy gradient in the study area, the model was run with hydraulic gradient as the downstream boundary condition. The hydraulic gradient was estimated from the peak annual mean tidal water levels of Islampur(SW 332) on the KushiaraRivers. For the selected reach based on the information collected during the field visit on the bed materials and the flood plains, the Manning's roughness coefficient of 0.0033 for the main river and 0.0035 for the overbanks are considered reasonable and hence were used in the model. Measured cross sectional data at 13 locations - 6 at the upstream, 6 at the downstream and one at the bridge location - covering a length of about 1km and a width of about 200 m were available that were used in the model set-up for Kushiarariver. Any additional cross section required in the model set-up was generated from these measured cross-sectional data, Google earth image, field observations and our own professional judgments.

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Parameter	Main Channel	Left Overbank	Right Overbank
Standard High-Water Level (m)	11.46	11.46	11.46
Flow Area(m^2)	2015.40	0	0
Hydraulic Depth (m)	12.76	0	0
Velocity (m/s)	0.39	0	0
Discharge (m^3/s)	784.02	0	0

Table: Computed hydraulic parameters at the bridge location for 'without bridge' condition for Kushiara River at Golapganj

The distribution of one-dimensional longitudinal velocity at different cross sections was computed with the HEC-RAS model by dividing the cross section into 70 segments.The model provided the average velocity for each of the segments. It is seen that the velocities in the main channel of the cross section vary from 0.00 m/s to 0.6 m/s, the average being 0.39 m/s. It is also seen that the velocities are higher, as expected, in the deeper segments of the cross section near the middle and lower in the shallower segments near the banks.

4.5.2Parameter computation for 'with bridge' condition

The next computation was done for the with bridge condition. A bridge on the main channel in the adjacent built areas with a length of 240m having 5 spans in case of KushiaraRiver at Golapganj.Mid span 80m and rest four are 40m each in length, viaduct at each end of the bridge is 210 m having 7 spans each of 30m, abutment at each end with the vertical slope of 2H: 1V, and 2 piers each with 1.3 m in diameter were included in the model. The model was then run for the design dischargecondition and the computed values of the hydraulic parameters at the proposed bridge section are presented inTable with theparameters computedfor 'without bridge' condition for easy comparison.

Parameter	With Bridge	Without Bridge	Difference
Bridge Opening (m)	660	-	-
Standard High-Water Level (m PWD)	11.46	11.46	0.00
Flow Area (m^2)	1971.32	2015.40	44.08
Hydraulic Depth (m)	12.79	12.76	0.03
Average Velocity (m/s)	0.40	0.39	0.01
Discharge (m^3/s)	784.02	784.02	0.00

Table: Comparison of hydraulic parameters of the main channel of the bridge section for Kushiara River at Golapganj.

The restriction to free (natural) flow due to bridge piers, abutments and approach roads typically causes the head of water to rise on the upstream of the bridge. The height by which the natural water level is raised at any point is referred to as afflux by comparing the 'with bridge' water level with the 'without bridge' water level at different sections, it was found that there would not be any major change in water level due to the construction of the proposed bridge.The plan form analysis presented above shows the nature of shifting of the river at the bridge site and around the vicinity of the bridge site for the last 21 years. In 1989, the position of the bank line of the river, where the bridge is located now, was almost in the same place where the bank line of the river is aligned now. This means that morphological activities were almost nil at the bridge site and around the vicinities of the bridge site of the river during the past 24 years. There are mild bends both at the upstreamand downstreamreaches of the bridge site. But these bends looked perfectly stable during the last 21 years.


Figure: Left and right bank of the river at the bridge location with the harbor entrance for Kushiarariver at Golapganj

As a consequence, the portion of the river, where the bridge as located now also remained stable the existing harbor (not shown in the image because of the small size). into which the bridge will intrude, also will remain stable because of the dead water zone created inside (will be shown later in the model results). There is no visible sign at this moment thatindicates anypossibilities ofchanging this stable condition in thenear and in the distant future. It can be logically expected that the bridge section will remain stable in the near, and also, in the distant future. Observation during the field visit also verified the above situation.

4.6Morphological Characteristics

4.6.1 Planform analysis using satellite images

Historical satellite images are used to evaluate the characteristic features of channel shifting and to estimate erosion. As satellite images at different times are available for the study reach, the analysis of the stability of the study river reach using satellite images is presented in this section

Planform analysis of the proposed bridge was conducted using google earth image. Three images of the years 2004, 2009 & 2017 were used.

Figure: Satellite image of bridge location on 2009. Bridge location is shown by white color dot.

The planform analysis presented above shows the nature of the shifting of the river at the bridge site and around the vicinity of the bridge site for last 14 years. In 2004, the position of the bank line of the river, where the bridge is located now, was almost in the same place where the bank line of the river is aligned now. This means that the morphological activities were almost nil at the bridge site and around the vicinities of the bridge site of the river during last 14 years. There are mild bends both at the upstream and downstream reaches of the bridge site. But these bends looked perfectly stable during the last 14 years. The bridge section will remain stable in the near, and also, in the distant future. Observation during the field visit also verified the above situation.

4.6.2Cross-sectional analysis

The cross-section data of a river are measured to investigate the shape and morphology of a river, to compare straight and meandering sections of the same river, to investigate discharge and velocity and the factors which influence it, both across the channel and along its length, to investigate changes in channel morphology along the length of the river and to compare rivers in different locations. A total of 23 cross-sections in a reach of 10 km were measured which included 1 section at the proposed bridge location and 11 sections at upstream and 11 sections at downstream to the bridge site. Both upstream and upstream sections were spaced at 100 m, 200 m, 300 m, 500 m, 1000 m, 2000 m, 3000 m, 4000 m, 5000 m from the proposed bridge site. The left and right bank (looking upstream) elevations are at mostly similar across the sections. The cross-sectional profiles are uniform and symmetric. From the cross-sectional properties, it appears that the river reach is stable.

4.6.3 Two-dimensional Flow Field

Use of the one-dimensional flow model, as presented in the previous section, gave flow parameters at an average condition. In order to compute a spatial distribution of the flow parameters (e.g velocity, water level, shear stress) in the river reach considered for analysis, a multi-dimensional 2D mathematical model, iRIC Nays2DH, developed by iRIC Software, has been applied (iRIC, 2010). Here iRIC Nays2DH, which is based on 2D model, is used to simulate the flows in a straight open channel with groin of 45°, 90°, and 135° angled with the approaching flow. The iRIC Nays2DH has hydrodynamic modules which solves the governing equations by finite difference technique. The equations are solved on a curvilinear boundary fitted grid. When necessary, the vertical grid is defined following the sigma coordinate approach.

The study reach is selected considering the proposed location of the bridge and availability of the necessary data. Discharge is specified as the upstream boundary condition and water level is specified as the downstream boundary condition of the model. As no measured water level data are available inside the model domain, the model is calibrated by using the Standard High Water Level estimated at the bridge location, which is 11.46 m PWD. The bank erosion model computes the likely locations of bank erosion in the model domain. To compute the bank erosion locations, the critical shear velocity is computed using the bank material size. The actual shear velocity is then computed by using the computed near bank velocity and the near bank water depth. When the ratio between the actual shear velocity and the critical shear velocity exceeds unity, the location is identified as erosion prone. According to this model, bank erosion basically depends on bank material size, near bank velocity and near bank water depth. Based on this model, attempt was made to compute the erosion prone areas of the banks of the model domain. It has been found that the entire banks in the reaches of the river where the bridge is located are not prone to erosion. The upstream and the downstream bends of the river reach are showing the similar characteristics. So, it can be concluded that the entire river reach of the bridge section including the upstream and downstream reaches are not prone to erosion. This is applicable for both of the banks of the river including the water body.

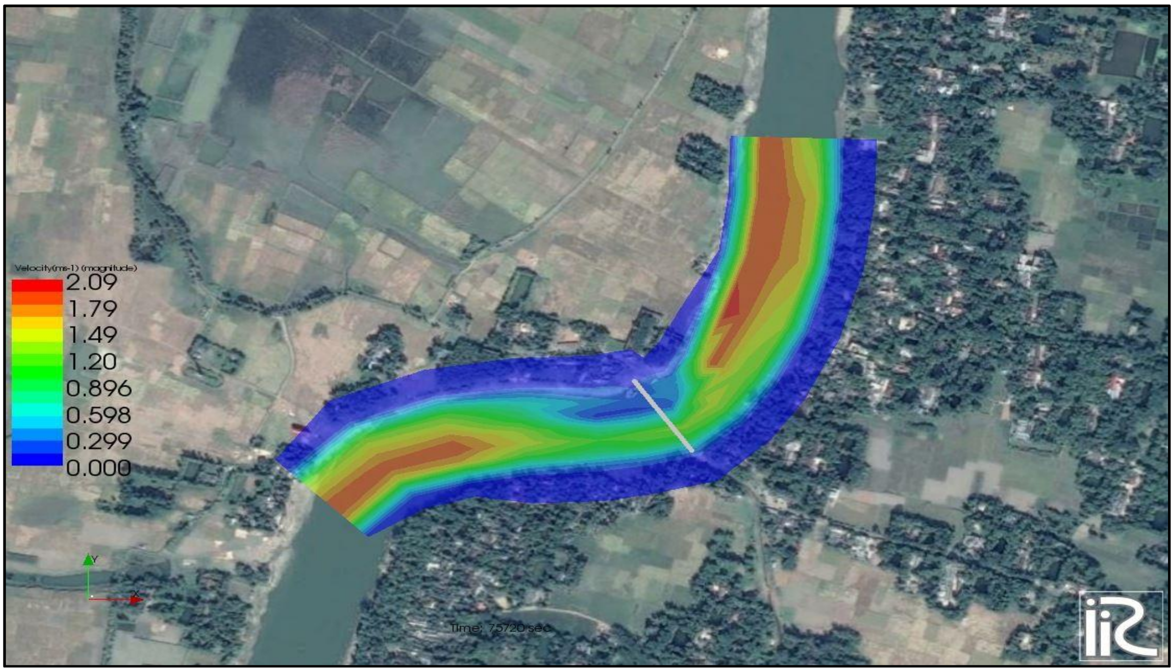

Figure:Two-Dimensional velocity distribution in the model domain

Figure: Variation of Water Bed Level in the model domain

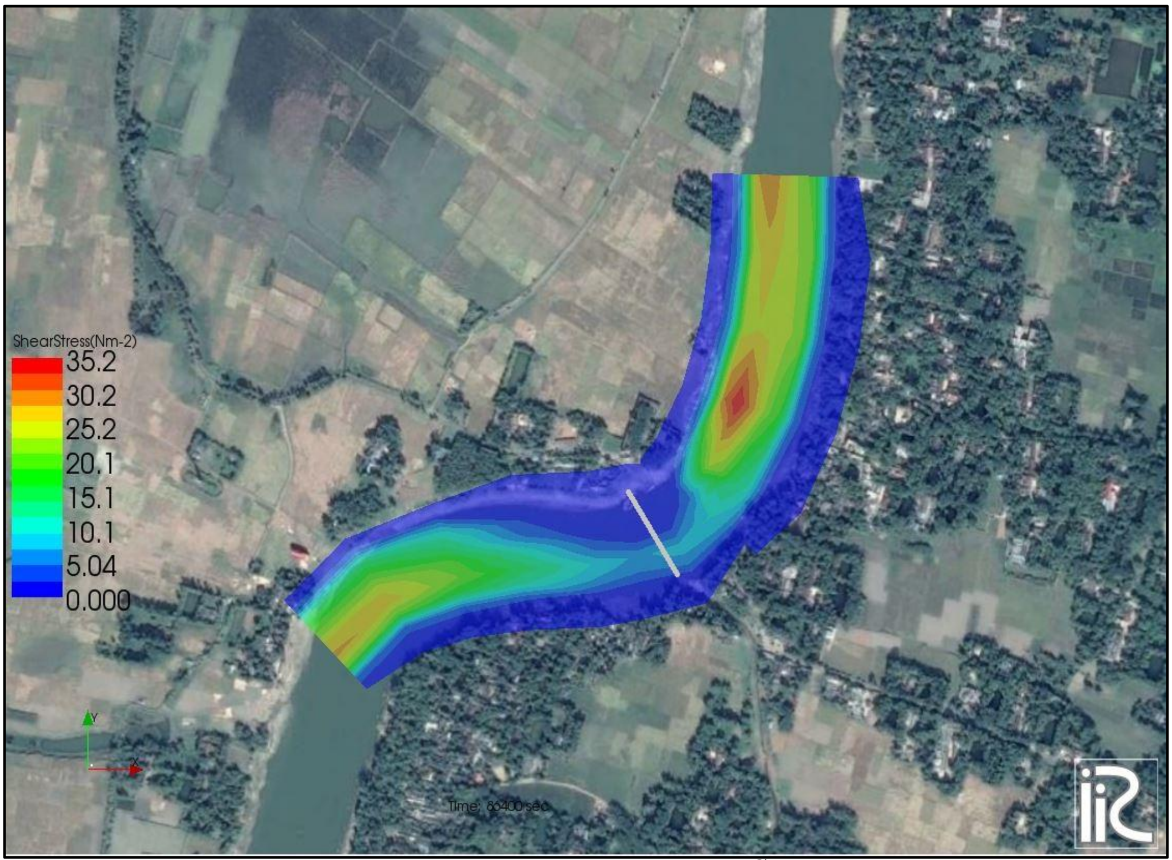

Figure: Variation of Computed Bed Shear Stress (N/m$^{2)}$ in the model domain

4.6.4Morphological stability and bank erosion

Plan form analysis shows that the bridge is located in a river reach where there are mild bends both at the upstream and downstream of the bridge section, but the bends are stable for the last 21 years. The bridge section is also stable during this period. Although the bridge sectionis slightly constricted, novisible instability isobserved in that constricted section during the past 21 years. It is expected that the river reach at the bridge section along with the upstream and downstream reaches of the bridge will remain stable in near and in distant future.

Cross sectional analysis shows no skewness and no asymmetry for all the cross sections. The bank to bank widths of the cross sections are almost constant. The bank position is almost static Also, there is no sign of any abnormal bed erosion near the banks in any of the cross sections. These are the evidences that show that the entire river reach at the bridge section and around the vicinity of the bridge sections are morphologically stable.Two-dimensional model results, particularly the bank erosion model, show the similar phenomena. Both of the banks of erosion. This feature is evident from the bed level variation. There is no sign of any abnormalities near bank considering bed uniform depth. All these together reveal that the river at the bridge section and at the upstream and downstream reaches of the bridge section is stable Observations during the field visit in the vicinity of the proposed bridge site also verified the above phenomena. Evidences of erosion were not observed at either of the banks at the bridge section.

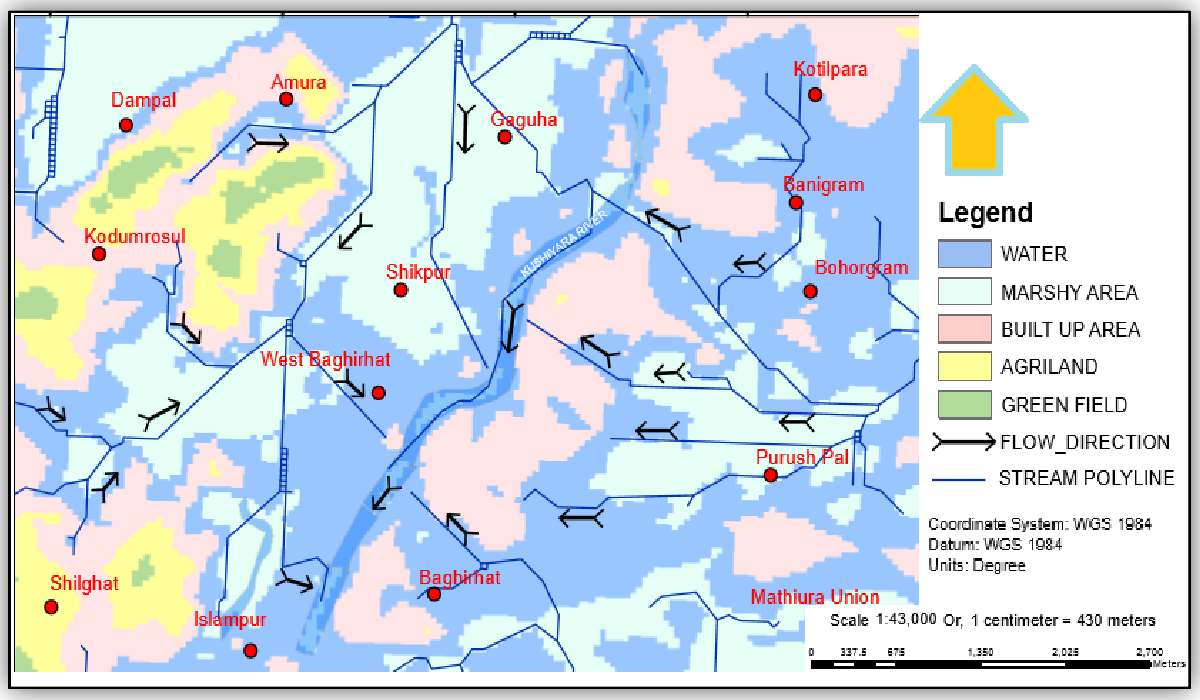

Figure: Flow direction and flow accumulation pattern in the study area.

Based on the plan form and cross-sectional analyses, two-dimensional model results and field observations. It can be concluded that the river reach at the bridge section is morphologically stable. Both the upstream and the downstream river reaches of the bridge section including the harbor section are also morphologically stable. There is no sign of changingthis stablecondition innear and in distant future. Under the circumstances, small scale river training and bank protection works can be introduced at either bank of the entire river reach surrounding the bridge section considering future demand.

4.6.53-Dimensional View of the Study

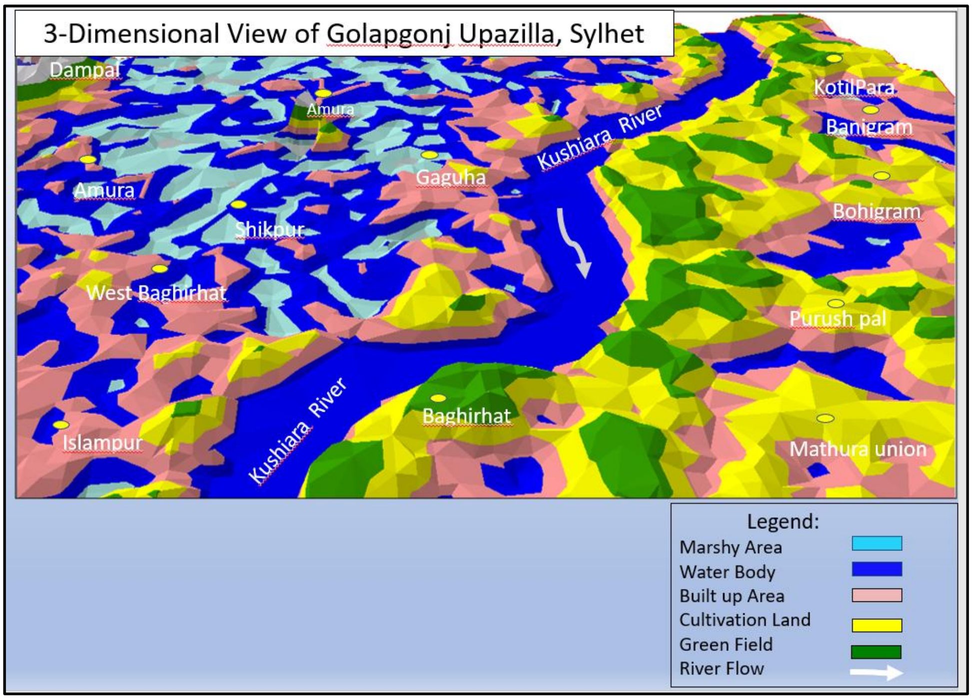

Figure: 3-Dimensional View of the study area.

The procedures which are followed are described below:
- Adding SRTM 30 DEM in ArcGIS.
- Selecting the Projection System.
- Creating TIN from Conversion Tools.
- Open ArcScene.
- Adding TIN and 3D View created.

V. Selection Of Bridge Location

5.1 General

The selected bridge location should enable construction of a safe, economical and easily maintained crossing, having river to approach requirement and to the nature of the waterway and its environment. The primary considerations for selecting appropriate bridge location are hydro-morphological characteristics of the river, existing communication network, field observations, and opinion of the local people.

5.2 Considerations for Selection of Bridge Location

5.2.1 Existing communication network

The proposed bridge will be constructed over the Kushiarariver at Golapganj and will connect a large part of Golapganjupazilawith other part of the upazilla. There is a huge traffic of people from these area as well as people travelling from Golapgonj to Bianibazar via ferry crossing. Hence, it is Likely to bring forth considerable social and economic benefits.The proposed bridges are thus expected to play a very positive role by enhancing socio-economic activities of the people of Golapgonjupazila at Sylhet.

5.2.2 Field observations

The river is narrower at upper reaches. The rivers have experienced significant encroachment, especially near the industrial zones. The river is navigable throughout the year and shows erosional tendency.

Figure: The proposed bridge location on the Kushiarariver at Golapganj.

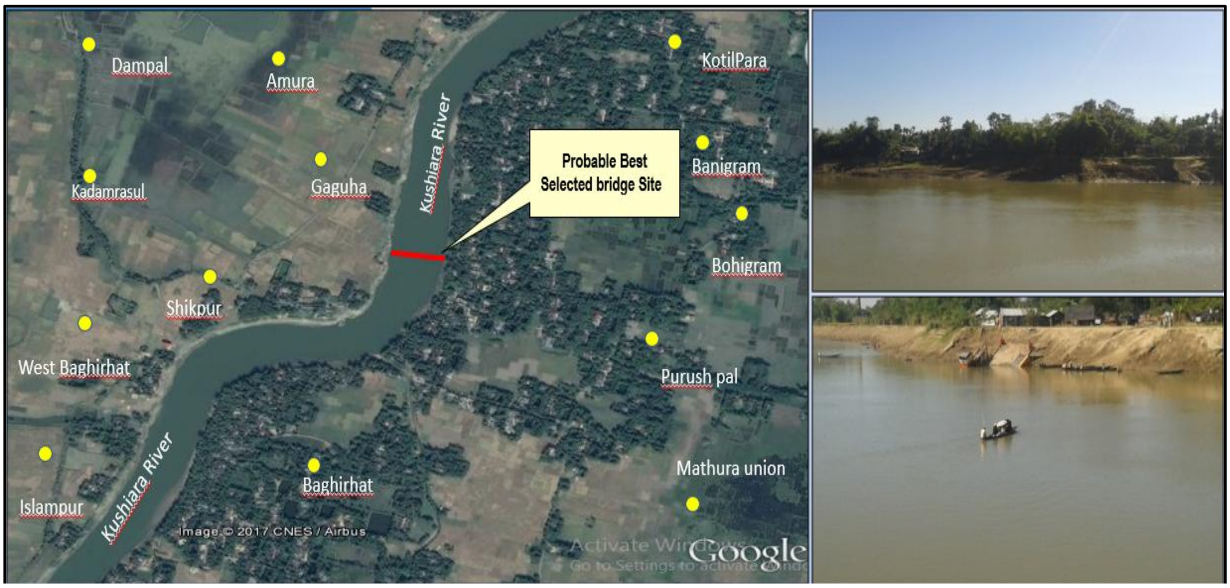

Figure: Proposed bridge location (Golapganj Bridge)

The reasons for selecting the probable bridge site are written below:

- Water gap is less ie. 280 m, so construction cost will be less
- Road is available in both the banks which facilitates better connectivity
- Water flow is less in this location
- Bringing and placing of construction resources will be easy
- Soil condition is good in this location

While the river width is relatively small at the proposed bride location, the required length of the bridge will be substantially higher because of the high navigational clearance requirement, existing infrastructures on both sides of the river and the desired connectivity with the existing road system. The river Kushiarais considered under Class type II (meant for navigational requirements for medium ships) under navigational route classifications of Bangladesh Inland Water Transport Authority (BIWTA). The recommended vertical clearance for Class II is 12.20m. In consideration of the medium vessels that ply through the river and the possible wave impact on the piers, the horizontal clearance between piers is also very high (at least 76.22 m according to BTWTA classification) The proposed bridges section are apparently very important for the local people as they were seen to cross the river by boats at this particular location.

The bridge site is located in a river reach with mild bends at upstream and downstream. No evidences of erosion were found at either of the river banks during field visit, the bridge section needs to be aligned with a curvilinear directionto minimize interference with important existing infrastructure and connect with approach roads.


Figure: Local People crossing the river by boats at the proposed bridge location

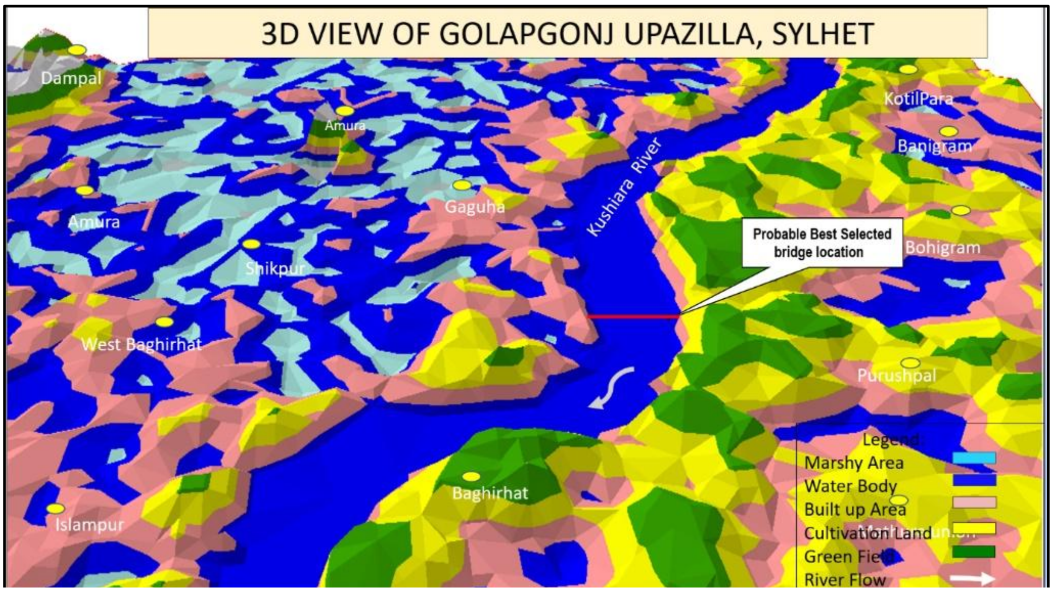

Figure:3-Dimensional View of Proposed bridge location (Golapganj Bridge)

5.2.3 Hydro-morphological characteristics of river

An analysis of hydrologic, hydraulic and morphologic behavior of the river at the bridge location was carried out, as presented in Chapter 4 Planform analysis indicated that the bridge is located in a reach in between mild bends; however, the bends together with the bridge section have been stable for the last 21 years. Cross sectional analysis showed no skewness or asymmetry at the bridge section as well as at sections upstream and downstream of the proposed bridge site within considerable distances. The bank to bank widths of the cross sections are almost constant, with a static bank position.

5.3 Selection of Bridge Location

In view of the consideration's selection of the bridge location, as illustrated above. The bridge site is considered as a feasible site for bridges construction over Kushiarariver at Golapganj. There is enough cross-sectional area available to allow passage of possible highest flood flow. The bridge will forth immenselybenefit to the people of Golapganj. The location is advantageous because of its proximity to the regional road network meaning that connectivity of the bridge with the road network could be established without much difficulty. The river reach is also morphologically very stable.

5.3.1 Bridge Location and Approach Road Alignment

I worked out a number of possible bridge locations and approach road including river cross section, land conditions and other relevant aspects in order to provide a comparative study for recommending the best bridge location and its alignment. As such I have performed all necessary field surveys and investigation both at proposed bridge location and other potential locations.

At earlier stage, the I have identified 3 (three) suitable locations of the proposed bridge over KushiaraRiver connecting two sides of Bohorgram mouza of GolapganjUpazila. Consequently, screening procedure of the Multi Criteria Decision Analysis (MCDA) was applied to recommend at the best suited alignment of the proposed bridge. This chapter also presents the optional study considering main bridge, approach road/ramp and other associated structures regarding fixation of bridge alignment and location.

5.3.1.1 First Order Screening of Bridge Alignments

Identifying the potential location of the bridge alternative included a quite number of integrated factors and issues such as skewness of main bridge alignment, public demand, availability of suitable land, transport network, constructability, environmental impact, socio-economic impact, costing, resettlement and land acquisition affairs etc. All these factors were considered by the me during comparative analysis among bridge location alternatives. To carry out the whole I have collected first-hand information by collecting google earth image, SRTM image, generating Digital Elevation Model (DEM), Preparing geo-morphological map, preparing 3 dimensional map, producing Land use map, conducting reconnaissance survey, topographic survey, traffic survey, hydrological survey, environmental survey, focus group discussion, individual interview assessment on resettlement and land acquisition and so on. Secondary data were also collected from relevant sources to justify the primary data as collected from the field.

Based on information, obtained from the reconnaissance survey,I critically analyzed three potential bridge location within 5kmupstream to 5km downstream by the MCDA method.

5.3.1.2 Reconnaissance Survey

The main goal of reconnaissance survey was to identify strength and weakness of each and every alignment alternative regarding transport network connection, public accessibility, availability of lands, property impact, social impact, impact on environment etc. During reconnaissance survey a number of discussions with local people and public representatives have been conducted by me. Based on the findings of detail reconnaissance survey, the first screening has been applied on three alternatives to prepare a comparative statement.

Alternative A

This alternative extends through a road goes to Golapganj with ShikpurFeriGhat. The major connecting roads for this alignment are Golapganj road at Shikpur and Basontapurr road at Bohorgram. Total length of this alternative is about 990 m in which 280 m may be dedicated for the main bridge. The main drawback for selecting this location is the width of the river. In this alignment the width is quite large from other part of the river.

Alternative B

This alternative starts from Golapganj road at Shikpur and meets with Basontapurr road at Bohorgram. Total length of this alternative is about 960 m, in which 300 m may be dedicated for the main bridge. The main advantage of this alignment is the availability of good road connectivity on both sides of the river and high public demand. Moreover, the width of bridge is much less than previous alignment.

Alternative C

This alignment connectivity runs from Shikpur to Basontapurr road at Bohorgram. Total length of this alignment is about 1050 in which 320 may be dedicated for the main bridge. The main drawback factor for selecting this alignment is the unavailability of good road connectivity on both sides of the river and the high requirement of land acquisition.

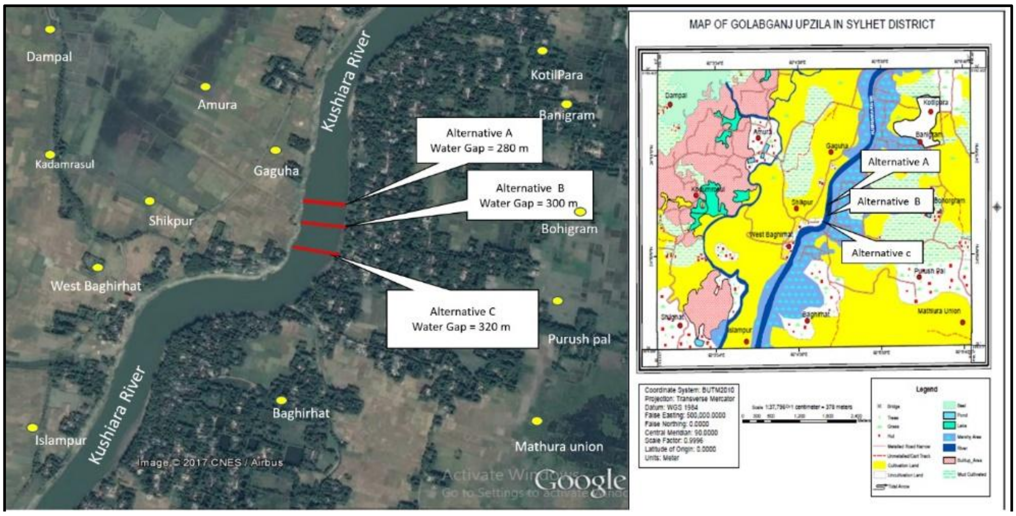

Figure: Probable Proposed bridge location (Golapganj Bridge)

VI. Expected Research Outcomes

6.Site selection indicates the practice of new facility location, both for business and government. It involves measuring the needs of a new project against the merits of potential locations.It is one of the most important factors affecting construction project management for chemical, power plants, fertilizer plants in Bangladesh condition. The geographical location of the plant contributes a lot to the success of any development and construction activity.The following factors have to be considered in selecting a ideal bridge site.

- Connected with roads.
- Strong embankment on both sides.
- Type of foundation.

- Requirement of material and labour.
- Flow of water.
- Straight stretch of river.
- Flow of river.
- Width of river.

6.1 The expected research outcomes are written below:
- Determining Elevation and terrain analysis of the study area.
- Identifying the nature and water flow of river.
- Determining Flow Direction, Flow Accumulation, Stream Links, Basin and 3D View of the area.
- Investigating Hydro-morphological data to determine probable best probable bridge site.
- Planning, designing and future maintenance of the study area will be benefited by the research.
- It will be beneficial for the planners as well as the concerned authorities to take relevant decisions for future construction works.

VII. Conclusion And Recommendation

7. This study focuses on the hydrological and morphological investigation of the proposed bridge site over the Kushiarariver at Golapganj in SylhetSadarUpazila in order to determine suitable location of the bridge, bridge height, waterway opening, alignment of approach roads, hydraulic design variables for bridge piers and abutments and bank erosion and river training works at upstream and downstream of the proposed bridge section. The following sections describe the findings of the study.

7.1 Selection of Bridge Location

The location of the bridge has been selected at the site.This site has been found feasible based on the analysis of existing communication network, hydro-morphological analysis, analyzing various types of maps, local people's view and field investigation.

7.2 Recommendation

Selection Criteria for Bridge Site is a preliminary study(Techno-economic Feasibility Survey). Following recommendation are suggested:
- Topography needs analyzed more carefully and meticulously.
- Catchment area is to be measured accurately.
- Hydrological and morphological analysis to carried out properly.
- Geo-technical data is to be analyzed very efficiently.
- Seismological data is to be analyzed prudently.
- Navigation has is to kept in mind.
- Availability of construction resources and its storage have to be planned.
- Location of near nearby bridges has to be kept in mind.

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