Asian Development Bank

Inception Report

on

Field-Based Research on the Impacts of Climate Change on Bangladesh Rivers

June 2009

Center for Environmental and Geographic Information Services
House 6, Road 23/C, Gulshan-1, Dhaka-1212, Bangladesh. Tel: 8817648-52, Fax: 880-2-8823128

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Contents

Chapter 1
Introduction

1.1 Background

The Asian Development Bank (ADB) is involved in a Pilot and Demonstration Activities programme for water (the "PDA Programme") which is a part of the regional technical assistance for knowledge and innovation support for ADB's Water Financing Programme. This program was approved by ADB in November 2008 and financed by the Water Financing Partnership Facility. The objective of the PDA programme is to enable testing of new ideas and validation of innovative development approaches that are highly replicable and can strengthen ADB's core operations, including policy dialogue with government, reform agenda formulation, country programming, and project preparation and implementation. This PDA programme will assess the effects of climate change on the Jamuna, Ganges and Padma rivers.

Bangladesh is one of the most vulnerable countries on earth to the effects of climate change (Mirza, 2002, 2003; CCC, 2006, Ahmed, 2006). Global warming with higher associated rainfall and relative sea level rise, will likely cause significant changes in sediment and flood regimes. Consequently, great rivers like the Jamuna, the Ganges and the Padma may be disturbed requiring long periods of adjustment in fluvial processes and morphological forms.

Flooding, floodplain sedimentation and bank erosion of these rivers influence life and livelihood of several millions of people. These rivers are very dynamic in nature as most part of Bangladesh has been formed by recent sediments and rivers that are loaded with huge sediment. As a result these rivers become very sensitive to changes in parameters like flood flow, sediment load and base level.

It is now time to assess the impact of climate change on the morphology of those rivers as well as the subsequent impacts on floodplain dwellers so that the nation can prepare itself to mitigate the effects. It is expected that this sort of study can be replicated for the other large rivers in Asia.

1.2 Objectives of the Study

The main objective of this project is to assess morphological responses of the main rivers of Bangladesh to climate change, which is expected to occur within the time-scale of 50 to 100 years. Specifically, this Pilot and Demonstration Activity (PDA) aims:

to have better understanding on the morphological processes of main rivers such as the Jamuna, the Ganges and the Padma;

to assess the impact of different aspects of climate changes such as sea-level rise and changes in flood and sediment regimes on the morphological processes of the main rivers:

to assess the impact of large-scale changes in the main rivers on the land and people of Bangladesh, and

to assess future risk of the river widening or becoming unstable with the specific risk to infrastructure placed in the vicinity of the rivers and existing river training structures.

1.3 Study area

The effect of climate change will be assessed for the Jamuna, the Ganges and the Padma within the territory of Bangladesh (Figure 1). The Jamuna River travels about 220 km from the international border to meet the Ganges River at Aricha. The average width of this river within Bangladesh is 12 km. The annual average flow as measured at Bahadurabad is 20,000 m^3/s with a maximum estimated discharge of 100,000 m^3/s. The average flood water slope of the river is 7.5 cm/km and the average median size of bed material at Bahadurabad is 0.20 mm. The river demonstrates a braided planform. The annual average rate of bank erosion is about 2,000 ha/year.

The Ganges enters Bangladesh from India at Nawabganj district and flows about 110 km along the international border of Bangladesh and India occupying the territory of both countries. The length of the river downstream of this reach flowing inside Bangladesh up to the confluence with the Jamuna River is 120 km. The average width of this reach of the river is 5.3 km but varies from 1.5 km to 14 km. The annual average flow as measured at Hardinge Bridge since the mid-1930s is about 11,000 m^3/sec. The average median bed material size at Hardinge Bridge is 0.15 mm. The planform of the river is mainly meandering with several chute channels at some reaches. The average floodwater slope of the river is 5 cm/km. The annual average rate of riverbank erosion is 1,000 ha/year.

The Ganges and the Jamuna meet at Aricha forming the Padma River, which flows southeastward until it reaches the Upper Meghna River near Chandpur. The length of this reach of the river is 100 km. The annual average flow of the river is 30,000 m^3/s. The reach-averaged width of the river is 10.3 km but varies from 2.5 km to 20 km. The average median size of the bed material at Mawa is 0.12 mm. The planform of the river oscillates from braided to meandering and straight. The annual average rate of bank erosion is 1,500 ha/year.

These three rivers will be the main focus for the assessing the impacts of climate change. In addition the impact on the rivers like the Arial Khan or Gorai will be assessed. Although the morphology of these rivers are largely affected by the local morphology and local or unpstream human interventions.

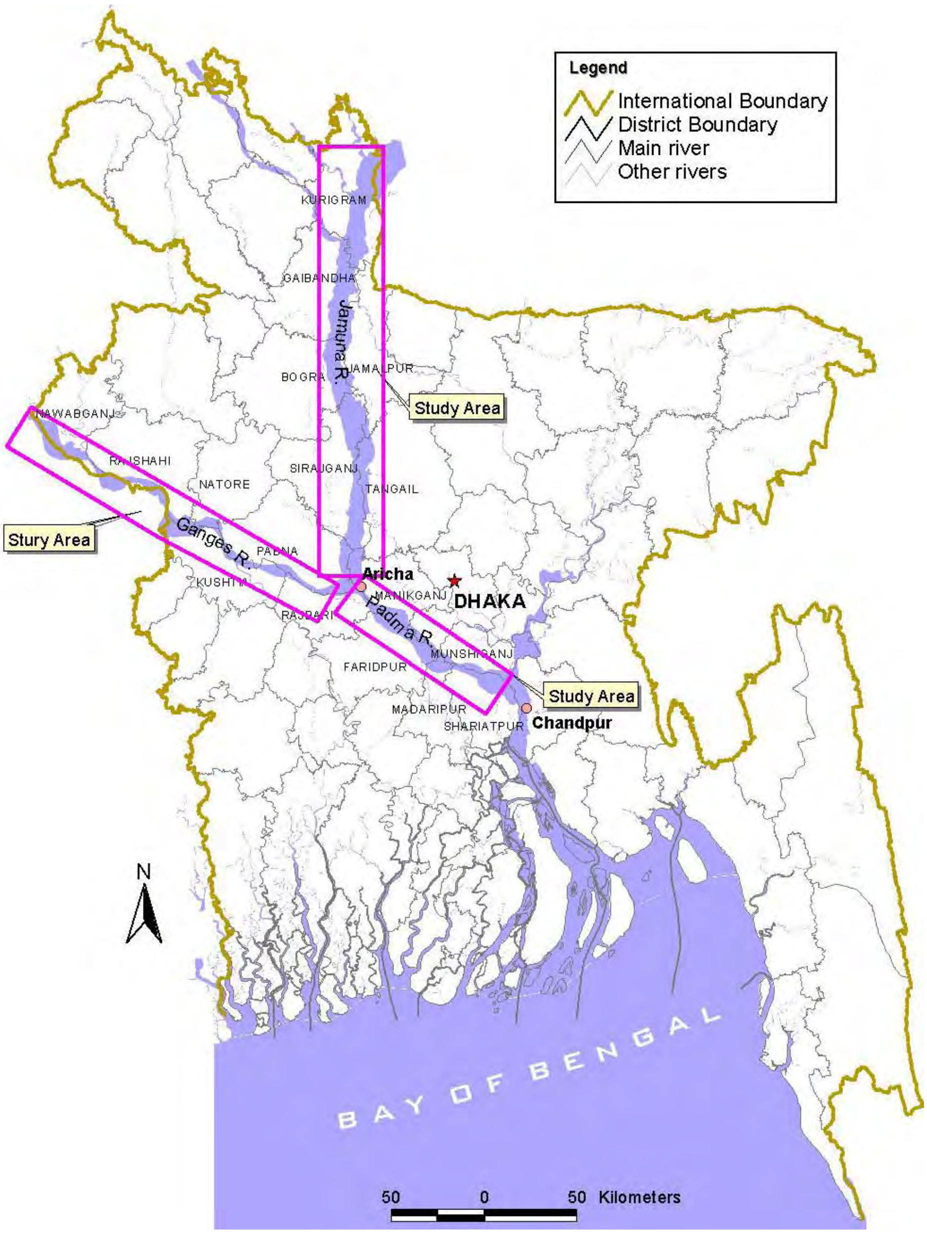

Figure 1. Map of Bangladesh showing the study area

1.4 Scope of Work

This study will cover the Jamuna, Ganges and Padma Rivers within the territory of Bangladesh. The scope of work includes:

Review literature on the morphological processes of the main rivers of Bangladesh;

Review literature on the probable changes that would occur in sea level and hydro-meteorological processes in this region due to climate change;

Review literature on the morphological responses of large sand-bed rivers to changes in hydro-morphological regimes;

Select different suitable analytical and empirical models responsive to the impacts of climate change in order to assess the impacts in both qualitative and quantitative terms;

Identify knowledge gaps on the morphological processes that are relevant to assessing the responses of the rivers to climate change;

Procure and process satellite images;

Analyse historical maps, time-series satellite images (available in CEGIS and if necessary, procure new images), discharge, sediment and cross-section data of these rivers to fill knowledge gaps;

Analyse bathymetry data and satellite images to understand the responses of the rivers to existing bank protection structures

Define climate change scenarios (different ranges of sea-level rise, different ranges of increase in rainfall intensity, different ranges increase in flood-discharge, different ranges of sediment yield due to increase in rainfall and changes in land use) for which morphological impact will be assessed;

Assess the range of tidal penetration and increase in flood level into the major non-tidal rivers for different climate change scenarios using a numerical model;

Identify the key variables of climate change scenarios causing morphological changes. Assess qualitatively and quantitatively (if possible) the morphological responses of the main rivers to the key variables for different scenarios using different types of selected analytical and empirical models;

Assess the risk to existing river training structures from morphological changes as assessed by the selected models;

Assess the impact of climate change on riverbank erosion/accretion and river widening/narrowing processes using the selected models;

Assess the impact of the changed erosion/accretion processes on the people and the nation extrapolating the information gathered from secondary sources and RRA surveys;

Assess the risk of avulsion of the river courses due to the backwater effect resulting from sea-level rise using the selected models;

Assess the risk of more and longer flooding associated with sea level rise and changes in planform of the selected rivers

Assess the impact of avulsion of the river courses in terms of displacement of people, flooding, and land and infrastructure loss extrapolating the information gathered from secondary sources and RRA surveys; and

Hold workshop for disseminating the findings and get feedback from stakeholders.

1.5 Structure of the report

A brief description on mobilization for the project and field work is presented in Chapter 2. A list of data that will be analysed during the course of the study is presented in Chapter 3. Chapter 4 describes the methodology of the study for assessing the effect of climate change. The work plan, staffing and financial schedule are all presented in Chapter 5.

Chapter 2

Mobilization

2.1 Office Setup

The project has been started from 1 June 2009 as per the agreement between ADB and CEGIS. The office for this project has been set up at CEGIS, House 6, Road 23/C, Gulshan 1, Dhaka 1212, Bangladesh. CEGIS has also mobilized personnel and logistics for the study. The following are the means of communication to be used when necessary:

Telephone: 8821570-1, 8817648-52

Fax: 880-2-8855935, 880-2-8823128

E-mail: cegis@cegisbd.com

Web: http://www.cegisbd.com

2.2 Field Visit

Several field visits will be conducted along the rivers the Jamuna, Ganges and Padma to understand the present morphological process of these rivers. The field visits will reconfirm and enrich information on the past and present social and morphological status of the adjacent areas of these major rivers.

Chapter 3

Data use

Analysis of different secondary and primary data will be required for a better understanding on the morphological processes of the Jamuna, Ganges and Padma rivers in order to assess the impact of the climate change on river morphology . The data required from the secondary sources are:

Historical maps and aerial photographs

BWDB cross-section surveys

BWDB water level, discharge and sediment gauging data

FAP 24 bathymetry survey, flow velocity and suspended sediment concentration, and bed material sampling data

Time-series satellite images available covering the Jamuna, Ganges and Padma rivers

JMREMP bathymetry survey data

Bathymetry surveys of the Jamuna River around the Jamuna Bridge by the Bangladesh Bridge Authority (BBA)

BWDB monitoring survey data for the Sirajganj protection works

Demographic data along the vulnerable river banks as collected and processed by the Bangladesh Bureau of Statistics (BBS)

Some of these data are being collected while some are available in CEGIS. The rest of the data will be collected and analysed over the course of the study.

Chapter 4
Methodology

4.1 Literature Review

Different national and international literatures will be reviewed to assess climate change induced probable changes that would occur in sea level and hydro-meteorological processes in this region and also the morphological responses of large sand-bed rivers to the climate change. Different suitable analytical and empirical models will be selected based on literature review and identification of knowledge gap regarding the impacts of climate change in order to assess the impacts in qualitative and, if possible, in quantitative terms.

4.1.1 Climate Change

Climatic parameters such as temperature and precipitation change, and sea level rise will effect the discharge and sediment concentration in the major rivers. Different models of climate change will be reviewed during literature review.

There are several models for gauging temperature change like IPCC-IV, 'Climate Change Country Studies Programme' (Ahmed et. al., 1996; Asaduzzaman et. al., 1997 and Huq et. al., 1998), and there are also a number of General Circulation Models (GCM) such as the Canadian Climate Change Model (CCCM), Geophysical Fluid Dynamics Laboratory (GFDL), GFDL - 1%/yr transient (GF01), and National Adaptation Programme of Action (NAPA) (GoB, 2005). NAPA has a modified model for temperature and precipitation change for the year 2030, 2050 and 2100. The standard deviation of temperature change would be 1.0, 1.4 and 2.4 ^{0}C for 2030, 2050 and 2100 respectively. The standard deviation of precipitation increase would be 5, 6 and 10 mm for those years.

There are various models for predicting sea level rise, some of which are the SAARC Meteorological Research Centre (*SMRC*), NAPA, IPCC-III, and IPCC-IV for 2030, 2050 and 2100. Seasonal temperature and precipitation change for Bangladesh are acquired using these models. Sea Level Rise (SLR) varies from 14 to 18 cm for 2030. Similarly it varies from 60 to 88 cm for 2100 in the previously mentioned models.

In 2008, the Institute of Water Modelling (IWM) enumerated the effect of climate change on monsoon flooding in the Jamuna and the Ganges rivers. Increase of flood level and its duration are key factors in identifying the impacts of flood due to climate change. It has been seen that peak flood level in the Jamuna River is increased by about 37cm in a moderate flood event (2004 flood event) and 27cm in a normal flood event (2005 flood event). Similar impacts have also been seen in the Ganges River, where the increase of flood level has been more than 50cm. The duration of flood at its danger level (danger level 19.5m, PWD as considered by the Flood Forecasting and Warning Center) increases from 10 days to 16 days and the flood level of the duration of 3 days (20m, PWD) extends to 8 days due to climate change in a moderate flood event in the Jamuna River.

A further study will be made to find out a suitable model for gauging temperature and precipitation change of this region. Finally, the accepted model will be used for assessing the climate change that will affect the morphology of major rivers in Bangladesh.

4.1.2 Morphology

The natural setting of Bangladesh between the Himalayas and the Bay of Bengal together with the meteorological characteristics of tropical monsoon are responsible for the prevalence of flooding and riverbank erosion in Bangladesh (Elahi, 1991b). The catchment area of the major rivers is about 1.65 million km^2 of which only 7.5% lies within the borders of Bangladesh (Sarker et al., 2003). This catchment generates 120 million ha-m of run-off annually, only 10% of which is generated within Bangladesh. In addition to vast quantities of water, these rivers carry about 1.1 billion tons of sediment every year (EGIS, 2000; Sarker et al., 2003). The large discharges and heavy sediment loads carried by these rivers result in highly variable and dynamic channel morphologies characterized by rapid adjustments to the cross-sectional geometry, bankline positions and planform attributes (Coleman, 1969). A number of studies have been carried out in the past, particularly concerning the morphological processes in the Jamuna and the Ganges since the late 1960s (Coleman, 1969; Bristow, 1987; Richardson et al., 1996; Best and Ashworth (1997), Richardson and Thorne (2001), McLelland et al. (1999), Ashworth et al. (2000); Klaassen and Vermeer (1988), Mosselman et al. (1995), Thorne et al. (1993), Thorne et al. (1995), and Zhou and Chen (1998), Sarker et al. (2003), Sarker (2004)).

Observations by the Center for Environmental and Geographic Information Services (CEGIS), based on analyses of a 30-year time-series of satellite images, reveal that the Jamuna and Padma rivers have widened more than three kilometers. During the last three decades these rivers have destroyed about 130,000 ha of floodplain land. Recent research such as Sarker and Thorne (2006) and Sarker (2009) addressed the reasons for such a huge widening of the rivers and developed models for explaining related morphological processes. These models could also be suitable for assessing the impact of parameters induced by climate change on the morphology of those rivers.

Goodbred and Kuehl (2000) showed that during the early Holocene the sediments yielded by the catchment of the main rivers of Bangladesh were several times higher than that of present time as monsoon was stronger and the rate of sea-level rise was very high – 1 meter per hundred years. Similar types of literatures will also be collected and reviewed for assessing the probable impact of climate change on river morphology.

4.2 Assessing impacts on the morphological processes

4.2.1 Assessing the impact of climate change on the overall morphology of the rivers

The main issues of climate change that may affect morphological processes are: (i) changes in base level due to sea-level rise, (ii) changes in flood regime due to changes in precipitation pattern and (iii) changes in sediment load also due to changes in precipitation. As a result, the main rivers may take long periods for adjustment in fluvial processes and morphological forms. Different analytical, empirical and conceptual models will be used such as Klaassen (1995), Schumm (1969), Sarker and Thorne (2006) and Sarker (2009) to assess the impact on morphology by climate change (Table 4.1). During the study more such models will be searched in the literature from the journals to assess the impacts.

Klaassen (1995) employed Lane's balance to derive relations between the variability of discharge, width and braiding intensity of the form:

$$SD^{p}W^{\frac{n-3}{3}} \propto \alpha_Q Q^{\frac{n}{3}} i^{\frac{n}{3}} \quad \text{……………………(i)}$$

$$SD^{p}k^{\frac{n-3}{6}} \propto \alpha_Q Q^{\frac{n+3}{6}} i^{\frac{n}{3}} \quad \text{……………………(ii)}$$

Where, S and Q are annual average sediment load and discharge, respectively, W = flow width, k = braiding index, i = channel slope, D = characteristics bed material size, p = exponent of grain size and n = exponent of velocity in a simplified sediment transport equation and α_Q = a factor that reflects discharge variability. This model can be used to assess the changes in width and braiding intensity of the rivers in response to changes in flood discharge, sediment load and slope due to climate change.

Schumm (1969) expressed the sense of adjustment of width, depth, meander wavelength, slope and sinuosity to changes in discharge (Q) and sediment load (S) in a series of qualitative relations. He presented relations for channel response to simultaneous changes in discharge and bed material load:

$Q^{+} S^{+} \approx W^{+}, d^{\pm}, \lambda^{+}, i^{\pm}, P^{-}, F^{+}$ ……………………(iii)

$Q^{-} S^{-} \approx W^{-}, d^{\pm}, \lambda^{-}, i^{\pm}, P^{+}, F^{-}$ ……………………(iv)

$Q^{+} S^{-} \approx W^{\pm}, d^{+}, \lambda^{\pm}, i^{-}, P^{+}, F^{-}$ ……………………(v)

$Q^{-} S^{+} \approx W^{\pm}, d^{-}, \lambda^{\pm}, i^{+}, P^{-}, F^{+}$ ……………………(vi) where, W = width, d = depth, i = slope, λ = meander wavelength, P = sinuosity and F , representing the width/depth ratio. In these relations, the + sign and – sign indicate an increase and decrease in each of the parameters.

Schumm's relations indicate that width and depth responses occur in different fashions depending on the nature of the causal changes in discharge and/or sediment load. This is consistent with previous ideas on stable channel geometry and can be used to assess the response of the rivers to changes of different variables related to climate change.

Through a recent research of Sarker and Thorne (2006) a conceptual model was developed to relate the changes in sediment load with the changes in bed level (indicator of changes in flood level), width and braiding intensity of the braided rivers (Figure 4.1). As this model was developed on the basis of data on the braided river system of Bangladesh, it would be a suitable model for the current assessment.

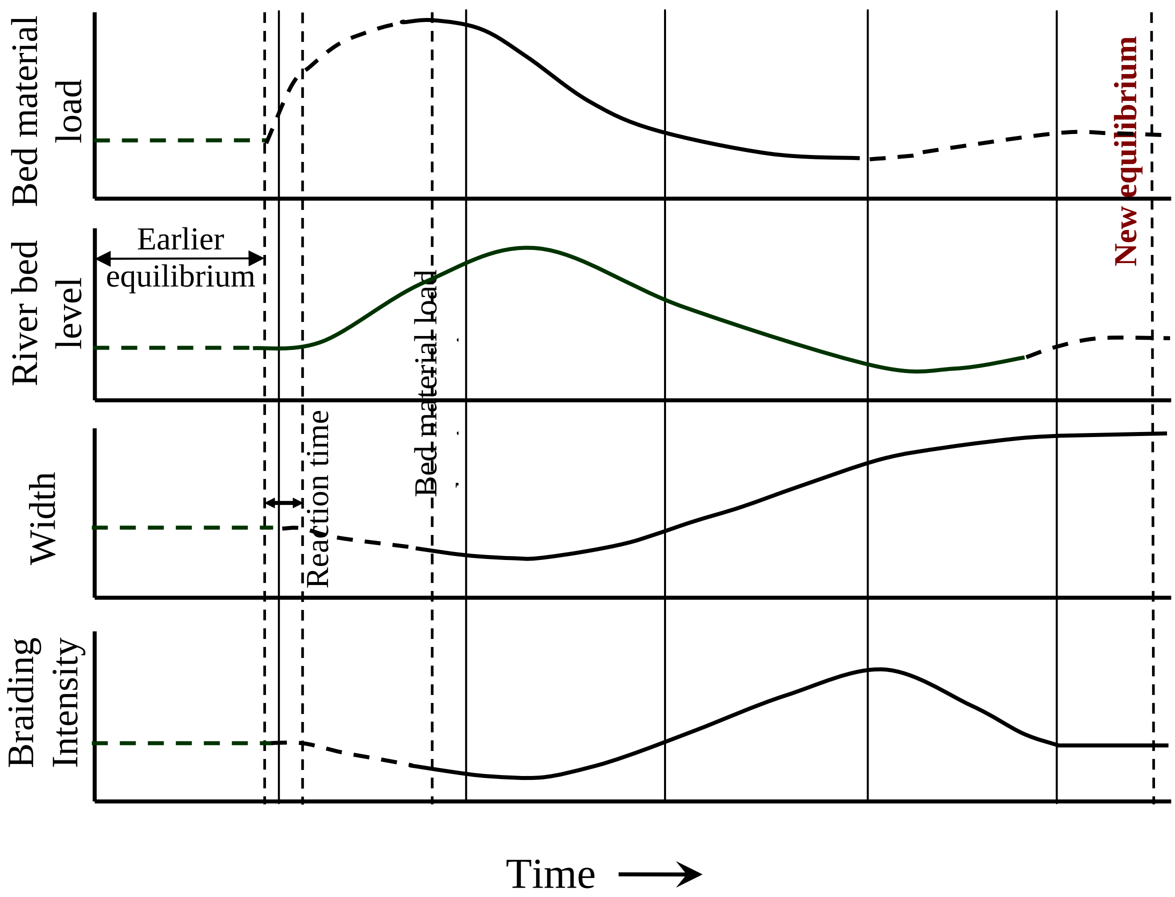

Figure 4.1. Conceptual model showing the impact of changes in sediment load on riverbed level, width and braiding intensity

A simplified scheme developed by Sarker (2009) for assessing the impact of sediment load on changes in river planform can also be used (Figure 4.2). This scheme has been found applicable to the large rivers of Bangladesh.

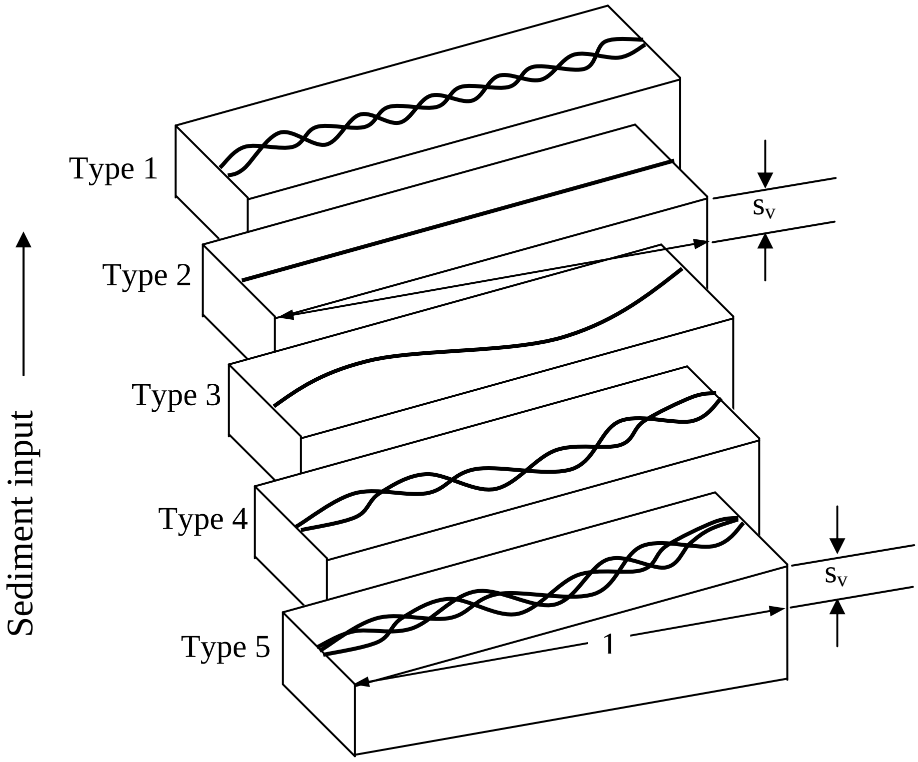

Figure 4.2. A scheme showing the relation between sediment load and changes in river planform (Sarker, 2009)

Bettess and White (1983) developed a framework for predicting the planform of a river with changes in slope (Figure 4.3). This frame can be used to predict the responses of rivers to rising base level, i.e. sea-level.

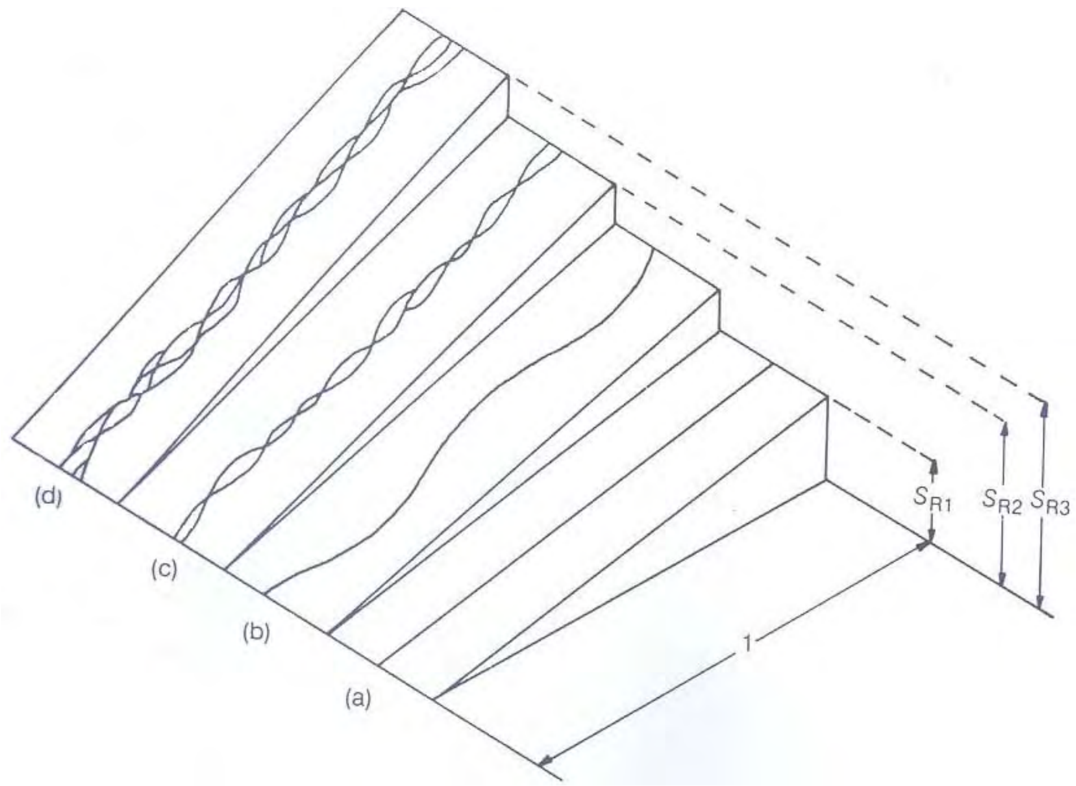

Figure 4.3. Framework showing the relation between planform and slope of a river (Bettess and White, 1983)

The morphology of the rivers like the Gorai and Arial Khna is largely depends on the morphology of the parent rivers at the off-take and also on human interventions locally or further upstream. The effect of climate change on these rivers will be assessed unsing the models in conjuction with the local morphological development.

The results from assessing the effects of climate change with different types of models will be compared and evaluated. These results will be presented in a workshop for relevant stakeholders and experts. Based on feedback from the workshop as well as technical judgment, the results will be finalised to indicate a range.

An attempt will be made to fill knowledge gap by analysing historical maps, time-series satellite images, and discharge, sediment and cross-section data related to these rivers.

4.2.2 Assessing impact on river bank erosion

CEGIS (2007) has found that the annual rate of bank erosion along the Jamuna River is dependent on the maximum discharge of the respective year and derived a relation between annual rate of bank erosion with maximum annual discharge (Figure 4.4). This type of relation can be used to assess the rate of bank erosion if flood discharge changes significantly due to climate change. As there is no such relation for the Ganges and Padma rivers, CEGIS will derive it by analysing satellite images and flow discharge of those rivers measured by the Bangladesh Water Development Board (BWDB).

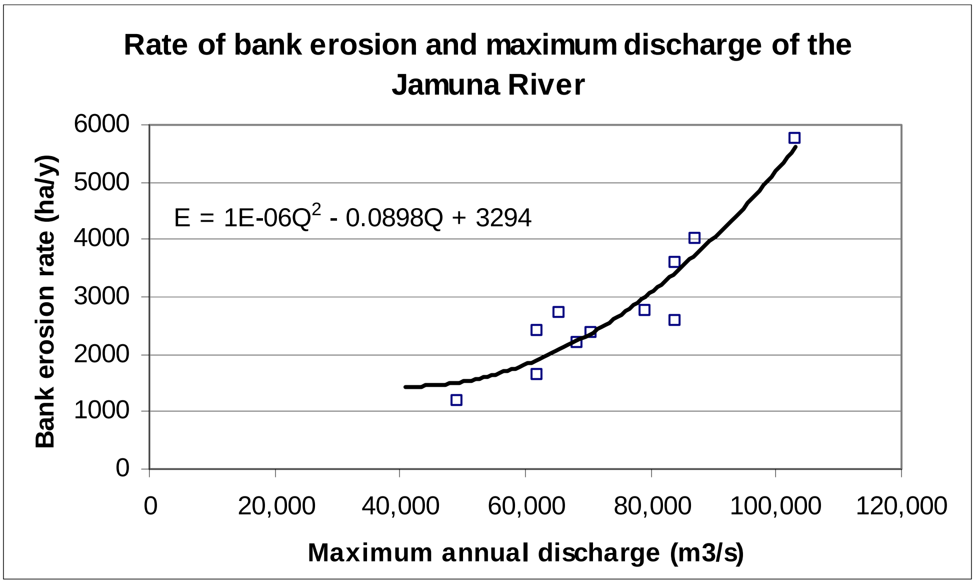

Figure 4.4. Relation between annul rate of bank erosion along the Jamuna River and maximum annual dishcarge

4.2.3 Assessing risk to river training works

Due to changes in the morphology of rivers substantial investments have been made in building infrastructure on the floodplain and along riverbanks, such as the guide bunds of the Jamuna Bridge and different bank protection and river training works. Climate change may put a large number of the riverbank protection schemes along major rivers at risk. The risk to river training works will be assessed based on experience of previously installed river training works on major rivers. Bathymetry data, monitoring data, and riverbed profile data of the vicinity of bank protection structures will be analyzed along with discharge data and satellite images of respective rivers to understand river responses to existing bank protection structures as well as maximum river discharge. An attempt will be made to relate the maximum scour depth and risk of outflanking of structures with the maximum discharge of the river. This type of analysis will help to assess the impact of climate change on scour holes and the risk of outflanking of bank protection or river training structures.

Table 4.1. Uses of different models and analyses for assessing the impact of the anticipated effects of climate change on the moprhololigcal processes.

Models	Anticipated impact of climate change that may trigger the morphological changes		
	Sea level rise	High flood	High sediment
Schumm (1969)		√	√
Klaassen (1995)	√	√	√
Bettess and white (1983)	√		
Sarker and Thorne (2006)			√
Sarker (2009)			√
CEGIS analysis for discharge, bank erosion and scour hole		√	√

4.2.4 Assessing risk to people and nation

Global warming with higher associated rainfall and relative sea level rise will likely cause significant changes in sediment and flood regimes. This adjustment may result in increased suffering of hundreds of thousands of people due to riverbank erosion causing loss of national resources.

The impact of climate change on the morphology of major rivers and its consequences for the people and the nation will be assessed with the help of previous records and Rapid Rural Appraisal (RRA) surveys. CEGIS has the National WaterResources Database (NWRD) and also the database on the infrastructures along the eroding river bank. Population data from Bangladesh Bureau Statices’s (BBS) data on population census 2001 will be used to assess the assess the erosion vulnerable population along the main rivers of Bangladesh. The losses and suffering of the people will be assessed from the RRA survey and also the CEGIS present activities on disseminating the erosion prediction to the community under the financial support from the UNDP.

Future projection of economic development and also the population will be made for the next 50 years and impact of bank erosion will be assessed based on the experience gain from the present pattern of effects of bank erosion on the population and also the nation.

It is expected that the impact of climate change on the tidal reaches and estuaries would be different than on the non-tidal rivers of Bangladesh. This research however, will concentrate on the non-tidal alluvial reaches of the major rivers of Bangladesh.

Chapter 5

Work Plan, Staffing and Financial Schedule

5.1 Work Schedule

The total project duration will be twelve months. The work schedule of the project is presented in Table 5.1.

Table 5.1. Work schedule

Activities	**Months of 2009**							**Months of 2010**				
	J	J	A	S	O	N	D	J	F	M	A	M
1. Literature review												
2. Identifying knowledge gap												
3. Procuring and processing satellite images												
4. Analysing satellite images, bathymetric surveys, discharge, sediment and other relevant data to fill the knowledge gap on morphology												
5. Assessing impacts on the morphology of rivers and risk of avulsion of river channels												
6. Assessing risk to river training works												
7. Assessing impacts on the people and nation												
8. Holding workshop											♦	
9. Mid-term progress report							♦					
10. Report drafting												

5.2 Manning Schedule

A multi-disciplinary team will be involved for the study. The involvement of professionals is shown in Table 5.2.

Table 5.2 . Manning schedule

SL No.	Name	Staff Input by Month												Staff-month Input
		Months of 2009							Months of 2010					
		J	J	A	S	O	N	D	J	F	M	A	M	Total
1	Team Leader/Senior Morphologist.	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	6
2	Morphologist	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	9
3	Climate change and Water Resource specialist	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪					▪▪▪	▪▪▪	▪▪▪	2
5	RS specialist				▪▪▪	▪▪▪								1
6	GIS specialist				▪▪▪	▪▪▪								0.5
7	Sociologist									▪▪▪	▪▪▪	▪▪▪		0.5
TOTAL														20

Intermittent Input ▪▪▪▪▪▪

5.3 Outputs and Reporting

The outputs of this study have been categorized under two broad heads: Deliverables and Milestones. Deliverables are the major outputs of the study, which have been demanded and scheduled according to the ToR. Milestones are the intermediate outputs for progress monitoring and need to be shared with the client. A list of major deliverables is presented in Table 5.3.

Table 5.3. Time schedule for report submission

Reports	Target Date
Inception report	30 June 2009
Mid-term progress report	15 December 2009
Holding workshop	14 April 2010
Final Report	31 May 2010

5.4 Financial Schedule

The breakdown of payment will be in several slots. Reimbursement for the project will be according to the scheme presented in Tbale 5.4.

Table 5.4. Financial schedule.

Item	Amount to be paid
Upon signing of Letter of Agreement	$10,000
Upon submission and ADB's acceptance and confirmation of the Inception Report, and the SOE	$15,000
Upon submission and ADB's acceptance and confirmation of the Mid-Term Progress Report and SOE	$15,000
Upon submission and ADB's acceptance of the Project Completion Report, and the final SOE	$ 9,200

The payments will be sent by telegraphic transfer to the bank account of CEGIS with the following details:

Account name:	Center for Environmental and Geographic Information Services (CEGIS)
Account no.:	05-2419181-01
Bank name:	Standard Chartered Bank, Dhaka main
Bank address:	SCB House, 67 Gulshan Avenue, Gulshan-1, Dhaka 1212, Bangladesh.
Bank tel. no.:	Enquiry Telephone no. 9550181
Swift Code:	SCBLBDDX

All cash advances to CEGIS will need to be liquidated with the submission of (i) Form 15: Liquidation of Advance – Project Financial Status (Appendix 5 of LOA) and (ii) Form 14: Liquidation of Advance – Statement of Expenditures (Appendix 3 of LOA), together with the original copies of invoice, receipts and other supporting documents acceptable to ADB. Claim for airfare should be supported by (i) used/e-ticket, (ii) receipts of purchase, and (iii) boarding passes.

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