**STUDY ON LOWCOST RIVER TRAINING WORKS IN A MEANDER BEND ALONG THE MADHUMATI RIVER**

By

Md. Qutub Al-Hossain

In partial fulfillment of the requirement for the

**MASTER OF SCIENCE IN WATER RESOURCES DEVELOPMENT**



**INSTITUTE OF WATER AND FLOOD MANAGEMENT**
**BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY**

**July 2009**

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

INSTITUTE OF WATER AND FLOOD MANAGEMENT

The thesis titled **'Study on Lowcost River Training Works in a Meander Bend along the Madhumati River'** submitted by Md. Qutub Al-Hossain, Roll No. M10062824P, Session: October 2006, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of M.Sc. in Water Resources Development in July 2009.

**BOARD OF EXAMINERS**

.................................... Chairman (Supervisor)
Dr. Md. Munsur Rahman
Professor
Institute of Water and Flood Management
Bangladesh University of Engineering and Technology, Dhaka

.................................... Member (Ex-officio)
Dr. M. Anisul Haque
Professor and Director
Institute of Water and Flood Management
Bangladesh University of Engineering and Technology, Dhaka

.................................... Member
Dr. G. M. Tarekul Islam
Associate Professor
Institute of Water and Flood Management
Bangladesh University of Engineering and Technology, Dhaka

.................................... Member (External)
Dr. Maminul Haque Sarker
Head, Morphology Divison
Center for Environment and Geographic Information Services
Dhaka.

## CANDIDATE'S DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree.

..............................

Md. Qutub Al-Hossain

*Dedicated to*
*My parents*

ACKNOWLEDGEMENTS

First, I would like to thank the almighty Allah for giving me the ability to complete this research work.

I would like to express my sincere and heartiest gratitude to my respective supervisor Dr. Md. Munsur Rahman, Professor, Institute of Water and Flood Mangement, Bangladesh University of Engineering and Technology, Dhaka for his constant guidance, valuable advice, generous help and constructive discussion to carry out this research. I consider myself proud working with him. His keen interest on the topic and enthusiastic support on my effort was a source of inspiration to carry out the study. I also express gratefulness to Dr. M. Masfiqus Salehin, Associate Professor, Institute of Water and Flood Mangement, Bangladesh University of Engineering and Technology, Dhaka and coordinator, Crossing Boundaries Project for supporting me financially to carry out the physical experiments, and JAFS for providing some apparatus facilities. I am also grateful to Dr. Hamidul Huq of crossing boundaries project for his helping in carrying out the field survey.

I also express my thanks to Mr. Rezaur Rahman, Sub-Divisional Engineer, Design circle-5, Bangladesh Water Development Board, Dhaka for his cordial cooperation and providing me necessary data, map and information. The initial guideline for social survey received from DeLpHE project is also greatly acknowledged.

I also express my thanks to Dr. G. M. Tarekul Islam, Associate professor, and M. Anisul Haque, Professor and Director, Institute of Water and Flood Management, Bangladseh University of Engineering and Technology, Dhaka, and Dr. Maminul Haque Sarker, Head, Morphology Divison, Center for Environment and Geographic Information Services, Dhaka for their comments on the draft thesis that helped me a lot to improve the quality of the thesis.

Finally, I would like to express a very special indebtedness to my parents whose encouragement and support was a continuous source of inspiration for this work.

# ABSTRACT

Bank erosion and sedimentation are major constraints to alluvial river management in Bangladesh. Bank erosion deteriorates the socio-economic conditions of floodplain inhabitants due to loss of valuable agricultural land and settlement. Bankline of the river Madhumati at Mollickpur has been shifted approximately 1 (one) kilometer during the last twelve years. Due to erosion, people lost their land and became helpless, jobless. Many of them having no buying capacity migrated to towns/cities. Some of the destitutes due to bank erosion now mostly depend on rickshaw for their livelihood.

The local people are very much concerned about the behavior of the river. They think that the river will continue its erosive characteristics at the bend if proper countermeasures are not adopted. The partial protective work aggravated the downstream erosion situation. The incomplete protective measure should immediately be completed. They suggested that the whole bend should be taken under protective measures.

Physical experiment was carried out to test whether erosion will propagate or not. The bend channel was then examined to determine its response under low cost protective measure i.e. permeable spur which are partially executed in a portion of the actual bend. A couple of combination was tested to figure out its performance.

It was clearly observed that the flow tends to shift towards the concave side from the mid section of the bend channel if there is no protective work along the concave side of the bend. In the permeable cases the flow is diverted remarkably from the structure and also from the embayment zone of the series of spurs. Dikes functioned as blockages to the flow. Although the flow was shifted and maintained its direction almost parallel to the bank, the magnitude of the velocity was significantly decreased in the embayment area and also in between the spurs.

The bed morphology in the test without permeable groin (T00) shows that the bed degradation occurs at the concave side through all over the channel. The bed morphology in the permeable case is quite different. At the heads of the dikes, the flow diverted, which led to local scouring. Local scouring occurs at the toes of all the dikes. The main channel in the dike zone degrades significantly. Although the main channel is deepened, deposition is found along the near-bank area in-between the dikes.

No significant deposition occurs between 1st and 2nd spur in both the permeable cases. But the test with seven spur (T07) vividly shows sedimentation in between 2nd and 3rd,

and 3rd and 4th spur. The test with ten spur (T10) also responses in sedimentation in between 2nd, 3rd and 4th spur that relatively less with respect to T07. The highest $h_d/h$ for T00 is 0.24 and that for T10 is 0.23, where $h_d$ is deposition depth and h is water depth. On the other hand maximum hs/h for T00 is 0.36 and that for T10 is 0.37, where $h_s$ is for scour depth. After the 7th spur, deposition occurs along the outer bank in both the cases. But in T07 fresh scouring happen after a certain length of deposited near bank.

These intuitive comparisons made it clear that the permeable dikes were able to decrease the velocity in the embayment while increase it in the main channel. As a result, they might be utilized to protect the river bank from erosion and improve the navigability by deepening the main channel. The T07 is incapable of preventing the erosion all through the outer bank. The T10 responses in a reliable manner of protecting the scour for the whole bend as indicated by the local people during social survey.

## ABBREVIATIONS

| | |
|---|---|
| BUET | Bangladesh University of Engineering and Technology |
| BWDB | Bangladesh Water Development Board |
| CC Block | Cement Concrete Block |
| FAP 21 | Flood Action Plan 21 |
| FGD | Focus Group Discussion |
| IWFM | Institute of Water and Flood Management |
| PWD | Public Works Datum |
| RHD | Roads and Highways Department |

## TABLE OF CONTENTS

## LIST OF SYMBOLS

$\phi$ = direction angle measured from the mean down valley direction.

$\phi_0$ = maximum angle the curve makes with the mean downstream direction.

$s$ = distance along the meander curve.

m = wave length, the total distance along one meander length.

k = sinuosity

B = channel width

M= meander belt

T00 = test run without any spur

T07 = test run with seven spur

T10 = test run with ten spur

# LIST OF TABLES

# LIST OF FIGURES

# CHAPTER ONE

# INTRODUCTION



## 1.1 Background

The Gorai-Madhumati river is a principal distributary of the Ganges. The same river has been named as the Gorai in the upper course and Madhumati in the lower course. The Gorai-Madhumati is one of the longest rivers in Bangladesh and its basin is also very wide and extensive. Agriculture and irrigation in southwest region of Bangladesh are very much dependent on the Gorai-Madhumati. The Gorai-Madhumati has a flood discharge of nearly 7,000 cumec but in winter its flow goes down to 5 cumec (Feasibility Report, 2001).

The river Madhumati at Mollickpur is severe erosion prone. From the field visit (October. 2007) it is found that due to bank erosion, people lost their land and became helpless and jobless. Many of them migrated to towns/cities for their livelihood. Some of the destitutes now mostly depend on rickshaw for their livelihood.

The villagers are discontent for the inadequate protective measure along the bend. The local people demand to prevent the bank erosion and reduce human sufferings along with economic losses.

## 1.2 Previous Bank Protective Works

A sub project was taken in the fiscal year of 2000-2001 to protect the Mollickpur high school and adjacent flood control embankment at Mollickpur in the upzilla Lohagra of the district Narail

In the year of 2002, design circle-5 of Bangladesh Water Development Board (BWDB) recommended 1125 m bank protection work on the basis of observed field data. But the recommended protective work was not executed In 2005 field official of BWDB felt that the protective work should be 1200 m along the river bend. But due to fund constraint all the protective work was not executed at a time. In the fiscal year of 2005-06 bank protective work was executed for only 145m. The cost was Tk.1.43 lakh/meter. During the next monsoon the river experienced a large flow of water. As a result the tendency of erosion aggravated in the both edge of the protective work and consequently the bank line shifted.

## 1.3 Objectives of the Study

The objectives of the proposed study are as follows:

i. To assess historical bankline changes at the study reach.

ii. To determine lowcost method for river training work for the study reach.

iii. To carry out physical experiment to test the effectiveness of the selected option for river training work.

## 1.4 Outputs

This study is expected to provide technically sound and low cost river bank protective method/option at the erosion prone bend in a river.

## 1.5 Limitations of the Study

For the low cost river training works only permeable dikes were considered. Due to lack of availability of geo referenced satellite images of the study reach the assessment of bank line shifting could not be done exactly to the real situation. The meander angle ($\phi_0$) for the study reach was $86^0$ but in the physical experiment the channel's $\phi_0$ was $32^0$. The experimental flume was insufficient to produce exactly such a channel. Actual $d_{50}$ = 0.17 mm for the river Gorai-Madhumati. But in the experiment the sediment used whose $d_{50}$ = 0.3 mm. Therefore, the results from the present research are rather indicative to the bank erosion problem in the real river.

## 1.6 Structure of the Report

Chapter 1 Gives introduction to the study including background, objectives of the study and outputs.

Chapter 2 Summarizes the profile of the study area providing overall information as to location of the study area, bank erosion situation, river condition, severity of the problem.

Chapter 3 Provides reviews of available literatures mainly on river bank migration at a bend of a meander river, erosion process at river bend, past studies on the river Gorai-Madhumati and its findings, practices to prevent bank erosion in Bangladesh.

Chapter 4 Briefly describes the methodology of the study.

| | |
|---|---|
| Chapter 5 | Provides brief description on local people's perception and mitigation measures on river erosion and their suggestion to prevent the erosion. |
| Chapter 6 | Provides detail description on the physical experiment in the laboratory to investigate the performance of low cost method (i.e. permeable spur) for river training work and the results and analyses of the laboratory experiments/tests for the protective measures. |
| Chapter 7 | Furnishes the conclusions along with recommendations. |

# CHAPTER TWO

# STUDY AREA

## 2.1 Location of the Study Area

The study area is located at Mollickpur under the Lohagara upzilla of Narail district. The study area is shown in Figure 2.1. The study reach is a portion of the river Gorai-Madhumati which lies in the Southwest region river systems of Bangladesh.

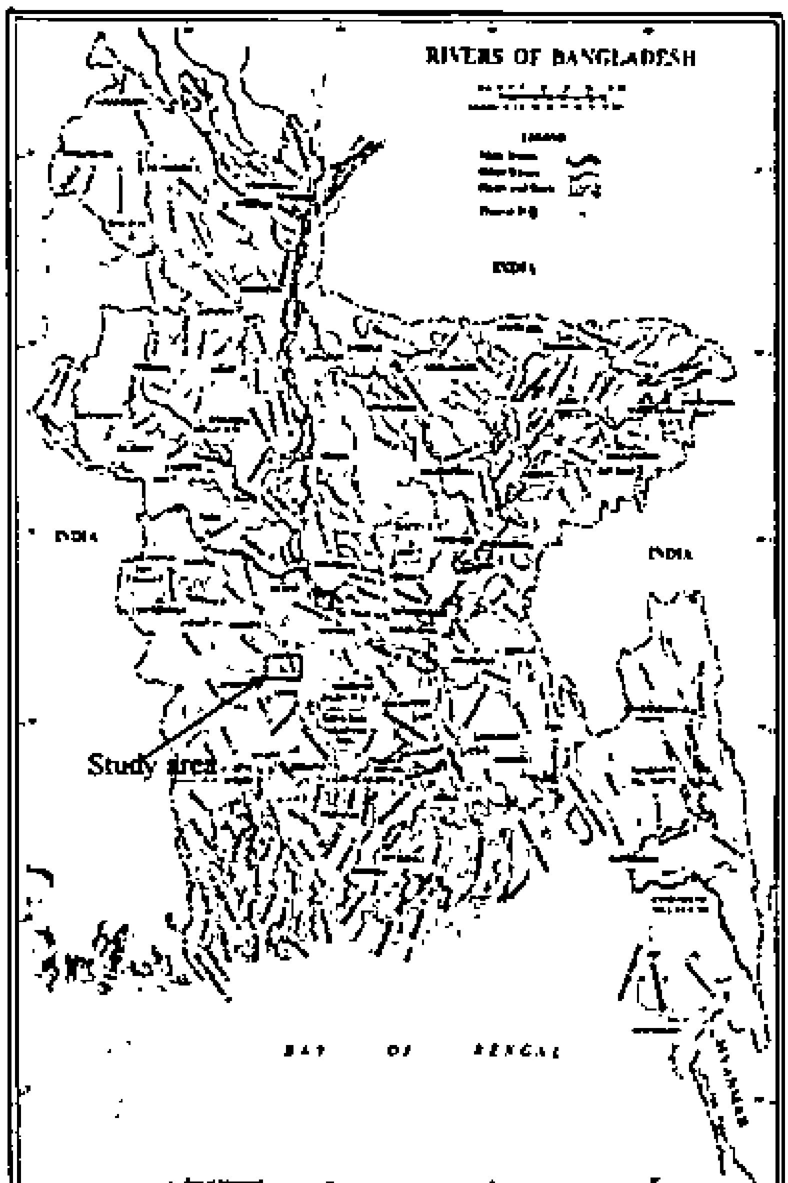
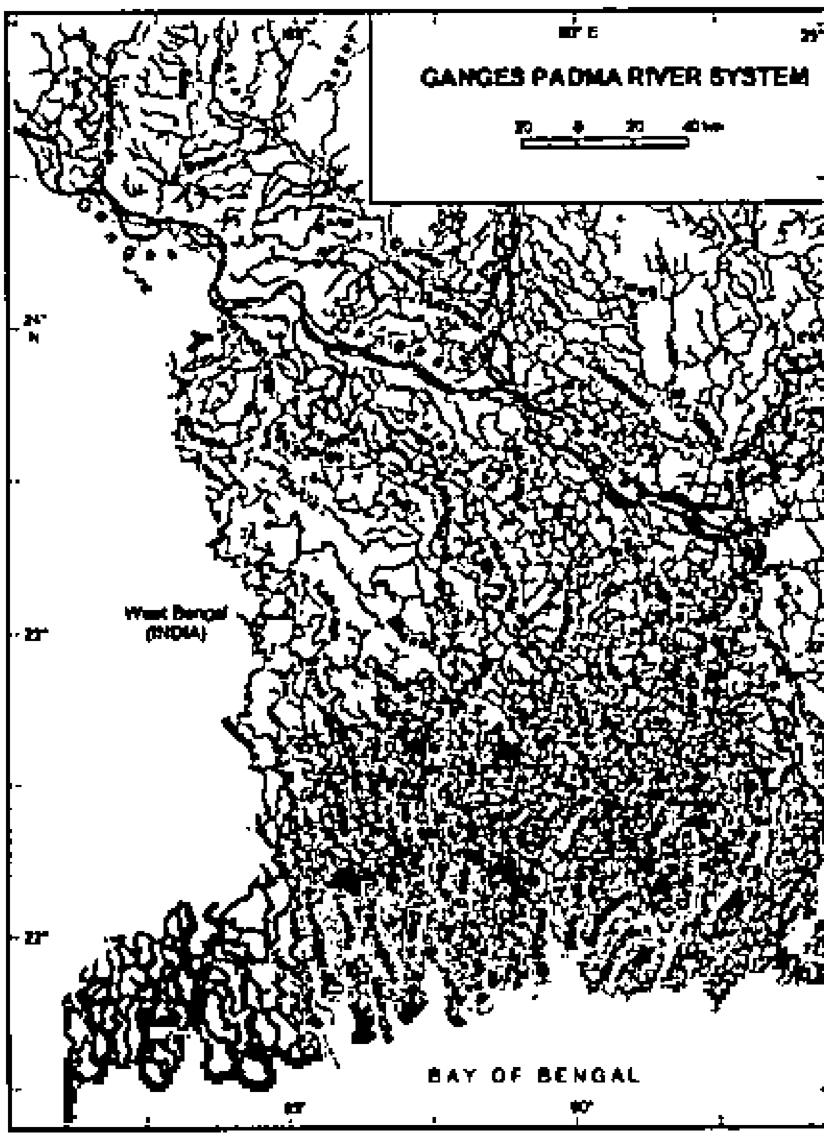



Figure 2.1: Study area shown with respect to the river systems of Bangladesh

## 2.2 River Systems

### 2.2.1 Southwest Region Rivers

98 rivers are included in Southwest hydrological region of Bangladesh. The river systems in the Southwest region are shown in Figure 2.2. It is seen that the main source of sweet water in these river systems is the Gorai river and characteristics of these rivers are greatly influenced by the tidal flow.




(Source: IWM)

**Figure 2.2: River systems in Southwest region**

## 2.3 The Gorai-Madhumati River

### 2.3.1 River Description

The Gorai-Madhumati river systems is shown in Figure 2.2. The river Gorai is the major right bank distributaries of the Ganges River. It branches off from the right bank of the Ganges some 15 km downstream of Hardinge Bridge near Talbaria. It flows through the district of Kushtia and enters the district of Jhenaidah at Goneshpur. There from it travels along the border of Kushtia-Jhenaidah and enters Rajbari district at Chadat. From Rajbari it flows along the border of Faridpur-Magura in the name Gorai-Madhumati to enter the district of Bagerhat. Then it flows through the district of Barisal and falls into the Bay of Bengal at Haringhata. Gorai is a long and meandering river. The total length of the river from its source to Haringhata is about 372 km of which 89 km upto Mohammadpur in the district of Magura is named as Gorai; therefrom upto 137 km downstream it is named as Madhumati and in the remaining 146 km upto Haringhata it is known as Baleshwar. Kumar, Kaligonga, Dakua, Burigorai etc are its main distributaries and Chandana is the tributary to Gorai. The river Gorai is a very old river and its former name was Gouri. The water level gauging stations of the river Gorai are situated at GORAI RLY Bridge, Kamarkhali, Nazirpur and Pirozpur. As the river Gorai-Madhumati flows through the districts of Kushtia, Jhenaidah, Rajbari, Magura, Narail, Gopalganj, Bagherhat and Pirojpur, the agricultural development and water environmental condition of this region are largely dependent on use of the water of this river. Due to large-scale siltation at the Gorai mouth, the off take of the Gorai was completely disconnected from the Ganges particularly in the dry season. Due to reduced dry season flow of the Gorai, environmental quality of Southwest region of Bangladesh is at stake. In 1998/99, Government of Bangladesh took up a project named Gorai River Restoration Project (GRRP) with financial assistance of donor agencies to augment the dry season flow through the Gorai. By early 1999 the river was re-opened through dredging. Then a second season of dredging was undertaken in 1999/2000. The maximum and minimum water discharges recorded at Gorai Railway Bridge during the year from 1998 to 2000 are 6145 $m^3/s$ and 103$m^3/s$ respectively. On the other hand those values measured at Kamarkhali for the same time period are 4550 $m^3/s$ and 57$m^3/s$ respectively (Feasibility Report, 2001).

### 2.3.2 Hydro-morphology

The Gorai-Madhumati River is mainly dependent on the Ganges flows both in the dry and wet seasons. The decline in the post-Farakka dry season Ganges flow resulted in a reduction in the dry season water levels in the Ganges. It caused the rise of bed level at the Gorai mouth from about 4 m +PWD in 1964 to 7 m +PWD in 1989. It is revealed from the feasibility study of GRRP that peak water levels along the Gorai River vary from 13.5 m+PWD at Gorai Railway Bridge to 4.8 m+PWD at Barida Flow through the Gorai River as measured at the Gorai Railway Bridge varies from 0 to 8,500 $m^3/s$. The annual flow volume during the post- Farakka period showed a clear declining trend. It is also reported that the Gorai has stopped flowing within the dry season every year since 1988. The reduction in the mean monthly discharges compared to the pre-Farakka period from November to May is also quite significant.

The average width and depth of the Gorai River is about 540 m and 6 m, respectively. Over the last 30 years the width of the upper reaches (upstream of Kamarkhali) increased and the depth decreased. In the lower reaches no significant changes have been observed. Changes in the upper reaches of the Madhumati River (Bardia to the confluence with the Beel Route) are very significant. The river decreased its average width from 310 m to 190 m and the average depth from 4.9 to 2.8 m (Feasibility Report, 2001).

### 2.3.3 Sediment Transport

The bed material of the Gorai-Madhumati River consists of fine sand having $d_{50} = 0.17$ mm. It is estimated that the annual average bed material transport in the Gorai is about $18 \times 10^6$ metric tons and the wash load transport is about $29\times 10^6$ metric tons. The total transport is about $50\times10^6$ tons/year. The concentration of fine sediments reaches more than 1,200 mg/l during the peak flow of the Gorai and drops to 30-40 mg/l during low flows from January to March (Feasibility Report, 2001).

## 2.4 Planform and Bank Line Changes at Study Reach

According to local people, bankline of the river at the study site has been shifted approximately 1 (one) kilometer during the last twelve years. Due to erosion, people lost their land and become helpless and jobless. Many of them migrated to towns/cities.

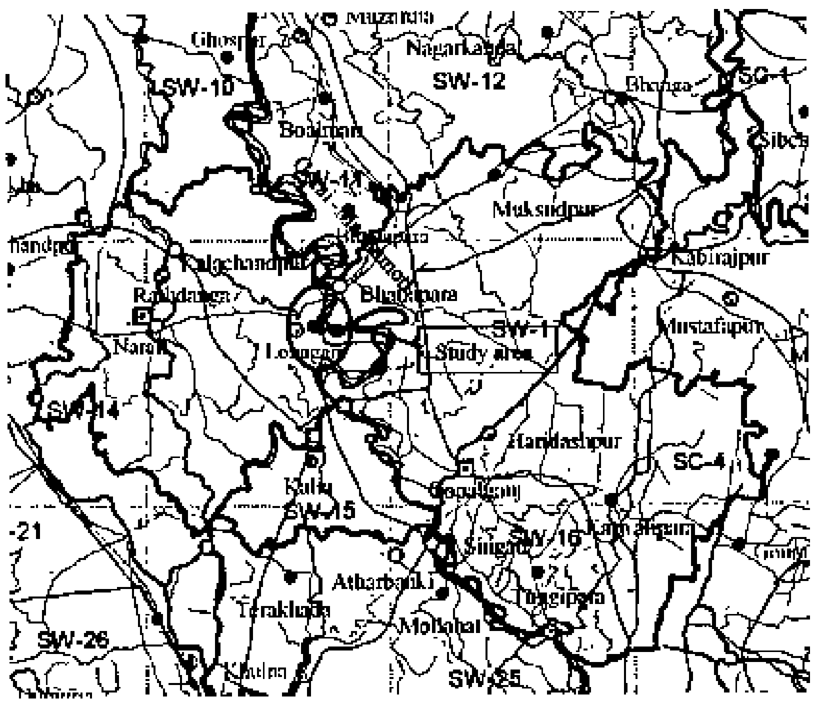



**Figure 2.3: Location of the study area**

The planform and bankline changes of the study site were tried to understand using satellite images (LANDSAT SPOT image for 1973, 1984, 1997). Figure 2.4 indicates the planform and bankline changes of the study site. Figure 2.5 and Figure 2.6 shows the temporal variation of sinuosity and meander angles at cross over of the study reach.

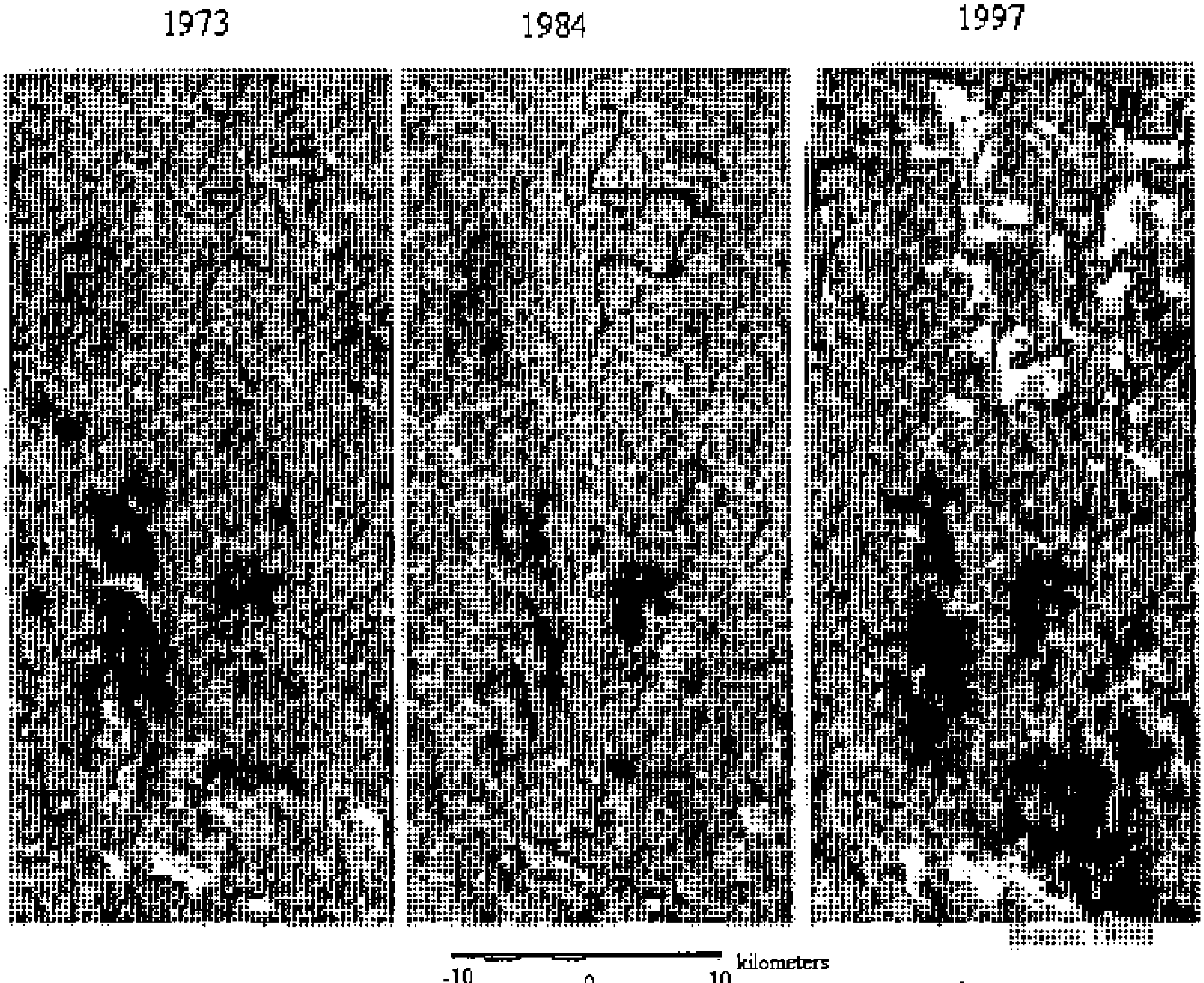



**Figure 2.4: Historical bankline changes of the Madhumati at Mollickpur.**

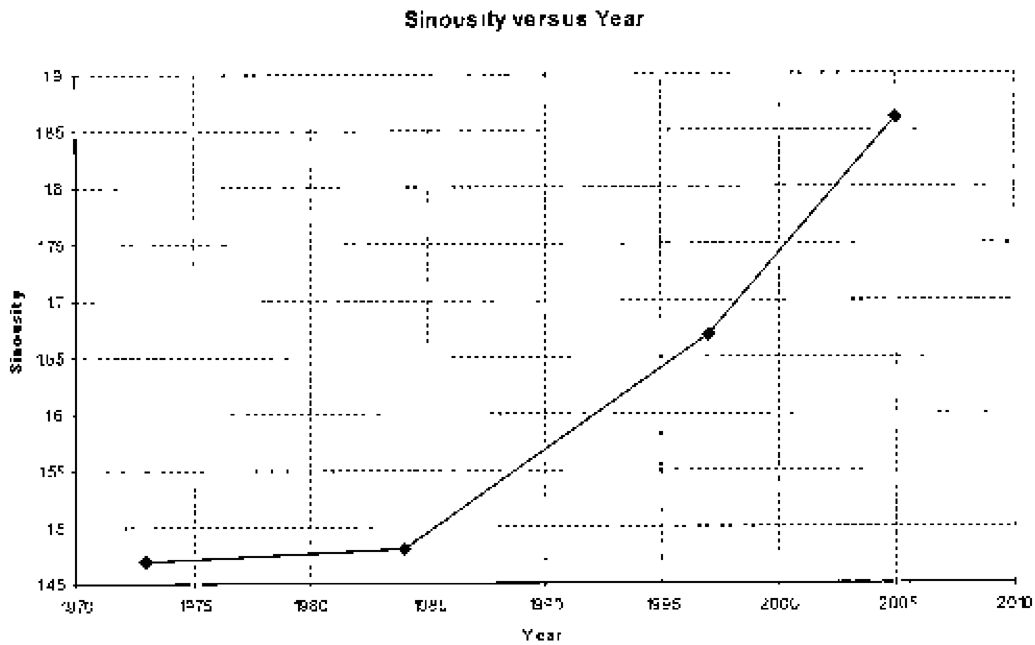



**Figure 2.5: Sinuosity at different years at the study reach**

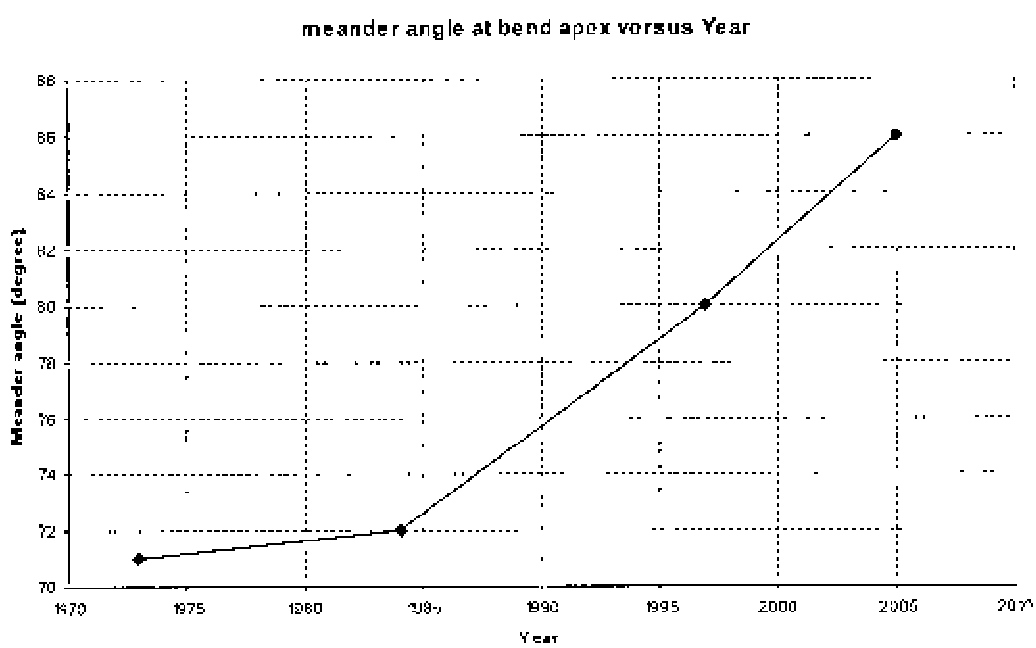



**Figure 2.6: Meander angle at cross over in different years.**

From the Figure 2.6 and Figure 2.7 it is observed that between 1973 and 1984 both the sinuosity and meander angle at cross over at the study site remain nearly unchanged. But after 1984 both the parameter for the study reach rise sharply and attain its maximum for the year of 2005.

# CHAPTER THREE

# LITERATURE REVIEW

## 3.1 Alluvial Rivers

Alluvial rivers are characterized by the fact that the alluvia, on which the river flows, are built by river themselves. Because the beds and banks of alluvial rivers are readily erodible, they are less permanent than most other aspects of the landscape. The main characteristics of these river reaches is the zigzag fashion in which they flow, called meandering. Material gets eroded constantly from the concave (outer) bank of the bend and gets deposited either on the convex (inner) side of the successive bends or between two successive bends to form a bar as shown in Figure 3.1. One would assume a large river flowing in alluvium would maintain a relatively uniform morphology because its dimensions should follow the rules of hydraulic geometry, and its gradient and pattern should reflect the type of sediment load and valley characteristics.

Rivers on alluvial plain may be broadly classified into (i) aggrading type, (ii) degrading type, (iii) meandering type and (iv) braiding type The classification depends on the size and amount of sediment entering the river and its transport capacity for the sediment load. All these four types may be found in a single river from its uppermost point on alluvial plain to its outfall. A particular section may also be aggrading, degrading, meandering or braiding at different times depending upon variation of sediment load and discharge. Among these types, the meandering type is the full and final stage of development (BWDB, 1999).

### 3.1.1 Meandering Rivers

Sinuous rivers or sinuous channels within a river are called meanders. The term 'meandering' refers to the process of forming a sinuous course through bank erosion, but is also used for any shift of the banklines (although, e.g., the widening of a river is not a form of meandering) and to distinguish certain planforms from those of straight and braided rivers. The term 'meandering', 'braided' and 'straight' are not mutually exclusive, because of different water stages the appearance of a river may change, dependent on the number of channels visible at certain water levels.

Where a river has enough capacity to carry incoming sediment downstream without forming large deposits, the whole or part of it will be meandering type. Most of the sediment load carried by the river is brought to the sea.

When a river deviates from its axial path and a curvature is developed (either due to its own characteristics or due to the impressed external forces), the process moves downstream building up shoals on the convex side, results in further shifting of the outer bank by eroding on the concave side.

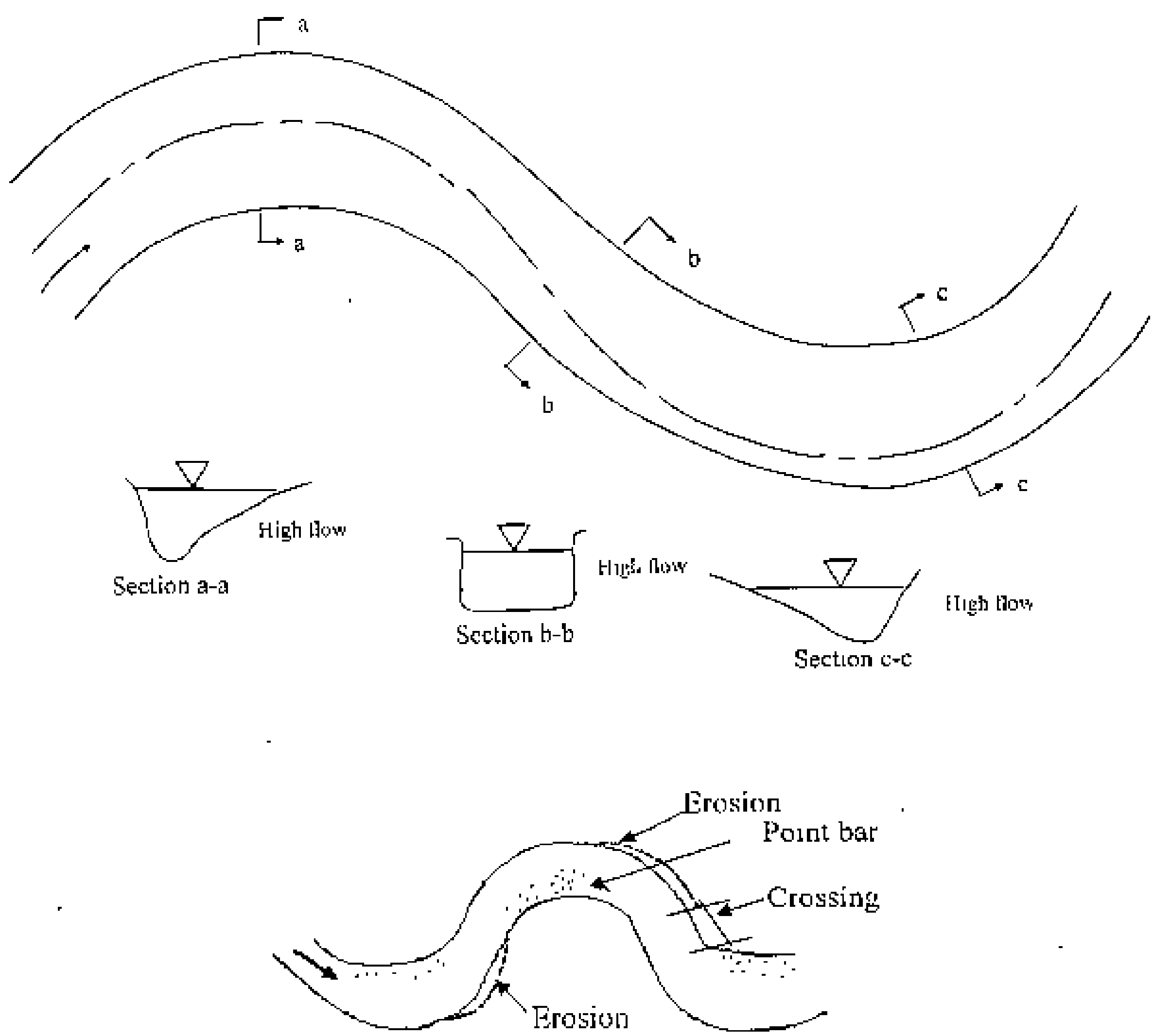



**Figure 3.1: Meandering process at bends**

Formation of successive bends of reverse order may lead to the formation of a complete S curve called meander. When consecutive curves of reverse order connected with short straight reaches (called crossing) are developed in a river reach, the river is stated to be a meandering river. Figure 3.1 shows the meandering process at bends.

### 3.2 Causes of Meander Formation

The widely accepted theory behind meandering is based upon the turbulence generated by the excess of river sediment during floods. It has been established that when the silt charge is in excess of the quantity required for stability, the river starts building up its slope by depositing the silt on its bed. This increase in slope tends to increase, in turn, the width of the channel if the banks are not resistant. Only a slight deviation from uniform axial flow is then necessary to cause more flow towards one bank than towards the other. Additional flow is immediately attracted towards the former bank, leading to shoaling along the latter, accentuating towards the curvature of the flow and producing, finally, meander in its wake.

Four variables, governing the meandering process are: (i) valley slope, (ii) silt grade and silt discharge, (iii) discharge, and (iv) bed and bank materials and their susceptibility to erosion. All these factors considerably affect the meandering patterns, and all of them are interdependent. On the basis of this theory and experiments, various empirical formulae have been developed for connecting different meander parameters, but much remains to be learnt about the meander process (FAP-21, 2001).

### 3.3 Shape of a Meander

Meander can be described as a circular curve, sine curve, parabolic curve or sine-generated curve in a meander delineated using circular curve, arc of a circle is used as the elementary form describing a meander. Figure 3.2 shows the definition sketch of a meander river. By locating the centers of circular curves of radius R at various distances d, channel meanders having tortuosity ratios varying from 1 to 5.5 can be generated. A tortuosity ratio of 1 implies a straight channel, while a value of 5.5 appears to be the limiting value when consecutive bends cut into one another.

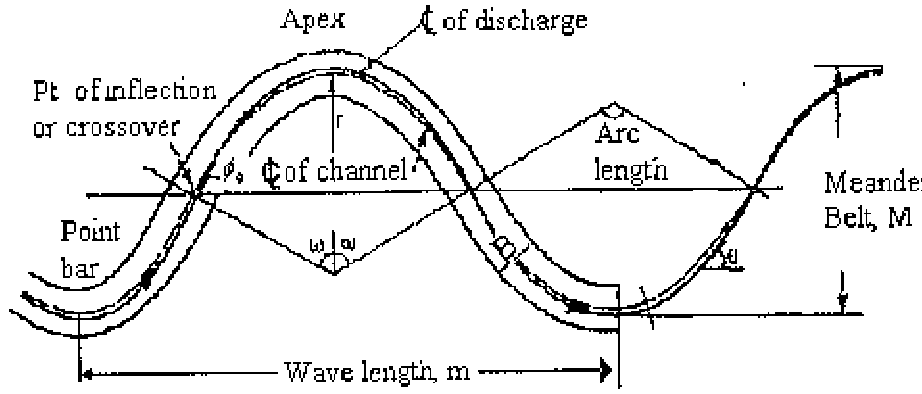



**Figure 3.2: Definition sketch of Meander River**

The planimetric geometry of a meander is that of a random walk, whose most frequent form is that which minimizes the sum of squares of the changes in direction, in each successive unit length. The direction angles are then sine functions of channel distance. This yields a meander shape typically present in meandering rivers. The equation of the sine-generated curve as defined

$$\phi = \phi_0 \sin 2\pi s / m \qquad (3.1)$$

In which $\phi$ = the direction angle measured from the mean down valley direction, $\phi_0$ = the maximum angle the curve makes with the mean downstream direction, $s$ = the distance along the meander curve, and m = wave length, the total distance along one meander length (Langbein and Leopold, 1960).

Sinuosity (k) is the ratio of the length along the channel (i.e. arcual length) to the direct axial length of the river reach. The sinuosity (k) of a meander channel can be expressed as (Langbein and Leopold, 1966)

$$k = \frac{4.84}{4.84 - \phi_0^2} \qquad (3.2)$$

From the series of satellite images sinuosity can be determined for different years and after that meander angle at cross over ($\phi_0$) is found.

## 3.4 Meander Geometry of the River Gorai-Madhumati

In describing the features of a meandering stream the meander wave length (m), the meander belt (M), channel width (B), radius of curvature, ($r_c$) and the sinuosity ratio (k) are important. But traditional meander scale and shape indices are the meander wavelength and radius of curvature (Ferguson. 1975).

For the river Gorai-Madhumati, meander wavelength and meander belt was strongly correlated with the average channel width in few cases. There is also a good correlation between dominant discharge and meander parameters. It was also observed that the ratio of average meander wave length to average meander belt was gradually decreasing with time (Islam, 1996).

Relationships were established between meander wavelength (m), and channel width (B) for each meander.

m = 13.60 B in 1953

m = 12.87 B in 1973

m = 14.32 B in 1980

m = 13.26 B in 1990

Relationships were also developed between meander belt (M) and channel width (B) for the river Gorai-Madhumati, using the meander bends considered. The relationships were

M = 8.62 B for 1953

M = 10.09 B for 1973

M = 11.75 B for 1980

M = 11.68 B for 1990

The bends were migrating in an unpredictable manner. The migration rates were ranges from 5-142 m/year and the average migration rate was about 40 m/year. The bend migration rate depends on the relative bend curvature (r/w). The maximum migration rate occurred with the relative bend curvature value r/w = 2.5.

The average bed slope of the river was gradually decreasing along the downstream direction. The average bed and valley slope of the river were $4.654 \times 10^{-5}$ and $7.47 \times 10^{-5}$, respectively. The overall sinuosity of the river was found to be in the range of 1.68 to 1.84 which is greater than 1.5 which indicates clearly a meandering river (Islam, 1996).

### 3.5 Flow in Bend

Flow in river bends is a problem of great importance from an engineering point of view and may further be characterized as one of the key problems in river morphology (Engelund, 1974). A systematic research on meandering appears to have been initiated towards the ends of the 19th century (Silva, 2006). Processes of river bank erosion play an important role in theories of meander development (Pizzuto and Mecklenburg, 1989). When water flows from a straight channel into a bend, the variation of the centrifugal forces will induce a so called secondary flow, which is transverse circulation. The range of problems involved in such curvilinear flow is very large and extremely complicated (Engelund, 1974). Rates of bank migration are linearly related to the magnitude of the near bank velocity (Pizzuto and Mecklenburg, 1989). Rohrer (1984) and Hooke (1975) emphasized on consideration on the evacuation of sediment from toe of the bank along with the magnitude of velocity and direction of near bank flow. Hickin and Nanson (1975) for their part, accounted for the complexity of meander evolution in terms of a hydraulic control, possibly related to flow separation, that modulates erosion according to local channel curvature (Lapointe and Carson, 1986). The ratio between radius of curvature to channel width is an important parameter controlling the pattern of river migration (Hickin and Nanson, 1975).

Bends occur frequently in natural water courses and need to be provided even in artificial channels because of the constraints in the alignment of such channels. The flow in bends is non-uniform and is more complex to analyze than that in straight channels because of the presence of normal acceleration in curved flows. It is often necessary for the engineer to understand and control the behavior of the flow around bends in rivers and canals.

A bend may introduce only small losses, but may at the same time also set up a disturbance in the flow, which persists for some distance downstream. Besides, when water flows in a bend, it confronted with spiral flow. Spiral flow refers to movement of water particles along a helical path in the general direction of the flow (Figure 3.3)

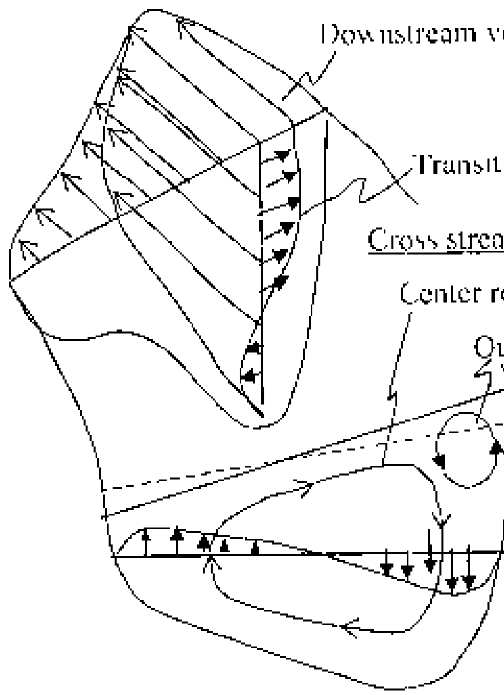



**Figure 3.3: Secondary Flow**

Figure 3.3 delineates that in addition to the major velocity components normal to the channel cross section, there are transverse velocity components in the cross section. These transverse components will create a so-called secondary flow (Ghahfarokhi et al., 2008).

## 3.6 Traditional and Low Cost River Training Measures

River training measures comprise of permanent and recurrent measures, which are built either on the mainland, the flood plain or attached chars. A large variety of traditional and low cost measures is existent. such as (a) bandals, (a) floating screens. (c) intelligent dredging. (d) closure dams, (e) artificial cut-offs. (f) porcupines. (g) retards, those are being used in Bangladesh and surrounding countries. In general, due to constraints of the natural material and hand driven equipment used, these measures are restricted to a certain range of applications and comparatively low hydraulic impacts. Selection of any one of the measures depends mainly on the strategy followed and on the expected hydraulic loads as well as on available materials and funds. If the ratio of structure service life versus structure life time approaches unity, the theoretical optimal design in economic terms is achieved. Therefore, structures that can be adopted and reinforced without difficulties after completion are to be favoured and are economically most feasible. (FAP 21, 2001)

### 3.7 Standard Practices

In this category two types of structures are used in Bangladesh which directly (revetment) or indirectly (groines) protect the bank from erosion. The past experience of using permeable groine as bank protective measure cost relatively low in various rivers of Bangladesh.

#### 3.7.1 Groines

Groines are stone, gravel, rock, earth or pile structures built at an angle to the river bank to deflect flowing water away from downstream critical zones to prevent erosion of bank. The words spur and groine are used almost synonymously. Groines vary considerably not only in their construction and appearance, but also in their action on stream flow. These are considered as partly active and partly passive measures. Groines may be constructed for multiple purposes to control erosion, to establish and maintain safe navigation channels as well as to reduce the flow velocity downstream from the structure to initiate siltation in that area (land accretion)

#### 3.7.2 Permeable Groine

Permeable groines (Figure 3.4) are generally constructed with timber, steel or reinforced concrete piles driven or sunk into the river bed in one or several rows. The individual vertical piles are mainly subjected to horizontal loads, by flow and wave attack. Floating debris (e.g., bamboo bundles, uprooted plant trunks, floating aquatic vegetations) may affect the performance of the groines by blocking permeable part of the groine. To prevent from flow separation and to achieve gradual deceleration of the flow velocities towards the river bank, maximum permeability (e.g., about 80%) should be provided at the groine head with a decreasing permeability (up to about 40%) towards the groine root.

To prevent local scouring close to the pile row a bed protective or a light falling apron of rip-rap or boulders is used. By increasing the permeability of the pile row towards the head of the groine the maximum depth of the local scour hole can be significantly reduced. The low scour is the main reason for applying permeable groines. They also reduce cost involved and risk of failure due to local scour around groine head (FAP 21, 2001).

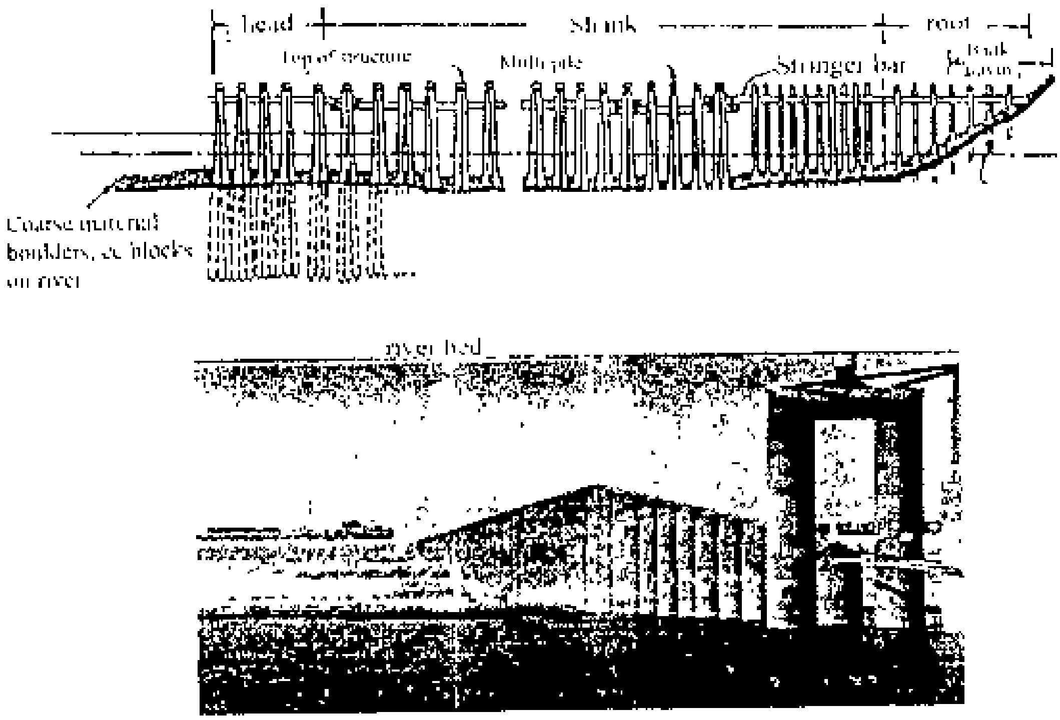


**Figure 3.4: Permeable Groine (adopted from Bhuiyan, 2007)**

### 3.8 Arrangement of Groines

Construction of a single dike or embayment is generally not preferred in the river engineering practice. In order to increase the efficiency and enlarge the improved stretch of the river system, dikes are usually arranged in sequences. A series of dikes (and hence the embayment formed by the consecutive dikes) are observed to differ in many aspects from a single structure. For instance, the exchange process between the embayment and the main flow will be more complex, the upstream flow pattern may have an influence on the downstream, etc. (Zhang et al., 2005).

# CHAPTER FOUR

# METHODOLGY

## 4.1 Reconnaissance Survey

Reconnaissance survey is essential for conducting a research, for understanding the magnitude of river bank erosion, its impact on socio economic condition and the local people knowledge to prevent the erosion of the concern area It is also essential for setting outline for the overall study.

For this study, a reconnaissance survey was conducted with the individual respondents and at the same time a number of respondents also interviewed. The objective of the survey was to quickly obtain the basic information and developing the overall understanding about the area. The formal questionnaire was designed in an understandable manner that is relevant to the rate of bank migration, impact due to erosion. A focus group discussion (FGD) was also conducted. The focus group was the poor people who met the fate of being eroded their land and home. The discussed topic was what the cause behind the river erosion and what might be the probable measure to prevent the erosion.

## 4.2 Sampling Techniques and Design

Random sampling technique has been applied as sampling procedure. Local person is considered as the sampling unit and respondent. Almost 20 no. of samples was distributed randomly out of nearly 200 affected persons.

This study is based on both primary and secondary data. Primary data were used for collecting indigenous knowledge about the erosion and its counter measure and suffering due to erosion.

## 4.3 Data Collection

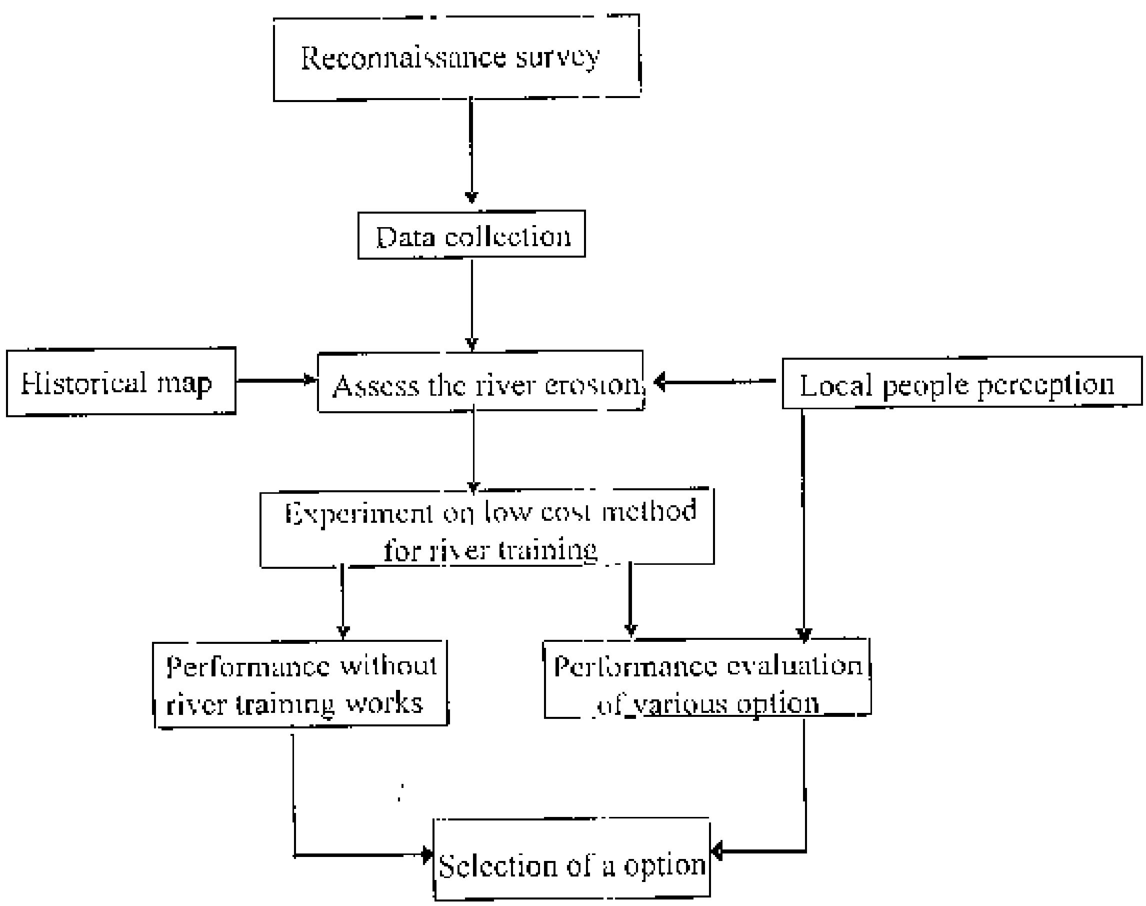
Historical hydrometric, cross section, sediment data, maps, satellite imageries and other relevant information have been collected from available sources i.e BWDB, IWM. Satellite imageries of the study area for the area 1973, 1984 and 1997 (LANDSAT SPOT image, jpg format) and 2008 (Google earth) have been collected.

Map showing the course of Gorai-Madhumati at the study site prepared by Narail Division, BWDB was collected. Information has also been collected from relevant past study reports. All the data have been compiled in a systematic manner aiming at analysis of the data to the required extent to have a clear picture of the study area and the river concerned to asses the existing conditions.

### 4.4 Erosion Prediction and Lowcost Protective Measures

Laboratory experiment was carried out to test whether erosion would propagate or not. The bend channel was then examined to determine its response under low cost protective measure i.e. permeable spur. Performance of the protective measures which had been executed by BWDB was tested. Local peoples' suggestion was taken consideration and laboratory experiments were also conducted to find out the complete solution to arrest the erosion according to the local people. Finally most effective protective option was determined.

### 4.5 Schematic Diagram of the Methodology



# CHAPTER FIVE

# LOCAL PEOPLE'S PERCEPTION ON EROSION AND ITS MITIGATION

## 5.1 Introduction

Field investigation was made to understand the impact of erosion on the local inhabitants over the study reach. From the time immemorial the villagers adjacent to the river bend experiencing the bank erosion. As a result a huge amount of people has become homeless. Being destitute many of them forced to migrate to some other places and change their occupation.

## 5.2 Questionnaire Survey

To figure out the sufferings of the local people a questionnaire survey was conducted on first November, 2008. Figure 5.1 shows the conduction of the questionnaire survey. The questions were open-ended unstructured questions (appendix-C).

The following three areas were considered in preparing the questionnaire:

- determining the question content, scope and purpose
- choosing the response format that will be used for collecting information from the respondent
- Figuring out how to word the question to get at the issue of interest

The questionnaire survey was developed considering the following issue:

Impact of river erosion

a. Direct consequences of the erosion (in terms of losses)

Findings:

i. The river bank eroded at bend every year in varying magnitude. So it exerts sufferings to the people every year.

ii Each year at least 20-25 family loses their houses.

iii. The poor also loses their cropland, homestead, trees, tube-well, pond, latrine, and also other movable and immovable properties.

iv. Due to erosion the victim become homeless and sometimes forced to take shelter on the earthen bund and have to lead miserable life.

v. Some of them become unemployed, day laborers, indebted and have to migrate to town for livelihood.

vi. Children are forced to leave school for financial crisis.

vii. Standing crop near the bank is also eroded away.

viii. They receive no relief or fund to stand again. No rehabilitation project is yet to be taken.

**Figure 5.1: Questionnaire survey**

## 5.3 Focus Group Discussion

A focus group discussion (FGD) was also conducted. The focus group was the poor people who met the fate of being eroded their land and home. The discussed topic was what the cause behind the river erosion and what might be the probable measure to arrest the erosion. Figure 5.2 shows the people participated in the FGD.

Focus Group: Victim of Bank erosion

Topic: Causes and remedy of bank erosion

Findings:

i. The depth at the concave bend of the river is much higher than the other side.

ii. Insignificant amount of water divert towards the lean channel at the bifurcation.

iii. The water flowing from the upstream directly hit the bank.

iv. The river will erode further.

v. The protective measure executed by Water Development Board is sufficient only for the portion of the bend.

vi. Groines and revetment covering the whole bend is required to combat with the erosion. Only the cc block is not enough against the erosion.

vii. The protruded length of the groine to the river is not sufficient to divert the water towards the convex bend.

viii. The existing char at the bend should be removed to distribute water all through the channel. So that the water pressure at the bend can be reduced.

ix. A few villagers think that the bank erosion is the act of ghost or supernatural power.

From the above findings it can be concluded that the local people think the executed protective measure is capable of preventing the erosion for the portion of the bend. But the whole bend needs to be protected with such measure.

**Figure 5.2: People participated in FGD**

# CHAPTER SIX

# LABORATORY EXPERIMENTS

## 6.1 Introduction

The local people are very much concerned about the behavior of the river. They think that the river will continue its erosive characteristics at the bend if proper countermeasures are not adopted. They suggested that the whole bend should be taken under protective measure. The partial protective work aggravated the downstream erosion situation. The incomplete protective measure should immediately be completed. So laboratory experiments/tests were conducted to gain the future erosion scenario of the river bank at the study reach, and also the performance of the permeable groines which were executed and which are proposed to be executed for the study reach.

## 6.2 Channel Properties

Three individual experiments were carried out with a series of permeable dikes and without dike i.e. virgin condition. Both experiments were conducted in a flume located in the IWFM Hydraulics Laboratory, BUET. The existing flume dimension is 16m long, 1m wide and 0.4m deep. But the experimental curved channel was constructed with brick within the existing setup (Figure 6.1). The sinuosity, width, depth, and radius of curvature at bend apex of the experimental channel were 1.07, 0.5 m, 0.4 m, and 11.35 m respectively.

**Figure 6.1: Experimental channel (Photograph)**

## 6.3 Structure Properties

Ten spur were built to conduct the laboratorial experiment. All of the structures have the same properties. The structures were built using wood and steel bar. These were designed to have permeability to 50%. The channel and structure dimensions for the laboratory experiment were maintained 1:200 to the existing field condition. Details of the structures are provided by the Figure 6.2.

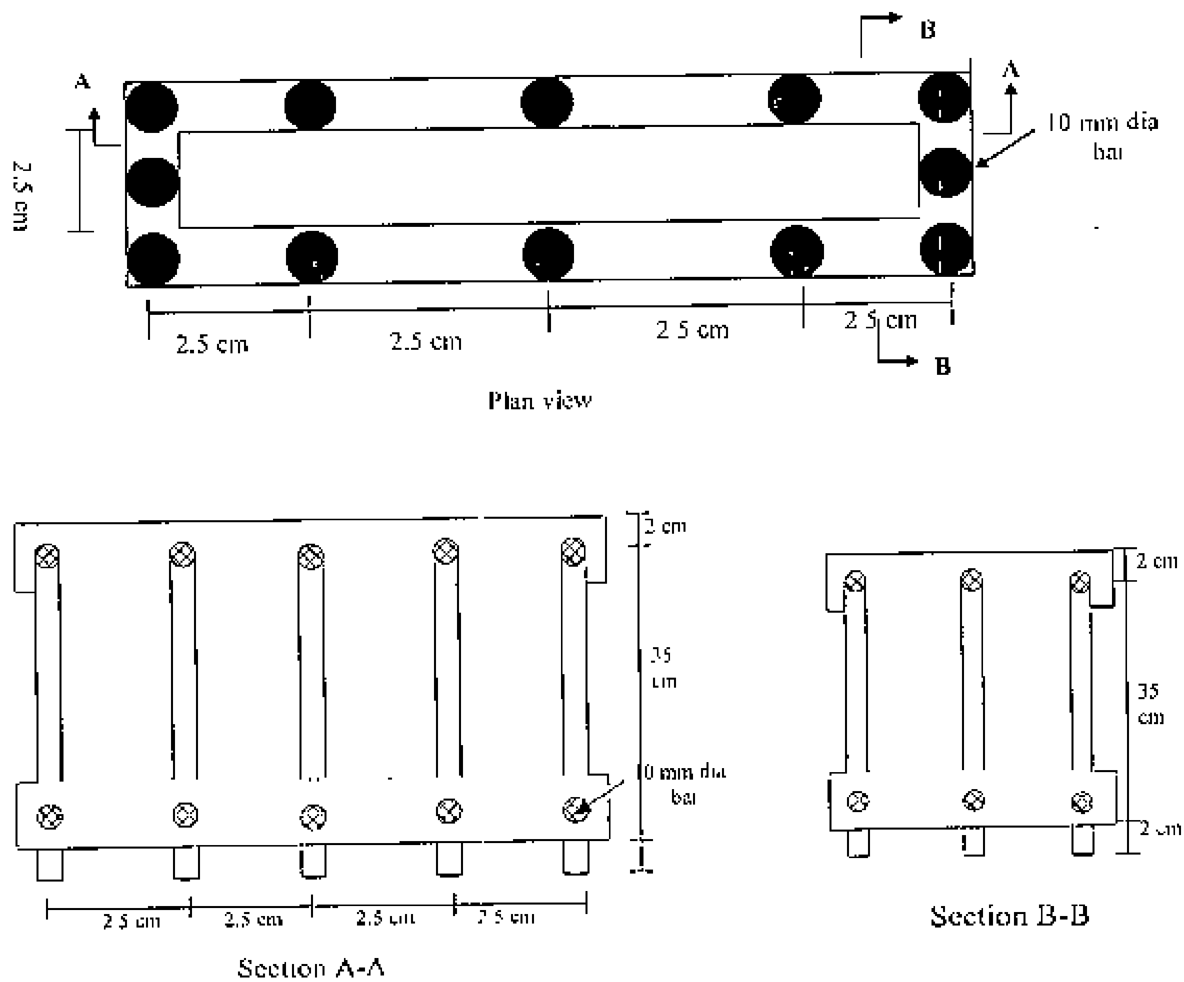



**Figure 6.2: Detail of permeable structures**

## 6.4 Experimental Set up

For the convenience to describe the tests and its results, the tests are named metaphorically. Table 6.1 provides the runs and combination summary.

**Table 6.1: Runs and test combination summary**

| Run / series of spur | $1^{st}$ | $2^{nd}$ | $3^{rd}$ |
|---|---|---|---|
| 1st (T00) | No groine | | |
| 2nd (T07) | 4 (T07X) | 3 (T07Y) | |
| $3^{rd}$ (T10) | 4 (T10X) | 3 (T10Y) | 3 (T10Z) |

T00 was carried out without any structure along the bend channel. Figure 6.3 shows the flow through the channel without any structural intervention. The purpose of the run was to determine/ observe the flow condition i e. streamline profile and surface velocity in response to the pre determined discharge through the channel. But the ultimate objective was to determine/figure out whether the bend migrate laterally or not. This can be calculated using the observed scour of bed at the outer bank.

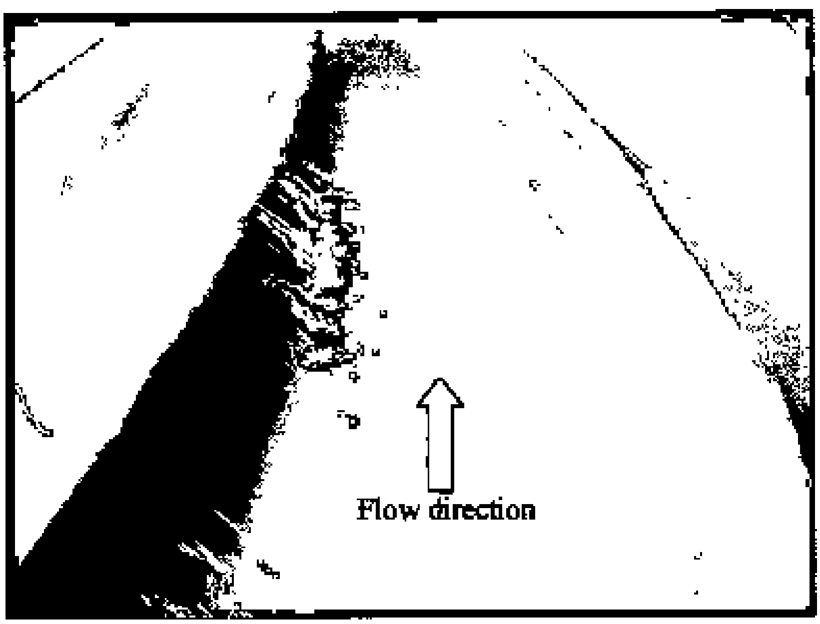



**Figure 6.3: Flow through the channel without structure (Photograph)**

T07 was carried out fixing seven permeable spur with known permeability (50% permeable) and geometric features (Figure 6.2).The structures were established with conformity to the field condition (Figure 6.4). The spur were scaled down according to the ratio of field: laboratory channel to 200:1 and the spacing for T07X were maintained 25 cm between $1^{st}$ and $2^{nd}$ spur, 30 cm between $2^{nd}$ and $3^{rd}$ spur and 30 cm between $3^{rd}$ and $4^{th}$ spur. The gap between the spur is three times of the spur-length. The T07Y was formed by the rest three spurs. The gap between the $4^{th}$ spur and 5th spur (i.e. the last spur of T07X and first spur of T07Y) was 150 cm which is twelve times of the length of a spur. The gap between the 5th and 6th spur was 30 cm and the gap between 6th and 7th spur was 30 cm. The spur length and gap between the spurs were reduced at 1:200 with respect to the field conditions. Figure 6.5 shows the setup for the experimental run T07

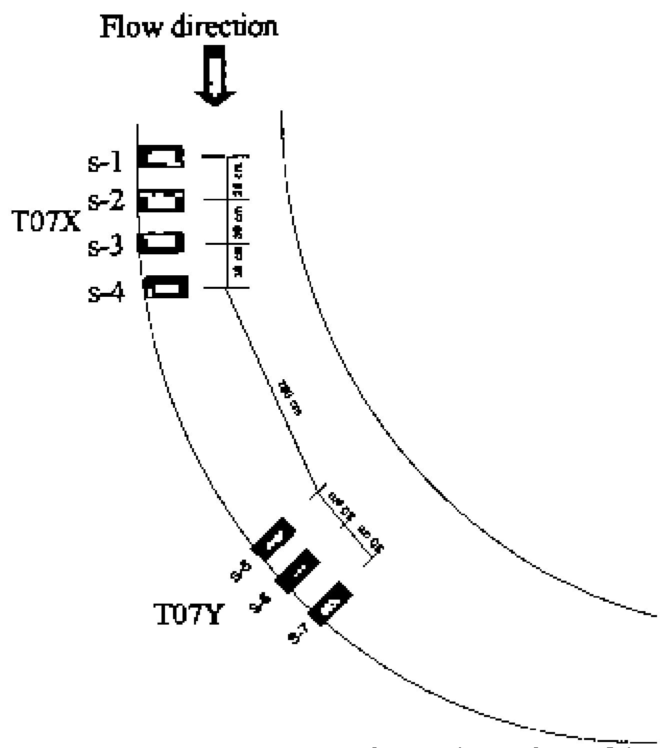



**Figure 6.4: Physical set up for T07 (not in scale)**

**Figure 6.5: Physical set up for T07 (Photograph)**

T10 was carried out with ten permeable spurs (Figure 6.6). There were three series of spur. The first two (T10X and T10Y) were as same for the second run. The T10Z started at a distance of fifteen (15) times of individual spur length from the last spur of the second series of spur. The distance between the spurs, and the distance between first and second series was same as in the second run. The gap between the $8^{th}$ and $9^{th}$ spur was 30 cm, and $9^{th}$ and $10^{th}$ was also 30 cm which represent the proposed field condition at the aforementioned ratio.

All of the experiments were conducted pumping the designed discharge through the artificial channel. There was no provision of gravitational flow. So the model channel was not adjusted for any bed slope. Relatively fine and uniform sands covered the bed of the channel with a thickness of 25.0cm. The sediment had a mean size of d=0.3mm. All these dikes were organized perpendicular to the channel banks (Figure 6.7). The center of the first spur dike was 5.6m away from the inlet boundary. Arrangement was adopted that the water flows in mild manner from the very entry of the flume (Figure 6.8).

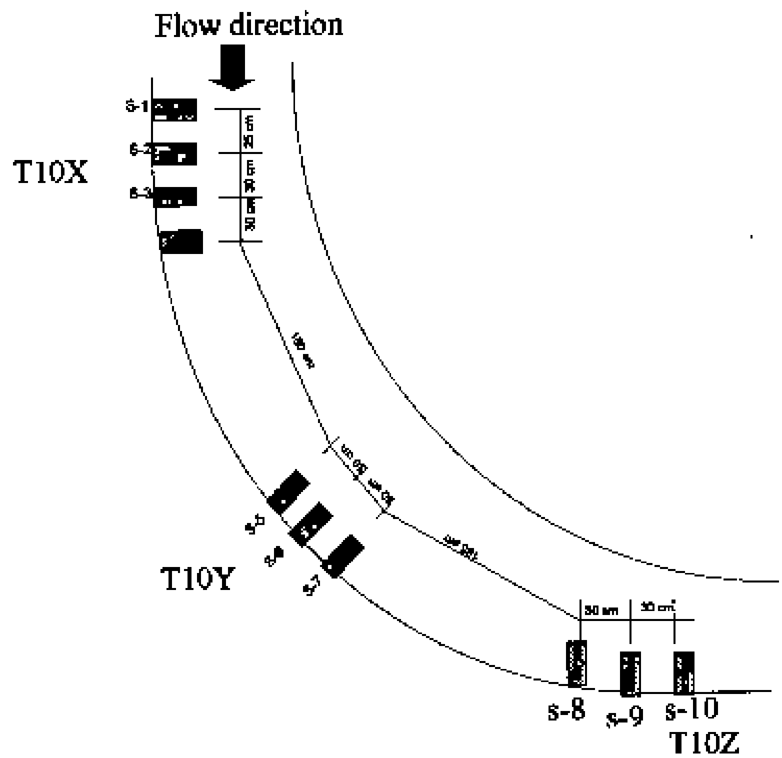



**Figure 6.6: Physical set up for T10 (not in scale)**

**Figure 6.7: Physical set up for T10 (Photograph)**

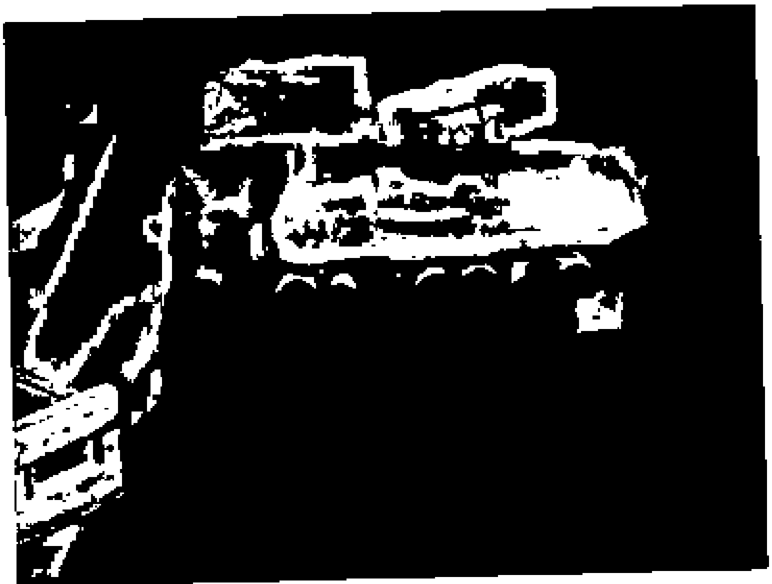


**Figure 6.8: Arrangement for mild entry of water flow into the channel (Photograph)**

Before each experimental run, the sediment bed surface was leveled with a scraper blade mounted on a carriage riding on the rails over the model channel banks. After that, the flume was slowly filled with water from the downstream side. When the desired water depth was achieved by adjusting the height of the tailgate at the end of the flume, the pump was started. In all cases, the dikes were non-submerged. Details of the experimental conditions were summarized in Table 6.2.

**Table 6.2: Details of the experimental conditions**

| Discharge | Mean velocity | Flow depth | $d_{50}$ | Shear velocity ratio | Froude number |
|---|---|---|---|---|---|
| Q (l/s) | u (cm/s) | h (cm) | Mm | ($u^*/u^*c$) | |
| 24.62 | 40.48 | 15 | 0.3 | 1 | 0.50 |

After a continuous running of design discharge for 8.5 hours for the permeable cases, and without spur the riverbed seemed to be unchanged. An equilibrium state was assumed to be reached.

The flow velocity was estimated by floating technique. The streamline was tracked using the punched piece of paper. A point gauge was utilized to measure the water level. And finally a meter gauge was used to determine the bed deformation after the flume was completely drained out. All these measurement devices were mounted on an instrument carriage that traveled on the rails.

## 6.5 Results and Analyses

### 6.5.1 Qualitative Observations

T00 was carried out without any intervention at the concave bend. The motive of this run was to observe the flow condition in the outer bend and determine bed scour which ultimately relates to the bank erosion. It was clearly observed from the Figure 6.9 that the flow tends to shift towards the concave side from the mid section of the bend channel. It was observed following the course of the punched piece of paper.

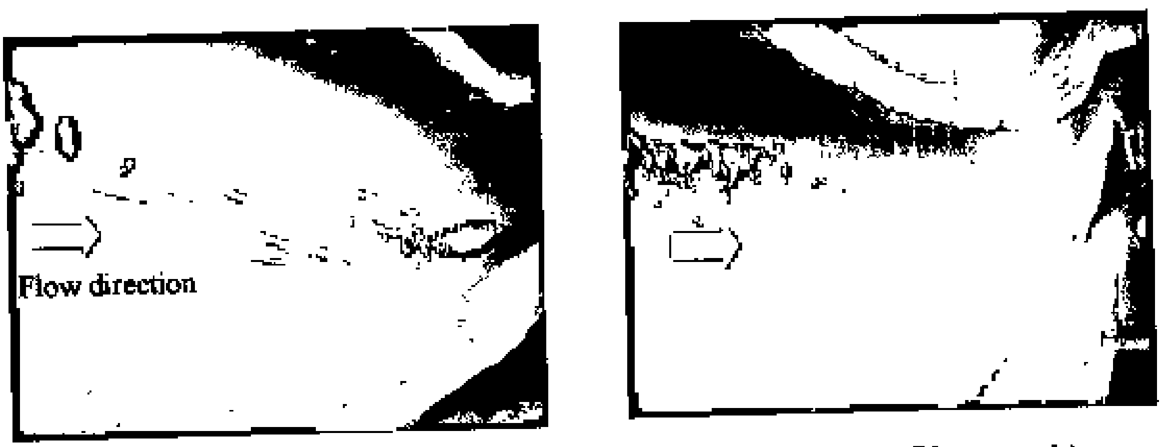



**Figure 6.9: Tendency of flow towards concave side of the bend (Photograph)**

In the permeable case the flow is diverted remarkably from the structure and also from the embayment zone of the series of spurs (Figure 6.10 and Figure 6.11). Dikes functioned as blockages to the flow. Although the flow was shifted and maintained its direction almost parallel to the bank, the magnitude of the velocity was significantly decreased in the embayment area and also in the gap between the spurs.

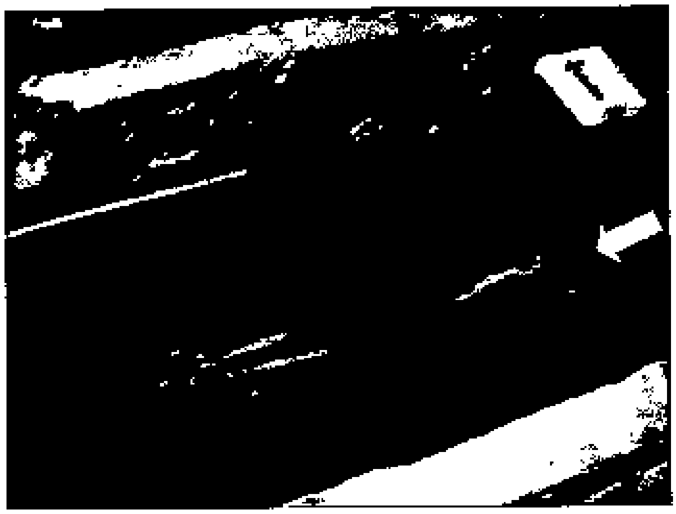


**Figure 6.10: Flow tendency towards the mid channel in the embayment zone (Photograph).**

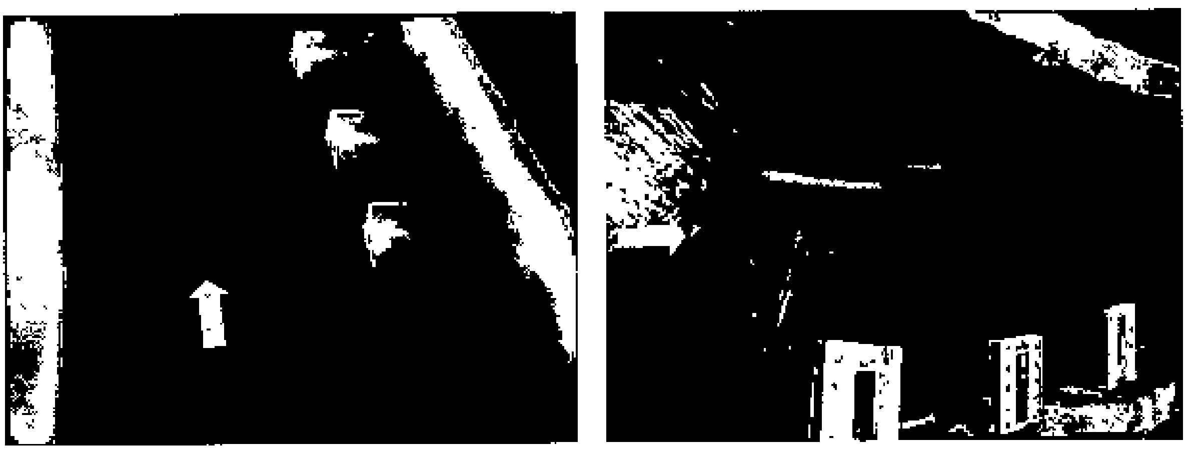
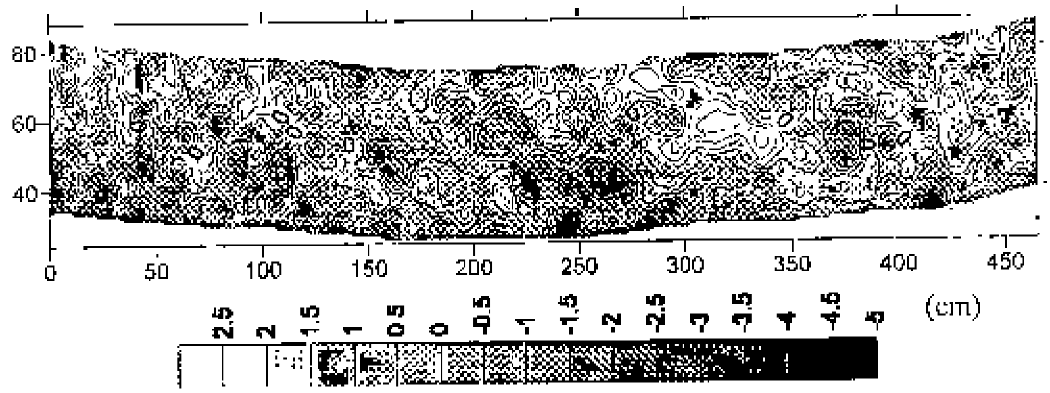


**Figure 6.11: Repulsion of flow from the spur (Photograph)**

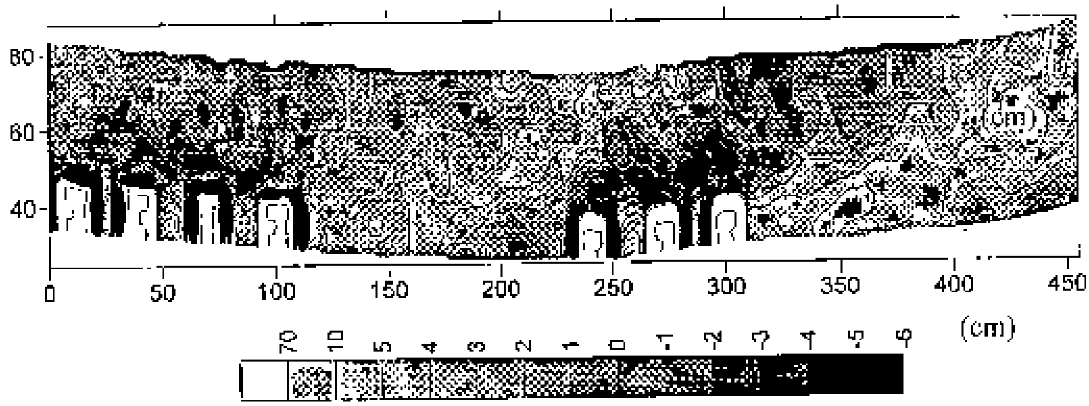
These intuitive comparisons made it clear that the permeable dikes were able to decrease the velocity in the embayment while increase it in the main channel. As a result, they might be utilized to protect the river bank from erosion and improve the navigability by deepening the main channel.

### 6.5.2 Bed Deformation



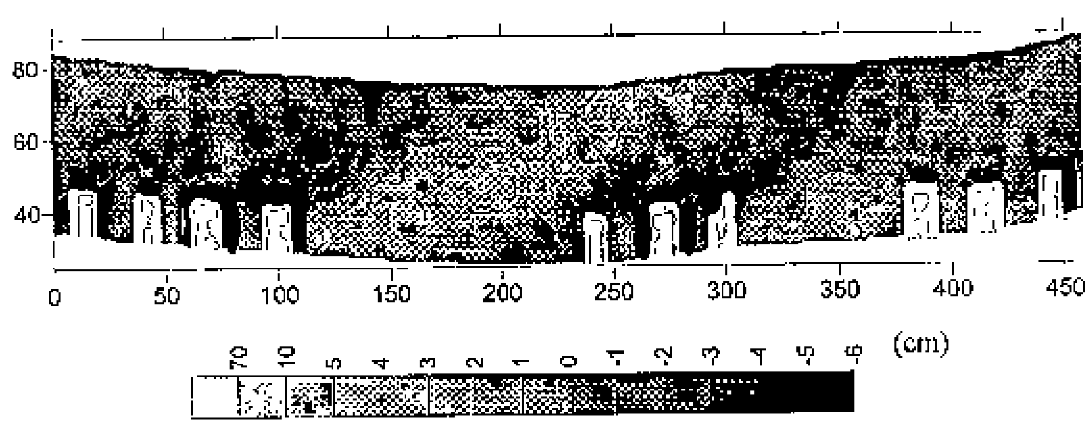

Scale: Bed level (cm), +ve-Deposition, -ve-Scouring

**Figure 6.12: Final bed contours (T00)**




Scale: Bed level (cm), +ve- Deposition, -ve- Scouring

**Figure 6.13: Final bed contours (T07)**




Scale: Bed level (cm), +ve-Deposition, -ve-Scouring

**Figure 6.14: Final bed contours (T10)**

The bed morphology in T00 (Figure 6.12) shows the bed degradation occurs at the concave side through all over the channel. The bed morphology in the permeable cases was quite different (Figure 6.13 and Figure 6.14). At the heads of the dikes, the flow diverted, which led to local scouring. Local scouring occurred at the toes of all the dikes. Compared with the approaching flow area where the bed level had almost no change, the main channel in the dike stretch was significantly degraded. Although the main channel was deepened, deposition was found along the near-bank area in-between the dikes (Figure 6.15).

No significant deposition occurs between 1st and 2nd spur both the permeable cases. But the T07 (Figure 6.13) vividly shows sedimentation in between 2nd and 3rd, and 3rd and 4th spur. The T10 also responses in sedimentation in between 2nd, 3rd and 4th spur that relatively lesser with respect to T07 (Figure 6.14).

There is remarkable gap between 1st series of spur and second series of spur (T07X and T07Y; T10X andT10Y). In both the cases sedimentation occur significantly but the T10 shows sedimentation through more portion of the outer bank in comparison to T07. The highest $h_d$ / h for T00 is 0.24 and that for T10 is 0.28 where $h_d$ is deposition depth and h is water depth. On the other hand maximum hs / h for T00 is 0.36 and that for T10 is 0.37 where $h_s$ is for scour depth. After the 7th spur deposition occur along the outer bank in both the cases. But in T07 fresh scouring happen after a certain length of deposited near bank bed (Figure 6.13). The T10 responses in more reliable manner for protecting the scour with compare to the aforementioned T07.

In case of the T07 and T10 the final bed level shows that the main channel distinctively shifts to the mid of the channel (Figure 6.13 and Figure 6.14). It was also observed that in all the cases the convex bend i.e bed near left bank aggraded hugely. In this case T10 shows the highest deposition. These observations explain why the dikes could be used to improve the navigability and protect the channel bank.

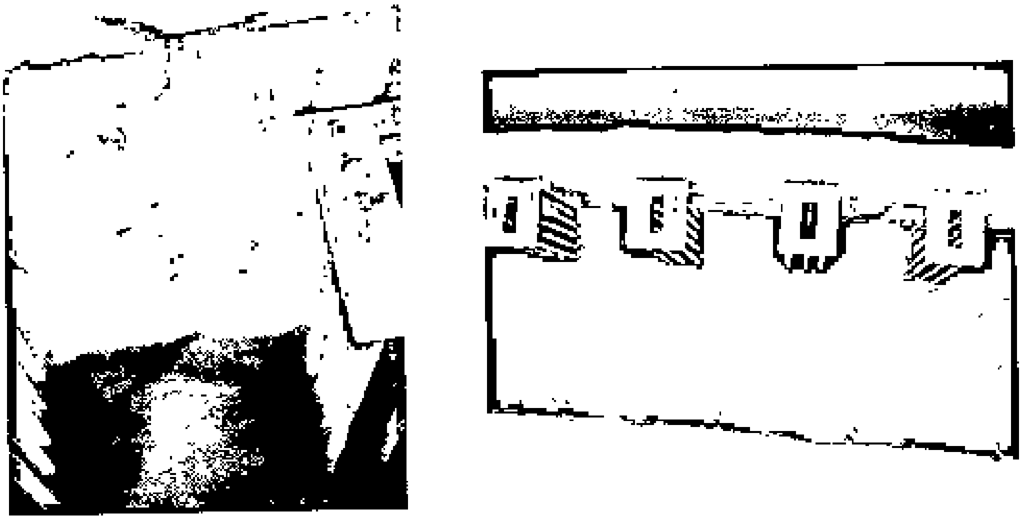


**Figure 6.15: Deposition in between spurs (Photograph)**

### 6.6 Conclusion

It is evident from the laboratory experiments that if there is no protective measure the bank will migrate to inland. The executed measure i.e.T07 shows effective against only for that particular portion of the bend in the field which matches with the test results. The test also shows that fresh erosion started just downstream of the $7^{th}$ spur. In the field it is also observed that after construction of the 7 spur the downstream at the bend experiences more erosion. But the T10 is more effective to arrest the erosion along the whole bend. So it is necessary to construct the remaining three dikes to prevent the erosion completely.

# CHAPTER SEVEN

# CONCLUSION AND RECOMMENDATION

## 7.1 Conclusion

- The erosion situation in the study reach is very much severe. From the time immemorial the villagers adjacent to the river bend experiencing the bank erosion. The river bank eroded at bend every year in varying magnitude. So it exerts sufferings to the people every year Each year at least 20-25 family loses their houses.

- Being destitute many of them forced to migrate to some other places and change their occupation.

- The Gorai-Madhumati is a highly meander river. The meander angle at the cross over and sinuosity of the study reach changed remarkably between the years of 1973 to 2005

- Though the existing protective structures are functioning very well but fresh erosion arises at the downstream of the protective work.

- Local people think that the protective measure executed by Water Development Board is sufficient only for the portion of the bend. It is in prime need to prevent the continuing erosion.

- From the laboratory experiment it is obvious that without any protective structure bank erodes all through the concave side.

- From the laboratory experiment it is evident that the permeable spur functioned as blockages to the flow. There is the tendency of flow outwards the concave side of the bend. The flow is diverted remarkably from the structure and also from the embayment zone of the series of spurs.

- In case of the second run (i.e. T07) and third run (i.e. T10) the final bed level shows that the main channel from the concave side of the bend shifts distinctively to the mid of the channel. In both the cases sedimentation occur significantly along the outer bank but T10 shows sedimentation through more portion of the outer bank in comparison to T07.

- It was also observed that in all the cases the convex bend i.e. bed near left bank aggraded hugely. In this case T10 shows the highest deposition. These observations explained why the dikes could be used to improve the navigability and protect the channel bank.

## 7.2 Recommendations

- Any structural intervention results in fresh adverse impact on the downstream reaches. So protective measure should be adopted over the whole reach.

- The head of the spur should be well protected. It should be designed in such a manner that the local scour cannot be able to topple down the structure.

- Prior to implement such low cost protective measure it will be wise to determine the performance of the series of spur. The gap between the spurs, and series of spurs is very much important to protect the bank over the reach.

- Further study can be conducted to compare the performance of the impermeable spur to permeable spur.

## REFERENCES


Bhuiyan A.B.M F. (2007), *River Erosion Mitigation and Sediment Control Technology in Bangladesh,* National Workshop on Soil, Erosion, Eco-degradation and Poverty Relation in Bangladesh Perspective, International Erosion Control Association, Bangladesh Chapter

BWDB (1999), *Guidelines for Riverbank Protection,* Jamuna Meghna River Erosion Mitigation Project (JMREMP).

BWDB (1990), *Morphological Survey Data of the River Gorai-Madhumati· Period of observation 1988-1989.*

Chang H. (2009), *Regular Meander Path Model.* M.ASCE.

Engelund F. (1974), *Flow and Bed Topography in Channel Bends, Journal of the Hydraulic Division,* Vol.100, HY11, pp 1631-1647.

FAP-21 (2001), *Guidelines and Design Manual for Standardized Bank Protective Structures,* Water Resource Planning Organization, Ministry of Water Resources, Government of Bangladesh.

Feasibility Report (2001). *Gorai River Restoration Project (GRPP).* Main Report, Volume 1.

Ferguson, R.I. (1975), *Meander irregularity and wave length estimation.* J. of Hydrology, Vol. 26

Ghahfarokhi et. al, (2008), *Evaluation of Super elevation in Open Channel Bends with Probabilistic Analysis Methods,* World Environment and Water Resources Congress.

Hickin E.J. and Nanson G.C (1975). *The character of Channel Migration on the Beatton River, Northeast British Columbia, Canada.* Geological Society of American Bulletin, Vol.86, pp. 487-494

Hooke, R.Le B.( 1975), *Distribution of sediment transport and shear stress in a meander bend,* J Geol.,83, pp. 543-565.

Islam M. (1996), *A Study on the Morphological Charateristics of the Gorai-Madhumati River,* M.Sc. Engg. Thesis, Department of Water Resources Engineering and Technology, BUET, Dhaka

Khan ME. Anker M, Patel BC, Barge S, Sadhwani H and Kohle R (1991); The Use of Focus Groups in Social and Behavioral Research: Some Methodological Issues; World Health.

Lapointe M.F. and Carson M.A. (1986), *Migration Pattern of an Asymmetric Meandering River. The Rouge River, Quebec.* Water Resources Research, vol. 22, No 5, pp. 731-743.

Langbein W.B., and Leopold L.B. (1960), *River Meanders,* Bulletin of the Geological Society of America, vol.71, pp. 769-794.

Pizzuto J.E. and Mecklenburg T.S (1989), *Evaluation of Linear Bank Erosion Equation*, Water Resources Research, Vol. 35, No 5, pp. 1005-1013

Rohrer W. L M. (1984), *Effects of flow and bank material on meander migration in alluvial rivers, in River Meandering, Proceeding of the Conference Rivers '83,* American Society of Civil Engineers, New York, pp. 770-782.

Schumm, S.A. (Ed.) (1972), River Morphology. Benchmark papers in geology. Dowden, Hutchinson and Ross Inc. Stroudsburg, Penn. USA, pp 429.

Silva A.M.F.D. (2006), *On why and how do rivers meander*, Journal of Hydraulic Research, Vol. 44, No 5, pp. 579-590

Zhang et. al, (2005), *Flow and Bed Deformation around a Series of Impermeable and Permeable Spur,* Proc. of the International Conference on Monitoring, Prediction and Mitigation of water-related Disasters (MPMD 2005), Kyoto,pp.197-202.

APPENDIX-A: Comparison of Cross Sections after Various Runs

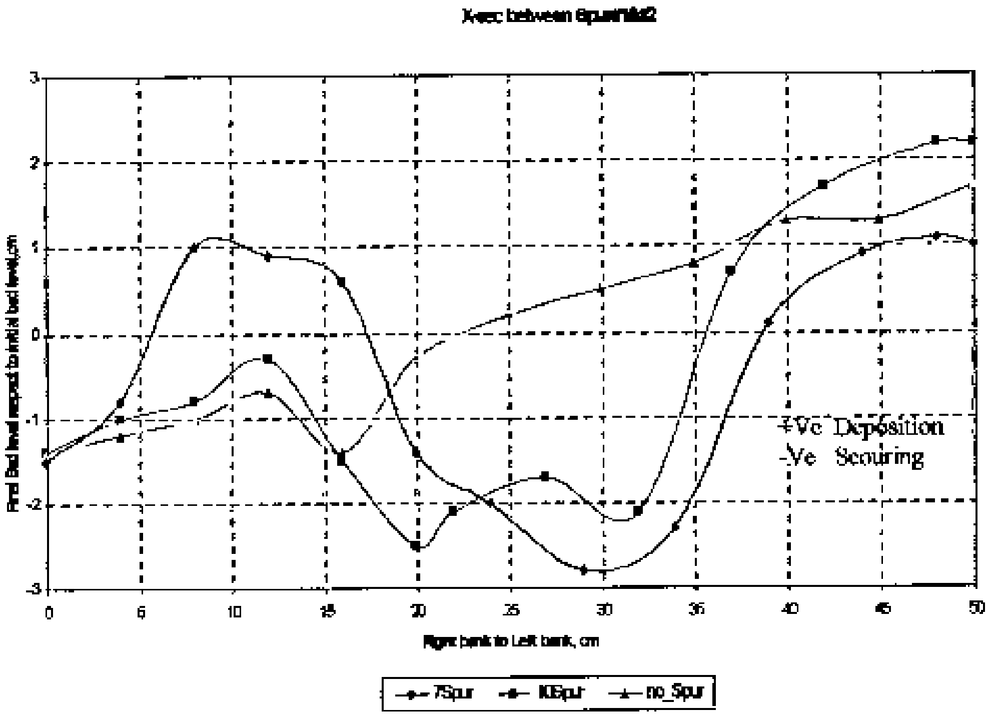



**Figure A1: Cross section in between spur #1 and #2**

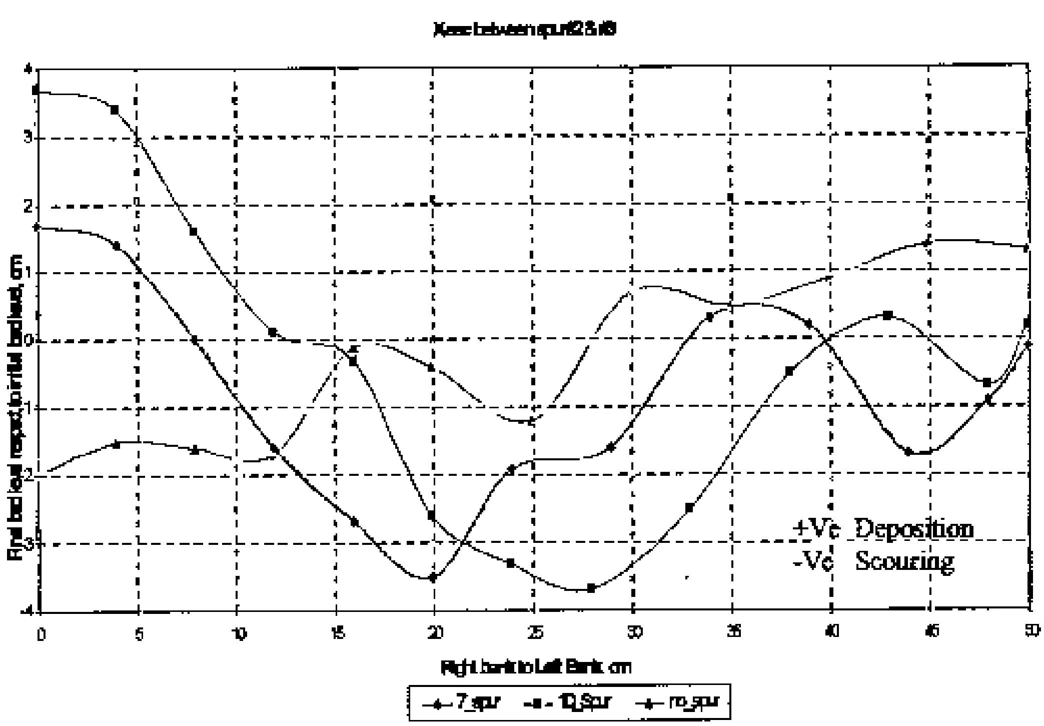



**Figure A2: Cross sections in between spur #2 and #3**

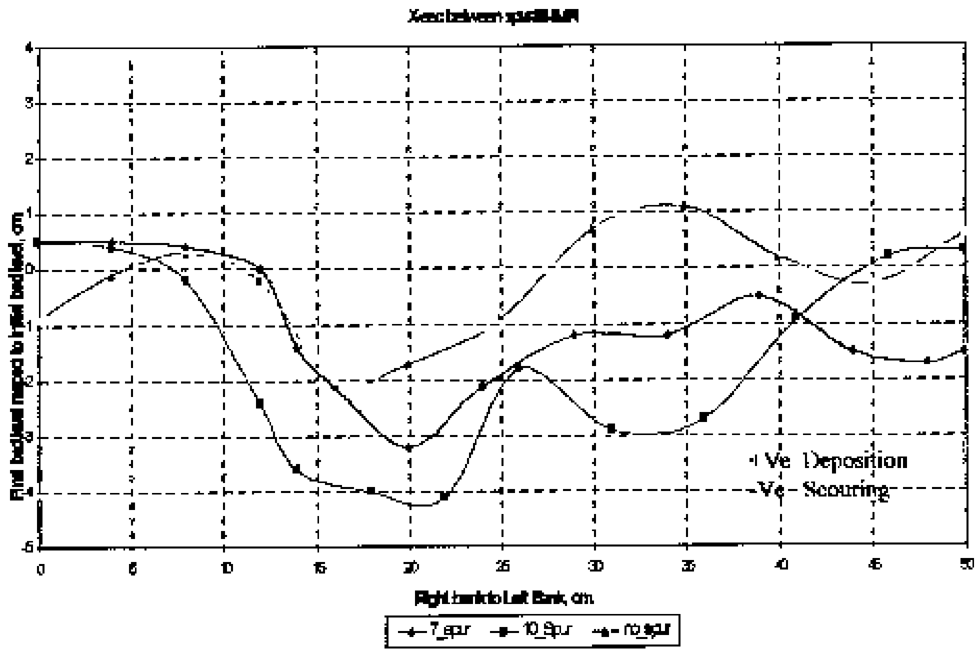



**Figure A3: Cross sections in between spur #3 and #4**

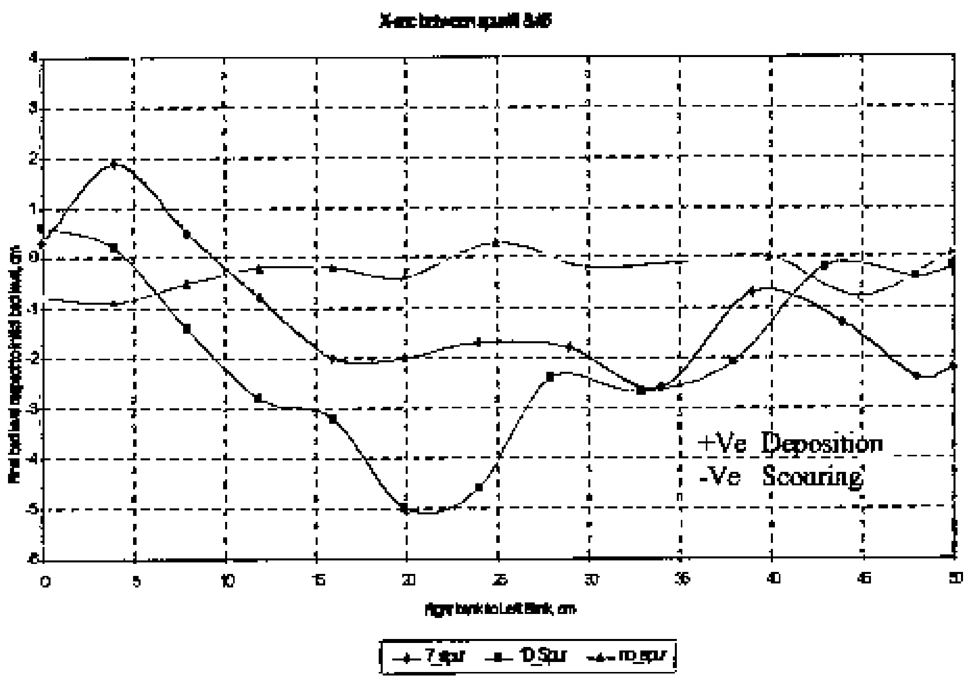



**Figure A4: Cross sections in between spur #4 and #5**

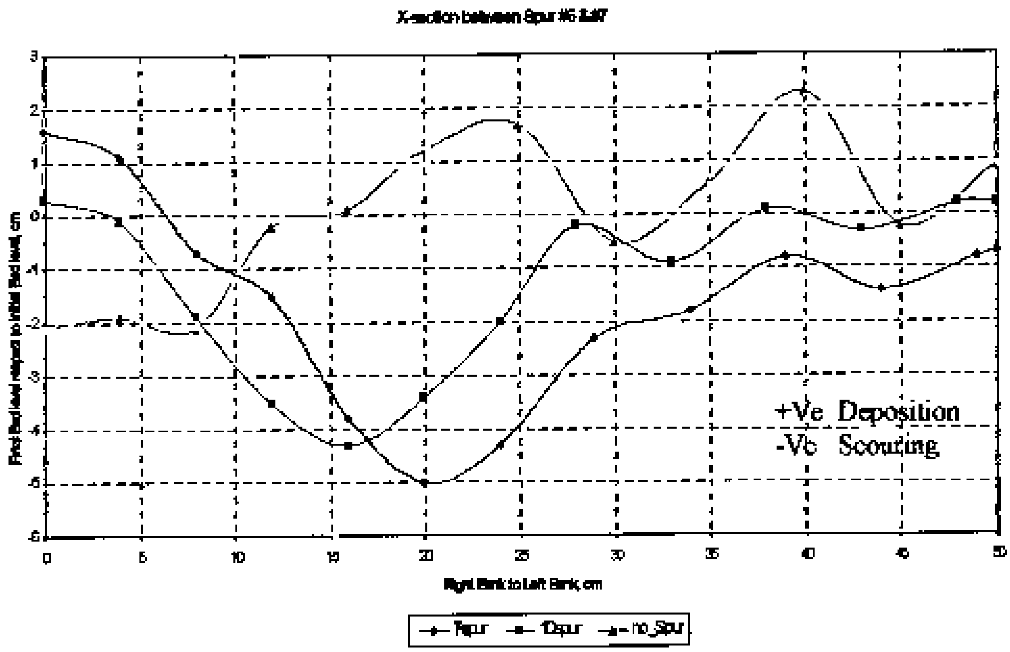



**Figure A5: Cross sections in between spur #6 and #7**

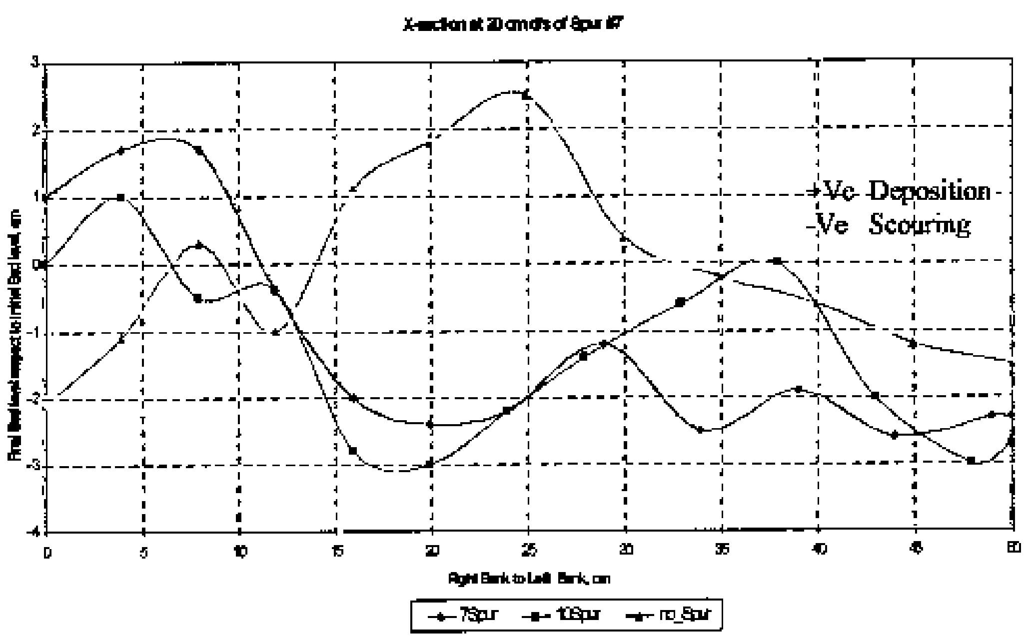



**Figure A6: Cross sections at 20 cm d/s of Spur #7**

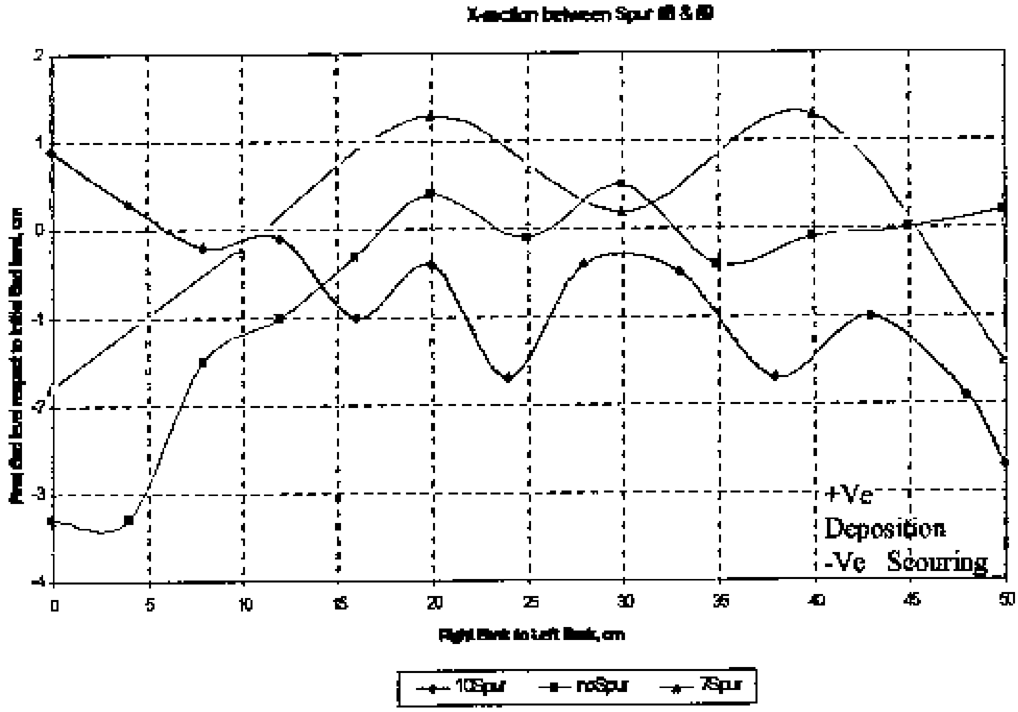



**Figure A8: Cross sections in between spur #8 and #9**

APPENDIX-B: Field Survey

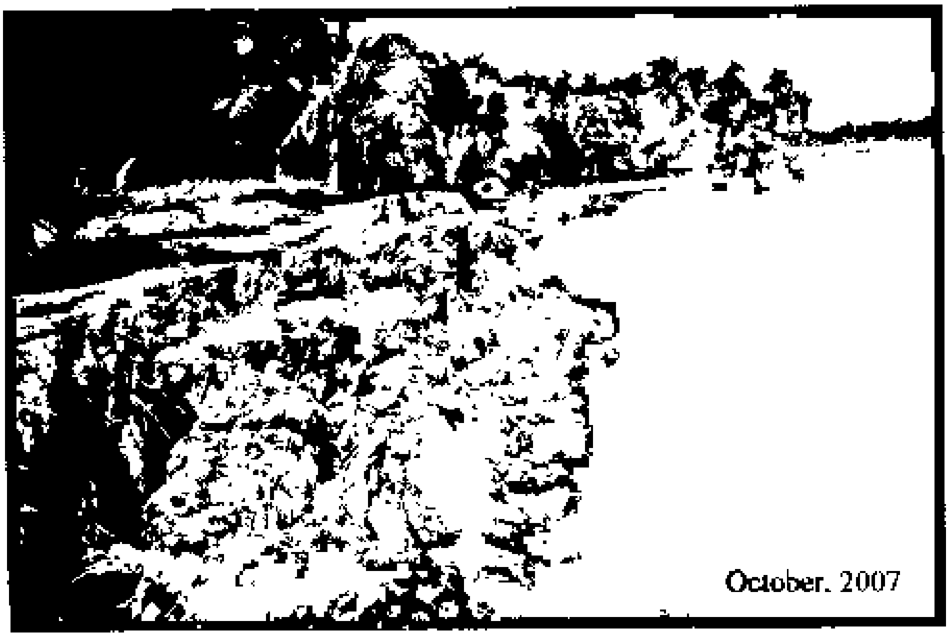



**Figure B.1.a: Erosion situation before any protection measure**


**Figure B.1.b: Erosion situation before any protection measure.**

Figure B.3.a: Continuing Erosion

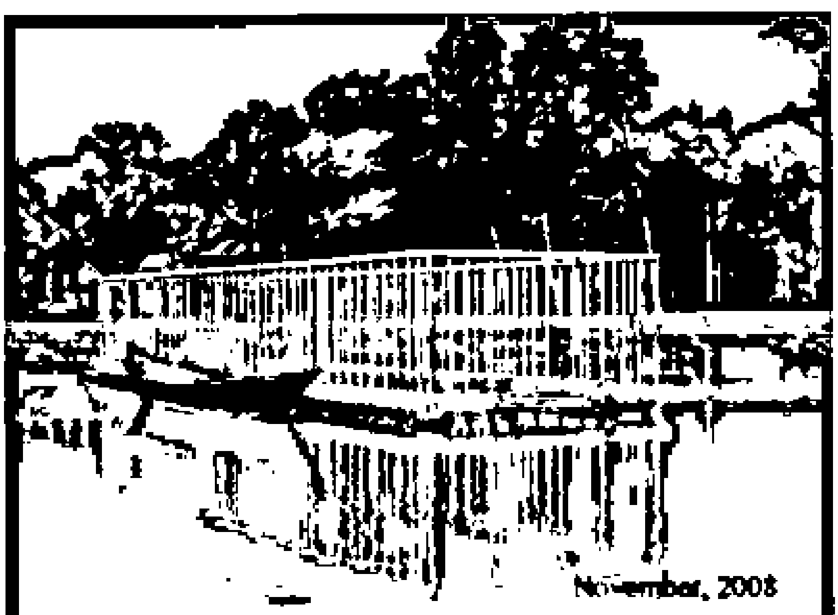



Figure B.3.b: Protective Work

Figure B.3.b: Protective Work

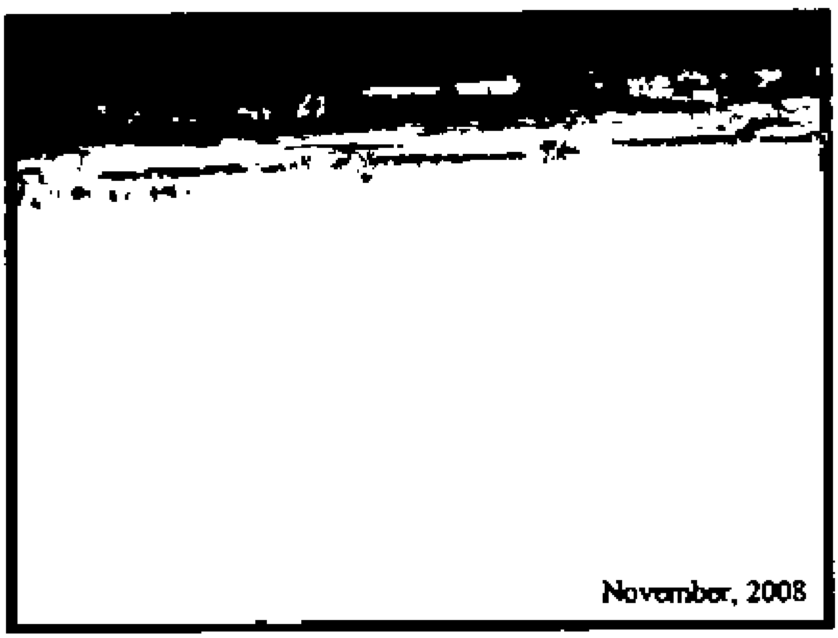



Figure B.4: Char at the Bend


**Figure B.5.a: Protective Work**

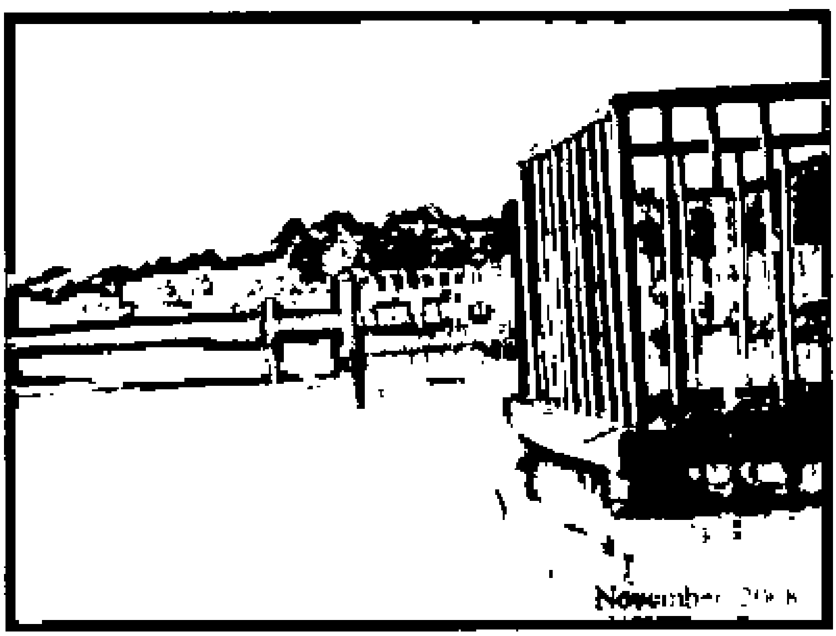


**Figure B.5.b: Protective Work**

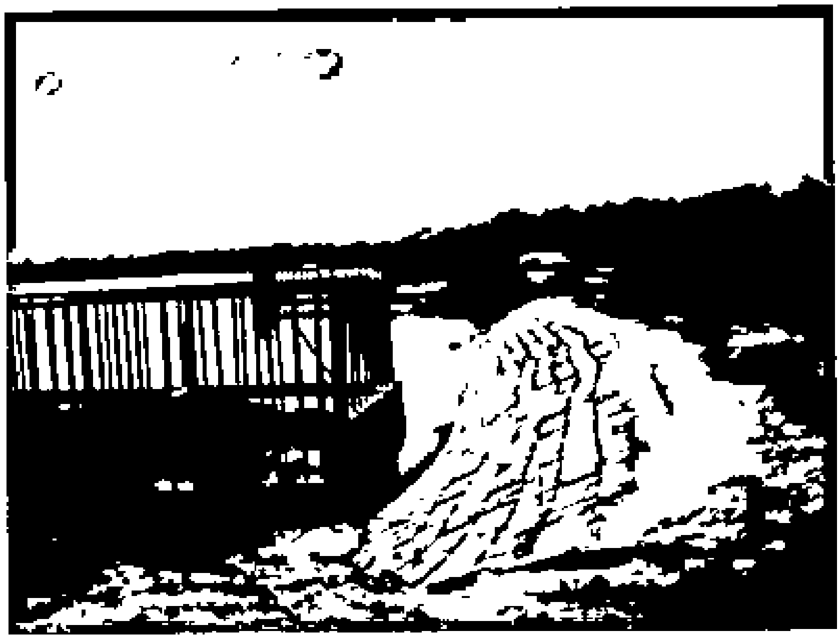


Figure B.5.d: Protective Work

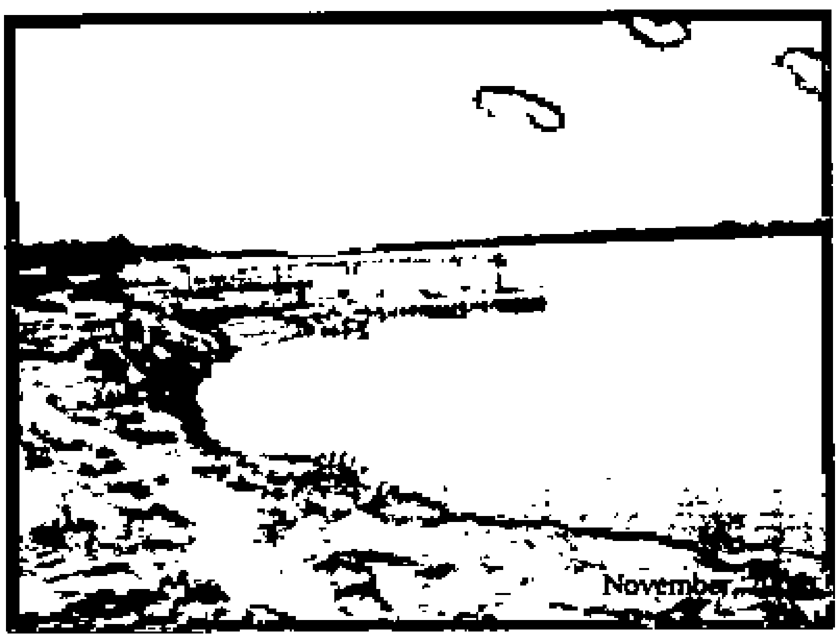



Figure B.5.d: Protective Work


Figure B.6.a: Fresh Erosion at Bend (Downstream of protective Works)


Figure B.6.b: Fresh Erosion at Bend (Downstream of protective Works)

# APPENDIX-C Questionnaire Survey

## Constructing Questionnaire

Constructing questionnaire is an art in itself. There are numerous small decisions that must be made -- about content, wording, format, placement -- that can have important consequences for the entire study.

### Question Content

For each question in the survey, we should ask how well it addresses the content we are going to address. Here are some content-related questions we can ask about the survey questions:

- Is the Question Necessary/Useful
- Are Several Questions Needed? This is a classic problem of the double-barreled question.
- Do Respondents Have the Needed Information?
- Does the Question Need to be More Specific?
- Is Question Sufficiently General?
- Is Question Biased or Loaded?
- Will Respondent Answer Truthfully?

### Types of Questions

Questions can be divided into two broad types:

1) Structured and 2) unstructured

Questions also may be of four categories.

- Open-ended questions: Respondent can reply with freedom
- Close-ended questions: Probable responses are given – respondent is to select one from them. To matters are to be taken care when questions are set: i) totality of the subject, ii) mutually exclusive
- Contingence questions: Some questions are specific and related to specific people or race. Moreover, sometimes a series of questions are needed to clarify a reply. Then questions of contingency types are needed.
- Matrix questions: If replies come to be same type and class, then questions are put in a definite shape and that is called Matrix table or Matrix questions.

**Institute of Water and Flood Management (IWFM)**
**Bangladesh University of Engineering and Technology (BUET)**

The Title of the Thesis: "Study on Lowcost River Training Works in a Meander Bend along the Madhumati River"

(Questionnaire for thesis purpose only)

SURVEY FOR PERCEPTION OF LOCAL PEOPLE ON RIVER EROSION, IMPACT AND MITIGATION MEASURE

Sample no..........

Date . ...........

---

Name: Age: Occupation:

01. Do every year the river migrates inward?

02. (If yes, what is the approximate migration rate?)

03. What are the sufferings due to erosion?

04. How much property is damaged every year?

05. Do you need bank protective work?

06. What may be the protective work?

07. How it will be effective /sufficient?

08. Do you think the executed work is appropriate or not?

09. (If not, what should be done?)

APPENDIX-D: Approved Thesis Proposal by CASR

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA OFFICE OF THE MEMBER SECRETARY OF THE COMMITTEE FOR ADVANCED STUDIES AND RESEARCH, BUET, DHAKA

**(Application for the approval of M.Sc (Water Resources Development) Thesis Proposal)**

**Date:** 26/04/2008

1. **Name of the student:** MD. QUTUB AL-HOSSAIN **Status:** Part – Time
   **Roll No. :** M10062824P **Session:** October, 2006
2. **Present Address:** House No.:711(3rd floor), West Shewrapara, Mirpur, Dhaka
3. **Name of the Supervisor:** Md. Munsur Rahman **Designation:** Professor
4. **Name of the Department:** Institute of Water and Flood Management
   **Programme:** M Sc. in WRD
5. **Name of the Co – supervisor (if any):** N/A **Designation:** N/A
6. **Date of First Enrollment in the Programme:** 6th December 2006
7. **Tentative Title:** STUDY ON LOWCOST RIVER TRAINING WORKS IN A MEANDER BEND ALONG THE MADHUMATI RIVER.

**8. Background and present state of the problem**

Gorai-Madhumati river is a principle distributary of the Ganges. The Madhumati river at Mollickpur bend in the upazilla Lohagara under Narail district is exhibiting severe erosion. A field visit was conducted to the area on 29 October 2007. According to local people, bankline of the river at the aforementioned site has been shifted approximately 1 (one) kilometer during the last twelve years. Due to erosion, people lost their land and become helpless, jobless. Many of them having no buying capacity migrated to towns/cities. Some of the destitutes is now depending on van for their livelihood.

There is a ferryghat at a little distance towards upstream from the bend. The villagers think that due to the protective work at the ghat the bend at Mollickpur is experiencing more erosion. However, the partial protective work (completed in 2005-2006) was insufficient and met the fate of being damaged.

Flow in river bends is a problem of great importance from an engineering point of view and may further be characterized as one of the key problems in river morphology (Engelund, 1974). A systematic research on meandering appears to have been initiated towards the ends of the 19th century (Silva, 2005). Processes of river bank erosion play an important role in recent theories of meander development (Pizzuto and Mecklenburg, 1989). When water flows from a straight channel into a bend, the variation of the centrifugal forces will induce a so called secondary flow, which is transverse circulation. The range of problems involved in such curvilinear flow is very large and extremely complicated (Engelund, 1974). Rates of bank migration are linearly related to the magnitude of the near bank velocity (Pizzuto and

Mecklenburg, 1989). Rohrer (1984) and Hooke (1975) emphasized on consideration on the evacuation of sediment from toe of the bank along with the magnitude of velocity and direction of near bank flow. Hickin and Nanson (1975) for their part, accounted for the complexity of meander evolution in terms of a hydraulic control, possibly related to flow separation, that modulates erosion according to local channel curvature (Lapointe and Carson, 1986). The ratio between radius of curvature to channel width is an important parameter controlling the pattern of river migration (Hickin and Nanson, 1975).

A wide range of socio-economic problems is created by bank erosion process in Bangladesh (Bhuiyan, 2007). In order to prevent erosion of river banks, suitable counter measures are required. In general, three relevant concepts of erosion counter measure are existent: (i) River training measures, which are intended to influence the flowing conditions or channel properties (active measure) (ii) Structures, which are aimed to decrease the hydraulic impacts directly in front of an area to be protected (iii) Structures to protect the actual bankline without relevant active interference on the fluid. A large variety of traditional and low cost measure is existent, such as bandals, bamboo groines, porcupines, sills, floating screen, cutoffs, intelligent dredging schemes, etc that are being used in Bangladesh and surrounding countries. The stability of unprotected river bank depends on a number of factors which to be assessed carefully in the process of selection and design of suitable protective measures (FAP-21, 2001).

## 9. Objective with specific aims and possible outcomes

The specific objectives of the proposed study are as follows:

i. Assessment on historical bankline changes at the study reach.

ii. Determination of low cost method for river training work for the study reach.

iii. Carry out physical experiment to test the effectiveness of the selected option for river training work.

Possible Outcome:

This study is expected to provide technically sound and low cost river bank protective method/option at the erosion prone bend in a minor river.

## 10. Outline of Methodology/Experimental Design

Field investigation will be made to understand the impact of erosion on the local inhabitants over the study reach. Their perception and suggestion regarding the erosion and its remedy (i.e. indigenous knowledge) will be collected. These will be conducted through observations, social survey and Focus Group Discussion (FGD). Information from related documents on the study reach (for example Bangladesh Water Development Board, and Roads and Highways Department) will be collected. A systematic analysis of bank line changes will be carried out on the basis of available satellite images. After that, protective measure will be determined on the basis of various established empirical and analytical methods. The achievement of low cost bank protective measure will be focused. To investigate the performance of the protective measure, a physical experiment will be carried out in the IWFM laboratory. The selected option will be discussed with the local people of the study reach. Their responses will be collected. The option will be readjusted according to the local people's comments (if required).

## 11. References


Bhuiyan A.B.M.F.(2007), *River Erosion Mitigation and Sediment Control Technology in Bangladesh,* National Workshop on Soil, Erosion, Eco-degradation and Poverty Relation in Bangladesh Perspective, International Erosion Control Association, Bangladesh Chapter

Engelund F. (1974). *Flow and Bed Topography in Channel Bends, Journal of the Hydraulic Division,* Vol.100, HY11. pp 1631-1647.

FAP-21 (2001). Bank Protective Pilot Project, Guidelines *and Design Manual for Standardized Bank Protective Structures,* Water Resource Planning Organization, Ministry of Water Resources, Government of Bangladesh.

Hickin E.J. and Nanson G.C (1975), *The character of Channel Migration on the Beatton River, Northeast British Columbia, Canada,* Geological Society of American Bulletin, Vol.86, pp. 487-494.

Lapointe M.F. and Carson M.A. (1986), *Migration Pattern of an Asymmetric Meandering River: The Rouge River, Quebec,* Water Resources Research, vol. 22, No 5, Pages 731-743.

Pizzuto J.E. and Mecklenburg T.S. (1989), *Evaluation of Linear Bank Erosion Equation,* Water Resources Research, Vol. 35, No 5, Pages 1005-1013.

Silva A.M.F.D. (2006), *On why and how do rivers meander,* Journal of Hydraulic Research, Vol. 44, No. 5, pp. 579-590.

12. **List of Courses so far taken with course no, name of the courses, credit hours, Grade, Grade Points and G.P.A.**

| Course No. | Course Name | Credit | Grade | Grade Point | G.P.A |
|---|---|---|---|---|---|
| WFM5202 | Socio-economic Analysis | 3 | S | - | 3.375 |
| WFM6101 | Alluvial River Processes | 3 | A+ | 4.0 | |
| WFM6202 | Remote Sensing andGIS in water Management | 3 | B+ | 3.0 | |
| WFM6303 | Integrated Water Resources Management | 3 | B | 2.5 | |
| WFM6304 | River and Floodplain Management | 3 | A+ | 4.0 | |
| WFM6000 | Thesis | 3 | - | - | |

.........................................

**Signature of the tabulator**

13. **Cost Estimate:**

a. Cost of materials:

i. Photocopy of books, reports etc. = Tk.2000

ii. Cost of Photographs (Film+Develop+Print) = Tk.1000

iii. Satellite image (one image) = Tk.35000

iv. Secondary data and map = Tk. 2000

b. Field survey cost:

i. Travel cost (Bus Fare) = Tk.3200
(4 visits @ Tk800 per visits)

ii. Local transport = Tk.1600
(4 visits @ Tk400 per visits)

iii. Living expenses = Tk.2400
(1 person 3 days/visit, Tk.200 per day, 4 visits)

c. Paper, Ink etc. = Tk.1000

d. Thesis typing, scanning, drafting and binding etc = Tk 2500*

Total = Tk.50700

(Taka fifty thousand and seven hundred only)

*Contribution from BUET. Others will be borne by Crossing Boundary project.

14. **Approximate Daily Time for BUET workshop facilities (In Hour):** N/A

15. **Justification of having Co-Supervisor:** N/A

16. **Doctoral Committee/ BPGS/ RAC reference:**

Meeting No.: Resolution No.: Date: / / 2008

17. **Appointment of Supervisor and Co-Supervisor Approved by the CASR Meeting No. (For Ph.D):**

**Resolution No.:** N/A **Date:** N/A

18. **Appointment of Doctoral Committee Approved by the CASR Meeting No. (For Ph.D):**

**Resolution No.:** N/A **Date:** N/A

19. **Result of comprehensive examination for Ph.D. (photocopy of results should be enclosed)**

**Date:** N/A **Satisfactory/ Unsatisfactory:** N/A

20. **Number of Post – Graduate Student(s) with Supervisor at Present:** 02

..............................

**Signature of Student**

..............................

**Signature of the Supervisor**

..................................................................

**Signature of the Head/ Director of the Department/Institute**