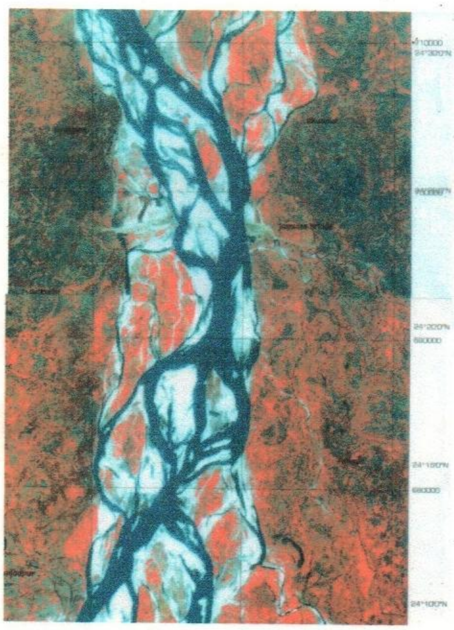
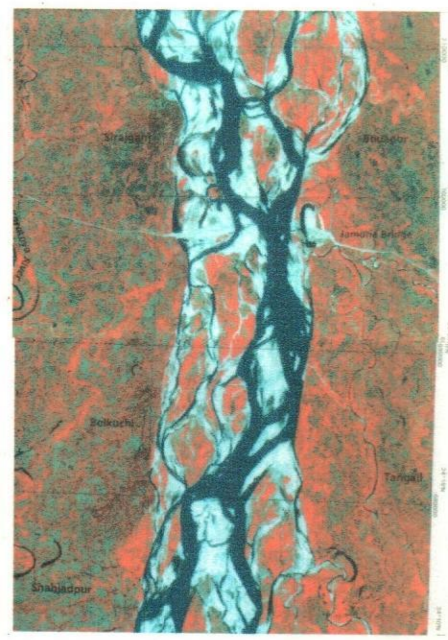
ASSESSMENT OF THE POSSIBILITY OF EROSION OF TANGAIL TOWN AND ITS ADJACENT AREA BY THE RIVER JAMUNA AND ITS PROBABLE REMEDIAL MEASURE





RESEARCH REPORT

REPORT NO. RES-4 (2001)

JUNE 2001

RIVER RESEARCH INSTITUTE, FARIDPUR
Ministry of Water Resources
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RIVER RESEARCH INSTITUTE, FARIDPUR

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RES-65/1

PREFACE

The Jamuna river is an extremely dynamic system. Extensive bank erosion and shifting of the river course are common in this river from the beginning. River bank erosion is a complex phenomena which is related to many factors such as flow characteristics sediment transport composition of bank materials, human activities etc. The river Jamuna causes extensive bank erosion due to its unstable nature and relatively cohesive bank material. Moreover, due to the human interventions at the u/s, the flow concentration at the d/s exerts adverse impact along the bank, which leads both bank and chars erosion. The adverse impact of construction of river training structure at the u/s of Bangabandhu bridge is very significant to left bank of the river at d/s of bridge. Recently Tangail district has been facing tremendous erosion of the Jamuna river.

River Research Institute (RRI) took up a study program to assess the possibility of erosion of Tangail town and its adjacent areas by the river Jamuna and to suggest possible remedial measure of erosion as per decision of the 17 th meeting of the Board of Governors (BoG) of RRI. Accordingly a five-member study team with a co-ordinator was formed to carry out the study. The study team collected and analyzed the available satellite images within the limited time period and reported their findings with recommendation. The findings of this study will provide comprehensive information on the erosion trend and history of bank shifting in the study area.

The researchers are very much grateful to the officials of the different concerned agencies particularly of SPARRSO & EGIS-II for providing necessary satellite images and to the respondents who participated spontaneously in the interview during questionnaire survey. If the study proves useful to policy makers and planners, the efforts of the research team would be considered fruitful.

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BWDB	Bangladesh Water Development Board
C C Block	Cement Concrete Block
EGIS	Environmental Geographic Information System
FAP	Flood Action Plan
R	Radius of curvature
R/W	Relative radius of curvature
RRI	River Research Institute
SPARRSO	Space Research & Remote Sensing Organization
W	Width of the channel

CHAPTER ONE

INTRODUCTION

1.1 Introduction:

Tangail district emerged as a full-fledged district on the first day of December 1969. Formerly it was a sub–division of Mymensingh district. The total area of the Tangail district comprising 12 police station (Thana/Upazilla) is 1309 sq. miles including the rivers. The latitudinal extension of Tangail district is from 23°59'50" North to 24°48'51" North and longitudinally it stretches from 89°48'50" East to 90°51'25" East (Fig.1.1). The district is elongated north and south and tapering towards the north with its base in the south. The north-south length varies from 110 to 120 km (70 to 75 miles) approximately, while east-west breadth ranges from 50 to 60 km. (30-35 miles). The southernmost base would not be more than 36 km. (22 miles) long east to west. Tangail district is bounded on the north by Jamalpur and Mymensingh district; on the south by Manikgonj and Dhaka district; on the east by Gazipur and Mymensingh district and the mighty river Jamuna on the west. The Dhaleswari, first an old channels of the Ganges and then of the Brahmaputra, cuts across the south-western corner of the district on its powerful sweep to join the Meghna near Narayangonj.

The head quarter of Tangail district is Tangail town. It lies on 24°15' N latitude and 89°55' E longitude. The Tangail Municipality comprises an area of about 15 sq. km. There are several degree Colleges, secondary schools and also other educational Institute. It also possesses a district hospital, a post and Telegraph head office, a district council Dak-Bangla, work divisions, rest house and branches of some banks. Tangail is famous for handloom and bell-metal industries, milk and milk products. It is a business center. There is a regular bus service between Dhaka and Tangail, Tangail and Jamalpur and Tangail to Mymensingh. Recently the town is connected with several district head-quarters of North-Bengal through Jamuna Multi purpose Bridge (Bangabandhu Jamuna Setu)

The great earthquake of 1762, 1897 and 1950 associated with other seismic phenomena created many rivers, beels and depression in the then Bengal and Tangail was no exception. Rivers of the district have changed their courses many a time. Many of the old rivers have left their traces, which are now filled with water forming basins, swamps and beels. It is obvious that by 1830, the diversion of old Brahmaputra was completed, ushering (preceding) in a gradual but radical change in the river system of the Tangail district. In 1850 Sir Joseph Hooker wrote " we are surprised to hear that within the last 20 years the main channel of Brahmaputra had shifted its course westwards, its eastern channel silted up so rapidly that the Jamuna eventually become the principal stream (Bangladesh District Gazetteer, Tangail, 1983).

The main source of the Jamuna is Manas Lake of Tibet. It originates as the Tsangpo form the lake and runs several hundred km towards east and through north-east corner of Arunachal state, it enters into Assam. It passes through Assam valley as the Brahmaputra towards west and enters into Bangladesh. In Bangladesh the river flows from north to south as Jamuna and divides the country into two sectors, apparently. The Jamuna then joins the Padma at Aricha-Daulatdia (Gualando) and the combined flow then meets the Meghna at Mohanpur-Eklaspur near Chandpur and has reached the Bay of Bengal. The total distance covered by the river from its source to the Bay of Bengal is about 2900 km. In Bangladesh originally the Brahmaputra was flowing towards south-east across Mymensingh district where it received the Surma river and joined the Meghna. This original course of the Brahmaputra is known as " Old Brahmaputra" and is still flowing across the Mymensingh district as an insignificant river.

To meet up the question when and why the Brahmaputra river changed its main old channel; two theories are advanced. As explanation of the division, one theory describes the gradual uplift of the Madhupur tract and a final trigger action of the Teesta diversion in 1787 as the chief factor. From Geotectonic study of Madhupur tract area, it has been observed that the main course of the Brahmaputra was obstructed by the upliftment of the Madhupur area and forced the main course to flow southward along its distributary Jamuna to become the main channel of the Brahmaputra.

The theory states that the Brahmaputra diversion resulted directly from a major increase in its volume of water due to beheading of the Tsangpo river of Tibet by Dihang, a tributary of the then small Brahmaputra. The great Tibetan river Tsangpo joined the Brahmaputra in about 1780 and this accession was more important than the Teesta floods in deciding the Brahmaputra to try a shorter way to the sea, Bay of Bengal. At the end of the 18^{th} century probably as a result of the great Teesta floods in 1787, the Brahmaputra changed its course and joined the Padma at Gualanda. Whatever might have been the cause, it is obvious that by 1830, the diversion of the Brahmaputra was completed to its present Jamuna channel. The Jamuna is a braided river with typically 2 to 4 channels. The river flows through fluvial depositions of fine sand and traces of silt. This dynamic river changes its planform rapidly from year to year resulting in major shifts of main channels in the braiding belt (Bangladesh District Gazetteer, Tangail, 1983).

River bank erosion is a complex phenomenon which is influenced by many factors. The rate of bank erosion is determined by flow characteristics, sediment transport mechanism, composition of bank materials and properties and human activities. The bank of Jamuna river are fairly steep and consists of material with apparently no or little cohesive characteristics (80% fine sand and 20% silt/Clay). Cohesive bank erodes by mass failure when a critical stability condition is exceeded. Non-cohesive bank erodes mainly due to wave action and undercutting due to existence of secondary currents. Investigations revealed that bank erosion has a cyclic behavior; the river bed erosion results in steeper slope of the bank and an increase in bank height.

The river Jamuna causes extensive bank erosion due to its unstable nature. Moreover, due to the interventions created by the construction of all river training works and bridge structure, the total flow concentration exerts adverse impact along both banks at the u/s & d/s of the bridge, which leads to simultaneous bank and char erosion. The adverse impact of construction of Jamuna-Bangabandhu bridge on the upstream is very significant to the left bank of the river at d/s of the bridge (RRI, Down Stream Model, 1998). Tangail district has been facing tremendous erosion of the Jamuna river. In order to protect Tangail Town and its adjacent/surrounding area from the probable erosion by the river Jamuna a study has been undertaken by RRI.

1.2 Objectives of the study

1. To find out the erosion rate of the Jamuna river along left bank and to asses the vulnerability of the Tangail town and its adjacent areas to the erosion.
2. To suggest possible bank protective measures to prevent further erosion by the river Jamuna.

CHAPTER TWO

THE JAMUNA RIVER

2.1 General

The river Jamuna cause extensive bank erosion due to its unstable nature. It originates in Tibet on the northern slope of the Himalayas and drains snowmelt and rainfall from China, Bhutan, India and Bangladesh. Before its confluence with the Ganges at Aricha, the river travels a length of 2,740 km. Its total catchment area is 570,000 km^2, of which only 7% is within Bangladesh. This river flowing from north to south and dividing the country approximately into two halves forms the lower part of the Brahmaputra-Jamuna drainage system. In the beginning of the 19 th century, the Brahmaputra, which at that time followed the course of the old Brahmaputra, started to flow through a new course that named as the Jamuna but the upper reach still retained the old name (Fig.2.1). It is believed that an abnormal flood in the late 18 th century led to the change in the course of the Teesta. This may have caused a diversion of the Brahmaputra into its present north south channel i.e., the Jamuna. The result of tectonic movements in between the Barind and the Madhupur Tracts may have been partly responsible for the change of river course. Already before entering Bangladesh, the river assumes braided patterns consisting of several channels separated by small sandbars called chars within the course. During the last 200 years or so, the channels have been swinging between the main valley limitations. As a result, during monsoon extensive over bank spill, bank erosion, bankline shifts and charland shifts have become typical for the Jamuna.

The river Jamuna is the part of the largest river systems in the world and its dimensions alone make it difficult to understand its behavior and morphological changes. As the river is highly mobile due to its fine sediments and the large floods, it is experiencing changing of its plan form in every year. Its plan form is changing completely within few years only.

Rivers of this magnitude and with these characteristics have hardly been studied in the past and therefore our theoretical understanding is still limited. The first comprehensive description about the Jamuna River was given by Coleman in 1969.

2.2 Hydrology

The mean annual rainfall on some selected stations varies from 2,372 mm to 1,440 mm with a well-defined seasonal variation. The mean estimates represent the drainage characteristics of the Brahmaputra basin in Bangladesh; the monsoon season rainfall is significant and it is about 75% of the annual rainfall whereas the dry season rainfall is a small fraction of the annual rainfall.

Maximum discharge of the Jamuna River at Bahadurabad is 100,244 m^3/s whereas minimum and average flows are 2,427 m^3/s and 20,177 m^3/s respectively. Average water surface slope is approximately 7.6 cm per km for the upper reach of the Jamuna River and 6.5 cm per km for the lower reach.

The water level during the months of July, August and September are generally high. The lowest water level generally occurs in February. The discharge starts increasing in April and the first peak flood generally occurs in June - July and is characterized by a rapid rise, the major peak occurs in August. The maximum flood of the Jamuna River is generally earlier than the one in the Ganges River. The flows in these two rivers are not in phase.

2.3 River Characteristics

The valley slope of the river decreases in downstream direction. Near Bahadurabad it is about 8 cm per km, while near the confluence with the Ganges River it is about 6 cm per km, hence varying between 0.000085 and 0.00006. The bed material of the river is fine sand with D_{50} varying between 0.22 mm at Chilmari and 0.165 mm near Aricha. The gradation is about 1.3, hence fairly uniform sediments. There is some vertical sorting also, the finer particles on the average being deposited at the higher char levels. According to an extensive sampling campaign carried out by FAP-1, 1993 bank material seems to be quite uniform also and consists of fine sand too, the highest chars being covered by a layer of 1 to 2 m thickness of deposition with more clayey particles. The little variation in bank material composition in downstream direction is different from what was suggested by Coleman, notable that the existence of nodal points is due to old clayey deposits.

The Jamuna River is a braided system, with several parallel channels in each cross-section. The dimensions of these individual channels were studied in the Jamuna Bridge Study, Phase 2 (Klaassen and Vermeer, 1988), and it was found that in first approximation regime equations could be derived for these channels as well (FAP-24, 1993). The bankfull discharge of the Jamuna River near Bahadurabad is about 44,000 m^3/s and can be slightly smaller for downstream from the offtake of the Dhaleswari River. The direction of the individual channel is varying between +90 and –90 Degrees, the larger channels show smaller deviations from the river axis (FAP-24, 1993).

Considering the depth and the slope of the Jamuna River in view of the fine particle size, the so-called Shields parameter is quite high. This parameter characterized the mobility of the sand (which in the Jamuna River is always moving, even during low flow conditions). High Shields numbers also causes the resistance of the flow to decrease. This is achieved through the bedforms that are present on the bed of the channels. Several types of bedforms have been identified (Coleman, 1969, Klaassen et al, 1988), but the sand waves are probably the most important one for the resistance to flow of the river bed. These sand waves have a length in the order of 100 m and a height of 0.1 to 0.2 times the water depth. According to the investigations carried out in the flood season of 1987 (Klaassen and Vermeer, 1988) the lee-side of the bedforms is fairly gentle, which explains the high Chezy coefficients of 70 $m^{1/2}/s$ and higher that have been observed (FAP-24, 1993). The sand waves move with celerity of about 100 m/day during floods. During low flows their dimensions and their celerity will be less. Also the Chezy coefficient is less during low flow conditions.

Suspended sediment transport rates are being measured at Bahadurabad on a regular basis, although there is some doubt on the accuracy of the measurements, because of the direction of the flow and hence the sediment flux is not perpendicular to the cross-section. At Bahadurabad, with FAP-24, coarse (coarse than 63 microns) suspended sediment data are available for the period 1966-1970 and 1976-1988 and fine (finer than 63 microns) suspended sediment data are for the period 1967-1988. A closer analysis reveals that the data from the period 1966-70 were 2-2.5 times higher sediment transport than that of suggested by the period 1976-1988.

FAP-24 has derived equations for the coarse and fine suspended material load in the Brahmaputra, which read as:
Coarse sediment:

$S = 0.349 * Q^{1.42}$ for the period 1966-1970

$S = 0.393 * Q^{1.407}$ for the period 1976-1988

Fine sediment:

$S = 0.44 * Q^{1.46}$ for the period 1966-1970

Where S is the transport rate of coarse suspended sediment in tons/day and Q is the water discharge in m^3/s. The average yearly coarse suspended sediment transport is approximately 200 million-ton and fine suspended sediment transport is approximately 390 million-ton (FAP-24, 1993).

2.4 Planform characteristics

As stated above the Brahmaputra Jamuna river is a braided system implying that in one cross-section there are more channels. The number of channels is variable in space and in time. It appears that the number of channels in the upstream reaches is about 3 and in the downstream reaches often only 2 major channels are present which tend to behave as meandering channels (FAP-24, 1993)

It was investigated whether the number of channels is related to the total width of the river in FAP-21 and FAP-22. This was done by plotting the number of channels versus the total width. The number of channels and total width both were determined from satellite images. There indeed It seems to be a relationship, but it cannot be determined whether the number of channels is a function of the total width or the other way around.

In between the channels islands and sand bars are present. These are locally called chars. Nowadays a distinction is made between so-called stable chars (also called megachars) and moving chars, the position of which is changing every year. In addition so called attached chars are differentiated, essentially being moving chars but connected to one of the river banks. Bristow (1987) makes a difference among 1-st order, 2-nd order and 3-rd order bars. Comparable terms are used in this report; the 1-st order channel being the river system in total, the 2-nd order channels being the channels for which regime equations were derived, and the 3-rd order being the channels in between the moving chars.

The total width of the channel pattern, comprising both the channels and the sand bars in between, is varying considerably both in space and in time. It can be observed that the total width varies between 3 and 15 km, while the total channel width varies between 3 and 10 km.

Finally some observations have to be made as to nodal points. According to Coleman (1969) a number of nodal points occur along the Brahmaputra Jamuna River, and he relates them to the possible presence of old and possibly more clayey deposits of rivers that have occupied the plains in historic times. The latest studies seem to suggest that these nodal points be not as stable as previously suggested. It could be well that they are related to fluvial morphological processes such as confluence rather than more stable reaches. This can also be deduced from the bank material data obtained under the FAP-1 study.

2.5 Shifting Characteristics

The Brahmaputra /Jamuna river is an extremely dynamic system. These dynamics can be divided into the dynamics of the 2-nd and 3-rd order channels and related bars and the changes in the location and the width of the 1-st order channel. The latter is discussed in subsequent paragraphs. Here the emphasis is on the changes of the smaller channels still having width up to 1 to 4 km, (FAP-24, 1993).

The dynamics of the lower order channels can best be illustrated by stating that the channel pattern usually has changed completely in some 3 years. In this period bends have eroded often more than 300 m/year, channel have widened and others have narrowed or even completely disappeared, while many cutoffs are taking place every year. Fig.2.2 to Fig.2.3 show the historical bank line positions of the Jamuna river from 1830 to 2001 and the differences are amazingly large. From an inspection of these figures it can be noted that:

(1) There are some places in the middle of river where never a major channel has been. These are the so-called stable chars or megachars.

(2) Only at a few places there has always been a major channel. Notable places are near Sirajganj, already for a long time definitely because of its pronounced protrusion.

(3) In most cross-sections the location of the channels tends to exhibit an almost normal distribution pattern.

2.6 Shifting and widening of the river system

In addition to the dynamic behavior of the 2-nd and 3-nd order channels also the 1-st order channel is subject to substantial changes, even over the limited period over which detailed information on the river system is available. According to the insight available now:

(1) some reaches of the river are moving in a western direction and some reaches are moving in a eastern direction.

(2) the upper reaches and lower reaches of the Jamuna River are widening over the last decades.

Although in the report on the Jamuna Bridge Study, Phase 2 (1989) it is still stated that no significant changes can be observed based on an analysis of the BWDB cross-sections which are surveyed every year, in the mean time the evidence is piling up that suggests that the 1 st order channel is subject to major changes.

The evidence quoted comes from the comparison of older maps with newer ones and from studies based on the satellite images covering the period 1973-2001. Although there is some doubt as to whether the coordinate system of the Wilcox map can be used for comparison with other maps, this comparison seems to support the movement in western direction. Also the satellite images appear to suggest that in the past most of the erosion was along the western bank. This is nicely illustrated by Fig.2.4 that provides the overall erosion from 1973 to 1992 in the reach between Gaibandha and Natuabari. This figure clearly suggests that the river has an overall tendency to move towards the West, but at the same time is widening substantially.

For other reaches of the river this tendency is less pronounced. Fig.4.6 provides an overview of the d/s part of the Jamuna River where the river courses are overlaid for the period 1988-2001. It is shown in Fig.4.6 that in the more downstream reaches the trend is even in eastern direction.

The cause for the supposed trend in either direction or the widening is not known. The overall movement could possibly be related to tectonic activities. The Brahmaputra-Jamuna river has a record of avulsive behavior, and it may well be that this overall movement has a similar background. The widening can be attributed to an advancing alluvial fan or to the fact that the river has not fully adapted itself after he shift to its new course around 1800. In this respect it is interesting to remark here that in 1830 the river showed, according to the Wilcox map, a clear meandering behavior also in the upstream reach.

Finally it is good to underline that the trends described here have not been established beyond doubt that the available information is too scarce and there is doubt as to reference levels and coordinate system. Yet putting all the evidence available now together, the described behavior of average movement in either direction or the widening seems likely.

2.7 Bends, bank erosion, cutoffs and widenings

Over the last years the understanding of bend evolution and bank erosion phenomena is increasing due to the use of satellite images. Especially in the present study much effort has been put into understanding the changes of the river system over the years. The results presented here are derived from an analysis of satellite images whereby images of subsequent years were compared.

It was found from the study of FAP that major bank erosion is related to the presence of large bends that have a life cycle of up to 7 years. In fact these bends are the most stable phenomena in the Jamuna river. Bank erosion along these bends was studied on the basis of satellite images as suggested by Hickin and Nanson (1984). First analysis was made by Klaassen & Masselink (1992) for the Jamuna river and they observed erosion rates along outer banks of major bends that vary between 200 to 700 m (and exceptionally even to 1 Km) in one year.

The balancing mechanism for increased bend formation is the occurrence of cutoffs. Klaassen & Masselink (1992) also reported upon results of a study into the occurrence of cutoffs and they suggest that the relative length of the two reaches downstream of the potential bifurcation is an important parameter. It was found, however, that the angle a channel makes with the upstream (un-bifurcated) channel is by far the most important parameter does not occur. Increasing the angle leads to an increased probability of the bend being cut off (FAP-21, 1993).

In the present study it was furthermore found that:

(1) Bifurcation disappear in three years or less

(2) Asymmetry of the bifurcation increases the probability of abandonment and

(3) Abandoned channels downstream of a bifurcation are most often situated in an inner bend.

Also widening was studied in the present study.

CHAPTER THREE

PRESENT SITUATION OF BANK PROTECTION IN BANGLADESH

3.1 General

A river system consists of more or less defined channels and tributaries conveying along with the water sediments eroded from their beds and banks. The erosive activity of a river depends mainly on its discharge, the current and the resistance to abrasion of the bed and bank material and its attrition. However, the volume and the rate of sediment are not proportional to the transporting power of the river. During low and medium stages the rate of sediment exceed the transporting capacity, but during high stages the river develops more energy than is required to move the sediments. This excessive energy attacks the bed and the banks resulting in an eroding process by which the overall shape, the dimensions and the planform of the river are developed.

Since bank erosion means loss of land, people living and housing alongside the river bank try to protect the banks against erosion from time immemorial. Many and varied methods of bank protection have been developed in the past with considerable regional differences subject to available materials, which may be naturally occurring materials, but also modern materials and highly developed engineering systems specifically designed for bank protection.

3.2 History of bank protection work in Bangladesh

Actually on long tradition in bank protection works exists in this riverine country, where not only severe erosion problems are encountered on most of the natural rivers but also a scarcity of suitable materials for bank protection works. The bank protection works on major rivers were mainly restricted to the upstream area of the Hardinge Bridge on the river Ganges, where stabilization of banks was tried by means of brick revetments, Rajshahi brick groyne and Serajganj Town Protection with brick mattressing on the Jamuna river in the country.

In 1984, BWDB prepared an unpublished report (quoted by Alam/Faruque 1986) stating that at those time 305 places on 565 km length faced severe erosion. It was estimated that about 1200 km of river banks were subject to erosion.

A number of plans for "Town Protection Schemes" were prepared but did not proceed much for fund constraints until the 1987/88 floods. Thereafter, a lot of efforts and money have been spend to construct both direct and indirect bank protection structures, generally creating " hard points" for preservation of townships and important infrastructure. Contingent on morphology and bed topography of the rivers, the location to be protected, the space available, etc. various types of direct bank protection measures e.g. revetments, retaining walls, porcupines or indirect (river training) measures, i.e. groyne, cut-off etc. were executed in the past with more or less success. The designs of bank protection works generally followed standard rules adopted in Bangladesh whereas scale model test were also carried out in the River Research Institute for important protection works.

3.3 Details of work executed

3.3.1 Flexible revetments

The bank revetments commonly practiced in Bangladesh are as follows:

- Herring bond bricks over a flat brick base course (soling) and graded filter with wire mesh nets over bricks

- Revetment with boulder or stone materials over khoa (brick chips) and sand filter with or without wire mesh over it and

- Revetment with brick blocks, Gabon or cement concrete blocks of different sizes over khoa layer.

Normally the revetments are placed by hand with gaps on the bank slopes 1:2 or 1:3 up to the low water level. The protection of the bank slope below low water level is arranged by dumping rip-rap of boulders or cement concrete (C.C) blocks and providing a falling apron at the toe of the revetment as per standard design. Where sliding of existing banks and revetments has occurred, scour holes are often filled with gunny bags filled with sand and subsequently covered by Gabon or cement concrete blocks.

In the revetment works executed till recently, BWDB used in general a 10 cm thick coarse sand and/or 15 cm thick chips layer as filter below the armor layer, but recently geotextile are also being used or at least shown on the design drawings below stones or C.C. blocks as filter material. Since the procurement of geotextile material requires foreign exchange the use of this material was often not possible. Geotextile bags filled with sand are also being used now a day for filling of scour hole and for protection of slopes and river bed against erosion and scouring.

In Chandpur Town Protection Scheme the revetment work with different sizes of cement concrete blocks over sand filled geotextile bags is being practiced since 1990. Whereas earlier works at Chandpur mainly consisted of stone rip-rap over khoa and sand filter. The latter method has not proven successful for the town protection works under severe conditions, particularly due to uncontrolled placing of the filter and the top layer under water.

In Rajshahi Town Protection Scheme almost all types of bank protection works have been practiced. Earlier works were carried out by brick pitching with wire mesh over khoa filter carried out earlier works. Recent work on bank protection also consisted of brick revetment over geotextile filter with C.C. blocks as toe protection.

Sirajganj Town Protection Scheme started in 1964 with brick mattressing, which was washed away in 1969. During the seventies more than 2 km revetment made of sand-cement blocks was built but was again destroyed during the 1985 flood. Since then repair works are going on by dumping C.C. blocks but out of total amount estimated less than 50% has been completed. (FAP-21, 1993)

3.3.2 Porcupines

Porcupines (bamboo crates filled with clay bricks) placed at the toe of banks and lower parts of the slopes have been found to be effective in smaller silt laden rivers where erosion could be stopped and thus the bank be stabilized with minimum cost. However, its use in flashy rivers like Teesta (e.g. at Belka) or the Jamuna (at Fulchari Ghat) did not prove to be successful for stopping bank erosion under high current condition. About 1200 nos. of porcupines were placed on a length of 450 m, but still the banks retreated by some 800 m within one month in 1985 (Huq, 1988). They are, however, still used as emergency meassures, though inadequate in number (FAP-21, 1993).

3.3.3 Groyne and Spurs

During the last 20 years a number of impermeable groyne have been built, not only on smaller rivers but also on the Ganges at Rajshahi, on the Jamuna at Sailabari, Sirajganj (Ranigram), Sariakandi (Kalitola) and Kazipur (Maizbari), on the Lower Meghna at Chandpur and on the Teesta at Tambulpur. With the exception of a series of groyne and spurs at Rajshahi all other structures were planned as single groyne aimed at a deflection of flow away from the river bank.

The cores of all groynes were constructed of locally available sandy soils with slopes mostly 1:2. The soil was to be compacted and the slopes to be covered with 6 inch khoa as filter layer and armored with brick mattressing along the shanks and cement concrete blocks of various size at the groyne heads. To provide for adequate protection against deep scours below the low water levels, falling aprons were constructed of C.C. blocks. As per original design and model tests the groyne heads were often to be of hockey or T-shape but due to construction problems on flowing water with high current velocities and fund constraints, most of the groynes were executed with bell shape heads.

It is difficult to assess the causes of failure of groyne at Chandpur, Kazipur and Tambulpur. The groynes at Sirajganj and Sariakandi were also seriously damaged after their completion but could be repaired and maintained by placing additional block material.

Bank protection by means of permeable groyne (bamboo/bullah spurs, RCC piles) has also been executed successfully, but mainly on smaller and medium rivers with limited scour depth.

3.3.4 Retaining structures

Anchor sheet piling wall has been provided at Khulna on the Bhairab river (Roosevelt Jetty) but it has been considered as unsatisfactory due to heavy erosion.

3.3.5 Cut-offs

Loop cutting has been executed near Ashna on the Surma river, on the Gumti river, on the Dharla river and on the old Brahmaputra river and those loop cutting are reported successful.

3.3.6 Closure dam

Closure dam of channels at Fulchari/Jamuna and Dewanji town/Old Brahmaputra have failed. In July 1992 a closure dam for a chute channel at Rajshahi/Ganges was completed, protected only with brick work at the head, situated on a char, and with sand filled jute bags on the shank slopes. Its effectiveness during flood seasons has still to be observed (FAP-21, 1993).

CHAPTER FOUR

APPROACH, RESULTS AND DISCUSSION

4.1 Approach

Analysis of the present study mostly concentrates on the pattern of the bank erosion along the left bank of the Jamuna river and d/s of he Bangabandhu bridge. Historical maps of he Jamuna river were collected and converted into 1:100,000 scale. The land sat and digital images that were used were collected for the period 1973-2001.

Bank line maps of the year 1830 (Wilcox), 1951 & 1953 were also collected. All the maps were converted into the same scale and superimposed. As the land sat and digital maps were for the dry season it seems difficult to identify exactly the location of bank lines. There may be some errors or debate in identifying the location of bank lines. There were some inconsistency and distortion in both the land sat and digital images. In the land sat co-ordinates were not shown correctly and on the other hand in digital maps though co-ordinates were shown nicely yet there were some inconsistency in the position of co-ordinates. However, adjustments were made applying own judgement and maps were corrected as consistently as possible.

Dry season digital images for the period 1996-2001 were used to develop a prediction tool to predict the possible bank erosion along these curved channels of the Jamuna river at the d/s of the Bangabandhu bridge. In developing the predicting tool mainly Hickin & Nanson (1984) and Klaassen & Masselink (1992) approaches were used with some modifications.

In the Hickin & Nanson's approach center line of the curved channels were used. But in drawing center line of the complex curved channel subjective bias was unavoidable which of course would influence the relative curvature (R/W) significantly and the result of the analysis. To avoid this inconsistency outer bank of the curved channels were used to measure the radius of curvature. Hickin & Nanson (1984) relationship had been derived for estimating the future erosion rate of the curved channels.

Average rate of bank erosion along the curved bank was taken into account instead of maximum bank erosion rate. The average bank erosion rate will make the prediction method more realistic. Observing the superimposed historical maps and recently available satellite images of SPARRSO & EGIS-II, it can be inferred that d/s part of the Jamuna river had been gradually shifting towards the west before 1973 but after that the shifting trend had reversed i.e., the river had been gradually shifting towards the east. After analyzing the super imposed bank.

Line maps of different years average bank erosion rates along the both banks were computed and presented in tabular form and in graphical form. Along the left bank, d/s of the Bangabandhu bridge, most vulnerable zones were identified and special attention were made to analyze the bank erosion rate and flow pattern in those areas.

Usually bank erosion along the Jamuna river occurs through the reach in monsoon i.e. in both straight reach and curved reach. Though bank erosion rate along the curved reach (concave) is more than that of straight reach. Widening of the river channel was analyzed in the present for the study reach comparing the bank line positions in different years.

4.2 Previous trend of river course shifting

Proper understanding of the historical channel pattern changes of alluvial river is very important for all river engineering projects. Investigations into the river channel changes of the Jamuna river downstream of Bangabandhu Bridge and western side of Tangail town have been extended. The practical aim of the research work was to collect the historical data and to draw conclusion for required river training works.

In Fig.2.3 bank lines of the Jamuna river in different years (1830,1951,1953,1989 & 2001) for the reach Bhuapur to near Aricha have been shown. Fig.2.3 shows that in 1830 the Jamuna river was almost a meandering river and its position was far Eastward than the present course. A large bend u/s of Tangail was extended towards the East and if a tangent was drawn at the peak of the bend, extension of that tangent might touch the Tangail town. That is, there is a historical record that in the past the Jamuna river was flowing near Tangail town. It was seen from superimposed bank line maps in Fig.2.3 that the river course is gradually shifting towards the west. Shifting of the river course from 1830 to 1951 is not that much especially for the reach d/s of Bhuapur. But overall river course shifting from 1951 to 1989 was significant. Immediately d/s of Bhuapur this shifting was almost 3.8 km in 38 years. On the other hand river course shifting from 1830 to 1951 i.e., in 121 years was max 1.4 km at d/s of Tangail town and at immediately d/s of Bhuapur this shifting was only 200 m towards the west. Historical river course shifting trend also can be seen in Fig.2.2. From Fig.2.2 it was seen that the river course had been shifting towards west from 1830 to 1953. But after 1973 shifting trend of the river course especially of the reach d/s of Bhuapur had been reversed. The river started to shift towards the East.

4.3 Recent trend of the river course shifting

From the superimposed bank line maps of the Jamuna river for the reach Bhuapur to near Aricha in Fig.4.1 it was seen that after 1973 the river bank (left bank) gradually shifted towards the East from 1973 to 1988. This shifting was about 900 m at some location. From Fig.4.1 shifting trend of the left bank of the Jamuna river can be seen. Maximum shifting of the bank lines from 1988 to 1995 was 1100 m and from 1995 to 2001 it was about 700 m towards the East. Overall shifting from 1973 to 2001 was 2150 m towards the East. In Fig.4.2 bank line maps of the Jamuna river for the year 2000 and 2001 can be seen. From this it was seen that left bank of the river course this year shifted towards the East by 450 m at same locations. That is, the river course is still shifting towards the East. River course is shifting towards the East due to bank erosion and the average bank erosion rate on the basis of data from 1973 to 2001 is 77 m/year. On the other hand bank erosion from 2000 to 2001 was 450 m i.e. 450 m/year.

4.4 Long term bank erosion rate

Using the satellite images for the period 1973-1995 analysis was done to find out the bank erosion rates along the both the left and right bank of the Jamuna river for the reach Bhuapur to about 45 km d/s of the Bangabandhu bridge.

The analysis shows that (Table-4.4) maximum bank erosion rate along the left bank in 1973-78 was 340 m/year at 35 km d/s from the bridge axis and 330 m/year at 5 km d/s from the bridge axis. Average bank erosion rate within 1973 to 1978 was about 230 m/year. Maximum bank erosion rates along the left bank in 1978-85, 1985-88, 1988-92, & 1992-95 were 450 m/year, 767 m/year, 500 m/year and 317 m/year respectively. The locations of maximum bank erosion rate were not the same. It varies widely. Locations of maximum bank erosion rates along the left bank in 1978-85, 1985-88, 1988-92 & 1992-95 were 23 km, 45 km, 10 km, and 6 km d/s from the bridge axis respectively (Table-4.4).

Average bank erosion rates in 1978-85, 1985-88, 1988-92 & 1992-95 were 306 m/year, 406 m/year, 344 m/y & 207 m/year respectively. That is, average bank erosion rate as well as maximum bank erosion rate in 1985-88 were significantly higher in comparison to other years. From analysis it is found that at the upper part of the Bangabandhu bridge along left bank rates of the bank erosion also significant (Table-4.3). It appeared from Table-4.3 that in 1973-75,1978-85,1985-88,1988-92 & 1992-95 the maximum bank erosion rates along the left were 300 m/year, 200 m/year, 383 m/year, 500 m/year, and almost zero m/year respectively. Average bank erosion rates in the previous sequences were 212 m/year, 131 m/year, 237 m/year, 194 m/year & 0 m/year respectively. That is, at the u/s reach of the Bangabandhu bridge the bank erosion rates were also significant but almost stopped after 1992.

From the results of analysis (Table-4.4) it is observed that most vulnerable zones for bank erosion along the left bank were 9 km to 19 km d/s from the bridge axis in 1985-88 and 6 km to 13 km d/s from the bridge axis in 1988-92. The vulnerable zone for bank erosion in 1992-95 was 4 km to 7 km d/s from the bridge axis along the left bank.

That is, the vulnerable zone for bank erosion along the left bank gradually shifted towards u/s from 1978 to 1995. But in 1973-78 this vulnerable zone was in 3 km to 7 km d/s of the bridge axis. That is, there is a cyclic process (Table-4.4).

From the analysis it was found that total shifting of the river in 1973 to 1995 was about 1550 m and in 1995 to 2001 total shifting was about 1100 m (Fig. 4.1). Total shifting (maximum) of the left bank to Eastward direction in 1973 to 2001 was in the order of 2000 m and that of right bank in 1973 to 1995 was 1600 m to Westward direction (Fig. 4.1). After 1995 shifting of right bank is insignificant. The maximum shifting of the river bank occurred at two locations at immediately d/s of the Bangabandhu bridge and at the u/s of Aricha for the left bank.

4.5 Short term bank erosion rate

From the analysis of bank erosion using the recent satellite images from EGIS-II for the period 1996-2001 it was found that along the left bank d/s of the Bangabandhu bridge the maximum bank erosion was 450 m in 2000-2001 (Fig.4.3 & Table-4.4). The maximum bank erosion point was 18 km d/s from the bridge axis. Average bank erosion rate in 2000-2001 was in the order of 200 m/year. The analysis also shows that along the left bank the maximum bank erosion rates immediately u/s of Tangail town were about 400 m, 100 m, 225 m, and 500 m, in 1996-97, 1997-98, 1998-99 & 1999-2000 respectively (Fig.4.3 & Fig.4.4), whereas bank erosion in these years along the right bank found almost nil.

It indicates that the river is gradually widening and this widening is happening due to bank erosion towards the East. Widening pattern of the river channel for the study reach can be seen in Fig.4.14. From that figure it is observed there is a gradual trend of increase of width of channel both at u/s and d/s of the Bangabandhu bridge axis. The maximum bank erosion i.e., shifting of the left bank to Eastward direction is in the order of 500 m/year.

During field investigation and questionnaire survey local riparian people opined that before 1995 bank erosion rate along the left bank d/s of Bangabandhu bridge was in the range of 50 to 75 m/year but after construction of bridge the bank erosion rate increases to around 250 to 300 m/year. Regarding position of bank line most of the local affected people opined that 5 years ago that is, in 1996 the bank line was about 2 km away from the present bank line position. That is, on average erosion rate was 400 m/year. Moreover, the riparian people think about future possible bank erosion along left bank that if present situation prevails then the bank line may be shifted 2 km in next 5 years and 4 to 4.5 km in next 10 years. It can be mentioned here that Tangail town is about 10 to 12 km away from the present ban line. A sample questionnaire is given in APPENDIX-C by which the people's opinion is collected.

4.6 Influence of high discharge on bank erosion

River bank erosion is closely related with the discharge of the river. With high discharge usual bank erosion rate may be higher in comparison to bank erosion rate during the low discharge. This hypothesis is investigated in the present study. Superimposing the bank line maps of the preceding and following years of the two major floods (1988 and 1998) in Bangladesh was investigated.

Fig.4.5 shows the superimposed bank line maps for the year of 1988,1989,1998 & 1999. Comparing the bank line positions, maximum bank erosion at three different locations along the left bank were measured and found to be 925 m, 1500 m & 1800 m in 1988 to 1989. The locations of these maximum erosion points were approximately 8.5 km, 15 km and 19.5 km d/s from the bridge axis.

Maximum bank erosion in 1998 to 1999 along the left bank at three locations were about 550 m, 950 m and 1500 m. The locations of these three points were approximately 11.5 km, 18 km & 22.2 km d/s from the bridge axis. On the other hand maximum bank erosion along the right bank were in the order of 650 m to 900 m in 1988-89 and 200 m in 1998-99.

Maximum bank erosion rate along the left bank in other years was found in the order of 400-550 m/year for the same river reach (Fig.4.6). Comparing the bank erosion rates in normal flood year with that of high food year it can be concluded that bank erosion with high discharge is much higher and erosion rate is strongly related with the river discharge in the Jamuna river. From Fig.4.5 & 4.6 it is observed that high bank erosion may occur even in convex bank and straight bank. Usually it is believed that high bank erosion occurs in concave bank. But in the Jamuna, highly braided river severe bank erosion can be occurred in straight bank also. It is clear from the bank line maps of different years as shown in Fig.4.5 & Fig.4.6.

4.7 Bend evolution and bend migration

Typical bend evolution immediately at the u/s of Tangail town is shown in Fig.4.7. In this figure the upper left figure gradual development of the bend from 1996 to 1998 is shown and in the upper right figure development from 1999 to 2001 is shown. Combination of the above figures is shown in bottom figure.

As it was found from FAP-1 study that major bank erosion is related to the presence of large bends that have a life cycle of between 3 and 7 years. Bank erosion along this bend was studied on the basis of satellite images for the period of 1996 to 2001.

Attempts were made to find out the relative radius of curvature and bend migration rate for consecutive years. But the numbers of data were very small and insignificant to plot on a graph. The radius of bend in 1999, 2000, and 2001 were found to be 2000 m, 2325 m and 3125 m respectively. Relative radius of curvature R/W were found to be 2.22, 2.58 and 4.16 for the years 1999, 2000 and 2001 respectively. Average bend migration from 1996-97, 1997-98,1998-99, 1999-2000 and 2000-2001 were found to be 196 m, 100 m, 500 m, 100 m and 870 m respectively.

We know from Hickin and Nanson (1984) study that maximum bank erosion rates occur for R/W values of about 2.5. For this bend the relative radius of curvature, R/W value was 2.58 in the year 2000. Coincidentally it is observed that average bank erosion rate from 2000-2001 was 870 m/year. That is, when relative radius of curvature was low (2.2) the erosion rate was also low and when relative radius of curvature value approaches to 2.5 the bank erosion rate becomes high. But after 2000, i.e., in 2001 the relative radius of curvature found to be 4.16 for the same bend. For this relative radius of curvature (4.16) it can be expected that the bank erosion rate will be reduced in consecutive years at this bend.

4.8 Possible future channel changes within the study reach

The Jamuna river in Bangladesh is a highly braided system with multiple parallel channels in each cross-section. The bankfull discharge of this river near Bahadurabad is about 44,000 cumec. Braiding characteristics of the river varies along the reach. At the u/s part i.e., above Bangabandhu bridge axis the river is highly braided i.e., number of channels are more than 3 even 4. But at the lower part d/s of Bhuapur the river is relatively less braided, number of major channels are often 2 which tend to behave as meandering channels.

From satellite images of the year 1973 to 2001 (Fig.4.8 & Fig.4.9) for the study reach it is appeared that in 1973 the main channel of the river at the d/s of Bangabandhu bridge was near the East bank but in 1980 the main channel shifted towards the West bank. Again in 1986 the main channel changed its position and moved to the East bank and from then the main channel remains close to the East bank up to 1998. After 1998 the main channel showed a tendency to gradual movement towards the inside of the river. From Fig.4.9 it can be seen that in 1999 the main channel at the d/s of Bangabandhu bridge bifurcated and this situation remains up to 2000. But in 2001 the main channel divided into three channels. Though from

Fig.4.9 it is observed that the channel close to the East bank is still prominent. Yet from the standpoint of regular channel geometry it can be expected that in near future this channel close to the East bank will be abandoned and river may follow the mid channel as main channel.

That is, bank erosion rate along the East bank, West side of Tangail town may not continue with such high rate like the present situation. After one or two year intensity of erosion will most probably be reduced at this site but erosion rate of the u/s of this area i.e., immediately d/s of Bangabandhu Bridge may be increased significantly as the main channel approaches the bank with sharp angle and from that point the main channel deflected towards the opposite bank.

4.9 Probability of erosion of Tangail town and its surrounding area

From the analysis of historical bank erosion rates with the help of satellite images it is found that average bank erosion rate was 550 m/year before 1995 and after 1998 the average erosion rate was 400 m/year. At the peak of the bend the erosion is much higher but that erosion not necessarily always the erosion of flood plains. With the present rate of bank erosion (400-550 m/year) within 20 years the river may reach near Tangail town. But this rate of erosion may not exists for the long time. Though from the analysis of bank erosion rate and trend of erosion it seems that possibility of erosion of Tangail town in near future is not so significant but the surrounding area of Tangail town is gradually eroding and in future it will further be eroded.

4.10 Possible remedial measures to stop further bank erosion

The erosion power of water of a river mainly depends on its discharge, intensity of current, location of flow concentration, resistance to abrasion of the bed & bank material etc. The volume and rate of sediment usually not proportional to the transporting power of the river. During low and medium flow the rate of sediment transportation exceed the transporting capacity. But during high flow more energy is developed by the river then is required to move the sediments. This excessive energy attacks the bed and the banks resulting in an eroding process by which the overall shape, dimensions and the planform of the river are developed. Bank erosion causes loss of valuable land, homestead and important structures. Due to bank erosion riparian people becomes homeless and landless. So it is important to protect the banks against erosion.

Many and various methods for bank protection have been developed using modern materials and highly developed engineering systems. In the past, bank protection works on the major rivers were mainly restricted to the most important locations and bank stabilization was done by means of brick revetments and groyne. Depending on river morphology, bed topography, location and space available various types of direct bank protection measures e.g. revetments, retaining wall, porcupines or indirect measures, i.e., groyne, cut-off etc. can be executed. In the past, in many places these types protective measures were executed with more or less success.

To stop further erosion and to stabilize the left bank of the Jamuna river down stream of the Bangabandhu Bridge revetments with CC blocks can be used instead of groyne.

Groyne was used at the upstream of Bangabandhu bridge along the right bank which is deflecting the flow towards the left bank and causes more bank erosion in the left bank. But if revetment is used on the left bank where more attack is observed the flow will be deflected more smoothly and there will be minimum adverse effect on the opposite bank.

Design of bank protection works generally follow standard rules and scale model investigation is necessary to select suitable measures and to find out optimum design parameters from hydraulic as well as scour standpoints. River Research Institute has the mandate, skilled manpower and necessary infrastructures to carry out scale model investigations for any river training and bank protection structures.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the study it is found that there is a history that once the Jamuna river was flowing close to the Tangail town (Wilcox 1830). After that river had a tendency to shift towards the west upto 1973. But after 1973 the river changed its shifting direction especially in the study reach. That is the river is gradually shifting towards the east i.e., towards Tangail town. The present average erosion rate is in the order of 400 m/year to 550 m/year. If this erosion rate exist for long time then within 20 to 22 years the river may reach near Tangail town. But the present erosion rate may not continue for the long time. As bank erosion is a cyclic process. For some time there may be severe bank erosion but after a few years vulnerable zone for bank erosion may change. A large bend is developed at the immediately u/s of Tangail town along the left bank. Flow from the u/s is attacking directly with a sharp angle. Bend was migrating towards the east rapidly. In the year 2000 relative radius of curvature R/W for this bend was around 2.58 and with this relative radius of curvature the migration of bend was 870 m/year that is quite high. But in the year 2001 the relative radius of curvature R/W for the same bend was about 4.16, which is far more than 2.5. As per Hickin and Nanson (1984) concept the bend migrations rate in the following years for this bend should be reduced. It is likely as from flow condition it is found that main channel has been divided into three channels immediately u/s of this bend. In near future, may be in the next year the channel close to the east bank may be abandoned.

5.2 RECOMMENDATION

The possibility of erosion of Tangail town is not significant yet surrounding areas of Tangail town is eroding significantly by the river Jamuna. It is expected that in near future more area of Tangail district will be lost due to severe bank erosion of the Jamuna. And also as there is a history, the Jamuna river may shift more towards east i.e., towards Tangail town in future. So it is necessary to stabilize the left bank of Jamuna river at d/s of Bangabandhu bridge upto at least 20 km from the bridge axis. To stabilize the bank and to stop further bank erosion, revetment type of structures may be useful instead of groyne like structures.

Revetment can deflect the flow relatively more smoothly and thus less adverse effect to the opposite bank and other areas. Suitable structure for bank protection and design parameters can be selected from detail scale model investigation with present bathymetry and flow conditions for the site. RRI has the necessary facilities i.e., skilled manpower, infrastructures and others to carry out scale model investigations for bank protection.

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TABLES

Table 4.1 Bank erosion rate along the right bank (u/s of Bangabandhu bridge)

Distance Measured from axis of Banga Bandhu Bridge in km	Bank migration meter/Year								
	2001-2000	2000-1998	1998-1997	1997-1996	1995-1992	1992-1988	1988-1985	1985-1978	1978-1973
2	0	37.5	-75	550	-400	0	-150	-21	120
4	0	250	0	-100	0	0	-183	-71	210
6	0	650	0	1400	0	-700	383	-50	400
8	0	50	650	900	0	0	0	0	0
10	250	-25	-50	200	0	0	0	0	0
12	0	0	0	300	0	0	0	0	0
14	0	0	0	-750	0	0	0	0	0
16	0	0	0	-150	0	0	0	0	0

NB- +ve sign stands for bank erosion and -ve sign stands for new bank build up

Table 4.2 Bank erosion rate along the right bank (d/s of Bangabandhu bridge)

Distance Measured from axis of Banga Bandhu Bridge in km	Bank migration meter/Year								
	2001-2000	2000-1998	1998-1997	1997-1996	1995-1992	1992-1988	1988-1985	1985-1978	1978-1973
2	50	-50	0	150	117	250	-33	36	150
4	0	0	0	0	100	250	-67	121	130
6	0	0	0	0	400	-175	0	250	130
8	-50	25	50	-100	67	113	150	164	210
10	0	0	0	-50	267	-25	67	-43	200
12	0	0	0	50	-100	0	33	36	150
14	0	25	-50	50	0	25	67	0	100
16	0	100	0	0	33	38	-50	14	200
18	0	100	-200	0	-33	-300	250	150	190
20	25	137.5	150	-50	-583	0	200	207	210
22	100	375	0	50	17	113	-183	164	310
24	0	300	0	50	133	163	50	114	200
26	200	150	50	150	250	38	283	86	20
28	500	25	150	150	17	50	233	0	80
30	200	0	-100	450	83	0	100	-7	10
32	150	-75	0	0	0	-225	233	-43	100
34	50	25	350	-550	0	-38	50	29	-40
36	0	0	-50	250	0	-213	283	29	-40
38	0	25	50	150	0	-38	50	0	0
40	0	50	-100	500	0	-25	67	-14	0
42	50	-25	0	700	0	-150	100	43	0
44	0	0	-100	450	0	-338	117	64	110
46	0	25	-100	250	0	-463	150	64	190
48	-150	75	250	-250	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0
52	0	0	-50	100	0	0	0	0	0

NB- +ve sign stands for bank erosion and -ve sign stands for new bank build up

Table 4.3- Bank erosion rate along the left bank (u/s of Bangabandhu bridge)

Distance Measured from axis of Banga Bandhu Bridge in km	Bank migration meter/Year								
	2001-2000	2000-1998	1998-1997	1997-1996	1995-1992	1992-1988	1988-1985	1985-1978	1978-1973
2	100	400	550	250	0	500	67	114	200
4	0	300	100	0	-33	250	333	186	200
6	0	0	0	400	-50	38	233	200	-20
8	100	275	350	200	0	0	-17	129	240
10	0	275	300	350	-200	13	150	29	300
12	0	50	200	200	0	0	367	-71	120
14	-100	0	100	0	0	-288	383	-71	100
16	0	37.5	125	-100					

NB- +ve sign stands for bank erosion and -ve sign stands for new bank build up

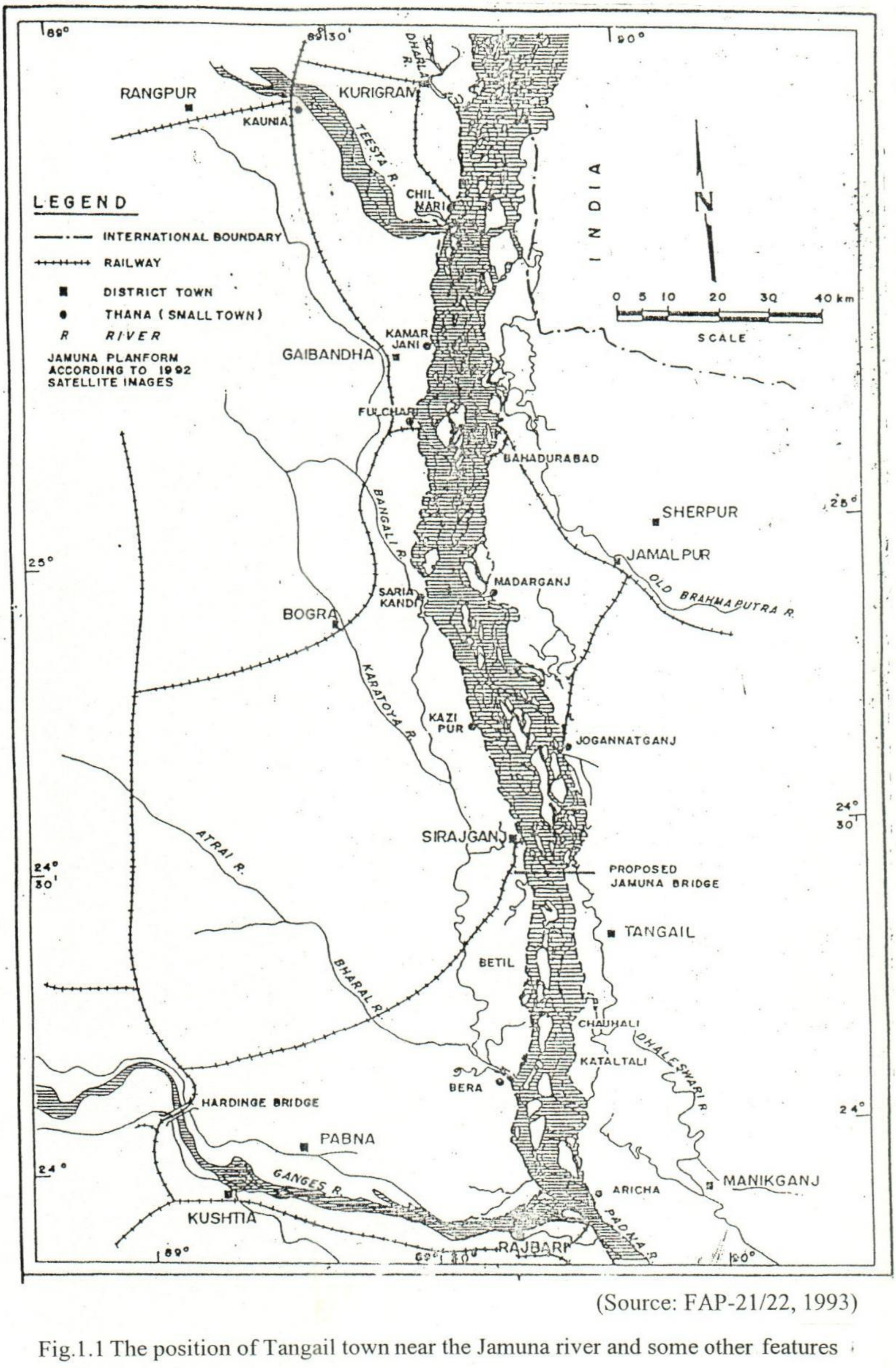
Table 4.4 Bank erosion rate along the left bank (d/s of Bangabandhu bridge)

Distance Measured from axis of Banga Bandhu Bridge in km	Bank migration meter/Year								
	2001-2000	2000-1998	1998-1997	1997-1996	1995-1992	1992-1988	1988-1985	1985-1978	1978-1973
1	0	750	0	-400	-817	458	157	114	0
2	50	500	300	-1050	-267	88	217	0	60
3	0	750	-300	-1100	-150	188	183	-114	160
4	0	600	-1050	-50	133	275	0	-157	260
5	0	100	50	50	283	263	200	-307	330
6	0	150	50	150	317	288	267	-286	300
7	100	200	200	100	267	275	333	-243	290
8	300	200	100	200	150	375	283	21	0
9	400	175	50	300	17	438	400	29	-40
10	50	125	100	350	0	500	433	14	-60
11	0	175	100	350	42	488	317	29	-40
12	0	225	300	100	50	400	250	57	0
13	100	275	150	100	100	213	150	143	0
14	200	250	200	0	133	63	267	121	0
15	100	50	200	-200	50	0	350	164	0
16	200	-100	200	0	83	-25	400	164	100
17	200	-85	270	50	25	38	500	93	-30
18	450	-25	0	0	50	75	750	-29	-40
19	200	50	50	-50	100	163	583	-14	20
20	0	150	50	50	33	238	-17	171	60
21	250	25	200	300	150	113	117	86	200
23	100	50	300	0	0	250	-17	450	20
25	0	500	100	-100	-100	150	267	429	-200
27	0	-50	100	0	-100	288	350	357	-420
29	150	175	200	-100	-67	400	33	343	-380
31	0	0	0	25	-100	88	-117	129	-180
33	100	25	50	50	100	188	-117	0	0
35	0	175	150	-100	50	450	33	-243	340
37	50	300	50	-100	0	375	-83	157	80
39	200	175	100	0	250	250	-400	314	80
41	0	700	300	300	267	-163	17	386	20
43					-100	0	583	236	280
45					-67	275	767	257	300

NB- +ve sign stands for bank erosion and -ve sign stands for new bank build up

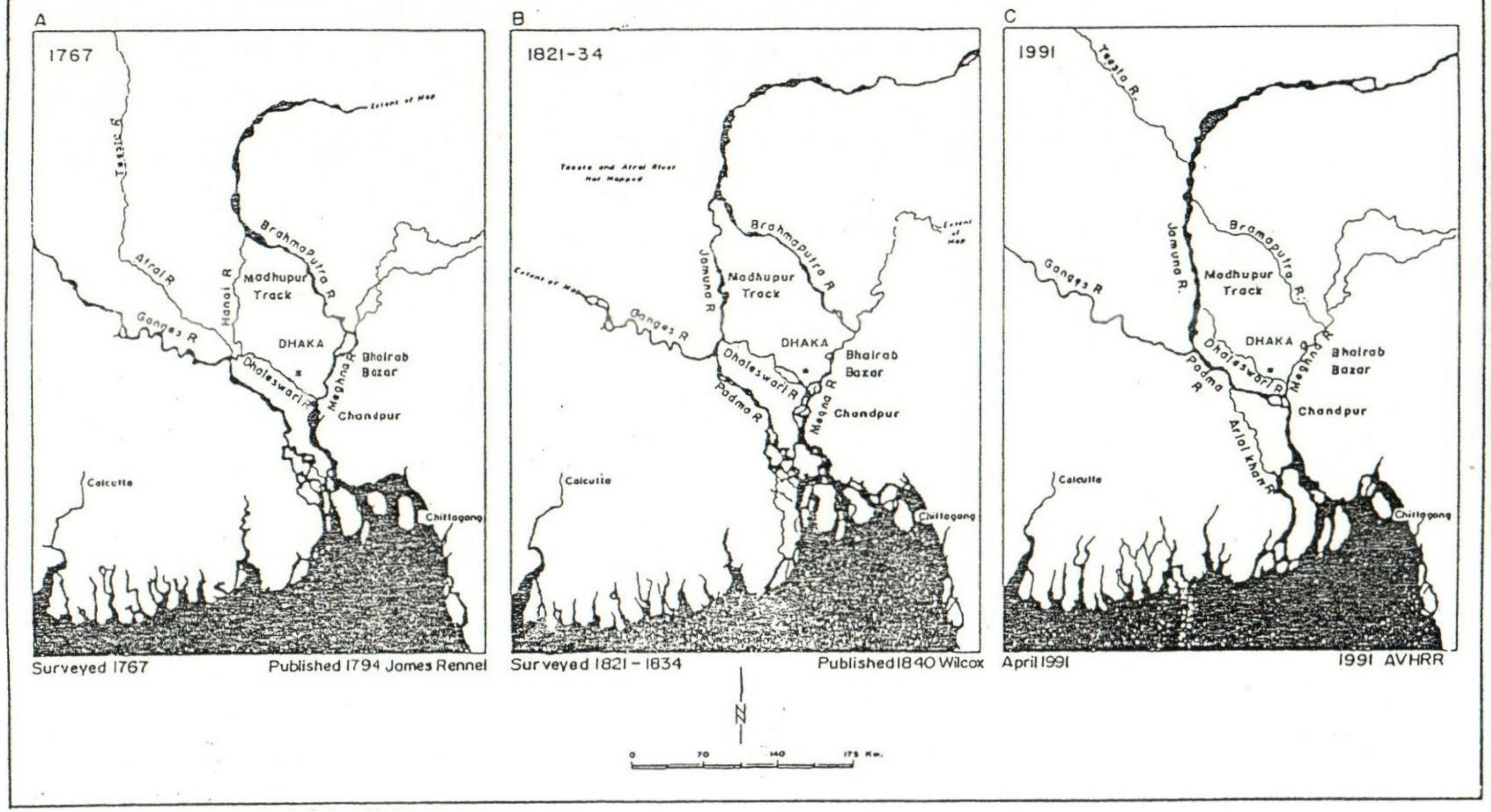
Table 4.5 Width of river channel in different years at four locations

sl. No.	Year	Width in km			
		0.5 km u/s of bridge axis	5 km d/s of bridge axis	10 km d/s of bridge axis	15 km d/s of bridge axis
1	1973	11.9	2.5	2.9	3.6
2	1978	14.6	3.2	3.8	6.7
3	1985	15.3	4.0	6.2	8.0
4	1988	13.3	4.7	7.3	8.8
5	1992	13.0	7.2	8.3	9.5
6	1995	13.1	8.2	8.7	9.7
7	1996	11.0	8.8	9.1	10.0
8	1997	13.1	8.6	9.4	9.4
9	1998	13.4	8.6	9.3	9.5
10	1999	15.5	8.8	9.9	10.1
11	2000	14.5	8.8	9.8	9.8
12	2001	14.9	8.9	9.9	10.1



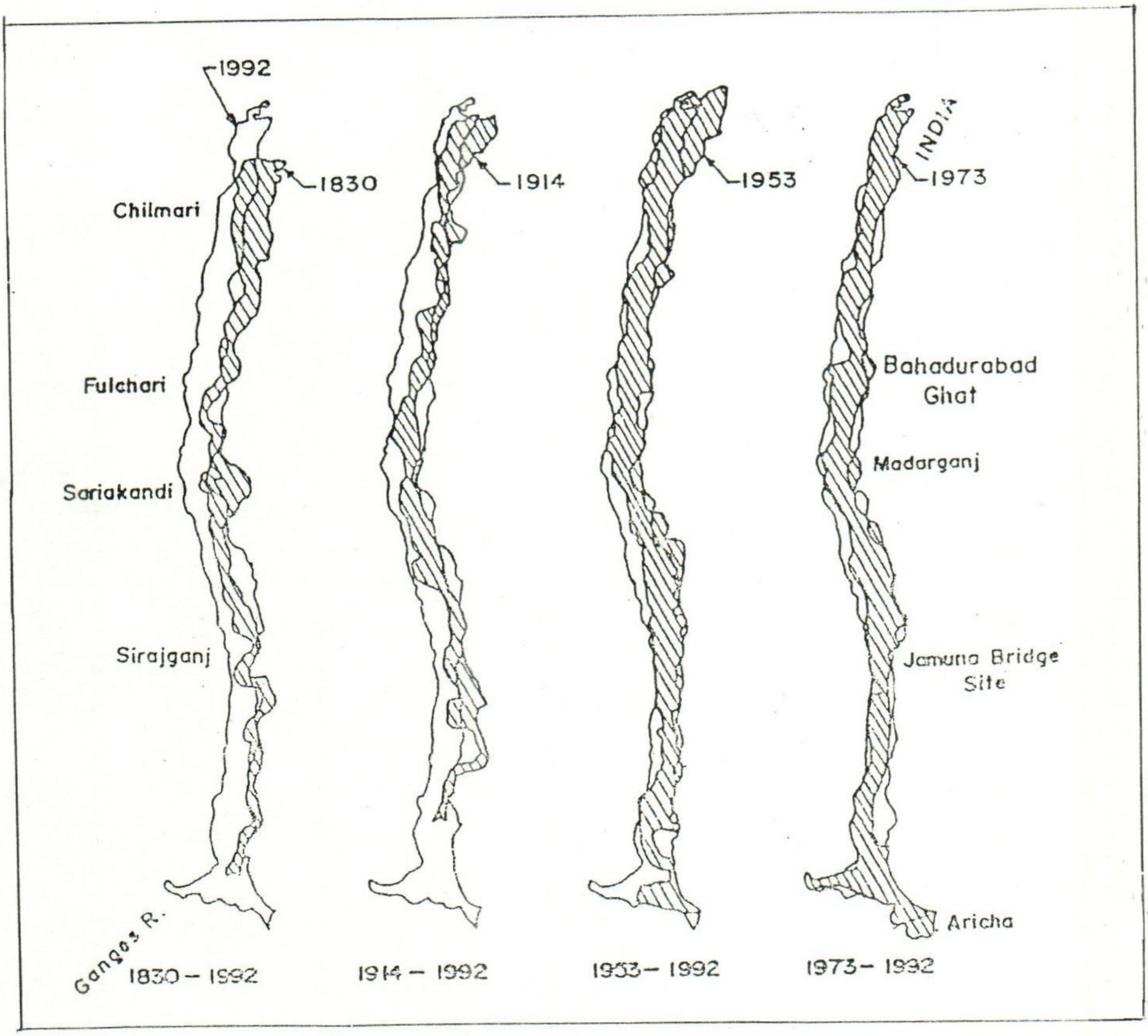
(Source: FAP-21/22, 1993)

Fig.1.1 The position of Tangail town near the Jamuna river and some other features



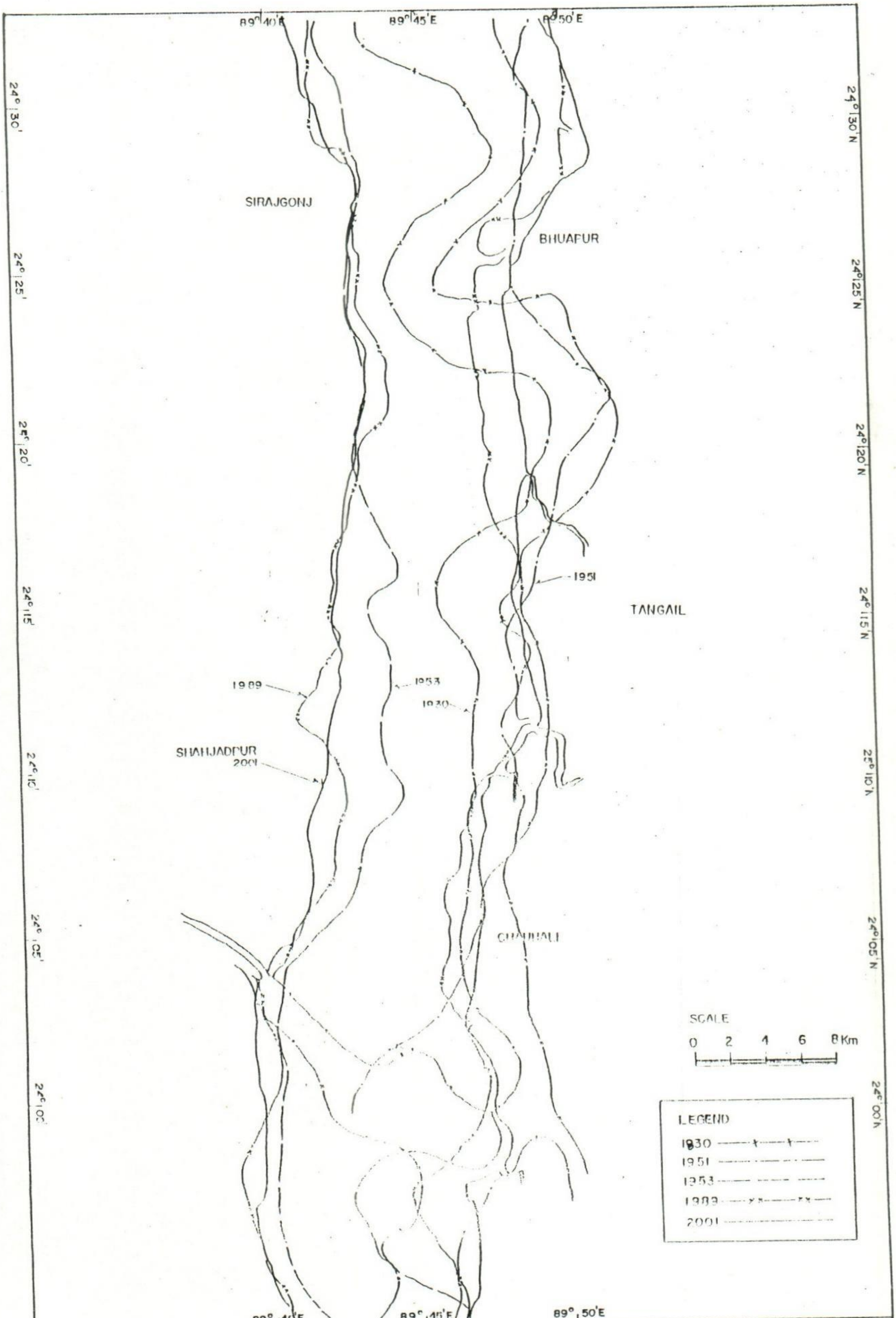
(Source: FAP-24, 1996)

Fig.2.1 Evolution of the Jamuna river in Bangladesh.



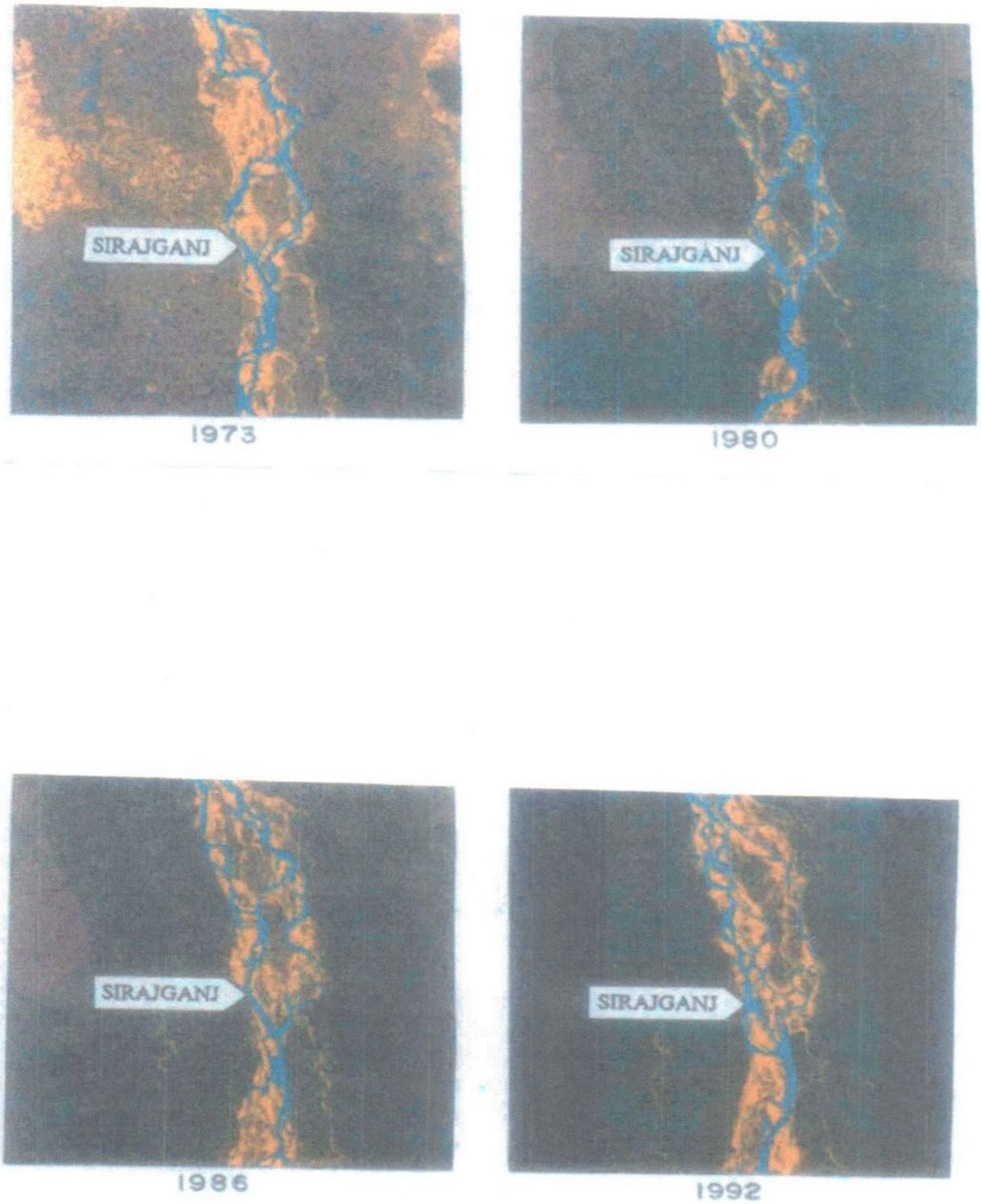
(Source: FAP-24, 1996)

Fig.2.2 Historical bank line positions of the Jamuna river.



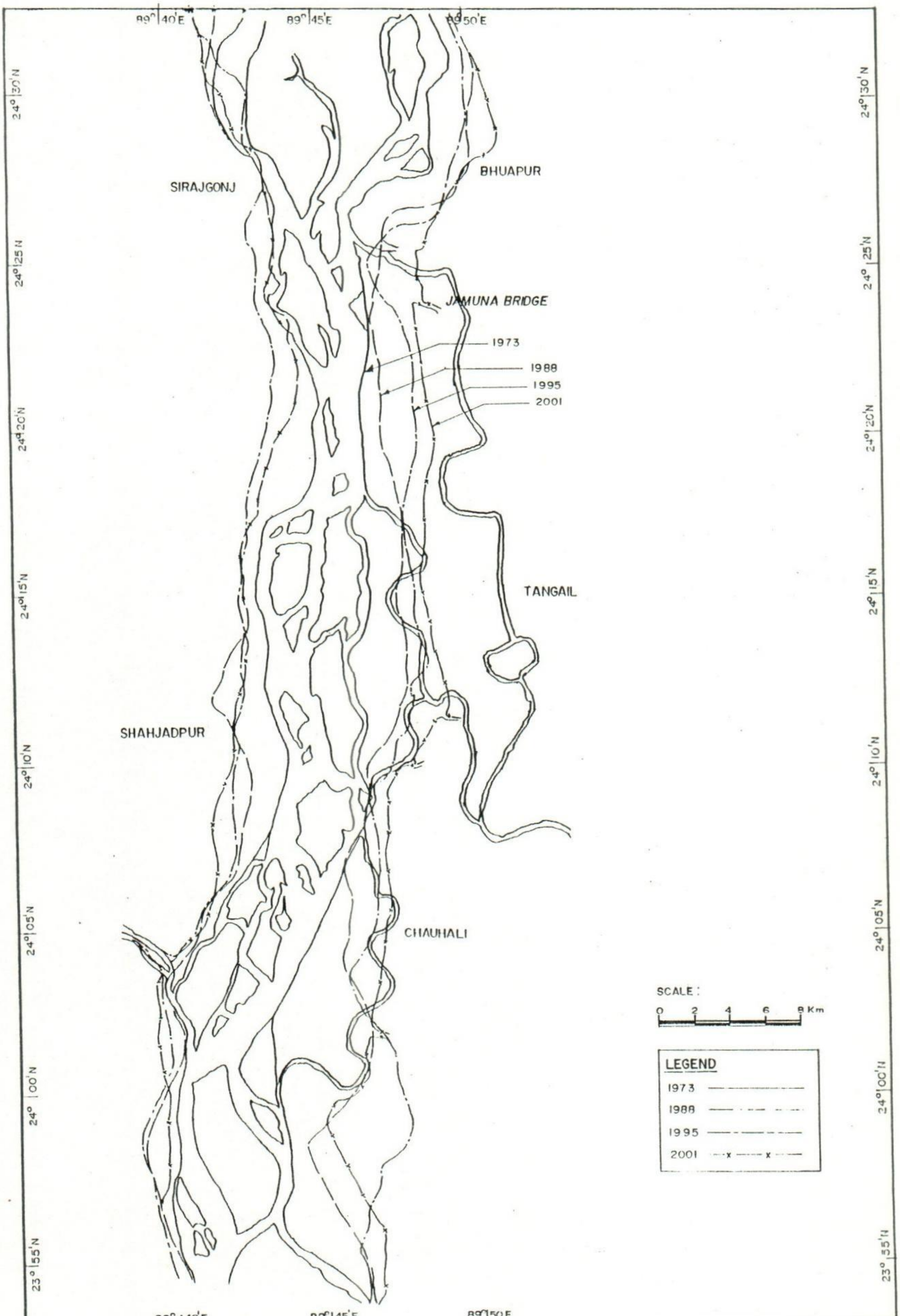
HISTORICAL BANK LINE POSITIONS OF THE JAMUNA RIVER FOR THE STUDY AREA

FIG.2.3



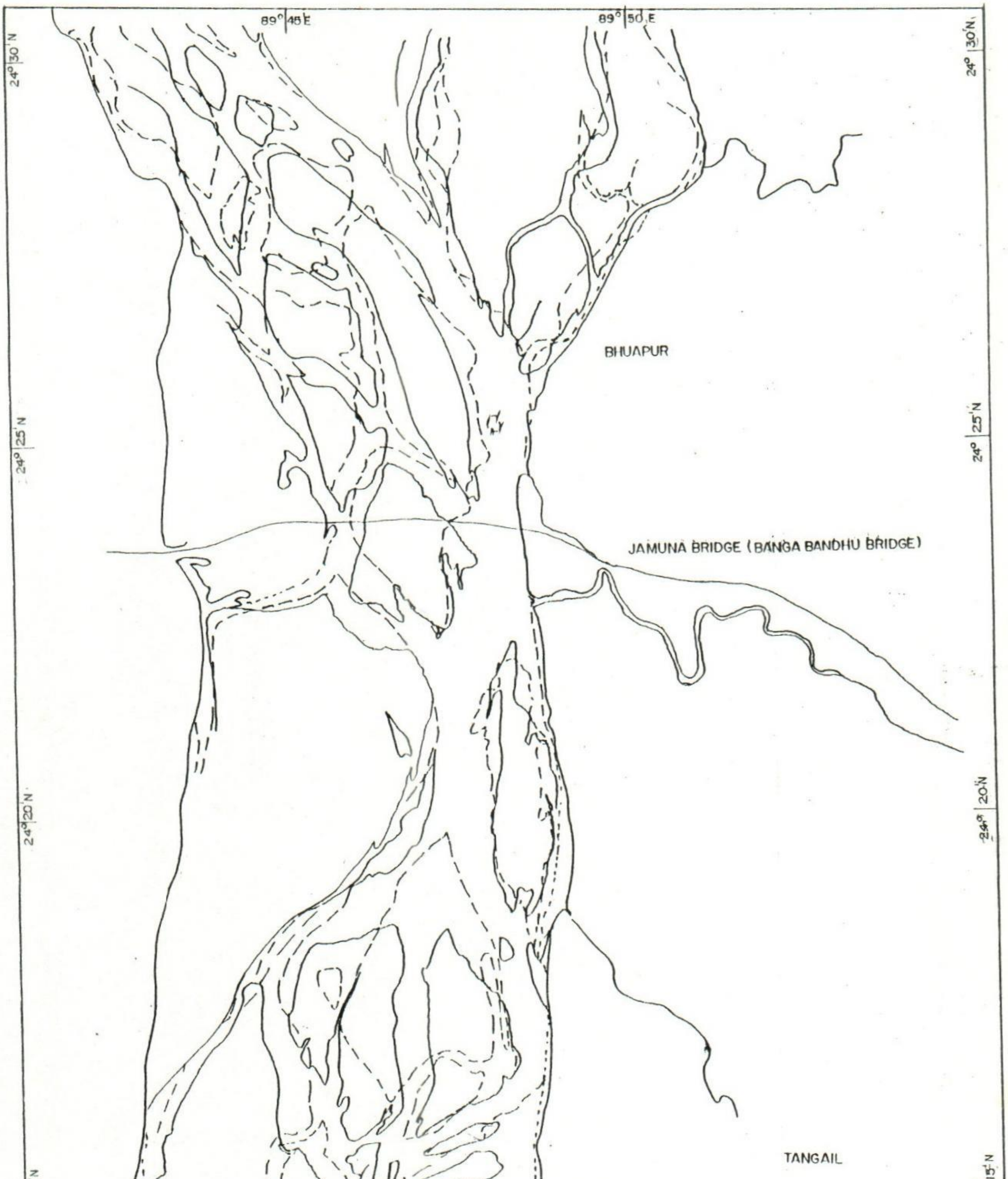
(Source: FAP-24, 1993)

Fig.2.4 Planforms of the Jamuna river in 1973 to 1992



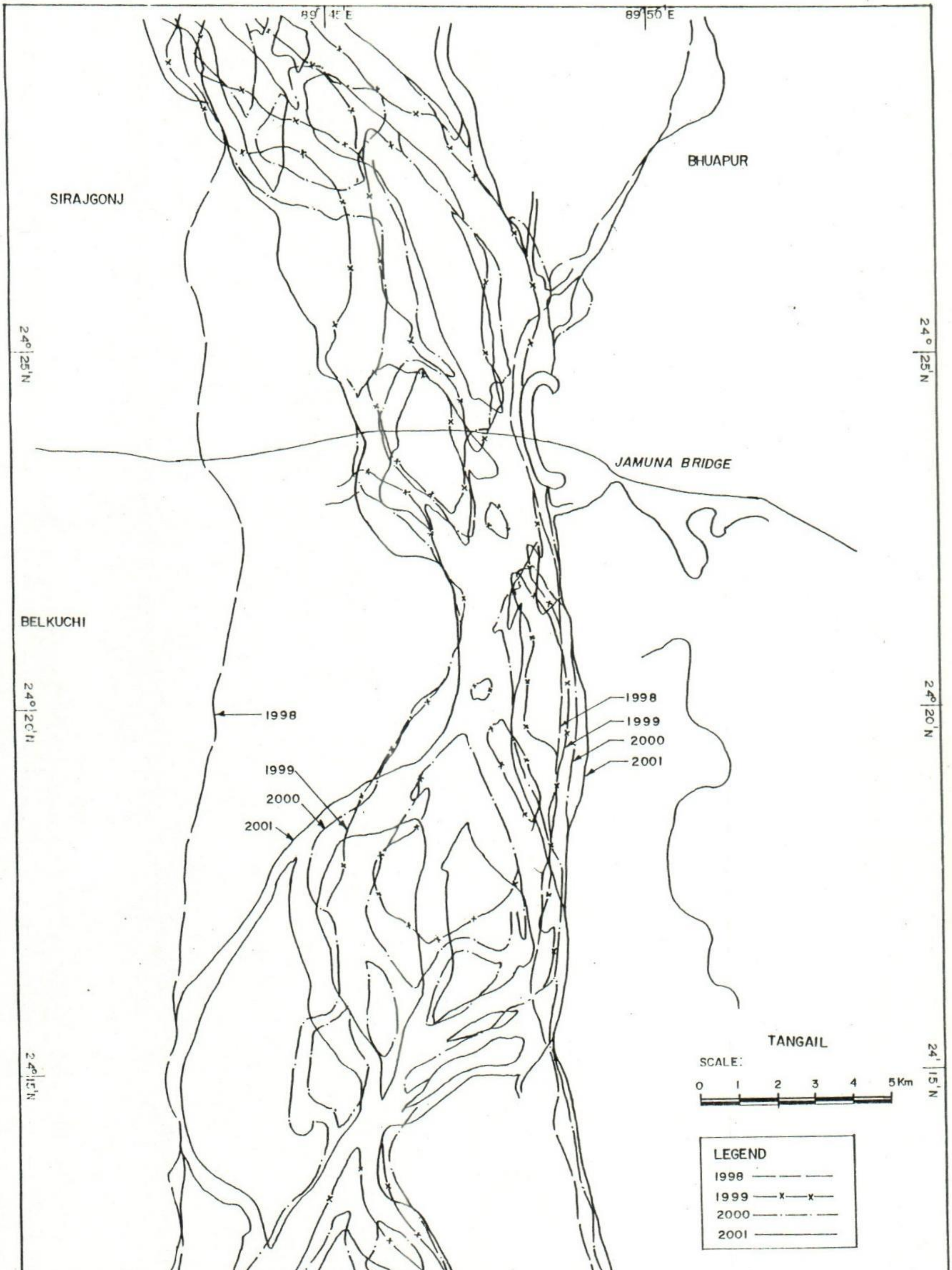
SHIFTING OF THE RIVER COURSE FOR THE REACH BHUAPUR TO NEAR ARICHA (THE JAMUNA)

FIG.4.1



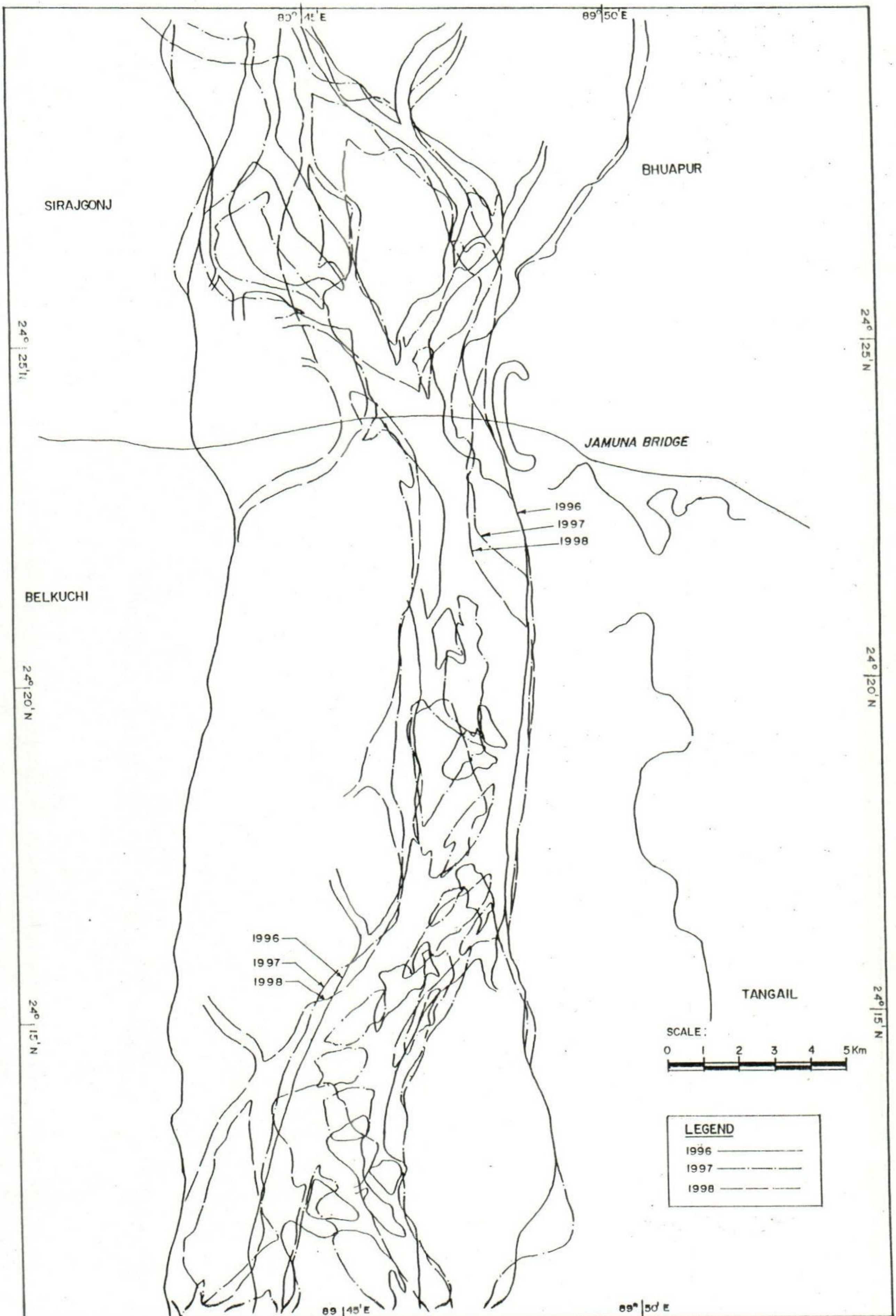
SHOWS THE RECENT CHANGE IN BANK LINES OF THE JAMUNA RIVER AT STUDY AREA.

FIG.4.2

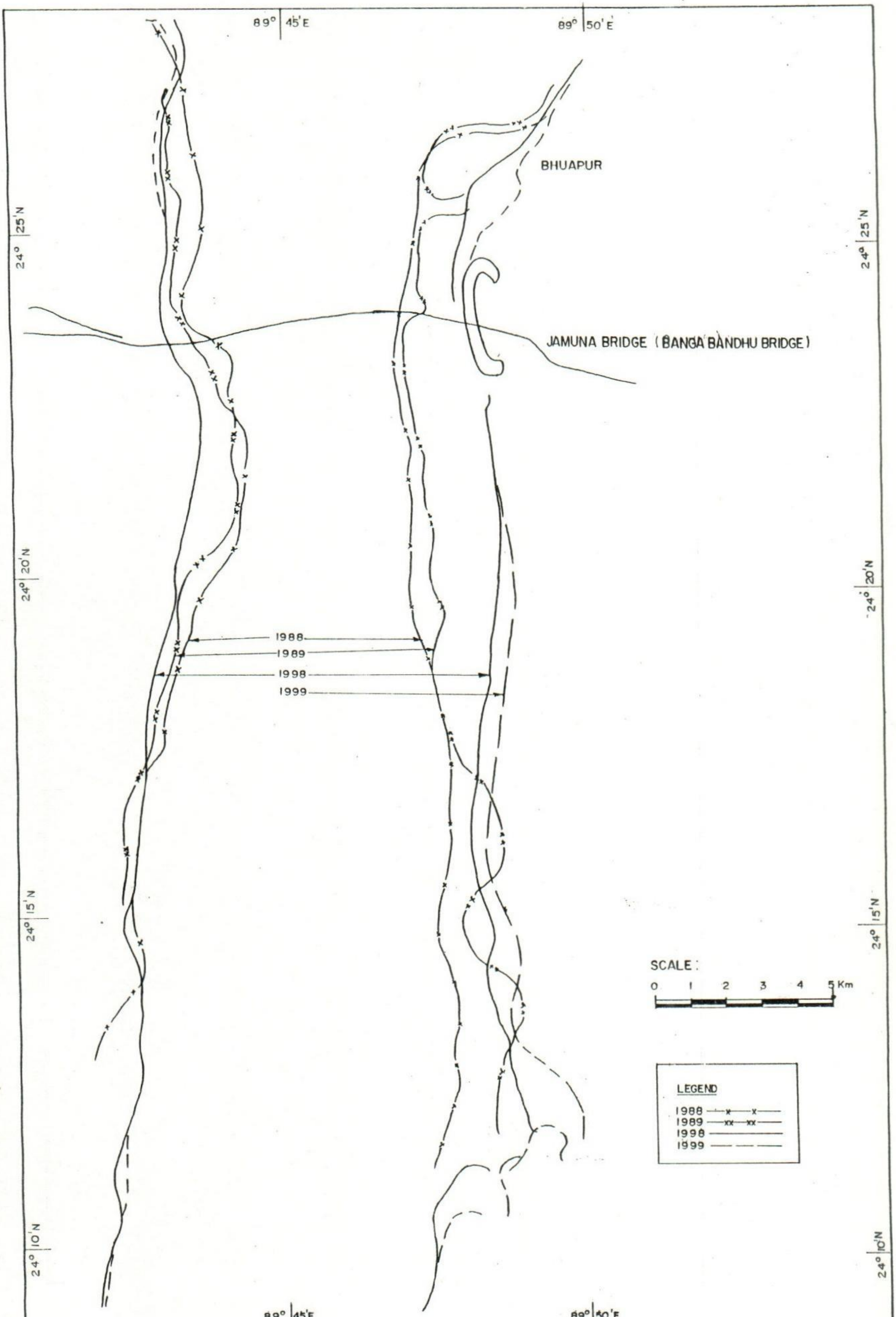


RIVER COURSE OF THE JAMUNA IN 1998 TO 2001

FIG.4.3

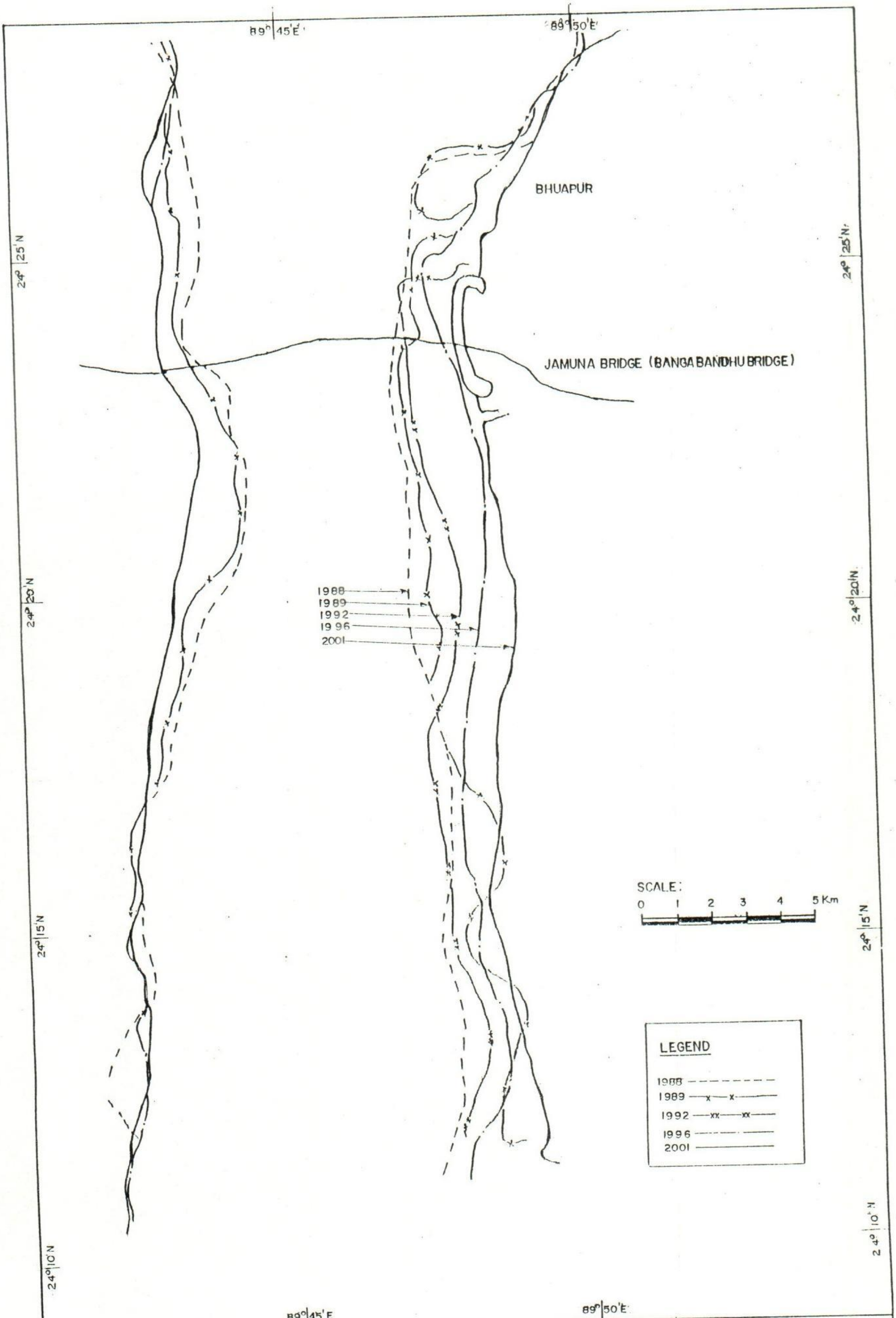


RIVER COURSE IN 1996, 1997 & 1998 FOR THE STUDY REACH. FIGURE : FIG.4.4



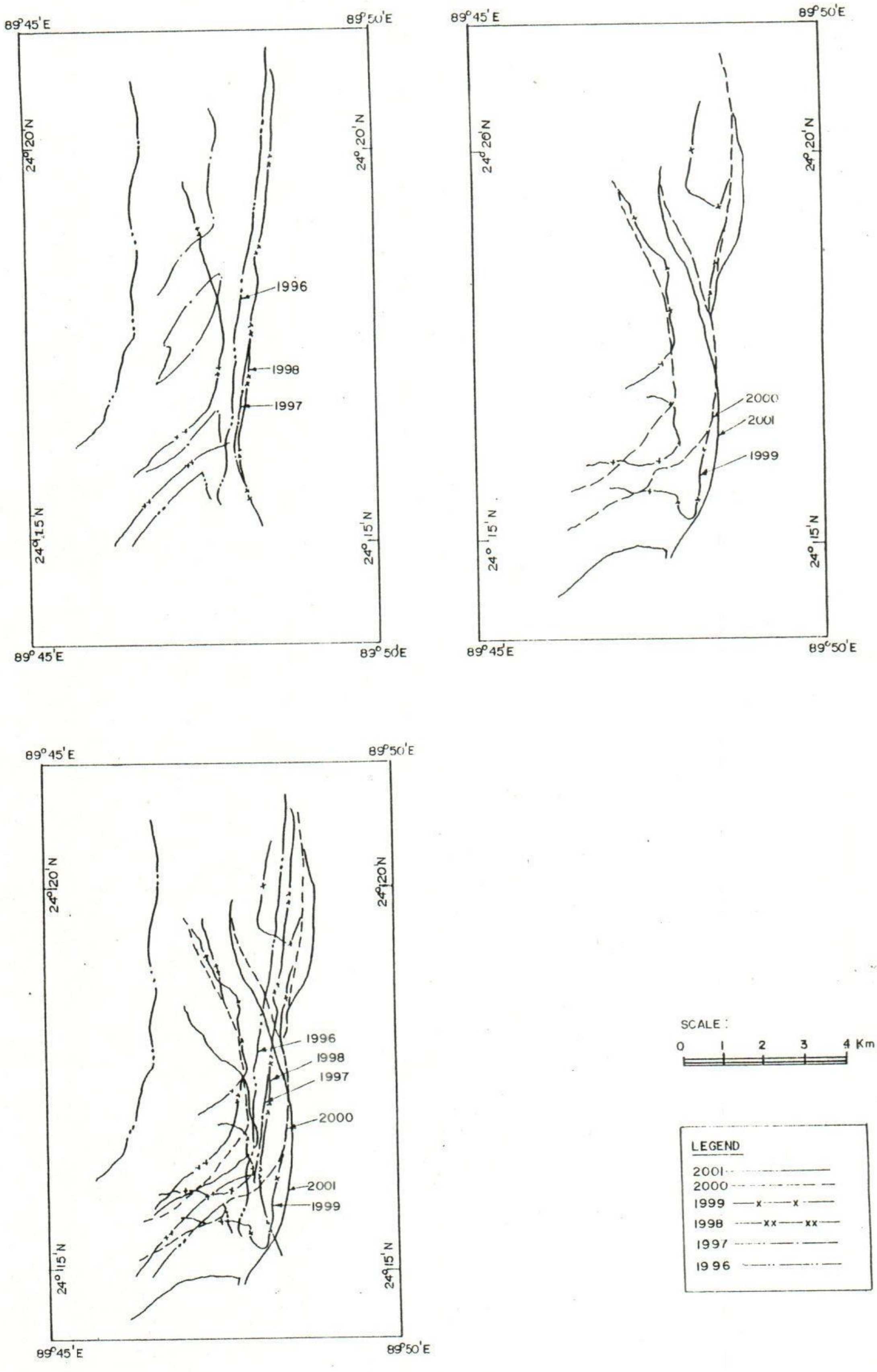
BANK LINES BEFORE AND AFTER MAJOR FLOOD IN BANGLADESH

FIG.4.5



BANK LINE POSITIONS OF THE JAMUNA RIVER FOR BHUAPUR TO NEAR ARICHA IN DIFFERENT YEARS

FIG.4.6

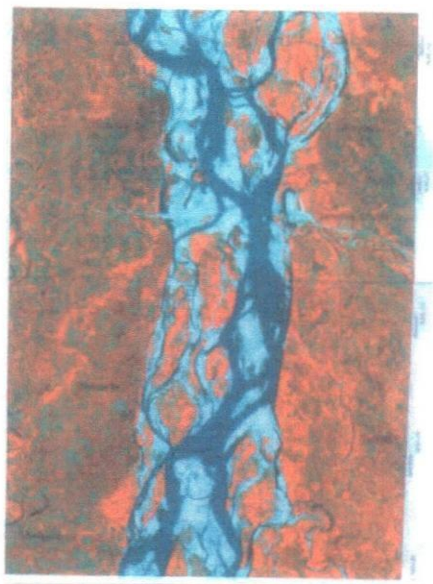


TYPICAL BEND EVOLUTION IN THE JAMUNA RIVER AT THE D/S OF BANGABANDHU BRIDGE (ALONG LEFT BANK)

FIG.4.7

1996

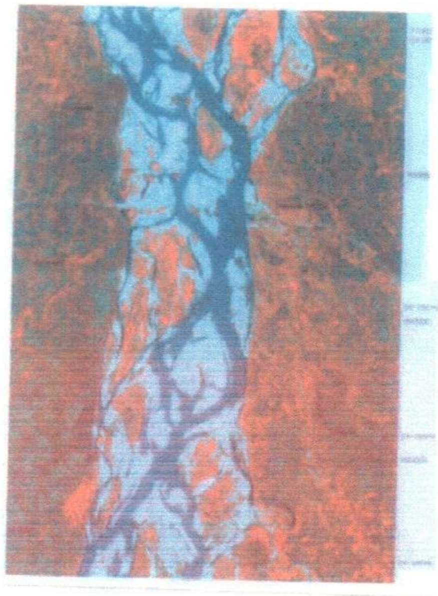
1997



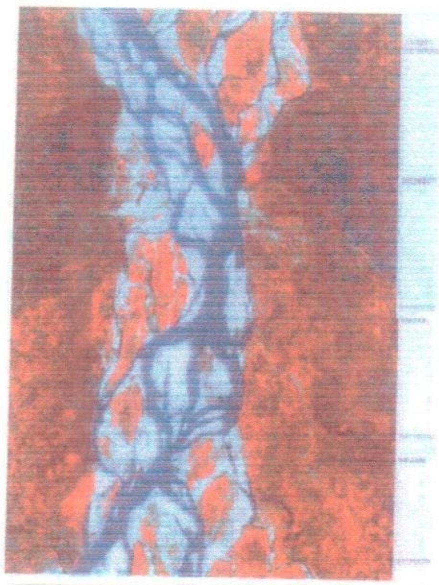
1998

Fig.4.8 Planforms of the Jamuna river in 1996, 1997 & 1998

1999



2000



2001

Fig.4.9 Planforms of the Jamuna river in 1999, 2000 & 2001

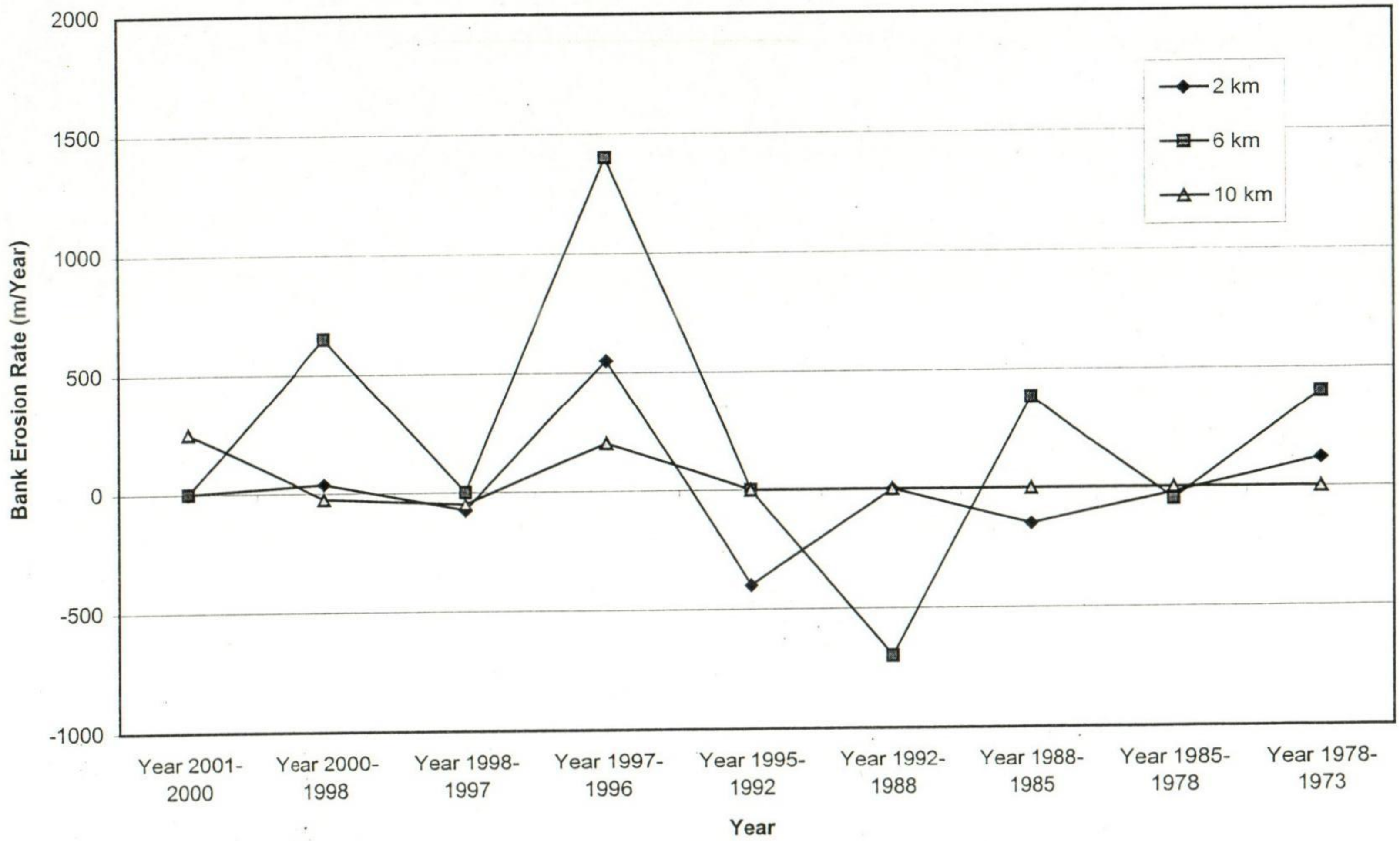


Fig.4.10 Temporal variation of bank erosion rate at the right bank, u/s of Bangabandhu bridge

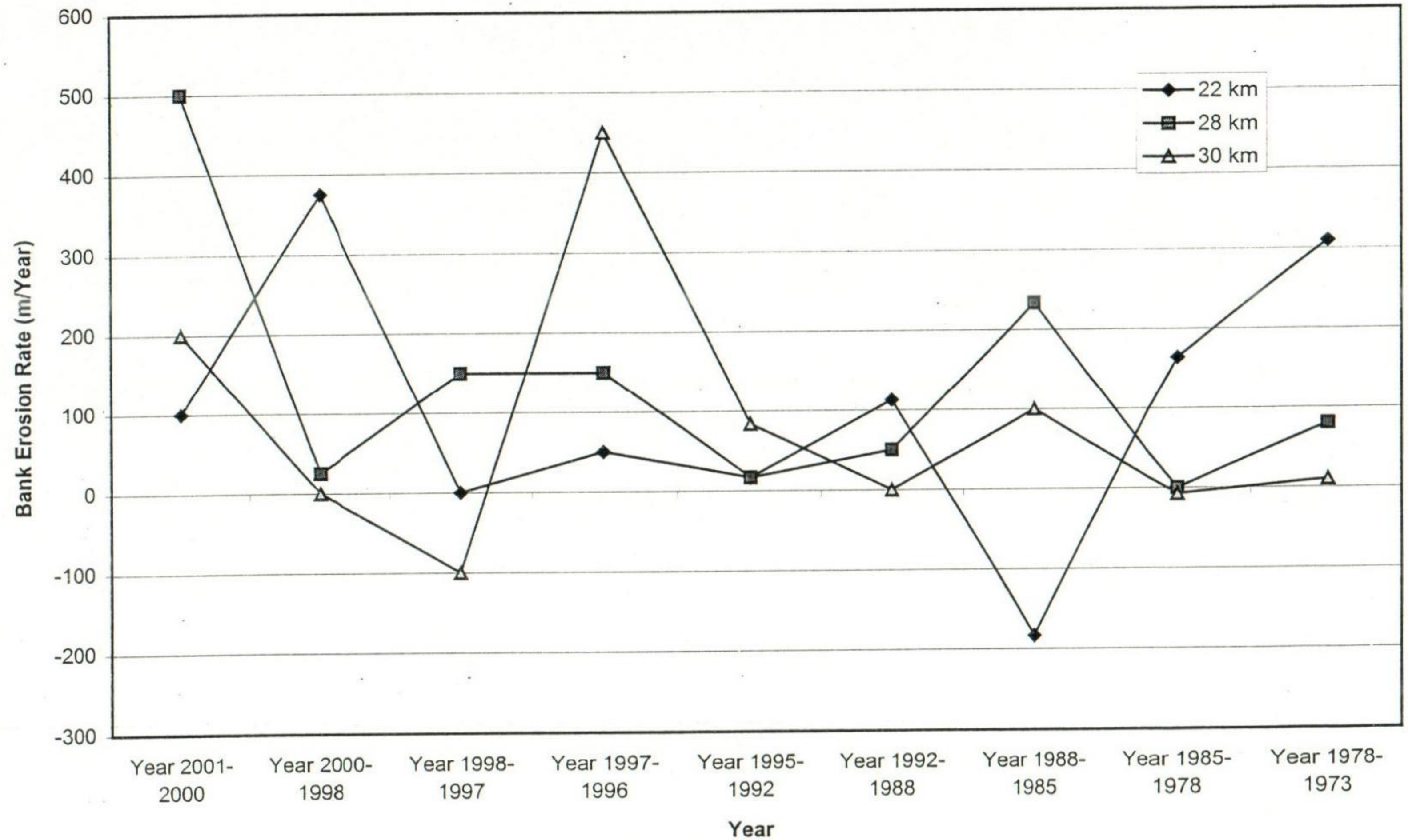


Fig.4.11 Temporal variation of bank erosion rate at the right bank, d/s of Bangabandhu bridge

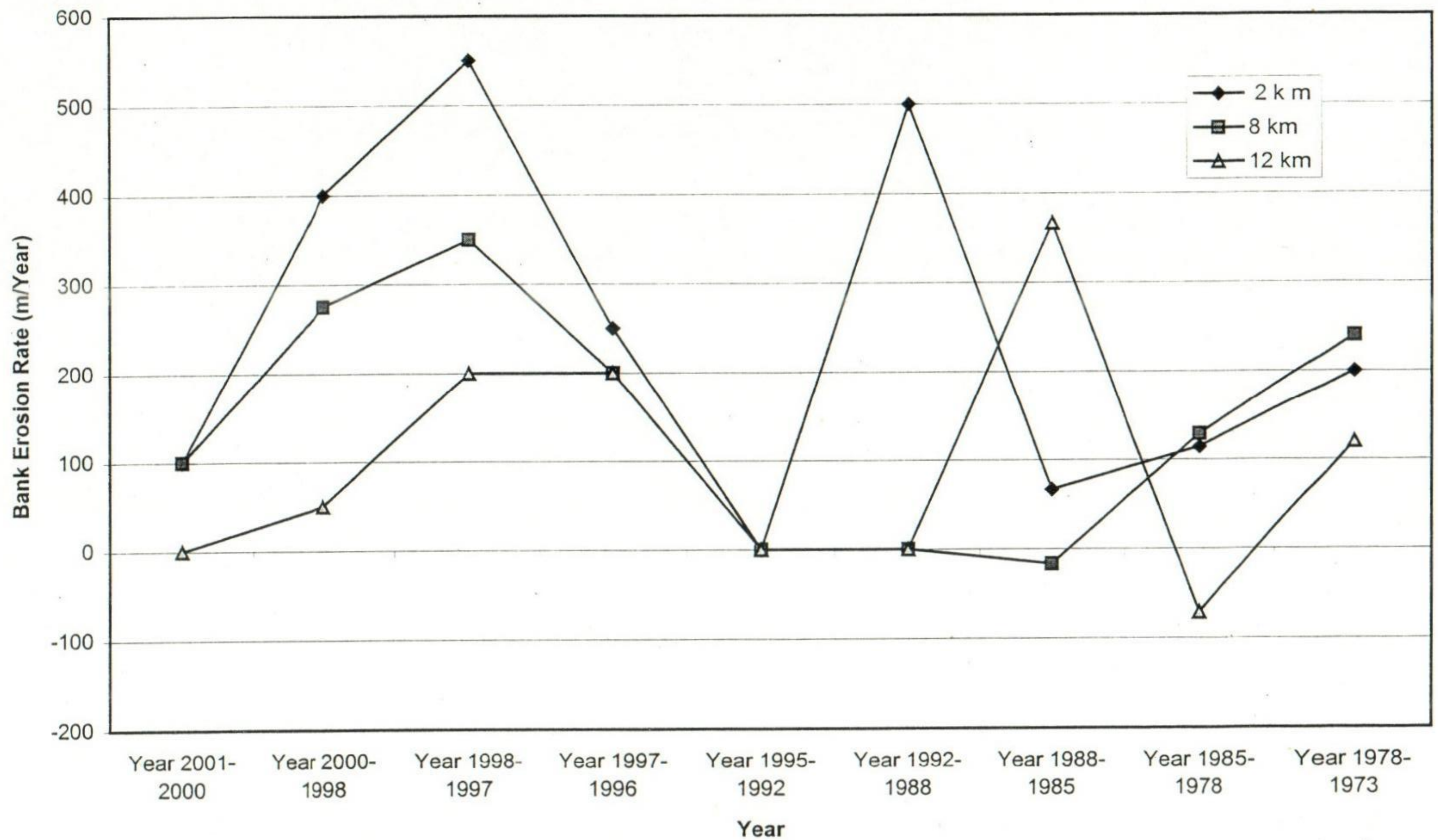


Fig.4.12 Temporal variation of bank erosion rate at the left bank, u/s of Bangabandhu bridge

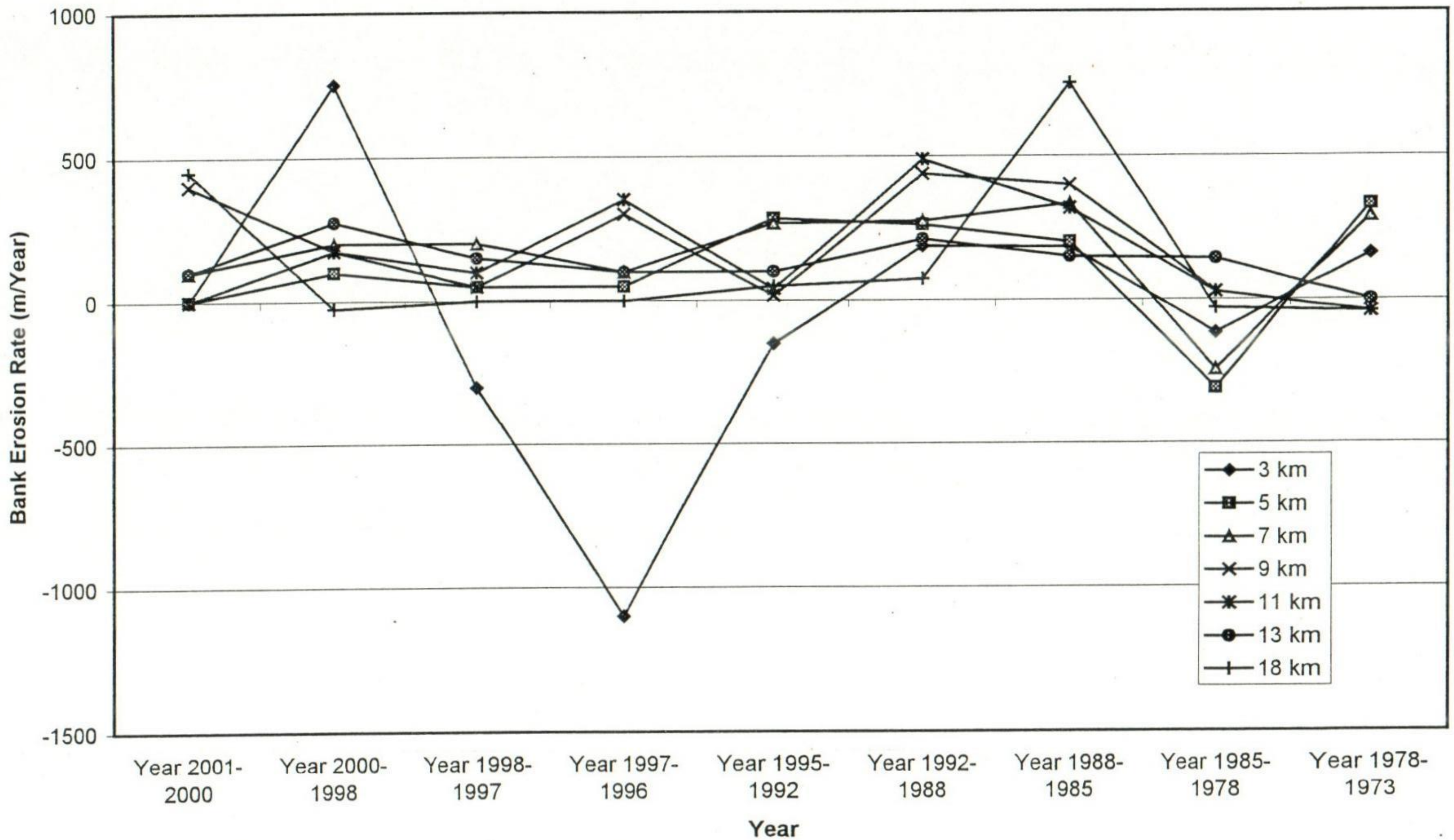


Fig.4.13 Temporal variation of bank erosion rate at the left bank, d/s of Bangabandhu bridge

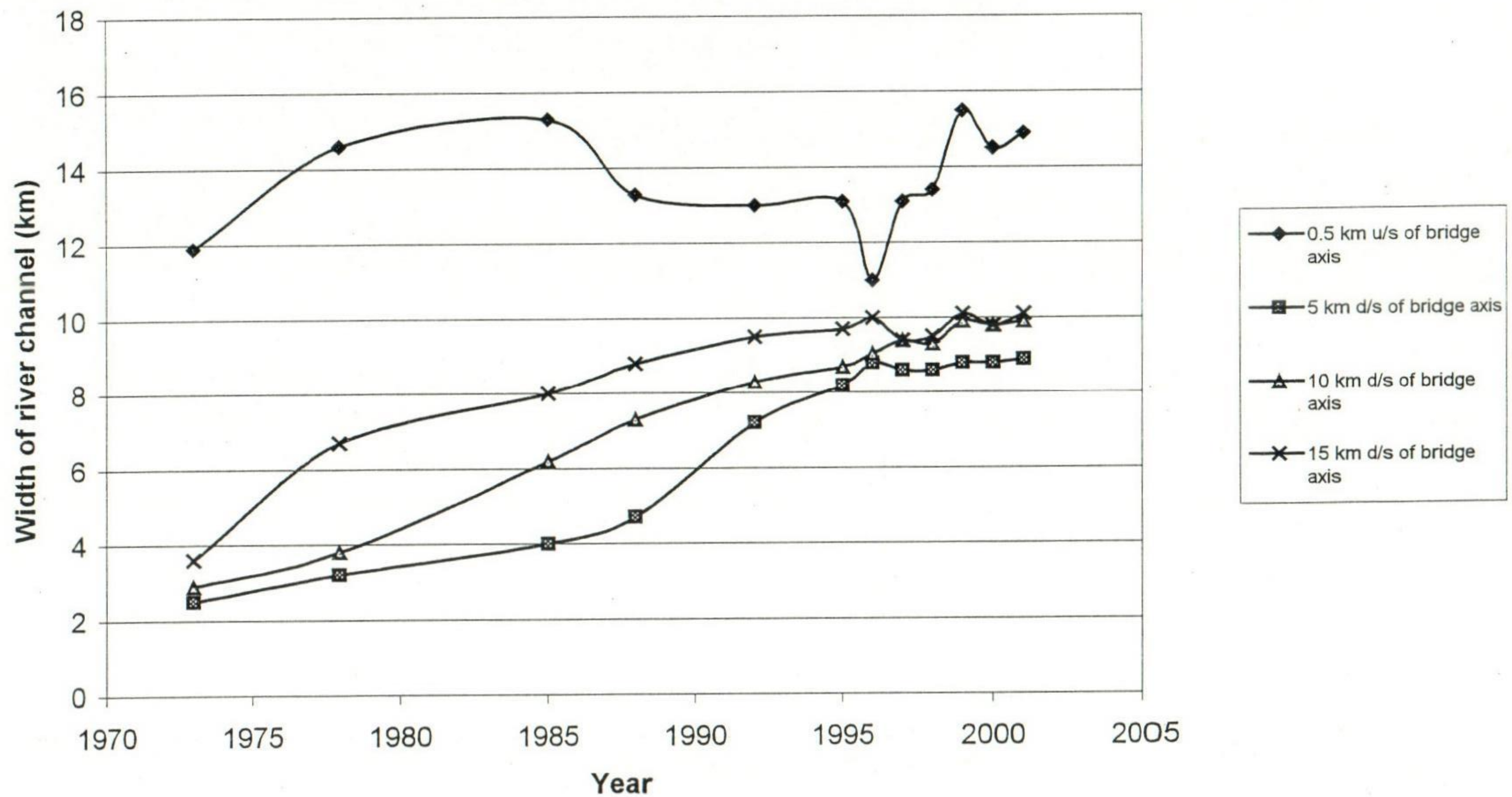


Figure 4.14 Temporal and spatial variation of channel width of the Jamuna river in study area

APPENDIX-A

ADDITIONAL TABLES

Table A-1- Bank erosion in different time period (1973-78,1987-85)along the right bank (u/s of Bangabandhu bridge)

Distance Measured from axis of Banga Bandhu Bridge in km	Bank migration in meter								
	2001-2000	2000-1998	1998-1997	1997-1996	1995-1992	1992-1988	1988-1985	1985-1978	1978-1973
2	0	75	-75	900	0	0	-450	-150	600
4	0	500	0	200	0	0	-550	-500	1050
6	0	1300	0	300	0	-2800	1150	-350	2000
8	0	100	650	-750	0	0	0	0	0
10	250	-50	-50	-150	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0

NB- +ve sign stands for bank erosion and -ve sign stands for new bank build up

Table A-2 Bank erosion in different time period (1973-78,1987-85) along the right bank (d/s of Bangabandhu bridge)

Distance Measured from axis of Banga Bandhu Bridge in km	Bank migration in meter								
	2001-2000	2000-1998	1998-1997	1997-1996	1995-1992	1992-1988	1988-1985	1985-1978	1978-1973
2	50	-100	50	-100	350	1000	-100	250	750
4	0	0	0	-50	300	1000	-200	850	650
6	0	0	0	50	1200	-700	0	1750	650
8	-50	50	-50	50	200	450	450	1150	1050
10	0	0	0	0	800	-100	200	-300	1000
12	0	0	-200	0	-300	0	100	250	750
14	0	50	150	-50	0	100	200	0	500
16	0	200	0	50	100	150	-150	100	1000
18	0	200	0	50	-100	-1200	750	1050	950
20	25	275	50	150	-1750	0	600	1450	1050
22	100	750	150	150	50	450	-550	1150	1550
24	0	600	-100	450	400	650	150	800	1000
26	200	300	0	0	750	150	850	600	100
28	500	50	350	-550	50	200	700	0	400
30	200	0	-50	250	250	0	300	-50	50
32	150	-150	50	150	0	-900	700	-300	500
34	50	50	-100	500	0	-150	150	200	-200
36	0	0	0	700	0	-850	850	200	-200
38	0	50	-100	450	0	-150	150	0	0
40	0	100	-100	250	0	-100	200	-100	0
42	50	-50	250	-250	0	-600	300	300	0
44	0	0	0	0	0	-1350	350	450	550
46	0	50	-50	100	0	-1850	450	450	950
48	-150	150	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0

NB- +ve sign stands for bank erosion and -ve sign stands for new bank build up

Table A-3- Bank erosion in different time period (1973-78,1987-85)along the left bank (u/s of Bangabandhu bridge)

Distance Measured from axis of Banga Bandhu Bridge in km	Bank migration in meter								
	2001-2000	2000-1998	1998-1997	1997-1996	1995-1992	1992-1988	1988-1985	1985-1978	1978-1973
2	100	800	550	250	0	2000	200	800	1000
4	0	600	100	0	-100	1000	1000	1300	1000
6	0	0	0	400	-150	150	700	1400	-100
8	100	550	350	200	0	0	-50	900	1200
10	0	550	300	350	-600	50	450	200	1500
12	0	100	200	200	0	0	1100	-500	600
14	-100	0	100	0	0	-1150	1150	-500	500
16	0	75	125	-100	0	0	0	0	0

NB- +ve sign stands for bank erosion and -ve sign stands for new bank build up

Table A-4 Bank erosion in different time period (1973-78,1987-85) along the left bank (d/s of Bangabandhu bridge)

Distance Measured from axis of Banga Bandhu Bridge in km	Bank migration in meter								
	2001-2000	2000-1998	1998-1997	1997-1996	1995-1992	1992-1988	1988-1985	1985-1978	1978-1973
1	0	1500	0	-400	-2450	1830	470	800	0
2	50	1000	300	-1050	-800	350	650	0	300
3	0	1500	-300	-1100	-450	750	550	-800	800
4	0	1200	-1050	-50	400	1100	0	-1100	1300
5	0	200	50	50	850	1050	600	-2150	1650
6	0	300	50	150	950	1150	800	-2000	1500
7	100	400	200	100	800	1100	1000	-1700	1450
8	300	400	100	200	450	1500	850	150	0
9	400	350	50	300	50	1750	1200	200	-200
10	50	250	100	350	0	2000	1300	100	-300
11	0	350	100	350	125	1950	950	200	-200
12	0	450	300	100	150	1600	750	400	0
13	100	550	150	100	300	850	450	1000	0
14	200	500	200	0	400	250	800	850	0
15	100	100	200	-200	150	0	1050	1150	0
16	200	-200	200	0	250	-100	1200	1150	500
17	200	-170	270	50	75	150	1500	650	-150
18	450	-50	0	0	150	300	2250	-200	-200
19	200	100	50	-50	300	650	1750	-100	100
20	0	300	50	50	100	950	-50	1200	300
21	250	50	200	300	450	450	350	600	1000
23	100	100	300	1000	41050	1000	-50	3150	100
25	0	1000	100	-100	-300	600	800	3000	-1000
27	0	-100	100	800	-300	1150	1050	2500	-2100
29	150	350	200	-100	-200	1600	100	2400	-1900
31	0	0	0	25	-300	350	-350	900	-900
33	100	50	50	50	300	750	-350	0	0
35	0	350	150	-100	150	1800	100	-1700	1700
37	50	600	50	-100	0	1500	-250	1100	400
39	200	350	100	0	750	1000	-1200	2200	400
41	0	1400	300	300	800	-650	50	2700	100
43					-300	0	1750	1650	1400
45					-200	1100	2300	1800	1500

NB- +ve sign stands for bank erosion and -ve sign stands for new bank build up

Table A-5 Bank erosion in different time period (1973-95,1973-85) along the right bank (u/s of Bangabandhu bridge)

Distance Measured from axis of Banga Bandhu Bridge in km	Erosion in meter								
	2000-2001	2001-1998	2001-1997	2001-1996	1973-1978	1973-1985	1973-1988	1973-1992	1973-1995
2	0	0	-100	450	-300	200	350	400	
4	0	0	100	0	100	0	0	0	
6	0	0	0	1400	400	200	200		
8	0	75	0	900	600	450	-		
10	250	500	500	700	1050	550	0		
12	0	1300	1300	1600	2000	1650	2800		
14	0	100	750						
16	0	200	150						

NB- +ve sign stands for bank erosion and -ve sign stands for new bank build up

Table A-6 Bank erosion in different time period (1973-95,1973-85)along the right bank (d/s of Bangabandhu bridge)

Distance Measured from axis of Banga Bandhu Bridge in km	Erosion in meter								
	2000-2001	2001-1998	2001-1997	2001-1996	1973-1978	1973-1985	1973-1988	1973-1992	1973-1995
2	50	0	0	150	650	300	-150	700	700
4	0	0	0	0	500	200	100	400	750
6	0	0	0	0	800	200	400	900	1900
8	-50	-50	0	-100	750	1000	900	1900	2250
10	0	0	0	-50	650	1500	1300	2300	2600
12	0	0	0	50	650	2400	2400	1700	2900
14	0	0	-50	0	1050	2200	2650	3100	3300
16	0	0	0	0	1000	700	900	800	1600
18	0	0	-200	-200	750	1000	1100	1100	800
20	25	50	200	150	500	500	700	800	800
22	100	200	200	250	1000	1100	950	1100	1200
24	0	200	200	250	950	2000	2750	1550	1450
26	200	300	350	500	1050	2500	3100	3100	1350
28	500	850	1000	1150	1550	2700	2150	2600	2650
30	200	600	500	950	1000	1800	1950	2600	3000
32	150	500	500	500	100	700	1550	1700	2450
34	50	550	900	350	400	400	1100	1300	1350
36	0	200	150	400	50	0	300	300	550
38	0	0	50	200	500	200	900		
40	0	100	0	500	-200	0	150		
42	50	0	0	700	-200	0	850		
44	0	50	-50	400	0	0	150		
46	0	100	0	250	0	-100	100		
48	-150	0	250	0	0	300	600		
50	0	0	0	0	550	1000	1350		
52	0	50	0	100	950	1400	1850		

NB- +ve sign stands for bank erosion and -ve sign stands for new bank build up

Table A-7- Bank erosion in different time period (1973-95,1973-85) along the left bank (u/s of Bangabandhu bridge)

Distance Measured from axis of Banga Bandhu Bridge in km	Bank migration in meter								
	2000-2001	2001-1998	2001-1997	2001-1996	1973-1978	1973-1985	1973-1988	1973-1992	1973-1995
2	100	900	1450	1700	1000	1800	2000	4000	4000
4	0	600	700	700	1000	2300	3300	4300	4200
6	0	0	0	400	-100	1300	2000	2150	2000
8	100	650	1000	1200	1200	2100	2050	2050	2050
10	0	550	850	1200	1500	1700	2150	2200	1600
12	0	100	300	500	600	100	1200	1200	1200
14	-100	-100	0	0	500		1150		
16	0	75	200	100	0				

NB- +ve sign stands for bank erosion and -ve sign stands for new bank build up

Table A-8 Bank erosion in different time period (1973-95,1973-85)along the left bank (d/s of Bangabandhu bridge)

Distance Measured from axis of Banga Bandhu Bridge in km	Bank migration in meter								
	2000-2001	2001-1998	2001-1997	2001-1996	1973-1978	1973-1985	1973-1988	1973-1992	1973-1995
1	0	1500	1500	1100	0	800	1270	3100	650
2	50	1050	1350	300	300	300	950	1300	500
3	0	1500	1200	100	800	0	550	1300	850
4	0	1200	150	100	1300	200	200	1300	1700
5	0	200	250	300	1650	-500	100	1150	2000
6	0	300	350	500	1500	-500	300	1450	2400
7	100	500	700	800	1450	-250	750	1850	2650
8	300	700	800	1000	0	150	1000	2500	2950
9	400	750	800	1100	-200	0	1200	2950	3000
10	50	300	400	750	-300	-200	1100	3100	3100
11	0	350	450	800	-200	0	950	2900	3025
12	0	450	750	850	0	400	1150	2750	2900
13	100	650	800	900	0	1000	1450	2300	2600
14	200	700	900	900	0	850	1650	1900	2300
15	100	200	400	200	0	1150	2200	2200	2350
16	200	0	200	200	500	1650	2850	2750	3000
17	200	30	300	350	-150	500	2000	2150	2225
18	450	400	400	400	-200	-400	1850	2150	2300
19	200	300	350	300	100	0	1750	2400	2700
20	0	300	350	400	300	1500	1450	2400	2500
21	250	300	500	800	1000	1600	1950	2400	2850
23	100	200	500	1500	100	3250	3200	4200	4525
25	0	1000	1100	1000	-1000	2000	2800	3400	3100
27	0	-100	0	800	-2100	400	1450	2600	2300
29	150	500	700	600	-1900	500	600	2200	2000
31	0	0	0	25	-900	0	-350	0	-300
33	100	150	200	250	0	0	-350	400	700
35	0	350	500	400	1700	0	100	1900	2050
37	50	650	700	600	400	1500	1250	2750	2750
39	200	550	650	650	400	2600	1400	2400	3150
41	0	1400	1700	2000	100	2800	2850	2200	3000
43					1400	3050	4800	4800	4500
45					1500	3300	5600	6700	6500

NB- +ve sign stands for bank erosion and -ve sign stands for new bank build up

APPENDIX-B

PHOTO PLATES

Plate-1: Bank erosion at the d/s of Bangabandhu bridge along the left bank

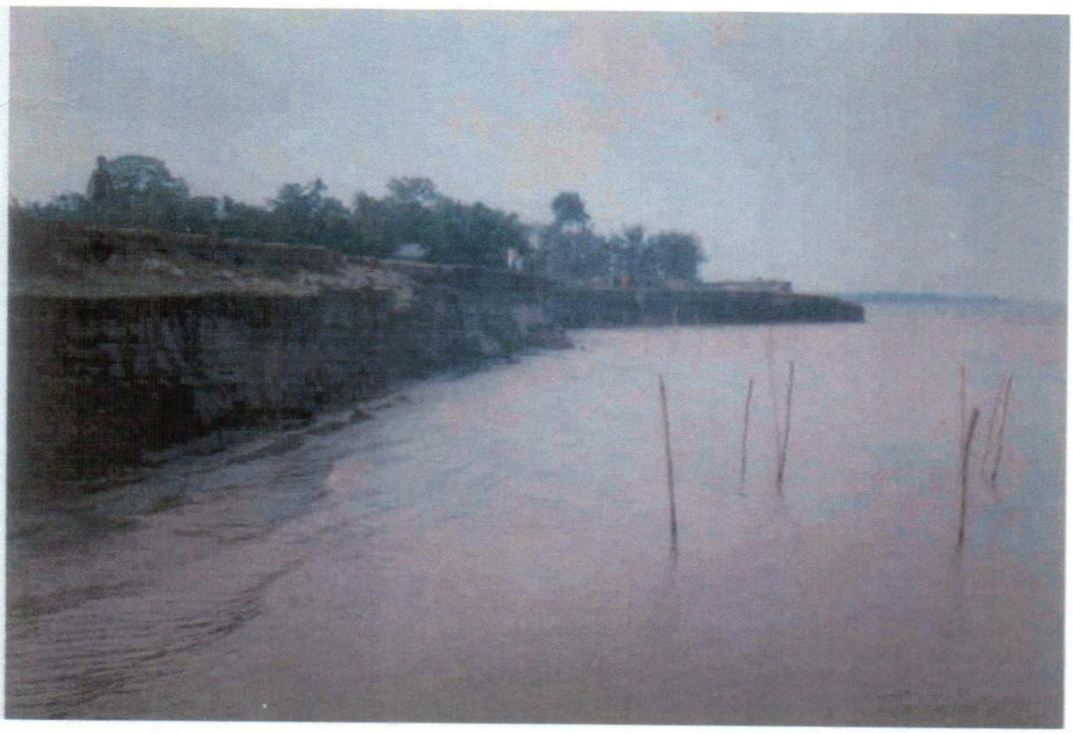


Plate-2: Bank erosion at the d/s of Bangabandhu bridge along the left bank

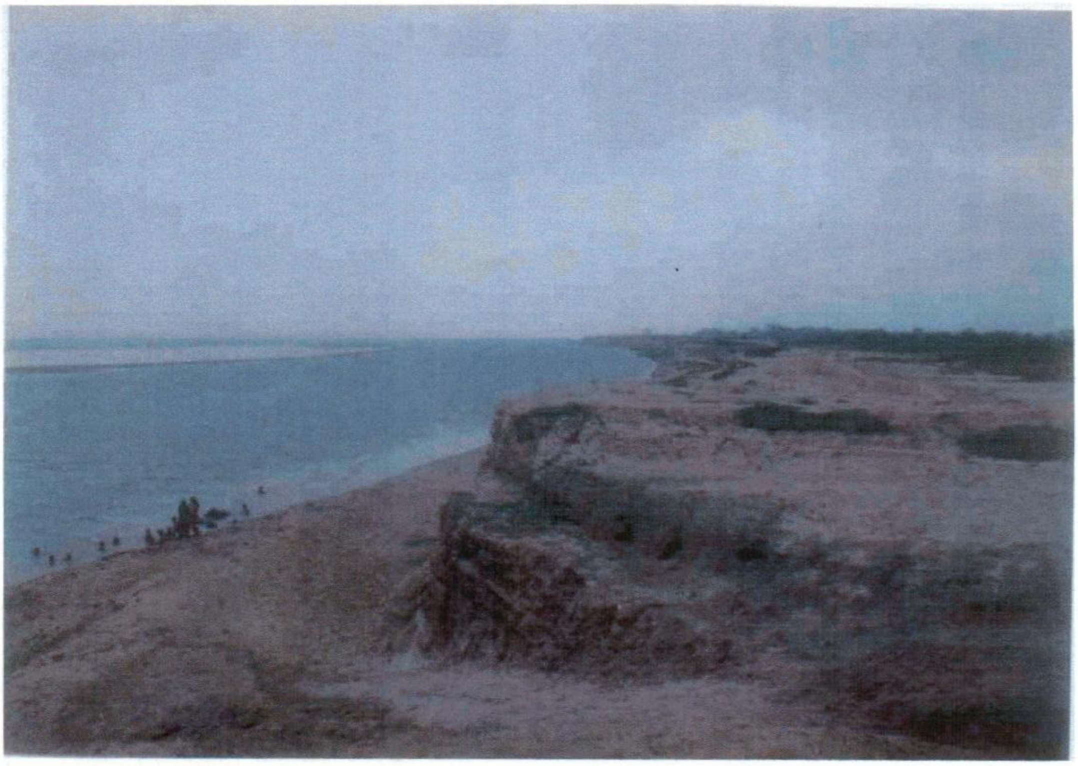


Plate-3: Bank condition at dry season along left bank

Plate-4: Bank condition at dry season along left bank

APPENDIX-C

SAMPLE OF QUESTIONNAIRE

Questionnaire Survey

1. Personal Information

a) Name :
b) Occupation :
c) Age/ Sex :
d) Education :
e) Social Statues :
f) Address :

Village : Union: PS:

2. Have you land of your own? * Yes *** No**

3. What is the location of your land?
* Mainland * River * Char

4. What is the size of your land?
- Acres

5. Do you cultivate your land by own?
* Yes * No

6. What is your household income per month/ year?

[ ] Tk.

7. Have you lost your homestead due to riverbank erosion?
* Yes * No

8. If yes, how many times?
* One *Two *More than two times

9. Have you lost your cultivable land due to riverbank errosion?
* Yes * No

10. How far is your present house from the riverbank?
[ ] Kilo or [ ] Mile

11. Is there any possibility of losing your present homestead due to riverbank erosion?
* Yes * No

12. When do you expect possible loss of your homestead?
- Within 6 month
- Within 1 year
- Within 2 years
- Within 3 or more years

13. How far is your cultivable land?

[ ] Kilo or [ ] Mile

14. When do you expect possible losses of your lands?

[ ] Year/Years

15. From whom you expect assistance in the event of displacement?

*Government * NGO * Union Perishad * Local leader * Relatives

16. What will you do if you lose your present homestead?

- Migrate to the char land
- Migrate to the inner main lad
- Migrate to the near by town
- Build a house in others land (temporary basis)

17. Riverbank erosion rate. Your candid opinion please.

How far the river bank line was in

- 1 year ago in Kilometer in may 2000
- 2 years ago in Kilometer in may 1999
- 3 years ago in Kilometer in may 1998
- 4 years ago in Kilometer in may 1997
- 5 years ago in Kilometer in may 1996
- 6 years ago in Kilometer in may 1995

18. What is the bank erosion rate after 1995?

[ ] Kilometer with Comments

19. What was the bank erosion rate before 1995?

[ ] Kilometer with Comments

20. Do you think riverbank erosion rate increased after 1995 or construction of Jamuna Bridge? Why? Your candid opinion please.

21. With the present erosion rate how far will the river be shifted towards the left bank in next 5 Years and in next 10 years?

22. Are you affected directly due to riverbank erosion?

* Yes * No

23. Do you think bank erosion control is necessary for this location?

* Yes * No With Comments

24. If you think erosion control is necessary what type of measures will be suitable for this location and why?

25. If bank erosion is controlled effectively do you think it will be helpful to improve the economic conditions of the local people?

* Yes   * No   With Comments

26. Bank erosion control measures should be constructed by the Govt. dept or by NGO or by local leaders. Which one and why?

27. Measurements taken by the Govt. (already) to control bank erosion is enough or not? Why?

28. Would you please comment on the loss due to bank erosion and benefit achieved from new char? Which one is more significant?

29. Due to riverbank erosion, change in occupations of the people is happened. What is your opinion?

30. Do you think if present rate of erosion exists and no counter measures are taken then Tangail town may be endangered in future?

* Yes   * No   *Comments

Signature of the interviewer:

Name of the interviewer:

Designation of the interviewer:

Date: