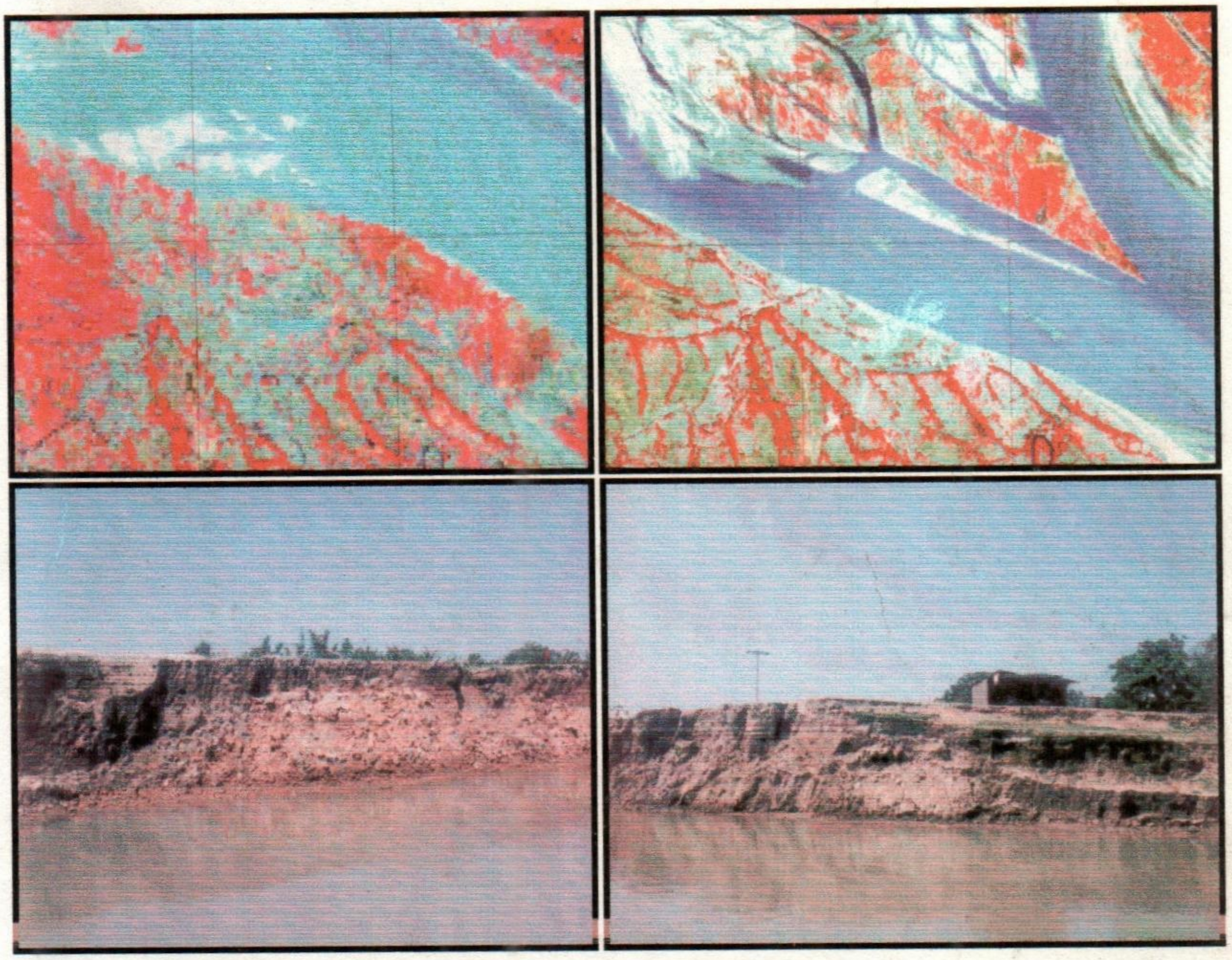
A STUDY FOR THE PROTECTION OF FARIDPUR TOWN AND ITS ADJACENT AREAS FROM THE EROSION OF PADMA RIVER



RESEARCH REPORT

REPORT NO. RES-2 (2001)

JUNE 2001

RIVER RESEARCH INSTITUTE, FARIDPUR

Ministry of Water Resources

Government of the People's Republic of Bangladesh

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PREFACE

Faridpur Town and its adjacent areas under Faridpur Sadar Upazila and Char Bhadrason Upazila are situated on the right bank of Padma river. Many permanent important installations, homesteads and agricultural lands within the aforesaid areas are under threat due to the continuous bank erosion of Padma river. To save these areas and its agrarian economy from the devastating bank erosion of Padma river, a study was undertaken by the River Research Institute (RRI) to protect the affected areas from the bank erosion of Padma river as per decision of the 17th Meeting of the Board of Governors of RRI. Accordingly a research team with a co-ordinator was formed to carry out the project. The team collected data from different agencies and finally the findings of research project with some conclusions and recommendations have been presented in this report.

The overall objective of the research project was to find out a viable solution from hydraulic point of view to save these areas in the vicinity of Padma river. After conducting a detailed literature search in the related field, this research report suggested construction of series of spurs from proposed retired embankment up to bankline or revetment along river bankline as protective structures to combat bank erosion. The study also recommended that the appropriate number, length, position, spacing and orientation of spur and proper block size of revetment should be finalized on the basis of physical model study.

The services given by RRI staff and officers concerned are gratefully acknowledged. Sincere thanks to all who have helped directly or indirectly in connection with this research project. Special thanks are extended to BWDB, WARPO, BIWTA, LGED, SPARRSO, EGIS, SWMC etc. for their supplying valuable data, information, maps and co-operation in this regard.

30.6.01

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LIST OF ABBREVIATIONS

BIWTA	Bangladesh Inland Water Transport Authority
BWDB	Bangladesh Water Development Board
CS	Cross-section
EGIS	Environmental and Geographic Information System
FAP	Flood Action Plan
ISPAN	Irrigation Support Project for Asia and the Near East
LB	Left Bank
LGED	Local Government Engineering Department
MBL	Mean Bed Level
PWD	Public Works Department
RB	Right Bank
RCC	Reinforced Cement Concrete
RRI	River Research Institute
SPARRSO	Space Research and Remote Sensing Organization
SWMC	Surface Water Modelling Center
WARPO	Water ResouOrces Planning Organization
WL	Water Level

1 INTRODUCTION

1.1 Background of the Study

A study was undertaken by the River Research Institute (RRI) to protect the Faridpur Town and its adjacent areas from the erosion of Padma river as per decision of the 17th Meeting of the Board of Governors, RRI, Faridpur. The study area starts from Decreer Char Union under Faridpur Sadar Upazila to Zajirtek Union under Char Bhadrason Upazila in the District of Faridpur covering around 10 km long reach along the right bank of Padma river. Many permanent important installations such as High School, Primary School, Hat, Bazar, Post Office, Food Godown, Family Planning Centre, Ghat, Homesteads and Agricultural lands are affected due to the devastating bank erosion of Padma river. The location of the study area can be seen in **Figure 1** and **Figure 2.**

1.2 Problem Identification

Bangladesh is a riverine country. The river system of Bangladesh is very much complex in nature. Devastating floods and other natural disasters are very common in this country. Due to the lack of advanced scientific knowledge and technology, still we are helpless against to that natural calamity. RRI is the only national research organization in our country to conduct applied and basic researches in the field of River Engineering, Hydrology, Hydraulics, Coastal Engineering, Sediment Transport, Flood Control, Drainage and Irrigation etc. by using physical modelling.

Faridpur Town and its adjacent area such as Decreer Char Union under Faridpur Sadar Upazila and Gazirtek Union under Char Bhadrason Upazila in the District of Faridpur are located on the right bank of Padma river. The present right bankline of Padma river recently surveyed in February, 2001 at the study area with existing embankment is shown in **Figure 3**. Every year the right bank of Padma river is shifting toward the right side at these areas. To save these areas and its agrarian economy from the devastating bank erosion of the Padma, RRI has undertaken a research project to find out the possible solution to protect the aforesaid areas.

1.3 Objective of the Study

The overall objectives of the present research project was to find out a viable solution from technical standpoint to protect Faridpur Town and its adjacent areas from the erosion of Padma river by constructing protective structures. However, in short, the objectives were as follows:

i. To conduct a detailed literature review in the field of river bank erosion, river bank shifting and river bank protection.
ii. To determine the geometric as well as bank shifting characteristics of the river at the study area.
iii. To suggest possible bank protective structures to combat river bank erosion.

2 LITERATURE REVIEW

2.1 The Padma River

The combined flows of Jamuna and Ganges rivers constitute the flow of the present Padma river. Before the avulsion of Jamuna river, the flow was a continuation of Ganges river only, and Rennel's map shows that the river passed further south than the present course. The annual mean discharge is 28,000 m^3/s, and the bankfull discharge is about 75,000 m^3/s (from FAP24 findings). The average size of the bed material is about 0.10 mm.

Geo-morphologically, the river is still young. A flow regime analysis by the FAP4 study shows that it is now in a dynamic equilibrium. A reach of about 90 km is almost straight and the planform of the river is a combination of the meandering and braiding type, indicating a wandering river. The meandering, sweeping bend and the braided belt swing within an active corridor. ISPAN (1993) found that both banks of the river often attack the active corridor boundary, probably still widening its active corridor.

The variation of the total width of the river is quite high, ranging from 3.5 km to 15 km. FAP9B related this phenomenon with the existence of cohesive bank material at the constricted reach. On the other hand, FAP4 report attempted to relate the width constriction with the high bank elevation. The present analysis shows that the explanation of FAP9B is more likely, though no detailed bank material data are available.

The bank erosion rate studied by ISPAN (1993) report shows that the rate (in the period of 1984 to 1993) is quite high, and even higher than for the Jamuna river. The braiding intensity of the river is low, and typically, there are only two parallel channels in the braided reach. Channel shifting processes are quite rapid.

The slope and the bed material sizes of the rivers vary within a range of 8.5 to 5 cm per km, and 0.20 to 0.10 mm, respectively. Bankfull discharges are within the range of 43,000 m^3/s to 75,000 m^3/s. With respect to planform, the Jamuna is distinctly a braided river, while the Ganges and Padma rivers fall in between braided and meandering rivers, i.e. wandering rivers. The bank erosion rates of the rivers are almost the same. However, there is a difference between the Jamuna river on the one hand and the Ganges and Padma rivers on the other. The bank erosion rates of the former are invariably similar, while the flow attacks any of its banks. The bank erosion of the Ganges and Padma river resembles the Jamuna river within the active corridor only. Unlike the Jamuna river, the rate is reduced significantly at the boundary of the active corridor. The corridor consists of alluvial/deltaic silt deposits, while the floodplain outside of it is more resistant to erosion, probably due to the presence of carbonate.

The river is almost straight, showing a braiding tendency with a low braiding intensity, please see **Figure 4**. The downstream part, near Mawa river, is constricted and proceeds as a straight single thread channel. **Figure 4** shows that the shifting of the banks at the constricted reach is moderate in the period of 1984-1993. A comparison with historical maps shows that the left bank has never been further to the left than today, which indicates the existence of erosion-resistant cohesive bank material. In region 3, the river has been somewhat further to the right as compared with its present bank, while recent maps and satellite image show that at Mawa, the river has remained constricted for many decades. Probably, fine sediment deposits over the old course of the river form pockets with a comparatively higher erosion resistance (FAP24, 1996).

2.2 River Bank Erosion

River bank erosion is a complex process in which many factors play a role. Important factors are flow, sediment transport, channel geometry and bed topography, vegetation and ground water level and their variation in time and space and bank material properties. The flow exerts shear stresses that can remove particles from the bank either via 'peeling off' or via mass movement. The near bank flow pattern is determined by the flow and the channel geometry. Bank material properties determine the cohesiveness of the bank, an important parameter for the type of bank erosion (Osman and Thorne, 1985), and is also important for how quick erosion products are transported by the river and thus determine the time needed for the typical cycle to-erosion-failure-transport important for mass failures. Vegetation does not play an important role in bank erosion processes along the Jamuna river. Groundwater flow may have an important effect on the bank erosion, especially during the recession of flood.

The flow in a river bend attacks the toe of the river bank, removing the sediment from the toe, resulting in an over-steepening of the river bank and causing the bank failure by slumping. Although bank erosion is quite a complicated process, over the recent years a number of methods were developed to predict the bank erosion rates along a river. These methods can be distinguished into two types: the first one is related to a 2-D mathematical model and developed to compute bank erosion on the basis of local channel geometry, flow and/or sedimentary processes (Mosselman, 1992 and DHI 1996). The other type of prediction method estimates the yearly bank erosion rate on the basis (i) overall channel parameters such as discharge and characteristics of bank materials, and (ii) local channel geometry (Hickin and Nanson, 1984). Thesis prediction methods for predicting the bank erosion rate will be compared later with the observed bank erosion rate.

2.3 River Bank Shifting

Bank shifting through erosion-deposition processes in an alluvial river is a characteristic feature and one of the most conspicuous changes affecting fluvial landscapes. At a meander bend high velocity occurs in the outer bank causing recession of bank and also the spiral flow tends to deepen the outer bank. In a river rates of such bank erosion can be rather high but such rates apply to certain bends only; others on the same river at the same time shift more slowly. Generally, the rate of bank shifting is determined by the strength of the bank on one hand and the fluid forces on the other hand. Under natural conditions regular pattern of bank shifting can not survive. This is due to the fact that apart from the effects of river flow fluctuations, river and valley floor sediments are rarely uniform and the lateral redistribution associated with bank cutting and point bar construction introduces size sorting. Continued shifting with spatially variable boundary conditions must inevitably lead to distortion of the waveform with some bends, or parts of bends, eroding faster than others as the pattern as a whole becoming irregular. A deterministic analysis of meander development is extremely complicated because an irregular meander pattern is even less likely to be in a steady state. However, a statistical equilibrium can be envisaged in which the pattern retains its aggregate characteristics despite changes in detail. If some bends grow, but others decline or are eliminated, the scale and degree of meandering, and the overall level of irregularity, may remain more or less constant over the years. The river occupies different positions at different times and experiences different spatial sequences of disturbances about the average condition. The precise course of the channel depends on the detailed pattern of these disturbances, but the overall nature of the waveform need not alter. But such a statistical equilibrium is possible only if no change occurs in hydrologic regime of sediment load and the disturbance sequences are realizations of a single stationary stochastic process. If changes take place the problems in approaching to establish whether lateral movement of channels can be discerned. From the various forms of evidence available are questions on their spatial and temporal distributions. Questions about the controls on movement, including the effect of specific disturbances such as alteration can be analyzed based on the knowledge of the relationship between form and movement and on identification of stable forms.

The problem in analyzing any aspect of riverbank erosion is to find a method which adequately demonstrates the properties of the course and planform, especially where meanders are ill-defined or irregular. The aim here is to characterize the channel pattern as objectively as possible whilst also being able to identify and measure change and movement in a meaningful way (Islam, Kanungoe and Zaman, 1999). In the recent past a number of important studies have been done. By various researchers to develop insight into the bank erosion process as well as rates of bank erosion. Wolman (1959), Osman and Thorne (1988), Hickin and Nanson (1984), Klaassen and Masselink (1992) and Hughes (1976) played a notable role in this regard. Hickin and Nanson (1984) presented channel bend shifting data for a range of meandering rivers in western Canada and assessment of the factors that control these rates. Channel shifting rates transformed to a reference bend of curvature (r/w =2.5) are show to be a simple function of stream power, outer bank height and a co-efficient of resistance to lateral shifting. An earlier study of the authors on the Beatton river showed that channel shifting rates are strongly controlled by bend curvature. Klaassen and Masselink studied the bank erosion of the braided Jamuna river of Bangladesh and found that in most of the cases erosion rate along the curved channels is between 0 and 500 m/year. The bank erosion rates analyzed within the framework similar to the work of Hickin and Nanson revealed that low relative curvatures lead to relatively fast erosion rates and vice versa. Hughes (1976) investigated the rates of bank erosion around the meander arcs in relation to peak discharges, based upon the data recorded at meander locations in the river catchment. From his study it was revealed that the pattern of period rates of erosion is similar for each of the arcs investigated. The values of mean loss per site for each arc were also similar. It is also revealed from his study that a discharge magnitude represents a threshold for major channel changes along the reach of the river. From the study a range of discharges representing the erosion threshold for the reach as a whole was recognized and three erosion classes based on erosion rates were indicated. The frequency distribution of the discharges representing the lower erosion threshold and the higher erosion threshold was determined (RRI, 2000).

2.4 River Bank Protection

In a broad sense, a bank can be defined as the sloping surface of land and coming into contact with a body of still or flowing water. Bank protection, therefore, includes any protective work that aims at maintaining the stability of land against the action of water. The purpose of bank protection is to save the banks furious of water-soil interaction. The purpose that can be brought out in the following points (Siddique, 1995):

- To check erosion of bank by current or wave.
- To check sliding of slope due to its gradual steeping because of erosion.
- To prevent undermining of the toe of the lower banks by currents, waves or eddies.
- To prevent sloughing or sliding of slope when saturated with water.
- To prevent piping due to various causes.
- To check sliding due to draw down of the flood.

River bank can be protected by providing embankment, revetment and groyne or spur, which has been is described in the next Articles.

2.4.1 River Bank Protection by Embankment

Embankments are generally earthen embankments, running parallel to the river, at some suitable distance from it. They may be constructed on both sides of the river or only on one side, for some suitable river length, where the river is passing through Towns or cities or any other places of importance. These embankment-walls, retain the flood water and thus, preventing it from spreading into the nearby lands and Towns. A levee or a dyke is mainly used for flood protection by controlling the river and not by training the river.

The alignment of levees should follow the normal meandering pattern of the river. The retirement of the levees has to be governed by technical as well as economical and political considerations, because the land falling within the levees, is either to be acquired by the government or remains susceptible to floods. The levees, are many a times, pitched on the upstream side (i.e. water side). Launching apron may also be provided, if the bank is close to the main river channel (Gerg, 1989).

2.4.2 River Bank Protection by Revetment

Revetment is a slope protective structure designed to protect the loss of soil and stabilize the slope from the action of currents and waves. It is used for the protection of the slope of the river bank, shoreline and the slope of embankment of the structure alike.

The use of revetments as a bank protective device depends on the nature of the problem area where there is a sloping bank as well as other possible measures do not seem to be fit. There are different types of revetments and they can be distinguished in several groups where the major types are rip-rap or uniform rock, concrete armoring units, regular placed stones or concrete blocks.

Revetment structures are mainly used in the guide bunds of the bridge, Town protection etc. The effective functioning of it depends on many engineering and physical considerations in the design process. These are stability, flexibility, durability, possibility of inspection of failure, easy placement and repairing, overall safety etc. The best revetment is one which combines all these functions (Verhagen, 1995).

The revetment should be sufficient rough to create a zone of intensified turbulence and low velocity in the vicinity. This trends hold the high velocity flow away from the revetment rather than in contact with it with the result that the revetment toe is less apt to be undercut by scour (Vanoni, 1997). In support of this criteria there is an example of experiment on the Missouri river with rough rock revetment. However, has been that the high velocity flow previously moving adjacent to the bank moves approximately 15.24 m riverward, thus holding the area of deepest scour away from the toe of the revetment and limiting the opportunity for undercutting.

The formula proposed by Isbach (1936) for the criterion of design by depositing rock in running water, modified to take into account the slope of the bank gives results that are in line with experience as given below:

$$W = (4.1*10^{-5} *G_sV^6)/((G_s-1)^3\cos^3\varphi_1) \qquad (1)$$

where, W = weight of the stone in lb, G_s = specific gravity of the stone, V = the velocity and φ_1 = the angle of the pavement with the horizontal.

In consideration of risk acceptability in comparison to other river training structures, revetment occupies an advantageous position. Damage to revetments can be accepted even with a much higher frequency. Annual damage to a revetment does not cause serious problems, if this damage is repaired regularly by a good maintenance program. The acceptable damage level in this case is completely determined by the optimization between initial costs and maintenance costs (Karim, 1988).

2.4.3 River Bank Protection by Groynes

Groynes are the embankment type structures, constructed transverse to the river flow, extending from the bank into the river. That is why, they may also be called 'Transverse Dykes'. They are constructed, in order to protect the bank from which they are extended, by deflecting the current away from the bank.

The groynes may be built either perpendicular to the bankline or they may be inclined upstream or downstream as shown in **Figure 5.**

A groyne may be built perpendicular to the bankline is normal groyne.

A groyne pointing upstream has the property of repelling the flow away from it, and scour holes caused by the formation of vertical eddies are developed away from the bank, and near the head of the groyne, is called repelling groyne.

On the other hand, groyne pointing downstream has the property of attracting the flow towards it, and is called an attracting groyne.

In an attracting groyne, scour holes are developed nearer the bank, as compared to those in a repelling groyne. Since such attracting groynes bring the water current as well as scour holes nearer the bank and make it more susceptible to damage, they are generally not used.

The groynes are, therefore, generally aligned either perpendicular to the bank or pointing upstream. The 'perpendicular alignment' is generally used on convex banks, and the 'upstream pointing alignment' is generally used on concave banks.

When the length of an upstream pointing groyne is small, such that it changes only the direction of flow, without repelling it, it is called a deflecting groyne, instead of calling it a repelling groyne.

Groynes may be constructed either singly or in series, depending upon the need. When constructed in series, they are more effective as they create a pool of almost still water between them, which resists the current and gradually accumulate silt between them, thus forming almost a permanent bank after certain time. The choice of using them is series arises, if the reach to be protected is long, or if a single groyne is neither strong enough to deflect the neither current nor quite effective for silt deposition upstream and downstream of itself.

The lengths of the groynes depend upon the position of the existing bankline and the designed or expected bankline for trained river. Too long groynes on easily erodible rivers, are susceptible to damage and failure. In such cases, the best results can be obtained by starting with a shorter length and to extend the groyne gradually, as silting between them proceeds. However, no general rule can be formulated for fixing the length of the groynes. It depends mainly upon the exigencies arising in a specific case. Fore example, if the entire river course is required to be changed by repelling it towards the opposite bank by means of a single groyne, the groyne must, necessarily be, sufficiently long. Erosion of the opposite bank caused by this shift of water, should be anticipated and allowed for, whenever necessary.

As each groyne can protect a certain length, the primary factor governing the spacing between two adjacent groynes, is their length. The spacing is, therefore, taken as a certain proportion of their length. Apart from the length, the spacing may be governed by the following factors.

- Larger spacing is required for location groynes on convex banks, and a smaller one for concave banks with intermediate values at the crossings. A spacing of 2 to 2.5 times the length of the groyne is generally adopted at convex banks, while spacing equal to the length of the groyne is mostly adopted for concave banks.

- For rivers of equal flood discharges, a larger spacing is preferred for wider rivers than for narrower rivers.

- A higher value of spacing may be used for permeable groynes as compared to that required for impermeable groynes.

Based upon their material of construction, the groynes may be divided into two types, namely impermeable groynes and permeable groynes.

Impermeable groynes are also called as solid groynes or embankment groynes. These groynes may be rockfill embankments or earthen embankments, armored with stone pitching, concrete blocks, etc. These groynes are called 'impermeable groynes' because they do not allow any significant flow through them.

Permeable groynes do permit restricted flow through them. Permeable groynes, simple obstructs the flow, reducing its velocity and causing silt deposition. They are, therefore, best suited for rivers carrying huge sediment load in suspension. In comparatively clear rivers, they reduce the erosive strength of the current, and thus, prevent local bank erosion. Permeable spurs do not change the flow abruptly as is done by impermeable spurs, and hence, intense and serious eddies and scour holes are not developed. They are cheaper and perhaps the best for silt laden rivers. When the groyne is to be submerged, then permeable groynes give much better results, because they do not generate so strong turbulence as is generated by submerged-impermeable groynes, making them susceptible to be washed away due to over-topping.

The groynes should be constructed after model studies. Their design is not much amenable to theoretical investigation and has to be checked and tested with model studies. Whereas, a series of groynes may be useful for general deflection of the river a single groyne placed suitably may best serve the purpose of controlling a river at a certain works-site (Gerg, 1989).

3 METHODOLOGY

3.1 Data Collection

Data required to carry out the research project "Protection of Faridpur Town and its adjacent areas from the erosion of Padma river" were cross-sectional data, hydrological data (Water Level and Discharge data), hydrographic data, satellite data (spot and landsat imageries) and base map of Upazila under Faridpur District. The cross-sectional data were collected from BWDB and SWMC. The hydrological data were collected from BWDB and WARPO. The Hydrographic chart was collected from BIWTA and satellite imageries were collected from EGIS and SPARRSO. The base map of Upazila under Faridpur District was collected from LGED.

3.2 Method of Data Analysis

Eight standard BWDB cross-sections (from downstream to upstream) were selected in the present study under Faridpur District. These were P3, P3.1, P4, P4.1, P5, P5.1, P6 and P6.1. The spacing between successive cross-sections was 6.436 km. The location map showing these standard BWDB cross-sections can be seen in **Figure 6.** The cross-sectional map was produced as distance along the cross-section as abscissa and elevation with respect to PWD datum as ordinate for each of the cross-sections for 1992 and 2000. The cross-sectional area for each cross-section was determined by dividing the cross-section into a number of segments by verticals. For each segment the cross-sectional area was calculated and finally summing up all the cross-sectional area of all segments to get the total cross-sectional area of that cross-section. The average depth of a cross-section was calculated by taking the average of all verticals or depths. The top width was determined as the distance between last vertical minus first vertical of a cross-section.

Area-elevation relationships were developed for selected BWDB cross-sections to determine the variation of cross-sectional area with elevation for the years 1992 and 2000.

The thalweg level (deep water level) was determined as the deepest point from the cross-sectional map for each of the selected BWDB standard cross-sections for the years 1992 and 2000 to observe the variation of thalweg level along the river reach.

The mean bed level (MBL) at selected BWDB cross-sections was determined by subtracting average depth from average bank level of each cross-section and plotted for the years 1992 and 2000 to observe the variation of MBL at these cross-sections. Change in MBL was also determined at selected cross-sections during 1992 to 2000. Assuming linear variation of change in MBL, the amount of sediment deposited throughout the study reach was calculated for a period of eight years.

The Baruria Transit Station (Water level plus discharge station) is the nearest station to the study area. The location of water level and discharge station (see Baruria, Code No. 91.9L) can be seen in the map showing hydrometric stations in **Figure 7.** The water level data were plotted against time for the years 1965 to 1995 to observe the fluctuation of water level with time. The discharge data were also plotted against time for the years 1966 to 1994 to observe the fluctuation of discharge with time. The trend of water level and discharge against time in each case was also determined from the developed relationship.

The stage-discharge relationship was developed at Baruria Transit Station using water level and discharge data for the years 1966-1994. A highly correlated relationship between stage and discharge was obtained and the trend was also determined.

The bankline shifting at the study area (Decreer Char Union under Faridpur Sadar Upazila, Zajirtek Union under Char Bhadrason Upazila) was determined from 1999 to 2001. It was done in order to determine the trend and amount of bankline movement.

The satellite imageries for the years 1973 and 1999 were traced with the same scale on the same map (superimposed). These were then utilized to observe the lateral bankline movement i.e. to determine the bank erosion and deposition with respect to 1973.

4 RESULTS AND DISCUSSION

4.1 Variation of Cross-sectional Area

Each of the cross-sectional map was superimposed for the years 1992 and 2000 which clearly shows the shifting of thalweg, change of top width as well as the location of the deepest point as shown in **Figure 8**. **Table 1** shows the results of cross-sectional analysis. The variation of cross-sectional area, average depth and top width of the selected cross-sections were shown in **Table 2**. The variation of cross-sectional area, average depth, top width against the selected standard BWDB cross-section is also shown in graphical form in **Figure 9, 10** and **11.** The cross-sectional area varies randomly over a period of eight years. The cross-sectional area at cross-sections P3, P4 and P5.1 had a decreasing trend while there had an increasing trend at cross-sections P3.1, P4.1, P5, P6 and P6.1 during the period from 1992 to 2000. This indicates aggradation and degradation of these cross-sections respectively. The cross-sectional area at cross-section P5.1 in 1992 was reduced to 0.7 times the corresponding cross-sectional area in 2000. The cross-sectional area at cross-section P6.1 in 1992 was increased to 1.34 times the corresponding cross-sectional area in 2000. The cross-sectional areas calculated were 660387.0 m^2 and 676235.0 m^2 in 1992 and 2000 respectively and the increase in cross-sectional area was about 2.4%. The average depth in 2000 is less than 1992 while the average width increases.

4.2 Area-elevation Relationship

Area-elevation relationships showing the variation of cross-sectional area with elevation (with respect to PWD datum) were developed for various standard cross-sections for the years 1992 and 2000. Graphical relationships between area and corresponding elevation were shown in **Figure 12.** Such type of analysis was done with a view to observing the effect of aggradation or degradation on cross-section. At sections P3, P3.1, P4 and P5.1 it was observed that at the same elevation, less area was obtained in 2000 with respect to 1992. This may lead to the aggradation. On the other hand, at sections P4.1, P5 and P6.1 it was observed that at the same elevation, more area was obtained in 2000 compared to 1992. This may be the result of degradation. At section P6, no considerable change was observed.

4.3 Variation of Thalweg Level (Deepest Water Level)

Table 3 shows the position of thalweg measured from left or right bank of river for the selected cross-sections over a period of eight years. The level of deepest point for the selected standard BWDB cross-sections is shown in **Table 4.** The variation of deepest point for the selected standard BWDB cross-sections is also shown in graphical form in **Figure 13.** The thalweg of the river shifted from one bank to another randomly. The thalweg of cross-section P3, P4.1 and P6.1 shifted to the right and P3.1, P4, P5, P5.1 and P6 shifted to the left. The average thalweg level in 2000 was 1 m above relative to 1992. An exceptional deepest point was found in P5.1, which was 18 m below the PWD datum. The MBL in 2000 was higher relative to 1992 indicating channel bed had rising tendency. The maximum bed level rises at cross-section P5.1 that was about 3.4 m.

4.4 Variation of Mean Bed Level (MBL)

Table 5 shows the location of MBL as well as change in MBL for the selected cross-sections over a period of eight years. The variation of MBL for the selected standard BWDB cross-sections is also shown in graphical form in **Figure 14.** It was observed that at all the selected BWDB standard cross-sections considered in the present study reach, the MBL rises in 2000 relative to 1992.

4.5 Calculation of Sediment Deposition from the Change in Variation of MBL

The variation of change in mean bed level (MBL) was also shown in **Figure 15.** From this figure it was revealed that sediment was deposited at all cross-sections within the study reach. Assuming linear variation of change in MBL, the calculated net sediment deposition was found as 9.4×10^8 m^3 during 1992 to 2000. It corresponds to about 22.0 cm sediment deposition each year throughout the study reach (P3 to P6.1) of Padma river during the period from 1992 to 2000.

4.6 Variation of Water Level and Discharge Data

The water level and discharge data were plotted individually against time. It is shown in **Figure 16** (the highest water level 9.35 mPWD on 2/9/88) and **Figure 17** (the highest discharge 132000 m^3/s on 2/9/88) for the years 1965-1995 and 1966-1994 respectively at Baruria Transit Station (Code No. 91.9L) which is nearest to the study area. A rating curve or stage-discharge relationship was also developed at the same station for the years 1966-1994, which is shown in **Figure 18.** Using **Figure 16** and **Figure 17** one can roughly determine the water level and discharge respectively at a particular time for the problem area. From **Figure 18** it can be also seen that maximum discharge was 132000 m^3/s recorded on 2/9/88 and the corresponding water level was 9.35 mPWD. Using the above figure, it is also possible to determine roughly the water level with known discharge and vice versa for the problem area.

The water level at Baruria Transit corresponding to 50 and 100 year return period was 9.32 mPWD and 9.57 mPWD respectively. The corresponding discharge was 132400 m^3/s and 141500 m^3/s respectively. These values were based on Log Normal Distribution and data used for the years 1965-1989 (FAP24, 1996). **Table 6** shows the variation of annual maximum & minimum discharge and corresponding water level for the Padma river at Baruria Transit Station. **Table 7** shows the variation of annual maximum, minimum & average discharge for the Padma river at the same Station. From this table it can be seen that the annual average discharge had an increasing trend. As a result, cross-sectional area had increased and fall of water level had occurred at Baruria.

4.7 Bankline Shifting from Index Map Supplied by BWDB

Decreer Char Union under Faridpur Sadar, Zajirtek Union under Char Bhadrason Upazila are located on the right bank of Padma river. Many permanent important installations, homesteads such as Decreer Char, Bhangi Dangi, Bhoider Dangi, Rokon Dangi, Romesh Bala Dangi, Nibaran Bala Dangi, Harun Sarker Dangi, Khondaar Dangi etc and many cultivable lands within the Faridpur District are under danger due to the continuous bank erosion of Padma River. **Figure 19** shows the bankline shifting of Padma river which cover some parts of Faridpur Sadar Upazila and some parts of Char Bhadrason Upazila for the period of 1999, 2000 and 2001 from which one can easily visualize the nature of devastation of bank erosion. The trend of right bank shifting is towards the right side. **Table 8** shows the amount of right bankline shifting of Padma river for various cross-sectio ns (shown in index map) of the river. From the table it can be seen that different amount of shifting was occurred at different places. The maximum shifting was occurred along cross-section No. 21, which was about 1005 m for a period of only 2 years (from 1999 to 2000) so the maximum rate of bankline shifting is 1005/2=502.5 m/year. This erosion was occurred at Romesh Bala Dangi under Char Bhadrason Upazila.

There was a pucca road between cross-section No. 43 and 15 from Lohertek regulator toward Faridpur Town which was already drowned under water within one year due to the devastating bank erosion. The embankment downstream of cross-section No. 8, 28 and 33 was also drowned under water. The embankment between cross-section No. 29 and 31 merged with the bankline. All these cause unmitigable losses of properties and unbearable sufferings to the people. RRI will execute the research study to find out possible solution to protect the aforesaid areas.

4.8 Bankline Shifting from Satellite Imagery Supplied by EGIS

Figure 20 shows the river bankline from satellite image for the years 1973 and 1999 at the same location of study area in order to get an idea about morphological changes of the river over the period of 26 years. The bankline of Padma river from satellite image was plotted and superimposed on the same map for the years 1973 and 1999 as shown in **Figure 21.** From the superimposed plan maps it was observed that various amount of shifting was occurred at various places. From the superimposed plan maps it was seen that the river bankline at 1999 along the study reach had become more or less wider relative to bankline at 1973. Only upstream of study reach (Grid 1, see **Table 9**) near C & B Ghat, 3.35 km deposition at the right bank was occurred. Especially near the Hazi Bari Ghat under Faridpur Sadar Thana, the right bank of river was shifted towards the right side, which causes unmitigable losses of properties and sufferings to the people. **Table 9** shows lateral bankline shifting along grid lines (Eastings) of Padma river at the study area. From the table it can be seen that the maximum left bank erosion was 9.15 km and the maximum right bank erosion was 3.95 km.

5 PROTECTION OF FARIDPUR TOWN AND ITS ADJACENT AREAS

5.1 Faridpur Town Protection and its Adjacent Areas from the Erosion of Padma River

A proposed embankment parallel to river bankline can be suggested as a temporary and low cost alternative to protect the affected areas from flood. If bank erosion continuously increases toward the countryside then a series of spur or revetment must be constructed. In **Figure 19**, it can be seen that the existing retired embankment is very close to the present bankline. In this moment, another embankment parallel to the present banklines from cross-section No.1 to 52 can be proposed as shown in the above figure. A series of solid RCC/earthen spurs can be introduced from proposed embankment to bankline for the protection of these areas. Due to this, the river bankline can not extend toward the countryside without disturbing the existing condition of river. As a result river is not affected naturally and no environmental impact has been occurred. The number, length and spacing of spur also depends on river reach to be protected and the distance between proposed embankment and bankline. As an alternative to spur, river bank can be protected by providing revetment. But it is too much expensive to protect for a long reach. The optimum number, length, spacing, orientation of spur and block size of revetment should be determined by physical model investigation.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The following conclusions can be drawn on the basis of the present research study:

- Over a period of eight years (2000-1992), the cross-sectional area varies randomly. The cross-sectional area at cross-section P3, P4 and P5.1 has a decreasing trend whereas P3.1, P4.1, P5, P6 and P6.1 has an increasing trend indicating aggradation and degradation of these cross-sections respectively during 1992 to 2000. The net increase in cross-sectional areas is about 2.4% in 2000 with respect to 1992. The study also reveals that the average depth in 2000 is less than 1992 while the average top width increases.

- The thalweg of the river moves from one bank to another in a random fashion. The thalweg of cross-section P3, P4.1 and P6.1 moves to the right whereas P3.1, P4, P5, P5.1 and P6 moves to the left. The average thalweg level in 2000 is 1.0 m above than that of 1992.

- The mean bed level at all BWDB standard cross-sections rises in 2000 with respect to 1992 which represents the channel bed has a deposition tendency during the period from 1992 to 2000. Assuming linear variation of change in MBL, the calculated sediment deposition was 9.4×10^8 m^3 over eight years period i.e. from 1992 to 2000 which corresponds to about 22.0 cm sediment deposition each year throughout the study reach of Padma river.

- From the developed rating curve nearest to the study area (at Baruria Transit Station, Code No. 91.9L) using data from 1965-1995, one can roughly estimate the water level with known discharge and vice versa for the study area. The general equation of rating curve with correlation co-efficient of 0.989 obtained in the present study using data for the aforementioned period is given by:

  $$WL = 2.2281 Ln(Q) - 17.221 \quad (2)$$

- From the index map supplied by BWDB, the trend of right bankline shifting towards the countryside. The maximum amount of shifting at right bankline is around 1005 m near Romesh Bala Dangi under Char Bhadrason Upazila. During the period from 1999 to 2001 i.e. bankline is shifted towards the countryside at a rate of 502.5 m per year which is dangerous if appropriate protective measures have not yet been taken. If bank erosion is continuous with this rate, then the affected area with homesteads will be engulfed into the river within a very short period of time.

- From the superimposed satellite imagery supplied by EGIS, the river bankline has been extended both in the left and right countryside in 1999 relative to 1973 at the study area. In other words the Padma river has become braided at the study reach which is clearly understood by observing the formation of char at the middle portion of the river. As a result left channel and right channel become dominant and the countryside is continuously eroded.

6.2 Recommendations

The following recommendations can be made on the basis of the present research study:

- A physical model study as well as mathematical model study can be conducted to get optimum solution for the affected study reach. It is nonetheless to mention here that the physical model study is more practical than that of the mathematical model. But to get more confidence about the prediction of protection, one study is supplementary to the other. RRI is able to carry out both of the model studies.

- A series of spurs having tentative number, length, alignment and spacing from proposed embankment to bankline can be recommended to protect the study area.

- The optimum number, length, spacing, orientation of spur and block size of revetment should be selected by adopting physical model study.

- The Padma is a very active and young dynamic river, which changes its morphology randomly every year. All the suggested spurs to be constructed in one year so as a consequence of joint hydrodynamic effect to combat bank erosion.

- As an alternative to spur, continuously double layer revetment (by placing 2 layer RCC blocks) along the bankline for the study reach can be suggested. But for the long reach, it will not be economical in practice. For localized problematic reach, it can be constructed.

- The research work was conducted on the basis of recent bathymetry of February, 2001. After this period bankline and morphology will be changed. For this reason, due care should be given to assess these changes before construction of any river training structure in the field.

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LIST OF TABLES

Table 1 Results of Cross-sectional Analysis

CS No.	P3/2000		CS No.	P3/1992	
Bank level	7.58	mPWD	Bank level	7.51	mPWD
Total cross-sectional area, A	70563.17	m^2	Total cross-sectional area, A	72679.28	m^2
Total wetted perimeter, P	10989.00	m	Total wetted perimeter, P	7613.85	m
Hydraulic radius, R=(A/P)	6.42		Hydraulic radius, R=(A/P)	9.55	
Top width, T	10945.00	m	Top width, T	7606.00	m
Hydraulic depth,D=(A/T)	6.45	m	Hydraulic depth,D=(A/T)	9.56	m
Average depth	6.37	m	Average depth	8.44	m
Mean bed level	1.21	mPWD	Mean bed level	-0.93	mPWD
CS No.	P3.1/2000		CS No.	P3.1/1992	
Bank level	8.23	mPWD	Bank level	7.82	mPWD
Total cross-sectional area, A	67944.12	m^2	Total cross-sectional area, A	61978.42	m^2
Total wetted perimeter, P	12204.37	m	Total wetted perimeter, P	10055.97	m
Hydraulic radius, R=(A/P)	5.57		Hydraulic radius, R=(A/P)	6.16	
Top width, T	12180.96	m	Top width, T	10049.00	m
Hydraulic depth,D=(A/T)	5.58	m	Hydraulic depth,D=(A/T)	6.17	m
Average depth	5.76	m	Average depth	6.80	m
Mean bed level	2.47	mPWD	Mean bed level	1.02	mPWD
CS No.	P4/2000		CS No.	P4/1992	
Bank level	9.12	mPWD	Bank level	9.12	mPWD
Total cross-sectional area, A	78996.41	m^2	Total cross-sectional area, A	85353.48	m^2
Total wetted perimeter, P	12152.49	m	Total wetted perimeter, P	12143.89	m
Hydraulic radius, R=(A/P)	6.50		Hydraulic radius, R=(A/P)	7.03	
Top width, T	12113.60	m	Top width, T	12127.00	m
Hydraulic depth,D=(A/T)	6.52	m	Hydraulic depth,D=(A/T)	7.04	m
Average depth	6.24	m	Average depth	7.17	m
Mean bed level	2.88	mPWD	Mean bed level	1.95	mPWD
CS No.	P4.1/2000		CS No.	P4.1/1992	
Bank level	8.43	mPWD	Bank level	7.50	mPWD
Total cross-sectional area, A	55041.47	m^2	Total cross-sectional area, A	47763.87	m^2
Total wetted perimeter, P	8109.40	m	Total wetted perimeter, P	7704.06	m
Hydraulic radius, R=(A/P)	6.79		Hydraulic radius, R=(A/P)	6.20	
Top width, T	8100.00	m	Top width, T	7699.00	m
Hydraulic depth,D=(A/T)	6.80	m	Hydraulic depth,D=(A/T)	6.20	m
Average depth	6.39	m	Average depth	7.55	m
Mean bed level	2.04	mPWD	Mean bed level	-0.05	mPWD
CS No.	P5/2000		CS No.	P5/1992	
Bank level	9.54	mPWD	Bank level	9.69	mPWD
Total cross-sectional area, A	77006.34	m^2	Total cross-sectional area, A	70444.62	m^2
Total wetted perimeter, P	11437.83	m	Total wetted perimeter, P	9798.75	m
Hydraulic radius, R=(A/P)	6.73		Hydraulic radius, R=(A/P)	7.19	
Top width, T	11400.00	m	Top width, T	9786.00	m
Hydraulic depth,D=(A/T)	6.75	m	Hydraulic depth,D=(A/T)	7.20	m
Average depth	6.91	m	Average depth	8.78	m
Mean bed level	2.63	mPWD	Mean bed level	0.91	mPWD
CS No.	P5.1/2000		CS No.	P5.1/1992	
Bank level	9.22	mPWD	Bank level	8.96	mPWD
Total cross-sectional area, A	81066.19	m^2	Total cross-sectional area, A	114235.43	m^2
Total wetted perimeter, P	13448.08	m	Total wetted perimeter, P	11433.01	m
Hydraulic radius, R=(A/P)	6.03		Hydraulic radius, R=(A/P)	9.99	
Top width, T	13441.80	m	Top width, T	11380.88	m
Hydraulic depth,D=(A/T)	6.03	m	Hydraulic depth,D=(A/T)	10.04	m
Average depth	6.27	m	Average depth	9.39	m
Mean bed level	2.95	mPWD	Mean bed level	-0.43	mPWD
CS No.	P6/2000		CS No.	P6/1992	
Bank level	9.98	mPWD	Bank level	10.04	mPWD
Total cross-sectional area, A	99880.43	m^2	Total cross-sectional area, A	99341.04	m^2
Total wetted perimeter, P	16836.02	m	Total wetted perimeter, P	15571.15	m
Hydraulic radius, R=(A/P)	5.93		Hydraulic radius, R=(A/P)	6.38	
Top width, T	16814.00	m	Top width, T	15532.00	m
Hydraulic depth,D=(A/T)	5.94	m	Hydraulic depth,D=(A/T)	6.40	m
Average depth	6.30	m	Average depth	7.41	m
Mean bed level	3.68	mPWD	Mean bed level	2.63	mPWD
CS No.	P6.1/2000		CS No.	P6.1/1992	
Bank level	10.91	mPWD	Bank level	10.71	mPWD
Total cross-sectional area, A	145736.97	m^2	Total cross-sectional area, A	108590.66	m^2
Total wetted perimeter, P	16421.94	m	Total wetted perimeter, P	14687.20	m
Hydraulic radius, R=(A/P)	8.87		Hydraulic radius, R=(A/P)	7.39	
Top width, T	16385.50	m	Top width, T	14669.00	m
Hydraulic depth,D=(A/T)	8.89	m	Hydraulic depth,D=(A/T)	7.40	m
Average depth	7.65	m	Average depth	8.63	m
Mean bed level	3.26	mPWD	Mean bed level	2.08	mPWD

Table 2 The Variation in Cross-sectional Area, Average Depth and Top Width for Selected Standard BWDB Cross-sections

BWDB	Area (m^2)		Average Depth (m)		Top Width (m)	
CS	1992	2000	1992	2000	1992	2000
P3	72679.3	70563.2	8.4	6.4	7606.0	10945.0
P3.1	61978.4	67944.1	6.8	5.8	10049.0	12181.0
P4	85353.5	78996.4	7.2	6.2	12127.0	12113.6
P4.1	47763.9	55041.5	7.6	6.4	7699.0	8100.0
P5	70444.6	77006.3	8.8	6.9	9786.0	11400.0
P5.1	114235.4	81066.2	9.4	6.3	11380.9	13441.8
P6	99341.0	99880.4	7.4	6.3	15532.0	16814.0
P6.1	108590.7	145737.0	8.6	7.7	14669.0	16385.5
	Sum=660386.8	sum=676235.1	avg=8	avg=6.5	avg=11106.1	avg=12672.6

Table 3 Location of Thalweg Measured from Left or Rright Bank for the Standard BWDB Selected Cross-sections

BWDB	1992	2000	Measured from	Shift	Shifting Direction
CS	m	m		m	
P3	720	3030	LB	-2310	right
P3.1	9134	2590	LB	6544	left
P4	3850	11055	RB	-7205	left
P4.1	6725	4494	RB	2230	right
P5	9293	5053	LB	4240	left
P5.1	11024	12531	RB	-1506	left
P6	4390	15685	RB	-11295	left
P6.1	6294	3540	RB	2754	right

Table 4 Level of Deepest Point for the Selected Standard BWDB Cross-sections

BWDB	Deepest Point	
	1992	2000
CS	mPWD	mPWD
P3	-12.4	-13.2
P3.1	-13.4	-7.7
P4	-9.2	-6.6
P4.1	-11.0	-12.9
P5	-9.5	-10.6
P5.1	-18.0	-10.8
P6	-6.9	-10.6
P6.1	-10.5	-9.9

Table 5 Location of Mean Bed Level and Change in MBL for Selected Standard BWDB Cross- sections

BWDB CS	Mean Bed Level		Change in Mean Bed Level
	1992	2000	2000-1992
	mPWD	mPWD	M
P3	-0.93	1.21	2.14
P3.1	1.02	2.47	1.45
P4	1.95	2.88	0.93
P4.1	-0.05	2.04	2.09
P5	0.91	2.63	1.73
P5.1	-0.43	2.95	3.38
P6	2.63	3.68	1.05
P6.1	2.08	3.26	1.18

Table 6 Variation of Annual Maximum & Minimum Discharge and corresponding Water Level for the Padma River at Baruria Transit Station

Year	Date	Annual Q_{max} (m^3/s)	Corresponding WL (mPWD)	Date	Annual Q_{min} (m^3/s)	Corresponding WL (mPWD)
1966-67	9/2/66	81300	8.43	4/1/66	5600	2.12
1967-68	7/25/67	63600	7.86	3/12/68	5350	2.16
1968-69	7/30/68	80200	8.43	3/15/69	5090	2.04
1969-70	8/30/69	72700	8.19	4/12/69	6000	2.38
1970-71	7/31/70	84200	8.40	3/23/71	6080	2.36
1972-73	8/5/72	76600	7.78	2/25/73	5910	2.39
1974-75	8/8/74	113000	8.60	3/15/75	5660	2.48
1980-81	8/21/80	109000	8.57	3/18/81	4490	1.85
1981-82	8/4/81	88200	7.96	2/19/82	4250	1.68
1982-83	9/22/82	89600	7.99	3/24/83	4760	2.03
1983-84	9/19/83	101000	8.48	2/28/84	4440	1.59
1984-85	9/20/84	107000	8.34	2/18/85	5010	1.70
1985-86	8/1/85	90200	8.06	3/21/86	5430	1.99
1986-87	8/6/86	81100	7.88	2/2/87	3040	2.35
1987-88	8/19/87	113000	9.04	2/15/88	5120	2.21
1988-89	9/2/88	132000	9.35	3/31/89	5200	2.14
1989-90	7/21/89	79800	7.74	4/1/89	5300	2.17
1990-91	7/28/90	83700	8.27	2/25/91	4570	1.89
1991-92	9/13/91	100000	8.49	2/29/92	4610	1.87
1992-93	9/1/92	72500	7.75	3/19/93	4750	1.85
1993-94	8/17/93	84700	8.09	3/10/94	4120	1.95

Table 7 Variation of Annual Maximum, Minimum & Average Discharge for the Padma River at Baruria Transit Station

Year	Q_{max} (m^3/s)	Q_{min} (m^3/s)	Q_{avg} (m^3/s)
1966-67	81300	5600	24352
1967-68	63600	5350	22593
1968-69	80200	5090	24546
1969-70	72700	6000	24820
1970-71	84200	6080	28135
1972-73	76600	5910	24643
1974-75	113000	5660	33501
1980-81	109000	4490	31261
1981-82	88200	4250	26085
1982-83	89600	4760	27366
1983-84	101000	4440	29335
1984-85	107000	5010	31611
1985-86	90200	5430	31470
1986-87	81100	3040	27645
1987-88	113000	5120	30530
1988-89	132000	5200	33583
1989-90	79800	5300	29505
1990-91	83700	4570	31766
1991-92	100000	4610	31779
1992-93	72500	4750	23759
1993-94	84700	4120	31683

Table 8 Amount of Right Bankline Shifting of Padma River at the Study Area from Index Map

Cross-section No.	Shifting from 1999 to 2000 (m)	Shifting from 2000 to 2001(m)
12	240	315
13	225	420
14	262.5	450
15	315	495
16	360	465
17	397.5	480
18	412.5	525
19	405	577.5
20	592	330
21	420	585
22	450	517.5
23	450	525
24	450	525
25	450	495
26	450	495
27	450	495
28	420	510
29	405	510
30	390	510
31	360	480
32	337.5	427.5
33	322.5	375
34	285	360
35	285	397.5
36	300	420
37	315	360
38	322.5	298.5
39	330	255
40	300	217.5
41	285	172.5

Table 9 Lateral Bankline Shifting along Grid Lines (along Eastings) of the Padma River from SatelliteImageries with respect to 1973

Grid Line	m Easting	Right Bank (km)	Left Bank (km)
1	485000	+3.35	-0.55
2	490000	-1.45	-1.40
3	495000	-1.90	-4.50
4	500000	-2.75	-9.15
5	505000	-3.95	-1.55

NB: (+) means sedimentation and (-) means erosion.

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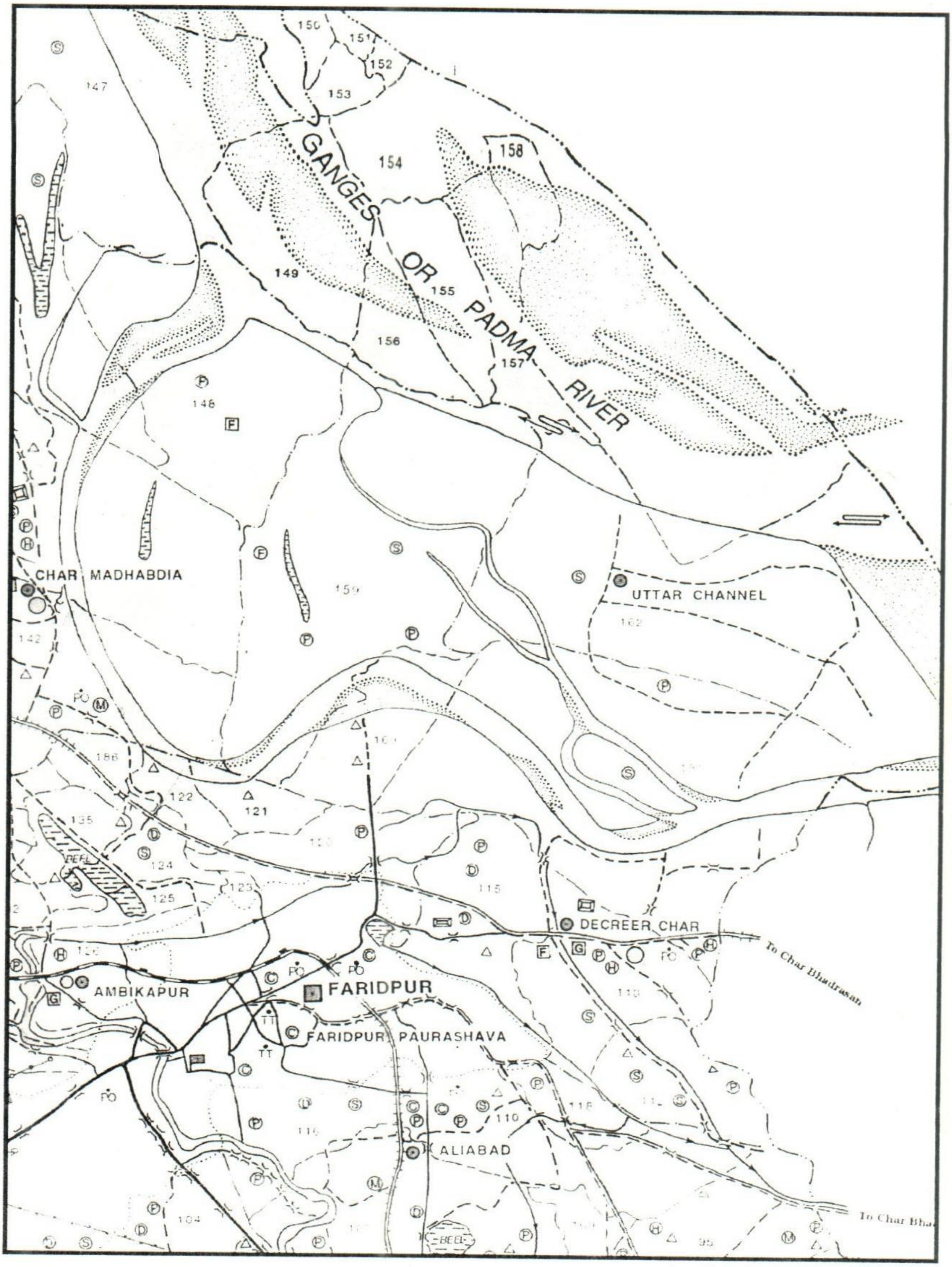
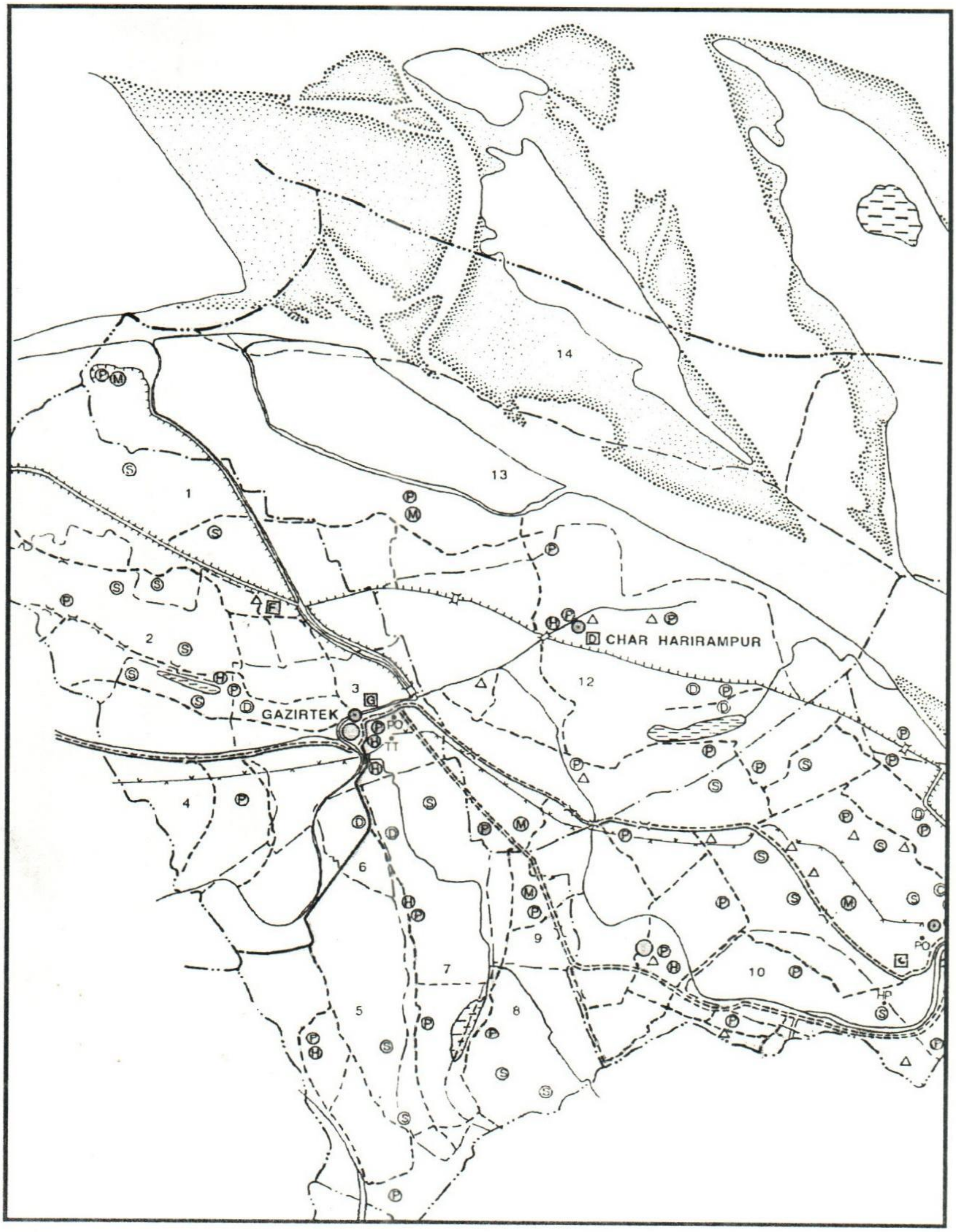


Figure 1 Location of Problem Area under Faridpur Sadar Upazila



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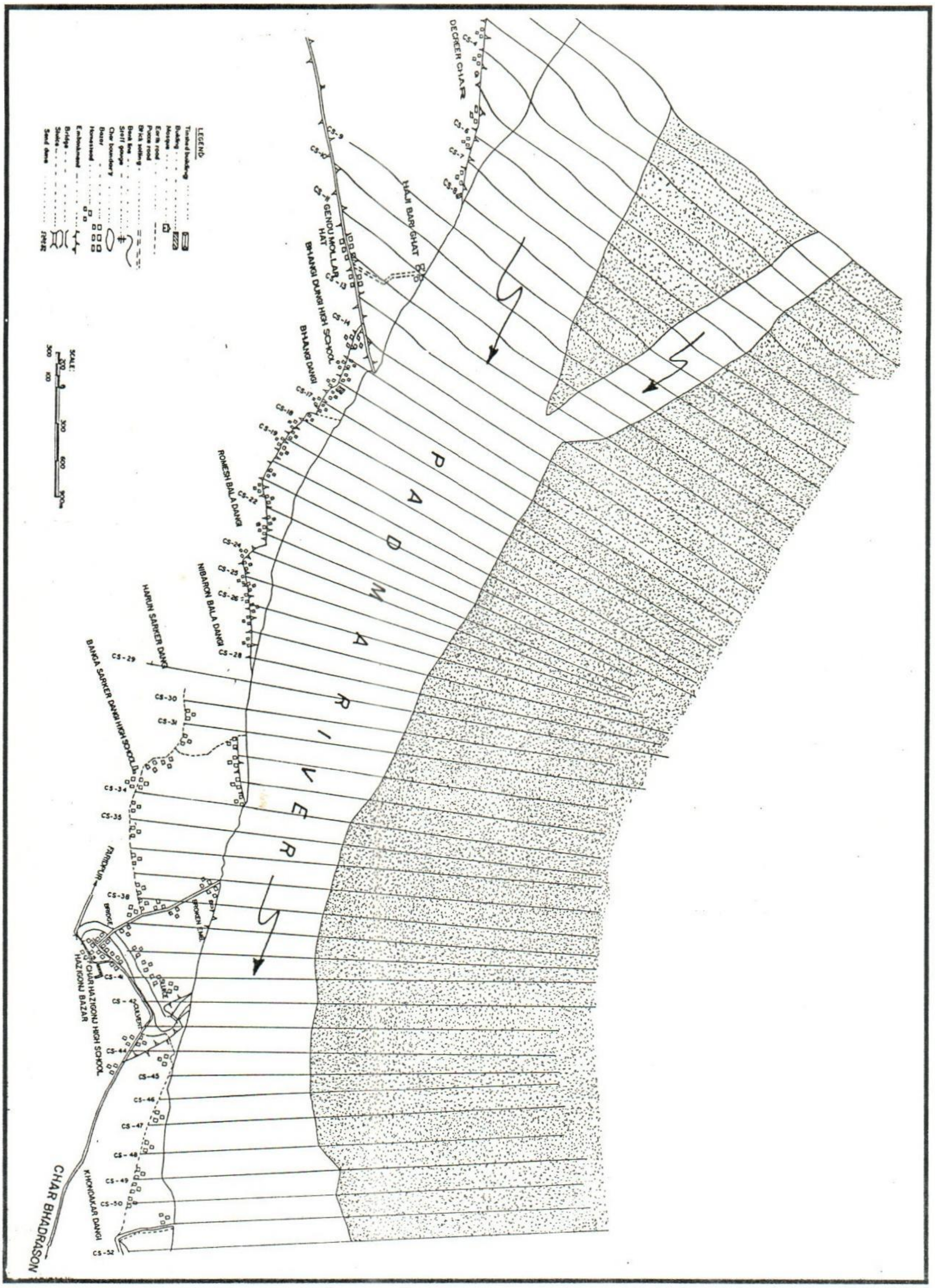

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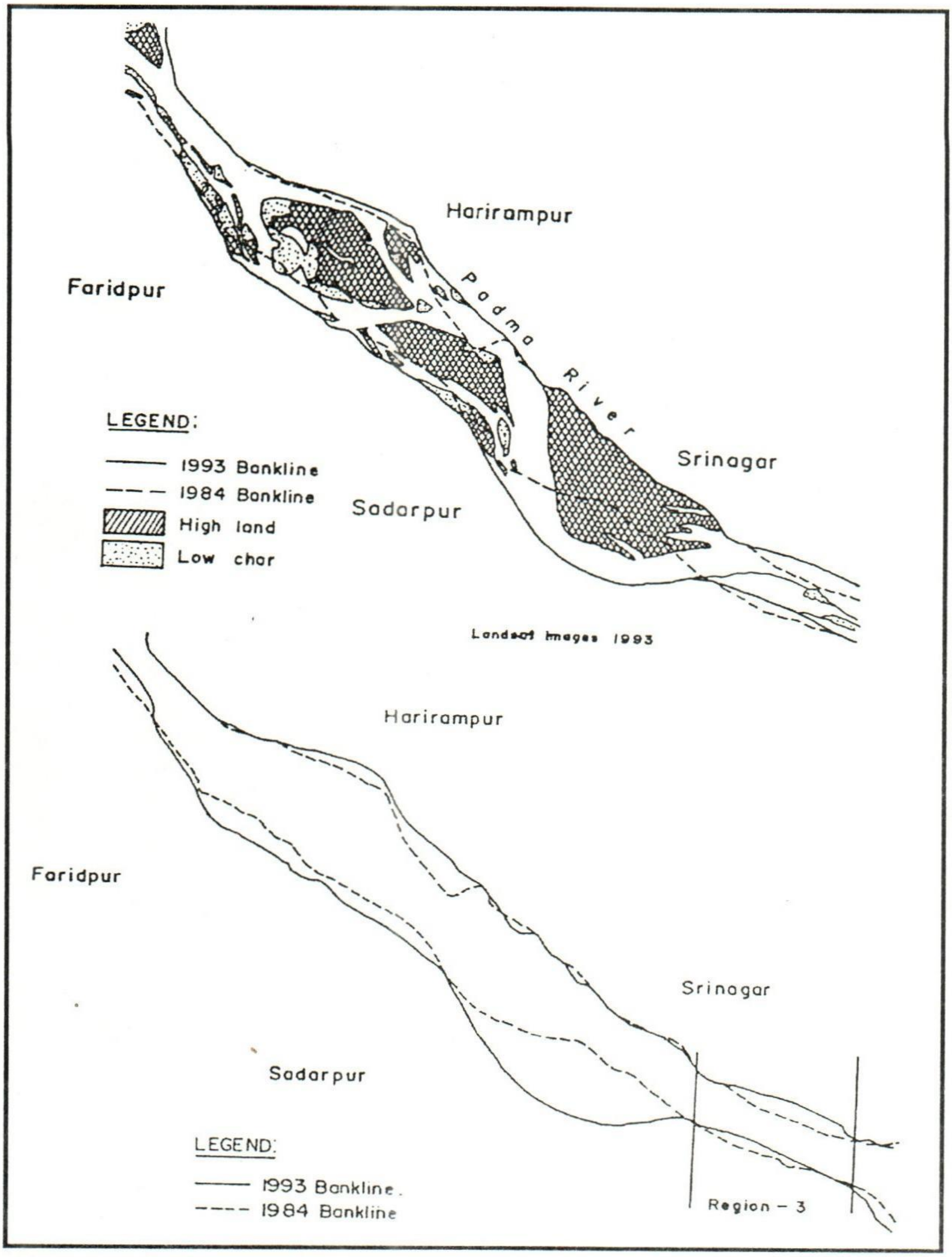

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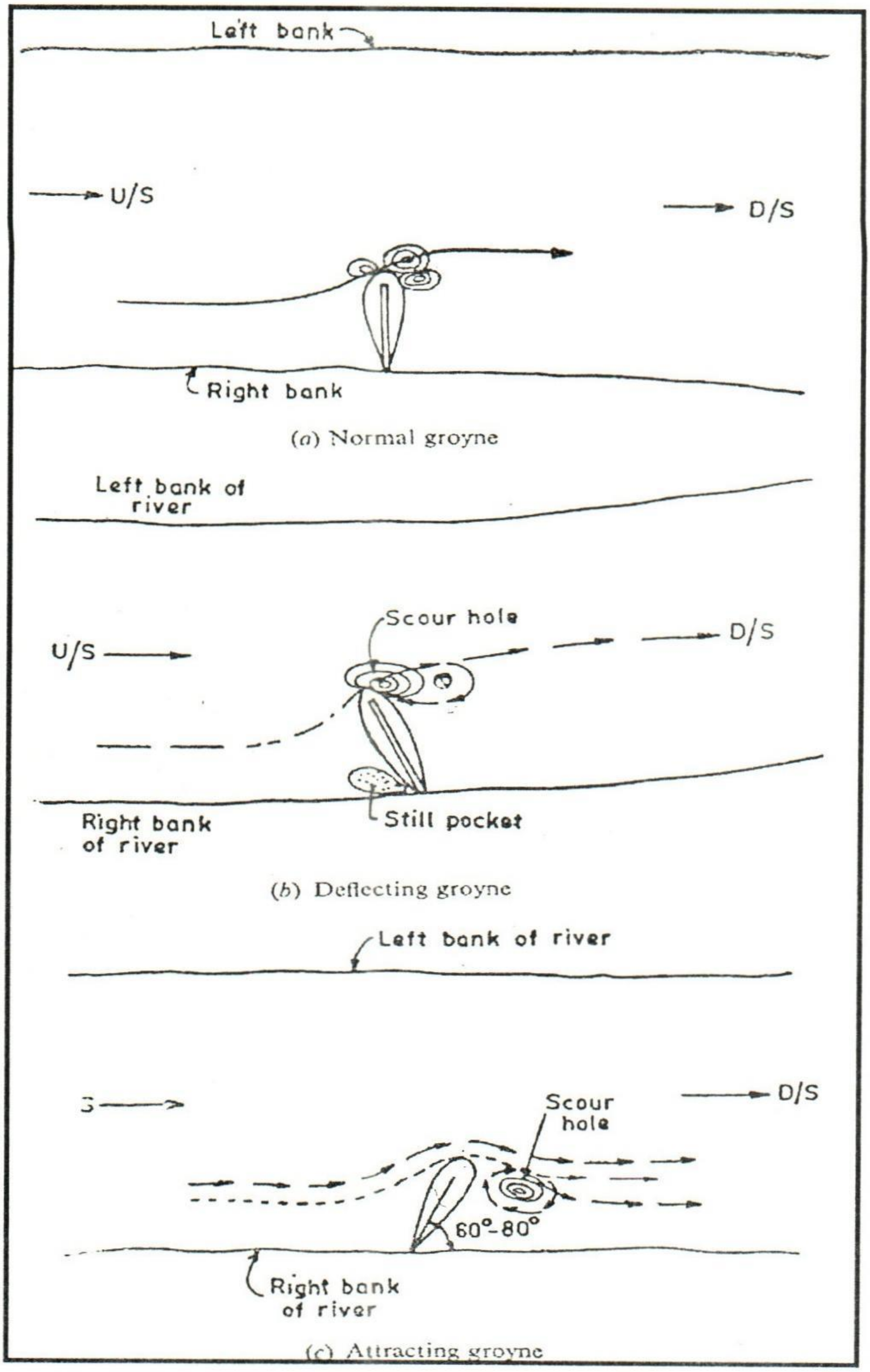

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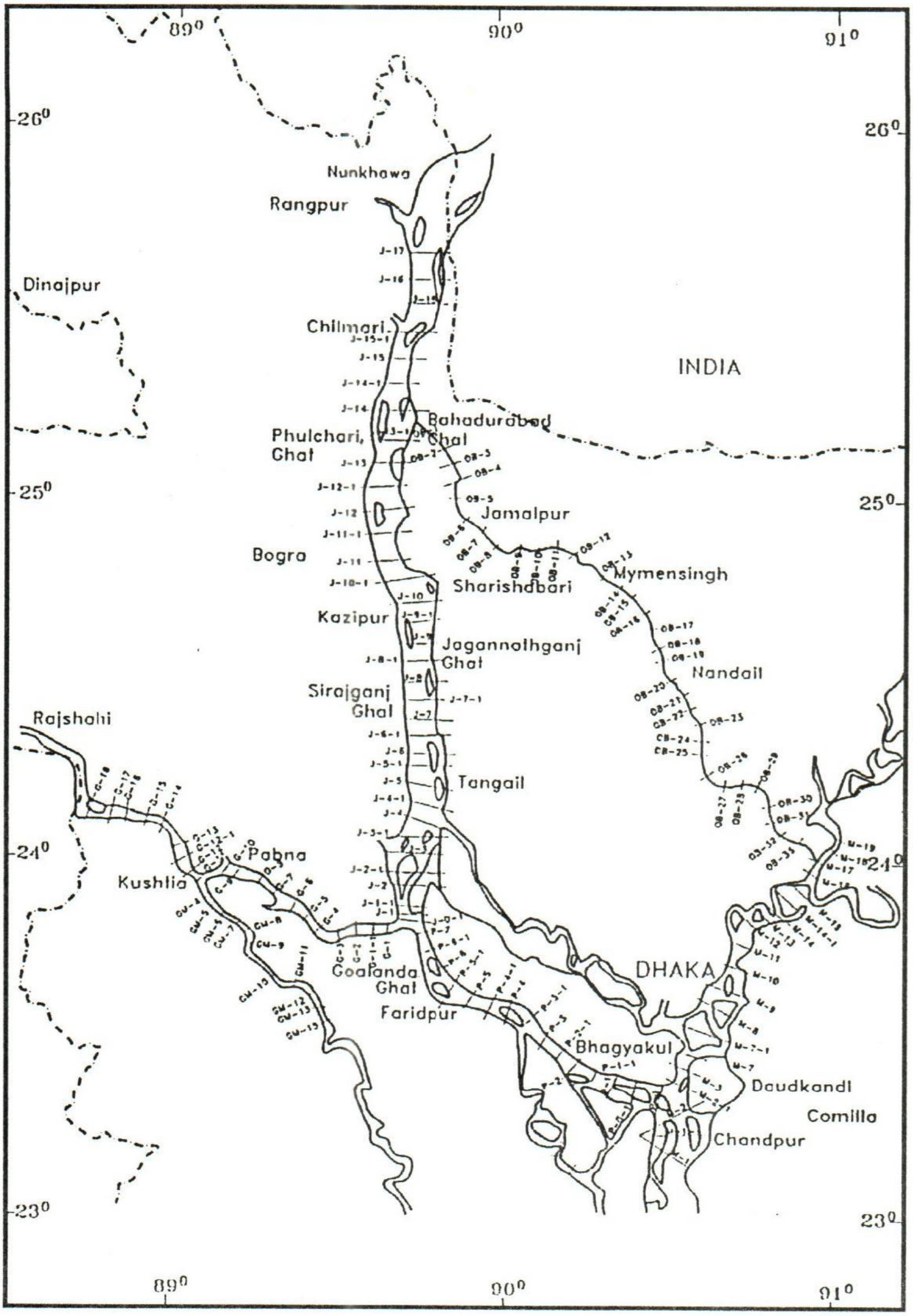

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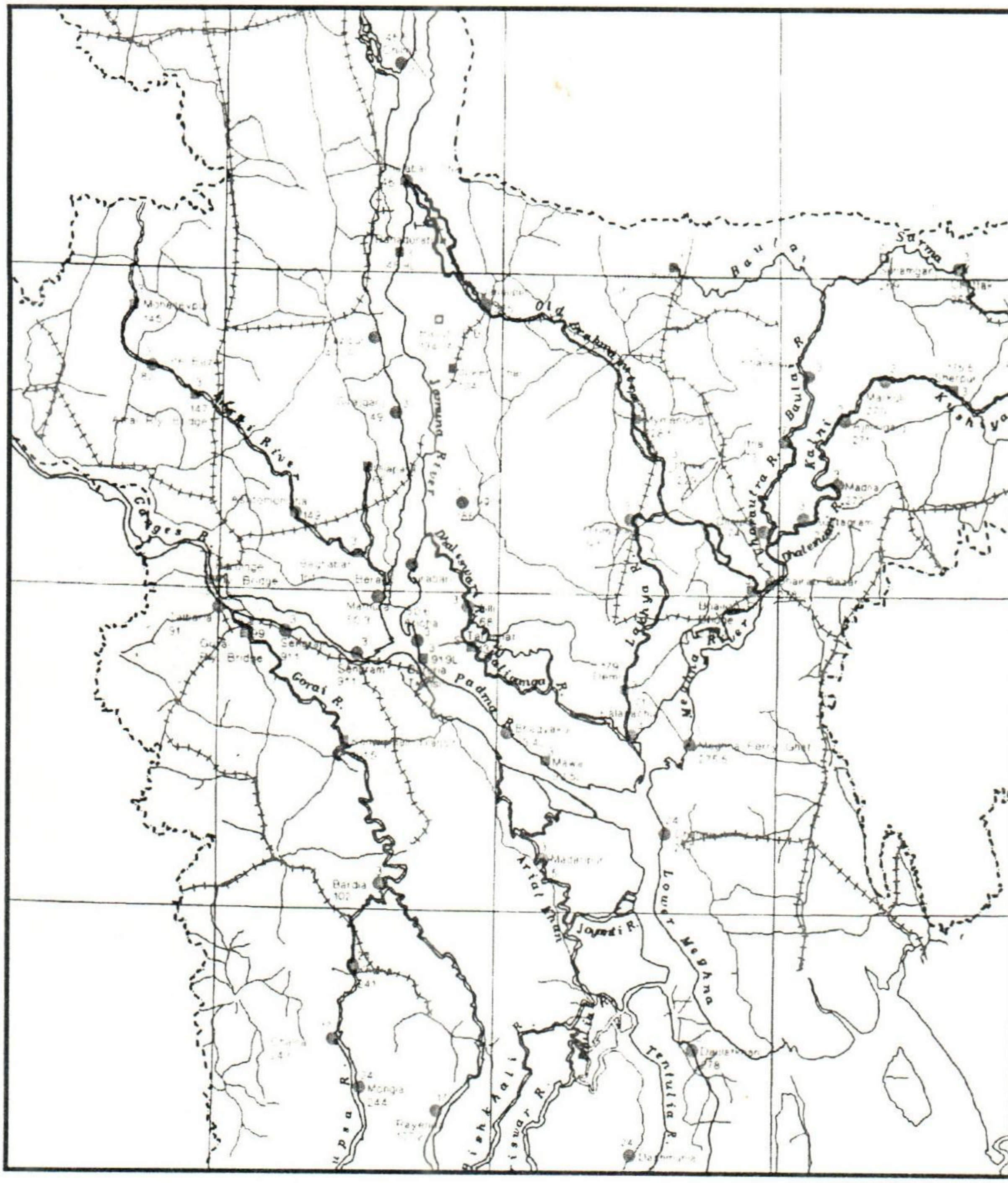

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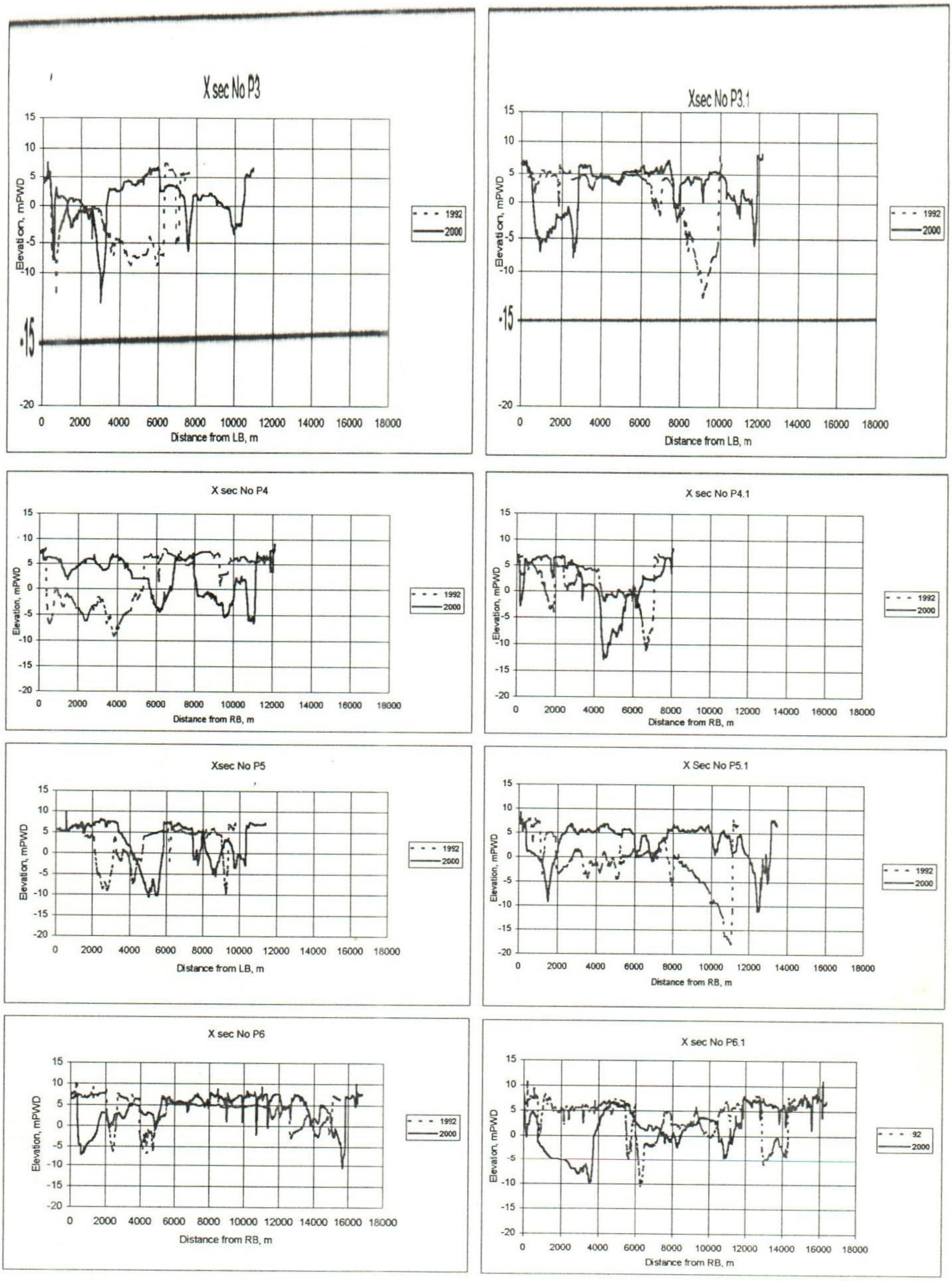

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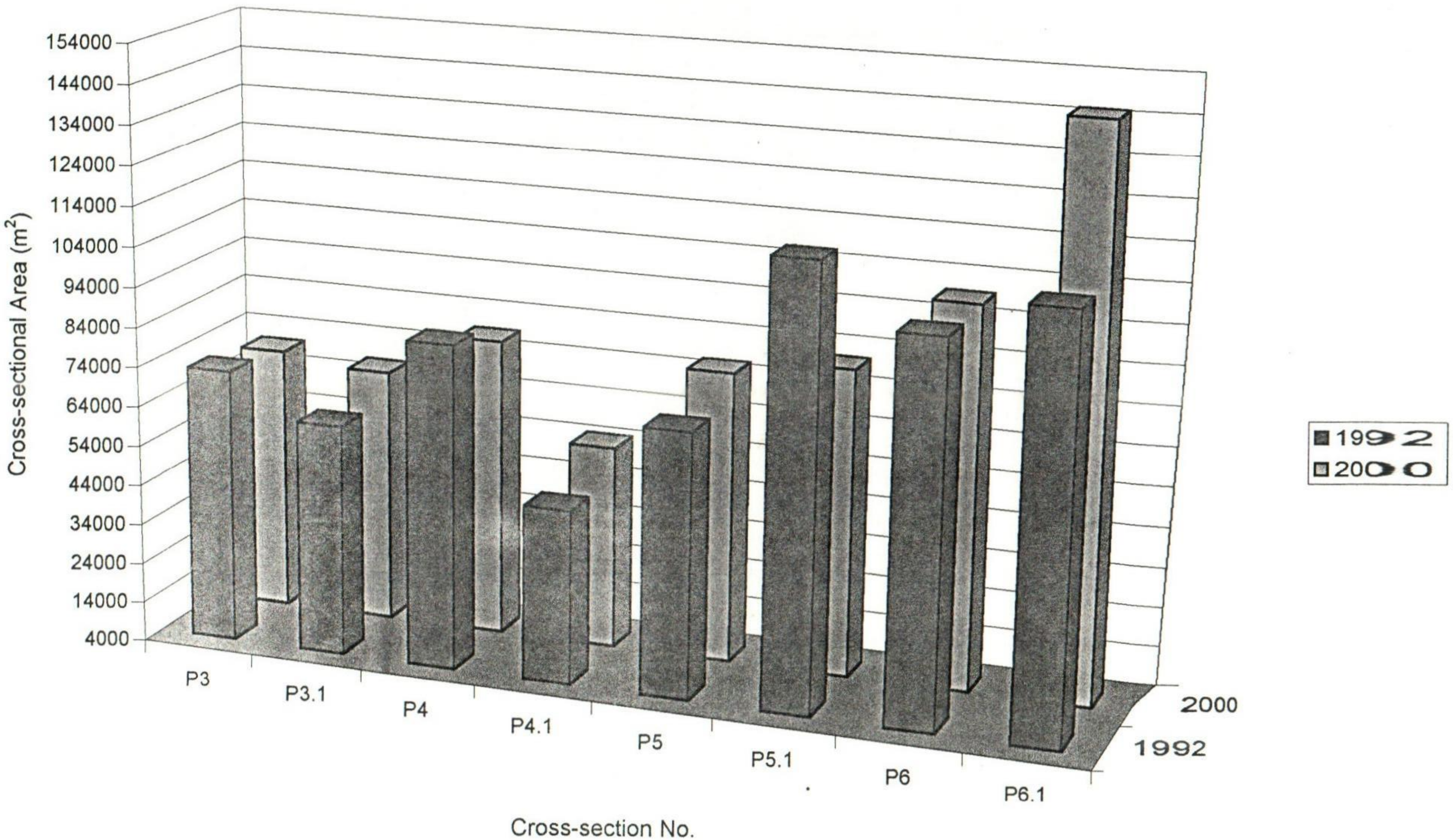

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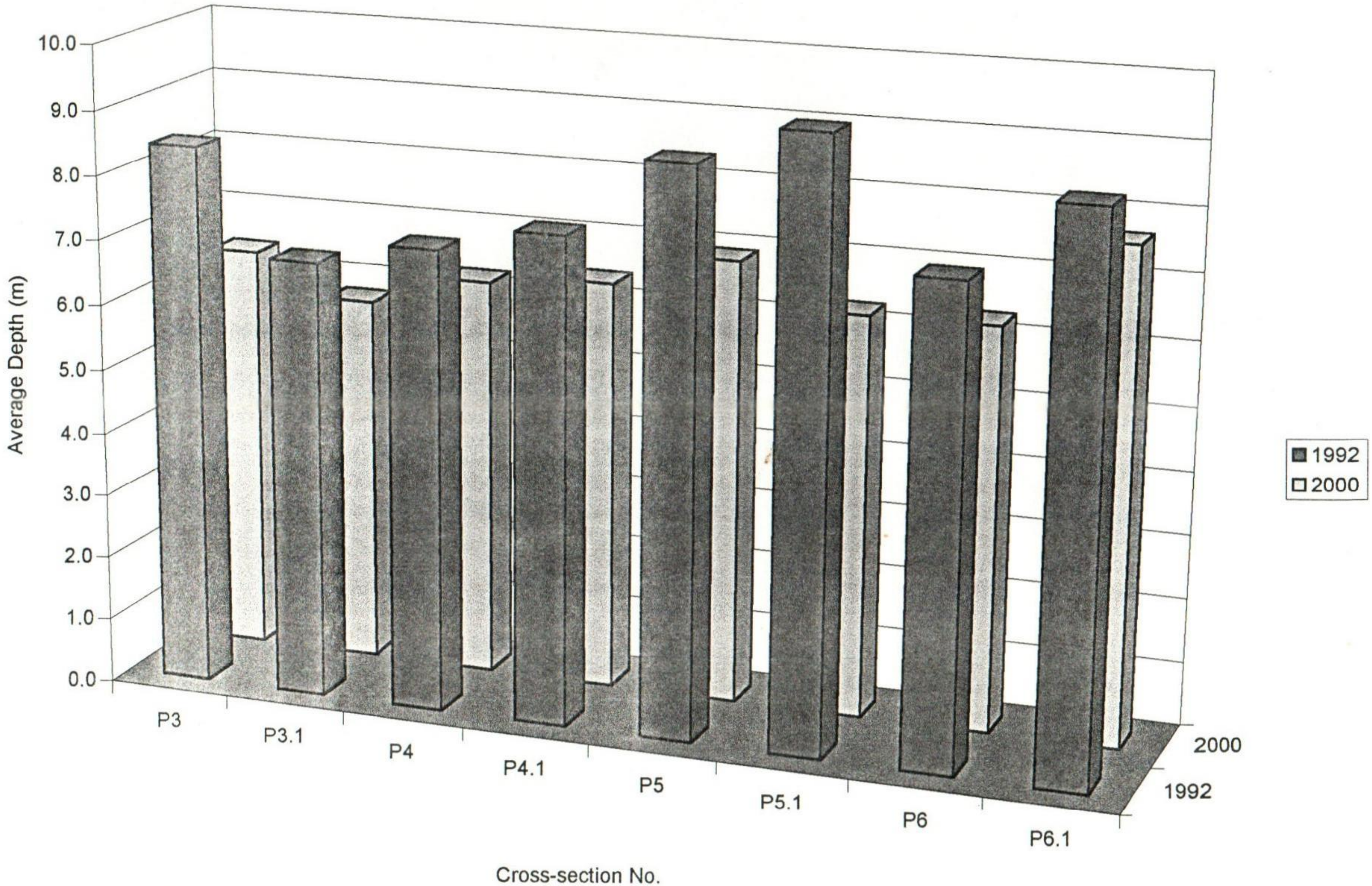

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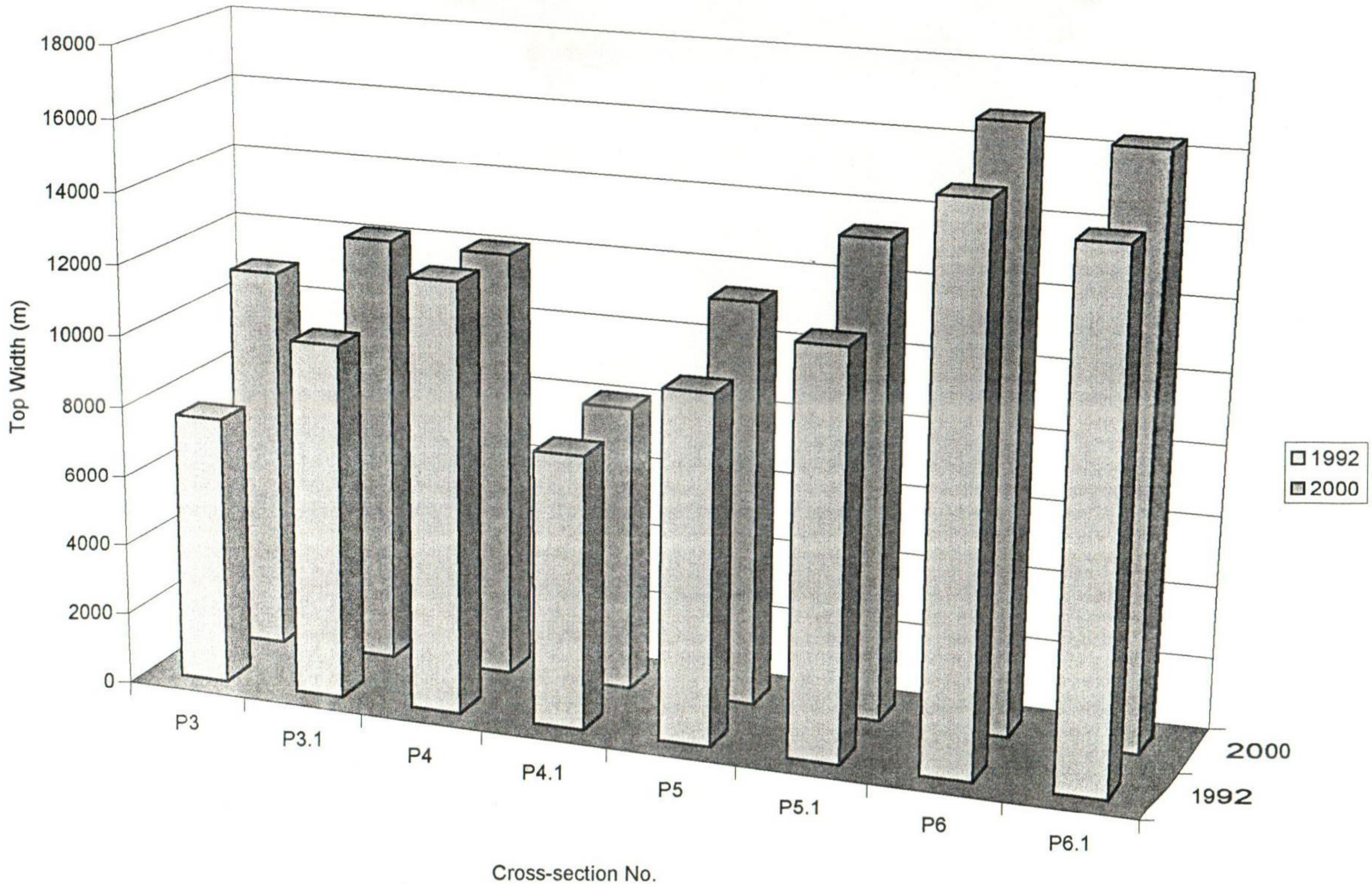

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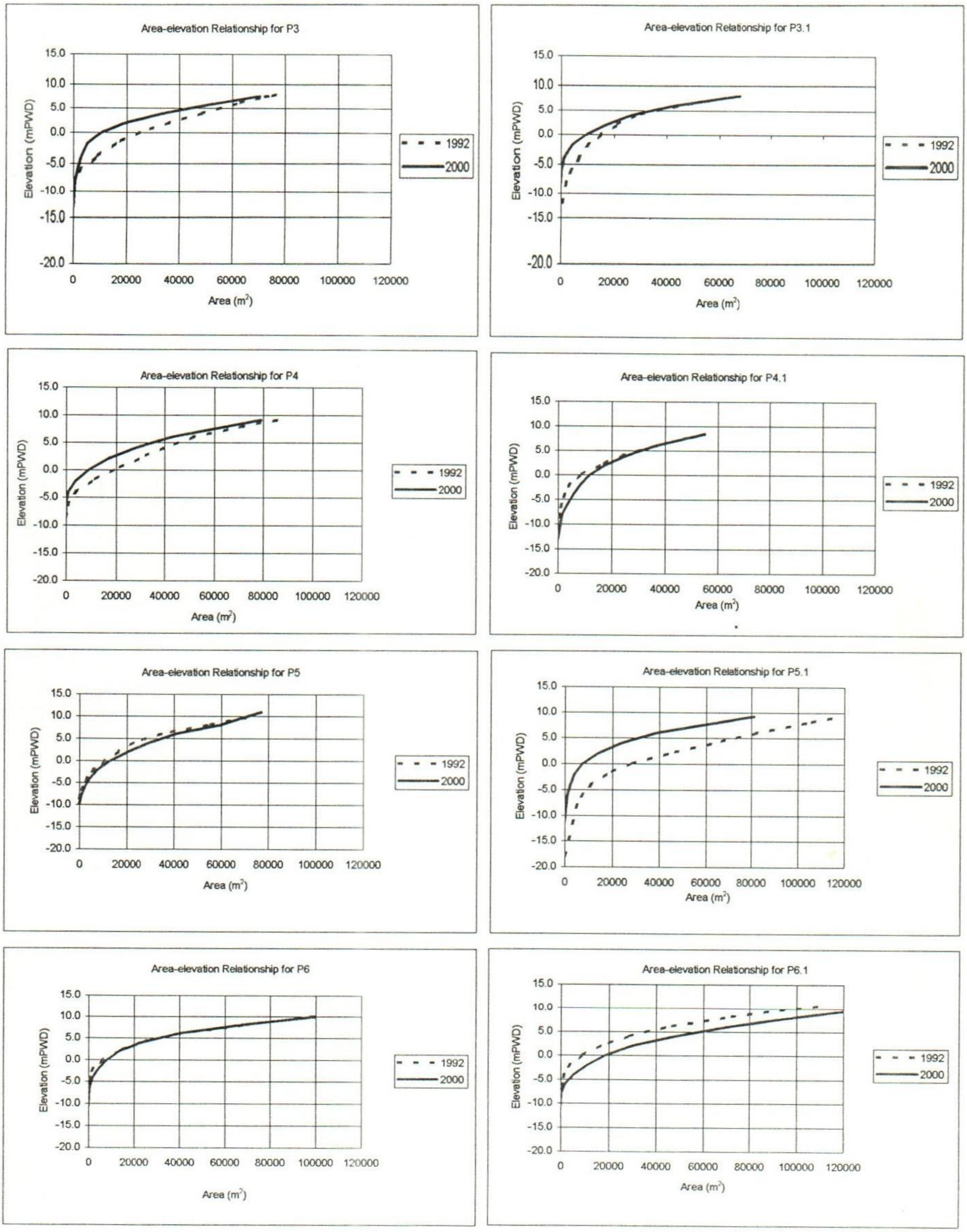

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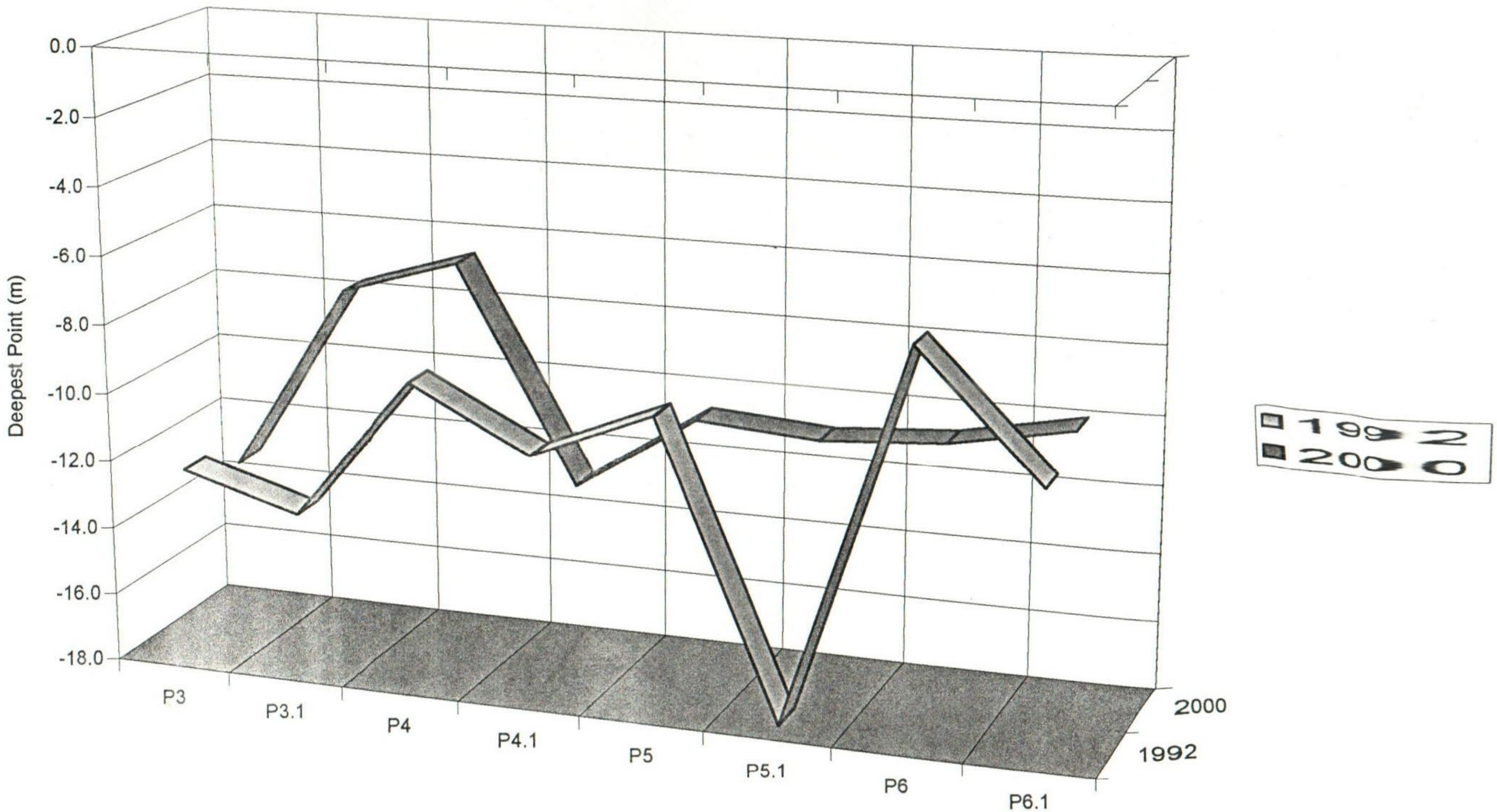

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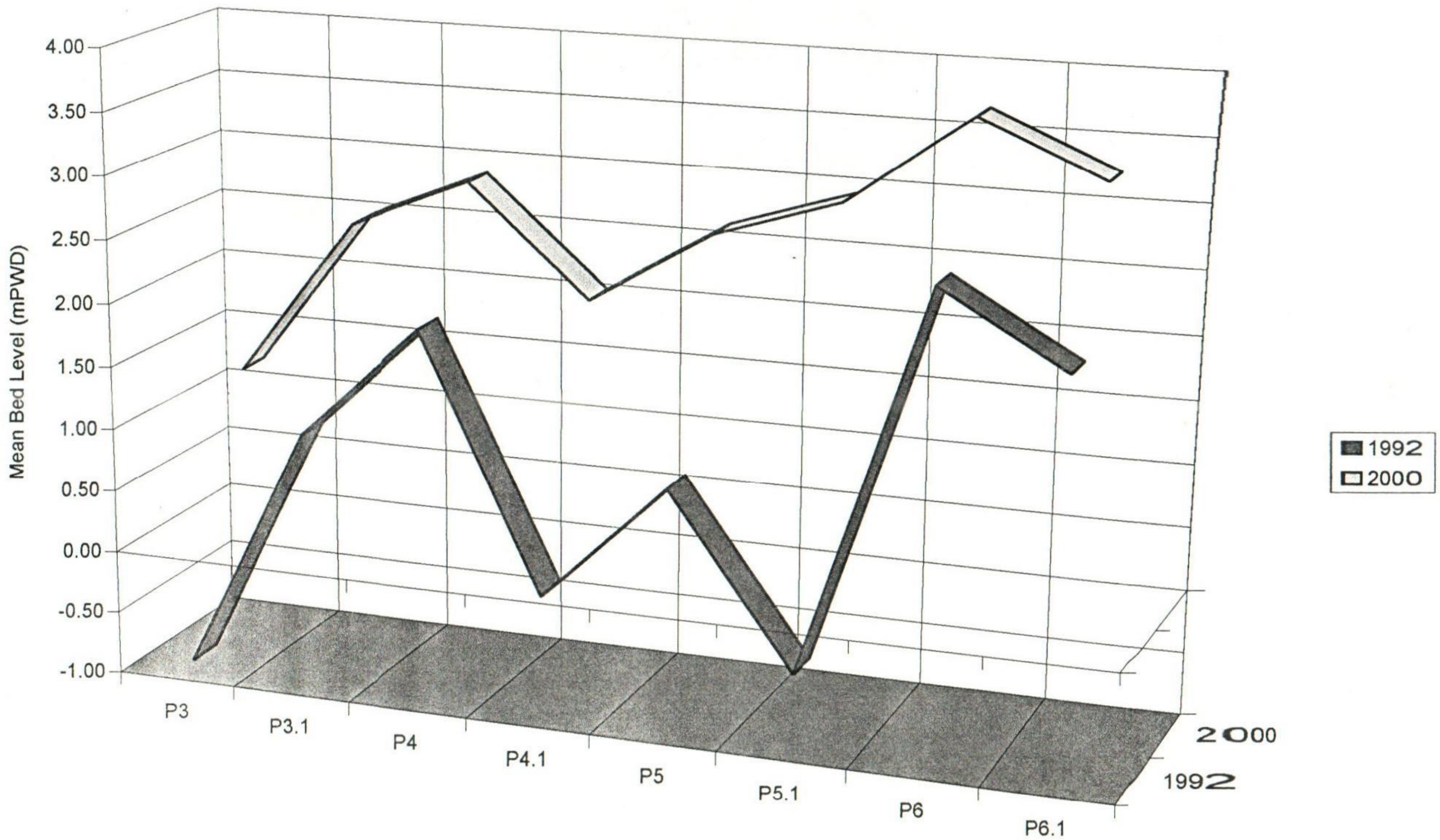

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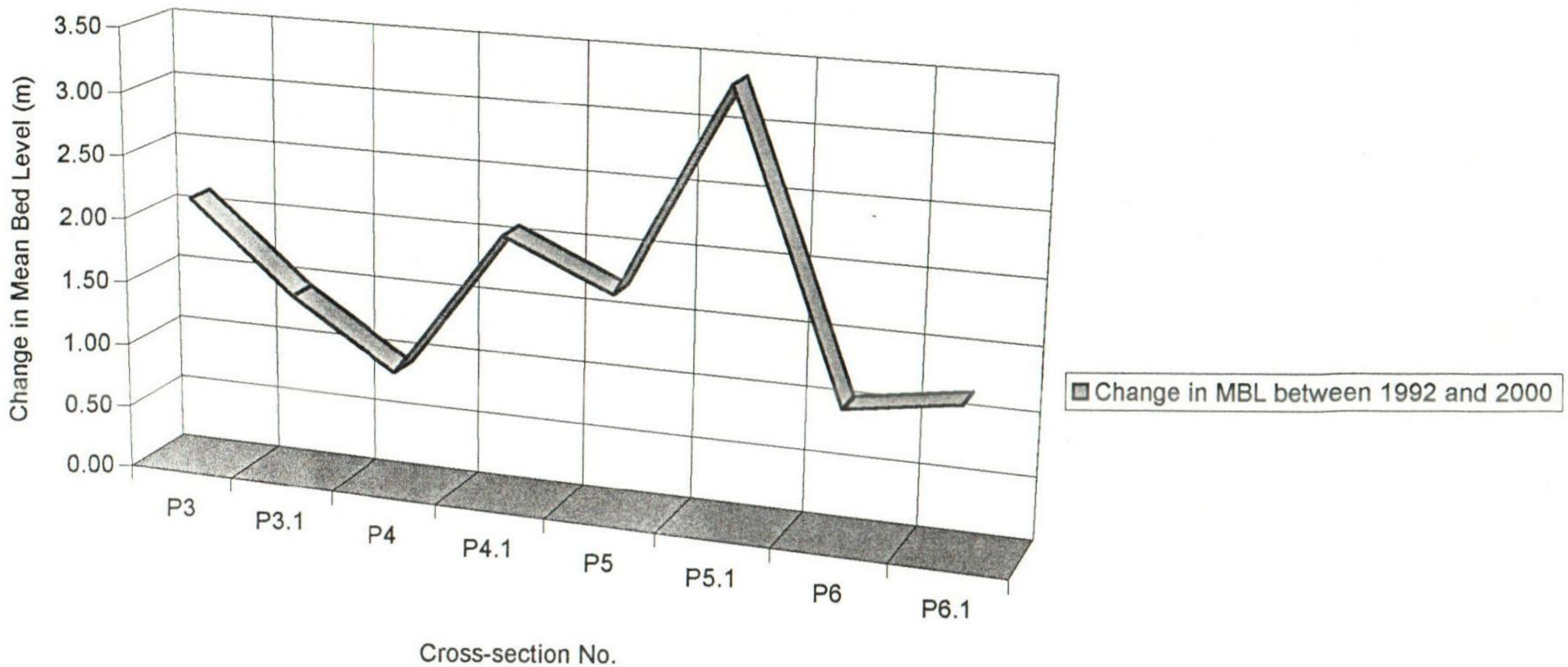

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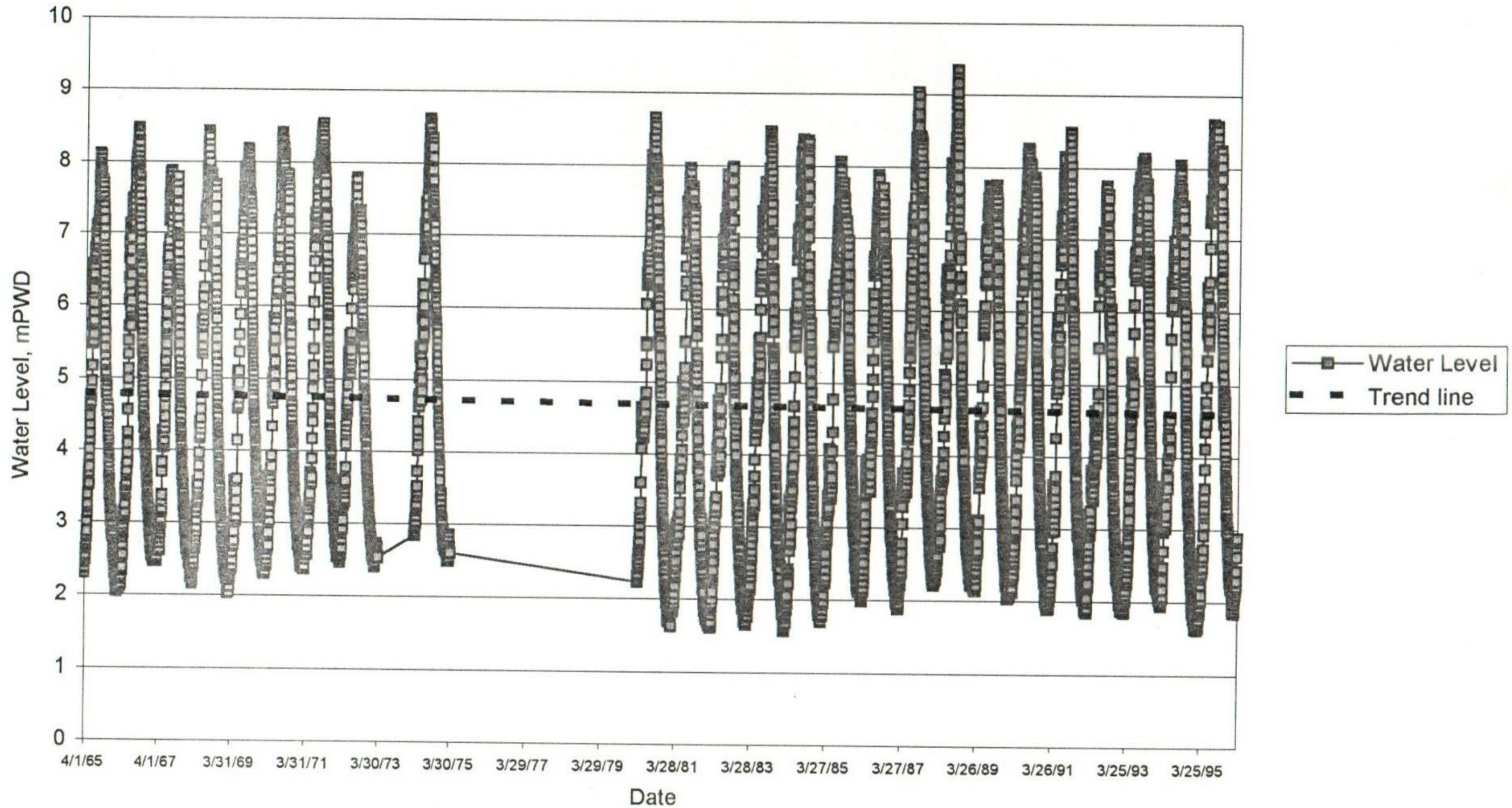
WL at Baruria Transit Station (91.9 L)



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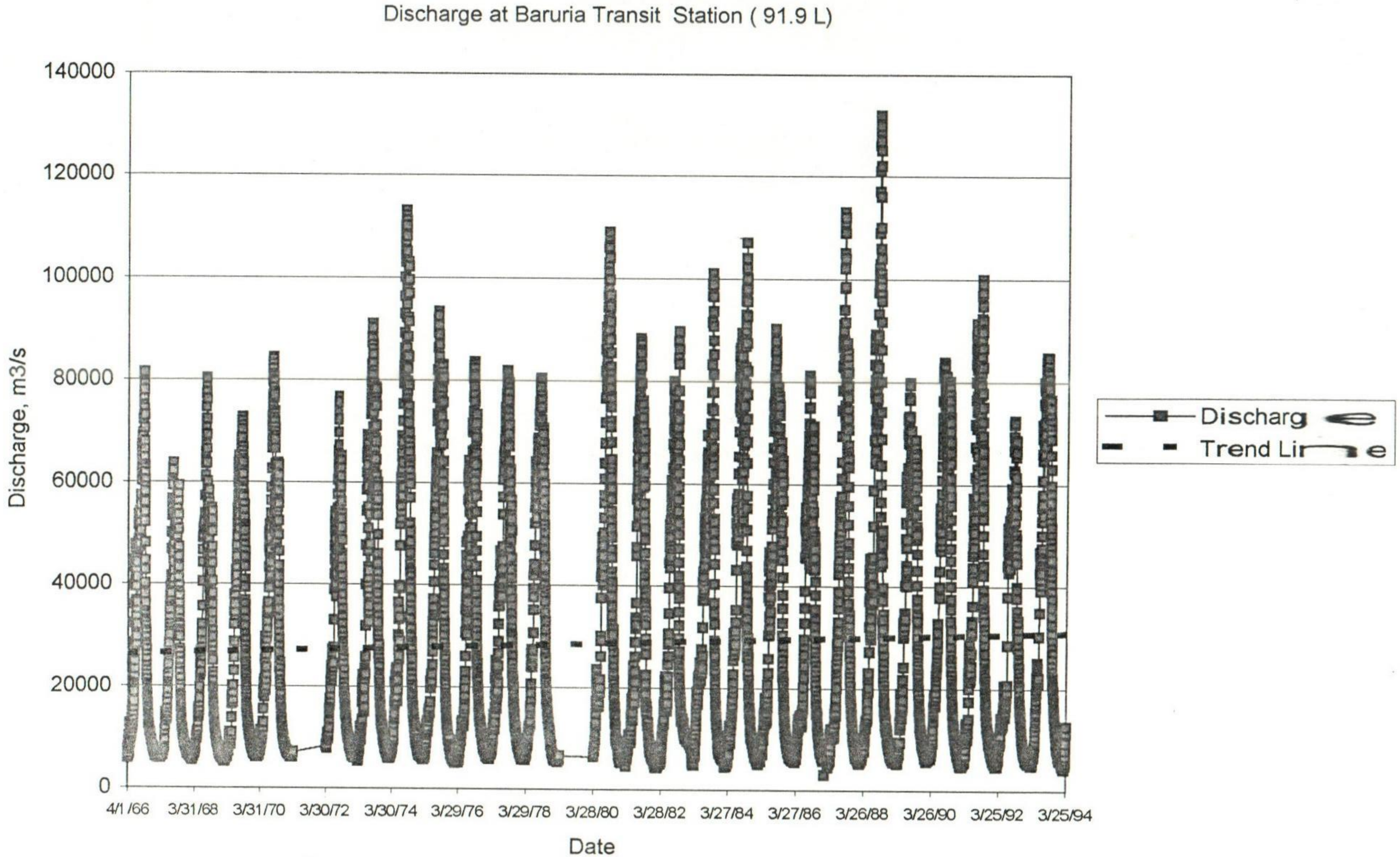

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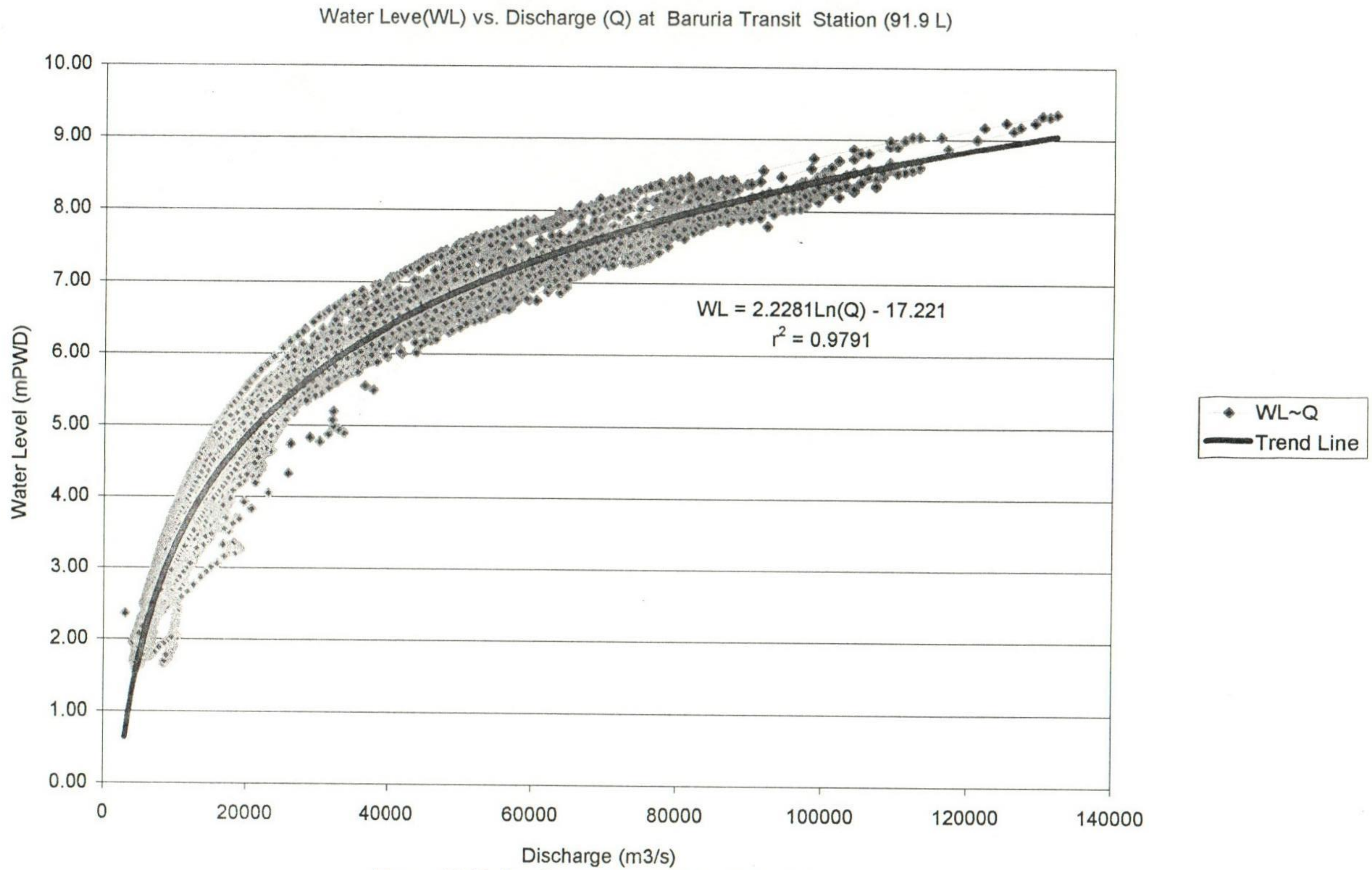

Figure 18 Rating Curve at Baruria Transit Station

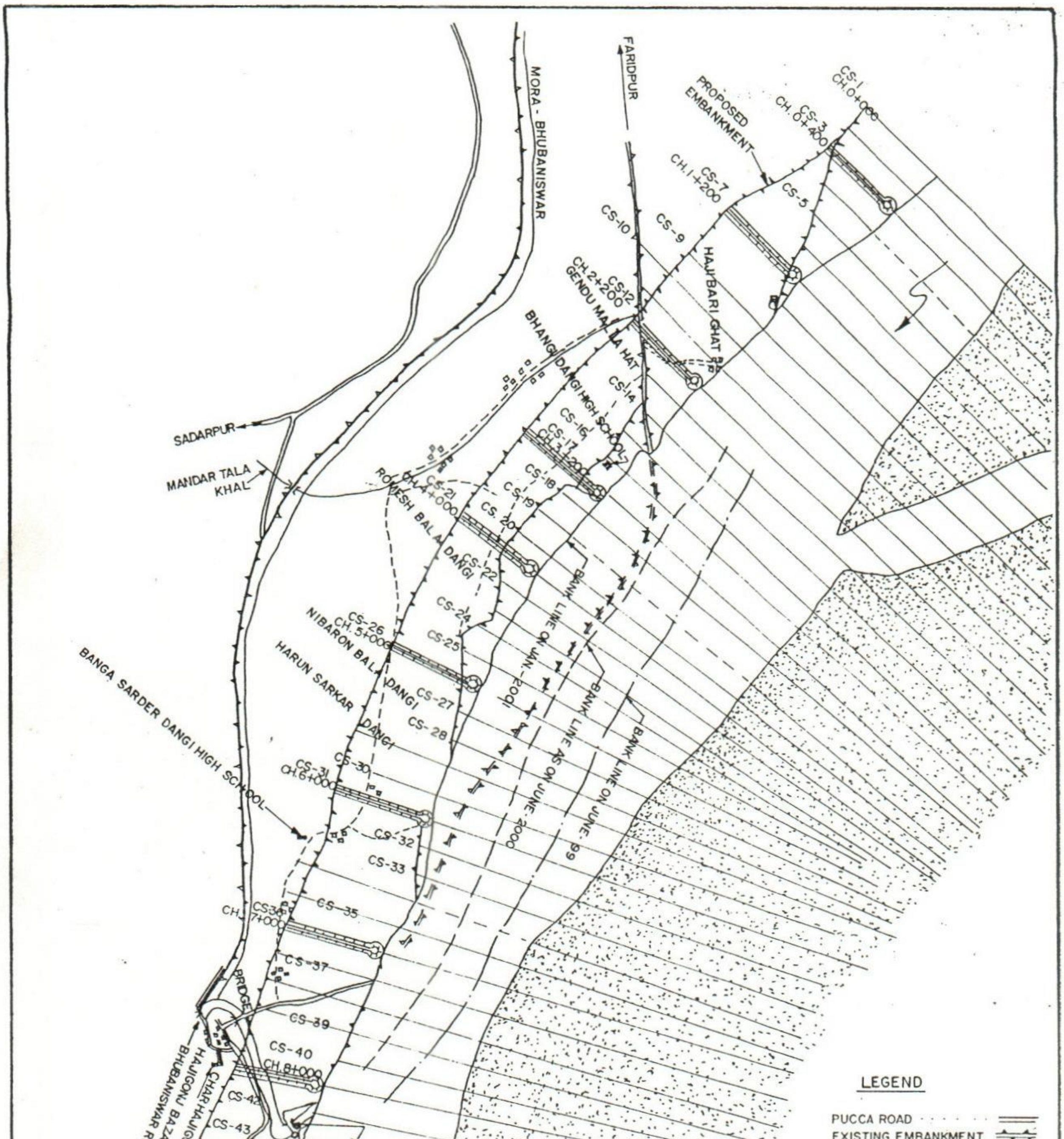

Figure 19 Bankline Shifting of Padma River and Location of Proposed Retired Embankment and Proposed Spurs

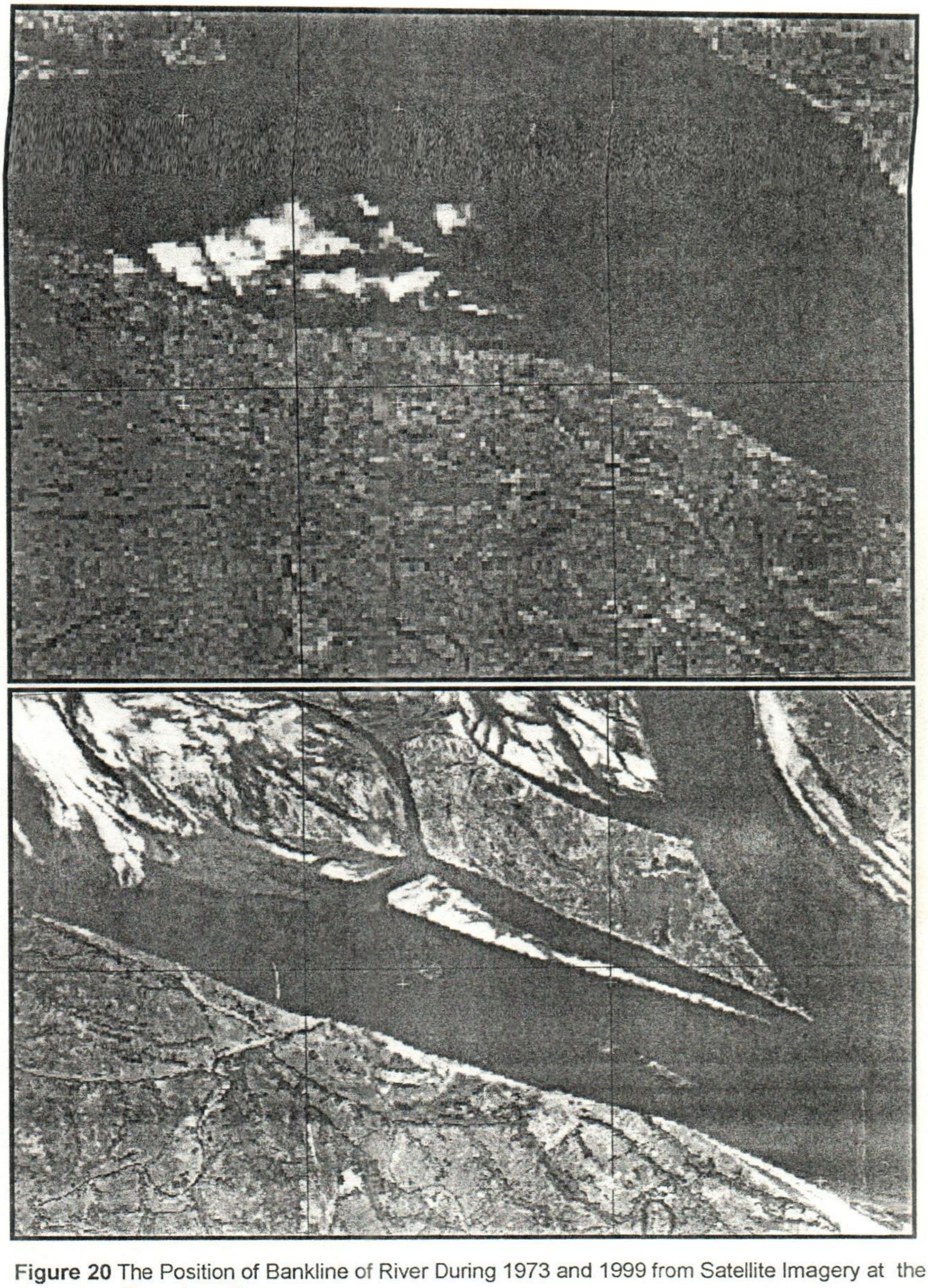

Figure 20 The Position of Bankline of River During 1973 and 1999 from Satellite Imagery at the Same Location

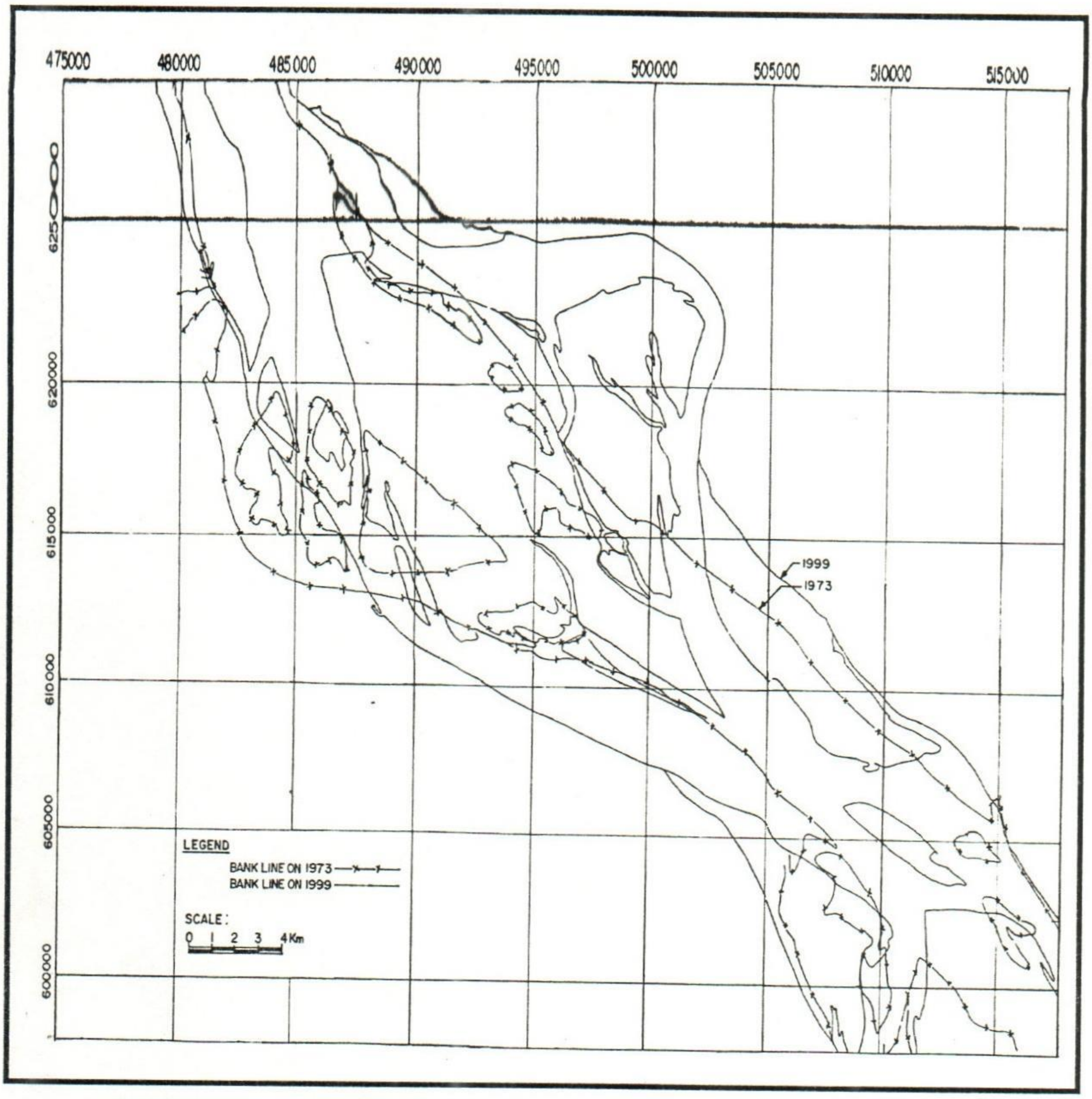

Figure 21 Superimposed Bankline from Satellite Imagery at the Study Area for the Years 1973 and 1999

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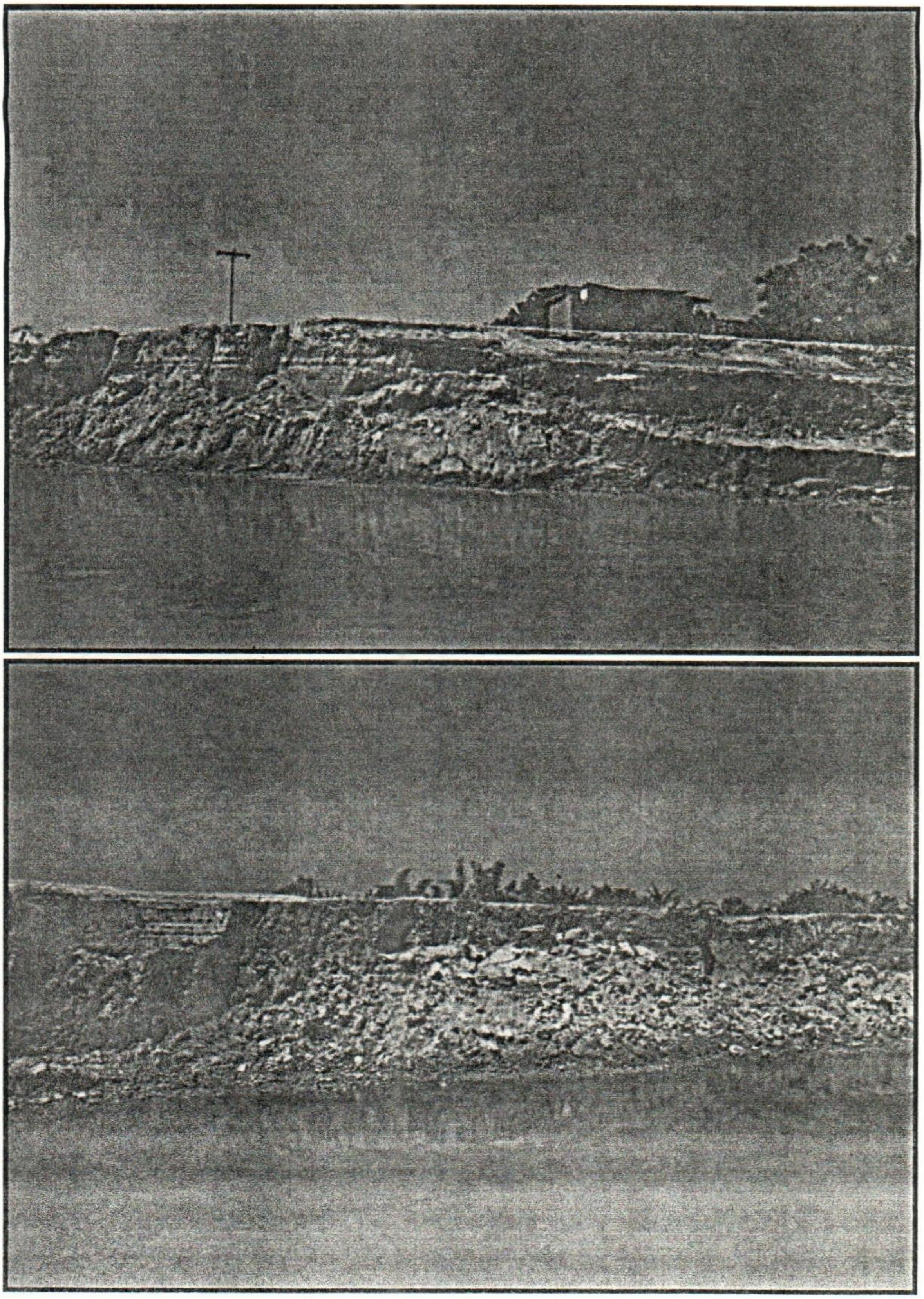
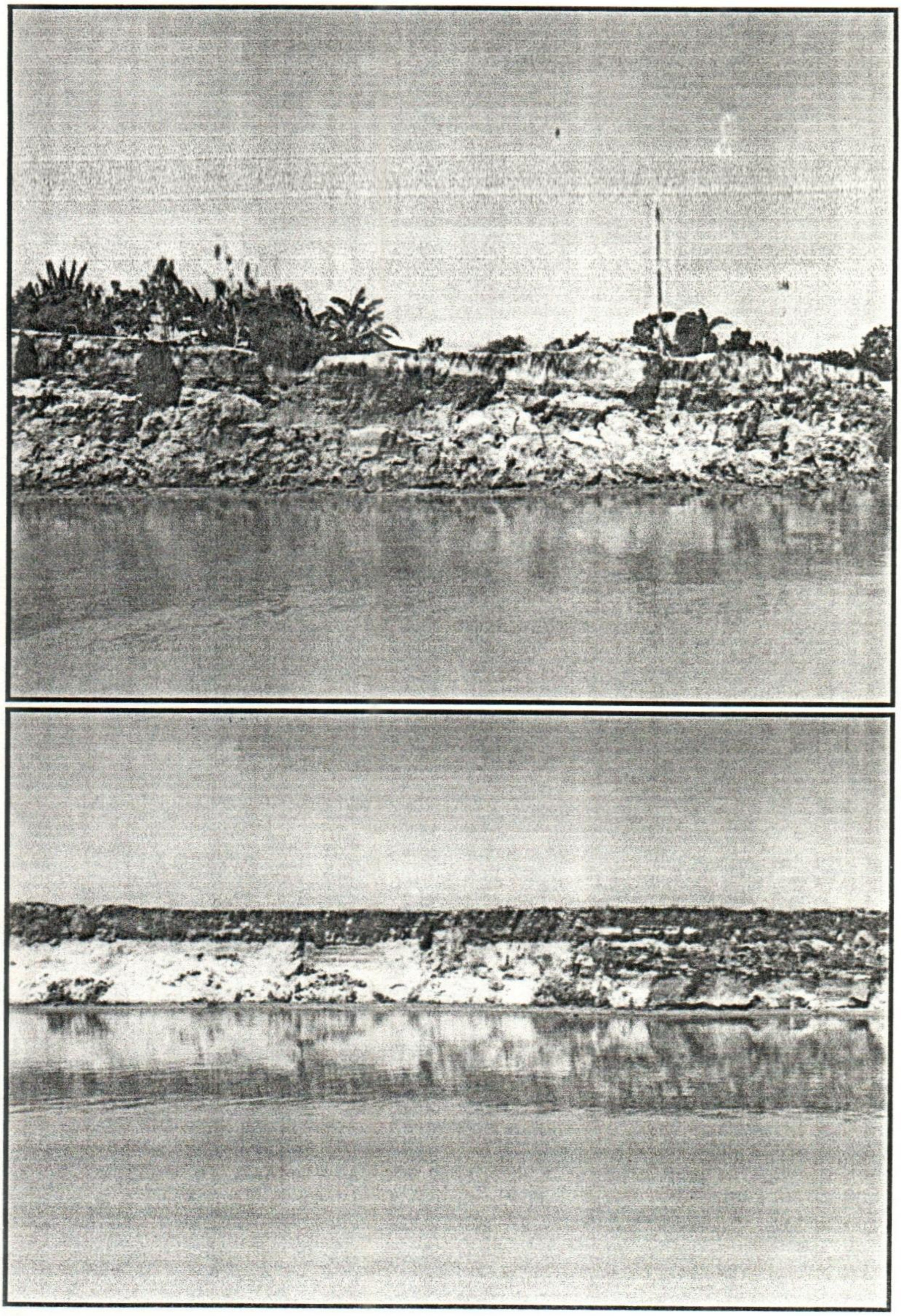
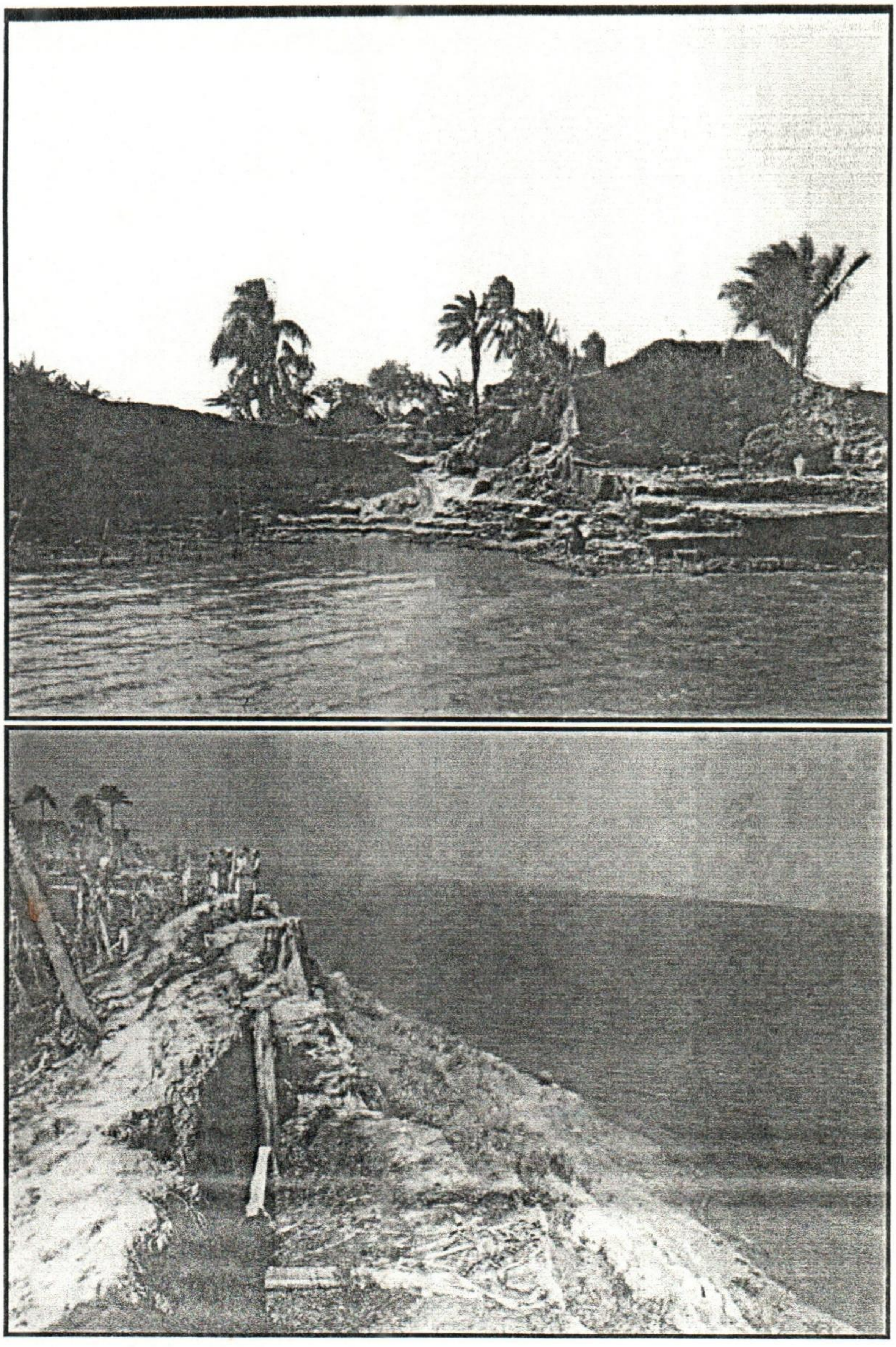


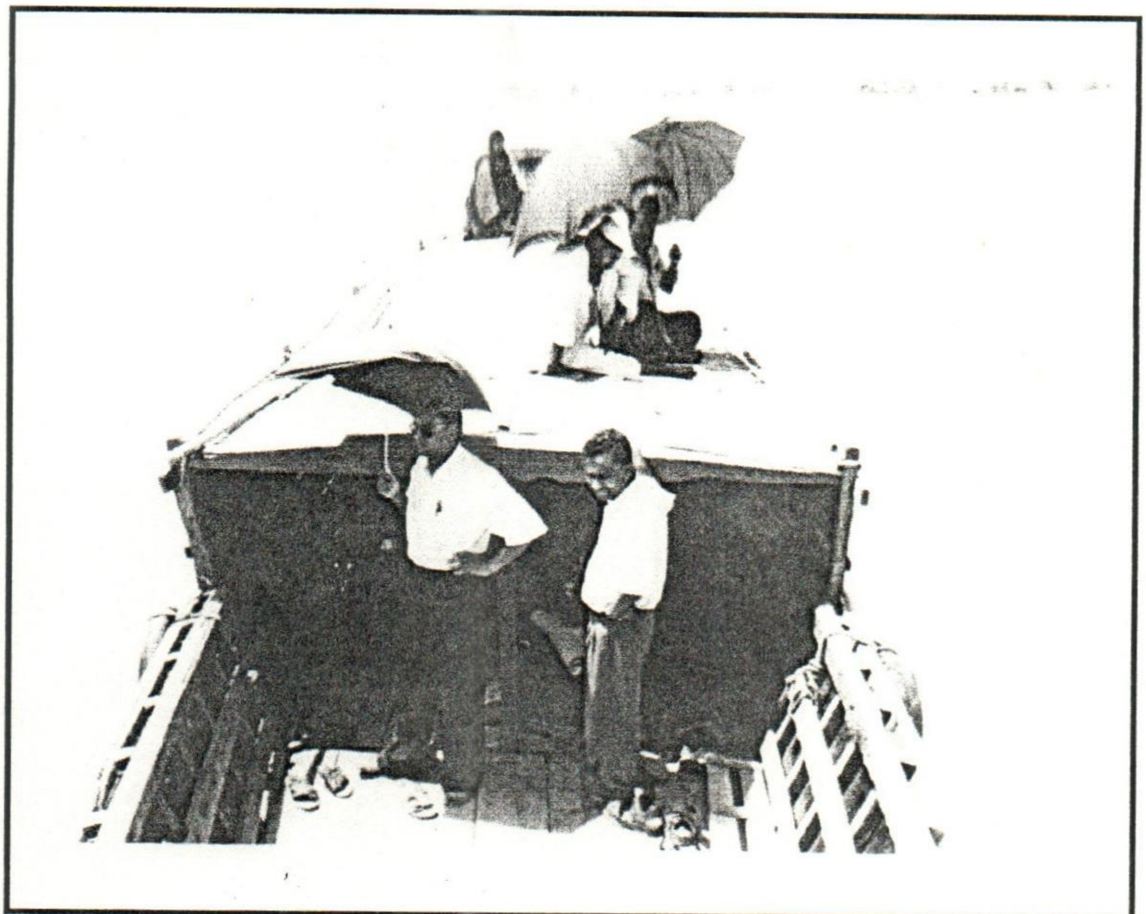
Photoplate 1 River Bank Erosion near Haji Bari Ghat

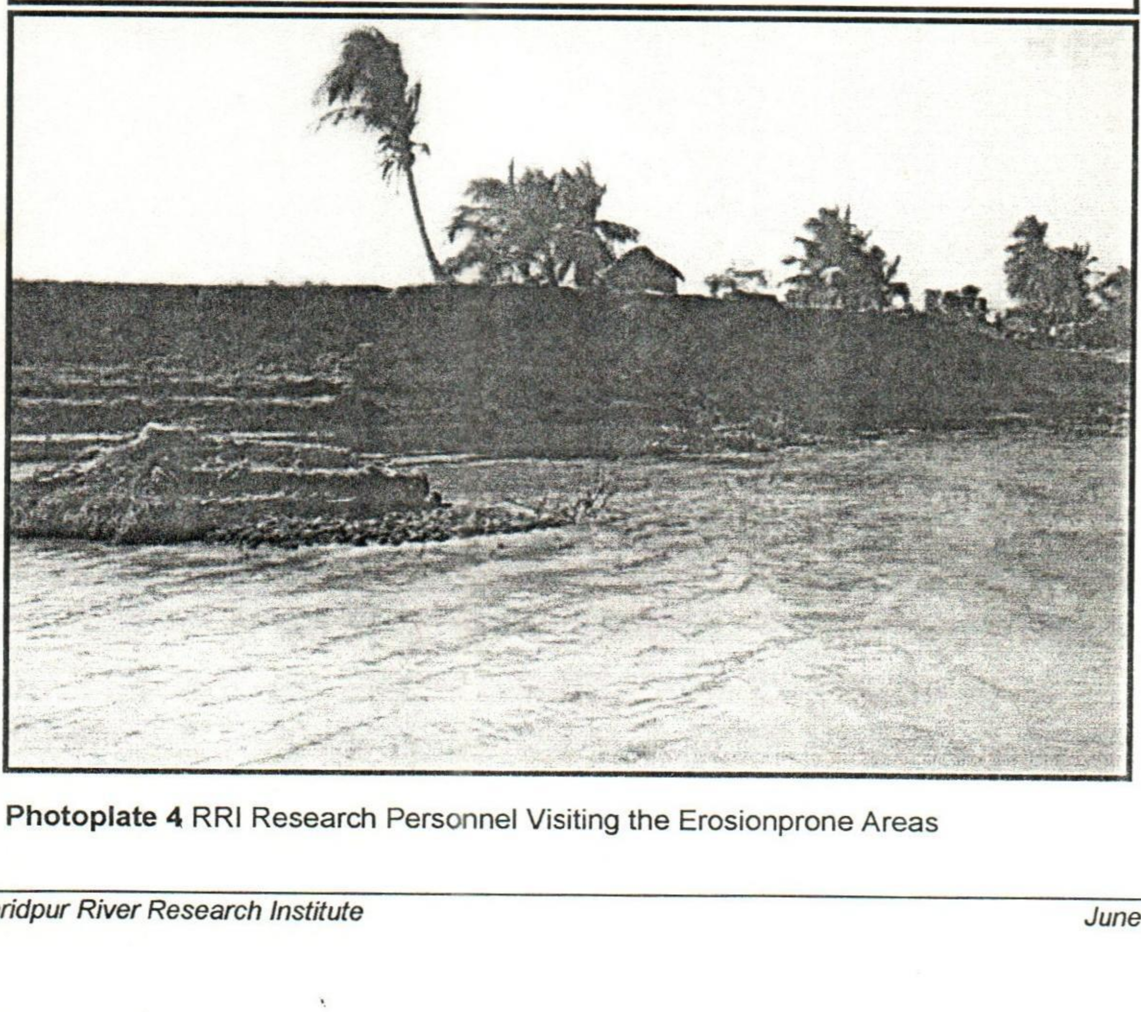


Photoplate 2 River Bank Erosion near Decreer Char



Photoplate 3 River Bank Erosion near Haziganj Bazar





Photoplate 4 RRI Research Personnel Visiting the Erosionprone Areas