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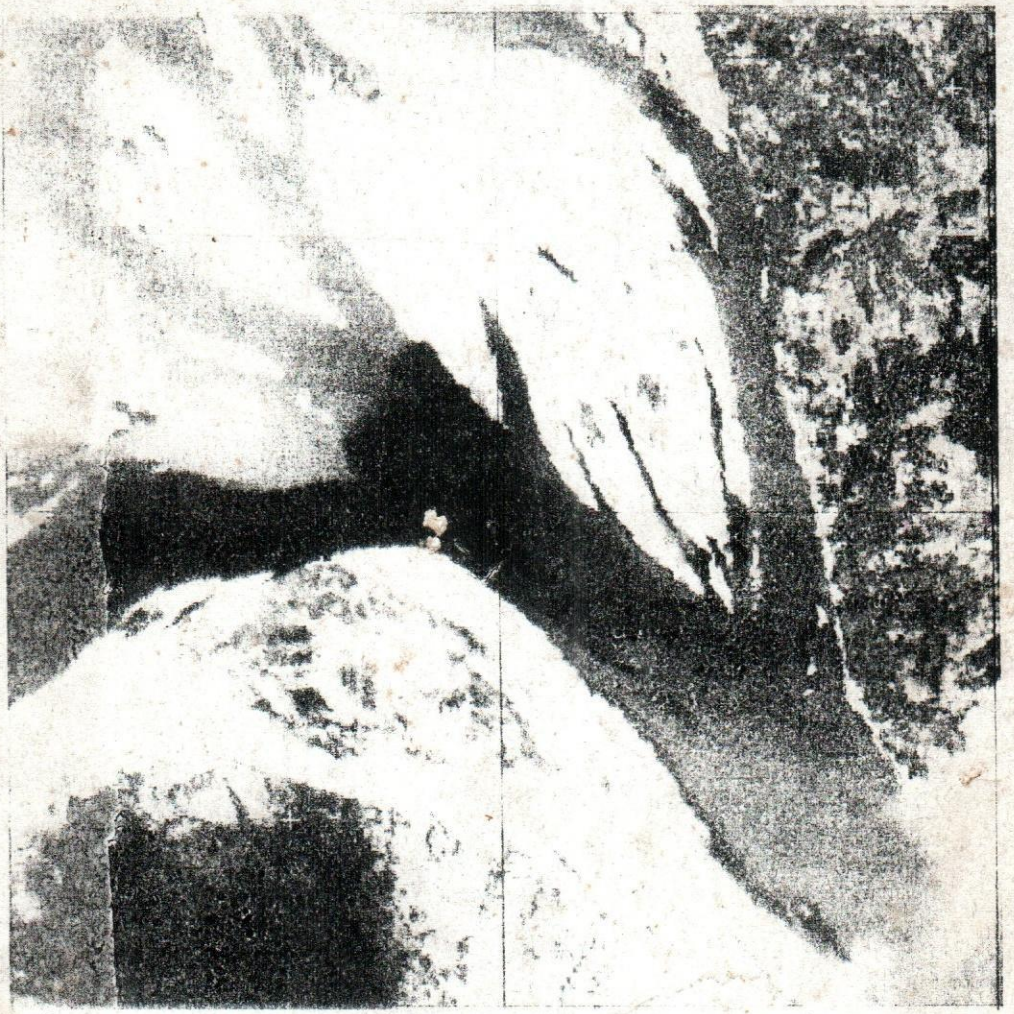
A STUDY ON THE SILTATION PROBLEM OF THE NAVIGATION ROUTE COVERING ARICHA-NOTAKHOLA-DAULATDIA



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RIVER RESEARCH INSTITUTE, FARIDPUR
Ministry of Water Resources
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A STUDY ON THE SILTATION PROBLEM OF THE NAVIGATION ROUTE COVERING NOTAKHOLA-ARICHA -DAULATDIA

Research Report

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Research Team

Co-ordinator	Md. Rafiqul Alam, PSO
Team Leader	Swapan Kumar Das, SSO
Research Member	Md. Azizul Haque Podder,SO
	Md. Rubayet Alam, SO
	Md. Moniruzzaman Khan Yousuf Zai, SO
	Muhammad Enamul Quadir, SO

River Research Institute, Faridpur

Ministry of Water Resources
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RES-04

PREFACE

This report presents the results and findings of the research project entitled "The siltation problem of the navigation route covering Notakhola-Aricha-Daulatdia". Siltation at this important navigation route through the passage of time has become acute and has made the navigation route very problematic during the low flow season. To investigate the siltation problem a study was undertaken by the River Research Institute (RRI) as per decision of the 17th Meeting of the Board of Governors of RRI. Accordingly a research team was formed to carry out the project. The team collected the available data from different agencies and finally the findings of research project with indicative conclusions and recommendations have been made.

The overall objective of the study was to identify the probable causes of siltation at the Notakhola-Aricha-Daulatdia navigation route and to make recommendation for the mitigation of the problem. After conducting a detailed literature search in the related field, along with some standard scientific approach, this research report suggested a detailed feasibility study to identify the real causes of siltation. The study also recommend the in-depth analysis of the complex Hydro-morphological process of these river systems in association with structural interventions and river training works which should be finalized on the basis of physical model study.

The services provided by the 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, SPARRSO, EGIS etc. for supplying valuable data, information, maps and co-operation in this regard.

(ENGR. SYED ABDUS SOBHAN)
Director General
River Research Institute
Faridpur

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CHAPTER ONE

1.1 Introduction

Bangladesh is a riverine country consisting of several hundred rivers and tributaries. It is located at the lower part of the basins of the three major rivers, the Ganges, the Brahmaputra and the Meghna. The extensive flood plain of these rivers and their numerous tributaries and distributaries is the main physiographic feature of the country. The river systems have played an important role in shaping the landscape of the flood plain, nursing its soil and sustaining its production system. The economy of this country is greatly influenced by the morphological and hydraulic behavior of the river systems. Bangladesh has a unique geographical set-up due to the existence of the great Himalayan Mountains at its North and the Bay of Bengal at its South. For topographical position many of these rivers and channels originated outside Bangladesh flowing through it to find passage to the Bay of Bengal. About fifty-four rivers coming from India and three rivers from Myanmar.

Bangladesh is located in the World's largest delta at the confluence of the three great rivers the Brahmaputra-Jamuna, the Ganges-Padma and the Meghna. The first two have the most dynamic morphology. The basins of the three rivers cover a total area of approximately 1.55 million square kilometers, spanning China, Nepal, India, Bhutan and Bangladesh. The downstream areas within Bangladesh account for only 8% of this total area and most of the flow in Bangladesh consists of water that entered into the rivers from outside of Bangladesh territory.

The Rivers in Bangladesh are characterized by severe bank erosion, silting up of the riverbed; scouring and the courses of the rivers are extremely unstable both laterally and cross-sectionally. The main cause of this is the geological tilting movement of the ground, the extremely flat and low-lying topography of the plains, the fact that riverbanks consist of mainly sand, the large volume of flood flows and the sparseness of vegetation along riverbanks.

The socio-economic life of the people of Bangladesh is significantly influenced by the characteristics of the rivers. It is, therefore, essential to have an understanding of the problems caused by the river erosion and siltation of specific interested area. So, in this research project an endeavor has been made to investigate the siltation problem at important Ferry route Notakhola - Aricha - Daulatdia.

1.2 Objectives of the Study

The objectives of the study are:

- To identify the probable causes of siltation at the Notakhola, Aricha and Daulatdia navigation route
- To evaluate the impact of dredging on the socio-economic aspect
- To make recommendation for the mitigation of the siltation problem

CHAPTER TWO

2.1 Present State of the Problem

The river system played a vital role for waterway transportation in the recent past, but the situation has aggravated due to reduced flow and excessive deposition of the rivers. During the monsoon a lot of sediment is transported through these rivers and significant amount sediment is also deposited during the falling stage of the discharge. Due to this indiscriminate deposition of sediment the morphology of the river is changing and some times the bed level rising, causing the reduction of the draft for the navigation route.

Due to the global change, deforestation in the catchment area, withdrawal of water as well as the man made intervention in the upstream of the rivers, the rising and falling time of the discharge hydrograph has been changed. This has infact a significant impact on the siltation of the riverbed. As a result the sediment transport capacity of the rivers is being reduced.

The Jamuna is one of the widest and braided international rivers changing its courses in a unpredictable way. Due to fall of water level, accumulation of silt, poor drainage facility and topographical condition causes hundred of shoal to emerge. Navigation system is seriously affected. Communication system is hampered due to emergence of numerous shoals and unabated erosion of the banks have rendered and devoured river ports or make the port useless.

Moreover, the Ferry Ghat basin and major parts of the channel are situated normal to the general flow for which there is no flow in the basin and channel during the dry season. Because of this fact, there is no significant improvement in navigation. On the other hand, due to such reduced flow, the eroded bank material deposits into the basin and channel and creating severe navigational problem.

Another important factor is that, the Jamuna has a tendency to shift from east–west direction for a particular period of time. Due to such adverse situation, Ferry Ghat basin and the channel is being detached from the main flow of the river.

For these reasons, sometimes it is impossible to change the Ferry Ghat and the instant dredging is required to make the river navigable. But it is not a permanent solutions because to keep open the navigation route by dredging is highly expensive.

2.2 Literature Review

Bank migration through erosion-deposition process in an alluvial river is a characteristic feature and one of the most conspicuous changes affecting fluvial landscapes. At a meander bend high velocity occur in the outer bend causing recession of the bank and also the spiral flow tends to deepen the outer bank. In a river, rate of such bank erosion can be rather high. Generally, the rate of bank migration is determined by the strength of the bank as well as the fluid forces. Due to effects of river flow fluctuations, regular pattern of bank migration can not survive. The problem in analyzing any aspect of riverbank erosion is to find a method, which adequately demonstrates the properties of the course, and plan form, especially where stable banks are ill-defined or irregular. In the recent past a number of important studies have been done by various research to develop insight into the bank erosion process as well as rate 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. Klaassen and Masselink studied the bank erosion of the braided the Jamuna river of Bangladash and found that in most of the cases erosion rate along the curved channel is between 0 and 500 m/year. The bank erosion rates analyzed within the framework of Hickin and Nanson revealed that low relative curvatures lead to relatively fast erosion rates and vice- versa.

The flow through the Padma and the Jamuna confluence largely depends upon the hydrodynamic and morphological conditions of the river. The wandering pattern of the major boundary rivers has particular implications for the hydrology, hydraulics and morphology of the regional rivers, which are distributary channels. The amount of water sediment spilled into the distributary depends primarily on the position of the mouth within the pattern of the wandering river. In turn, the channel characteristics and morphology of the distributary depend on the inputs of water and sediment and their annual variation are controlled firstly by channel dynamics in the parent river and secondly by condition of the off-take mouth. Recognizing the morphologically dynamic nature of a wandering pattern river, it is to be expected that large variations in inputs to distributaries will occur, to which the size and the morphology of the distributary river constantly adjust (Navera, 1996).

Stuart N. Lane (1998) reported the combined mixing process at river confluences using both field monitoring and numerical modeling using LES (Large Eddy Simulation) process in a simplified way. The result illustrates that mixing occurs on a number of temporal scales, but that the nature of the link between periodic flow field fluctuations and suspended sediment transport varies with distances through the confluence. There is a strong correlation between cross-stream velocity variation and suspended sediment transfer at the entry to the confluence, associated with the presence of a stagnation zone. After rapid development of these instabilities, their further evolution is associated with eddy stretching, such that whilst there remain strong fluctuations in suspended sediment concentration further downstream, these are no longer correlated with velocity variation.

Confluence scour represents critical components of drainage system geometry and the point at which river morphology and hydrology can be changed drastically. It was found that scour depth was a function of confluence angle, relative tributary discharge and relative sediment discharge through the confluence. Confluence angle was found to be the major control of scour depth. Tributary discharge and sediment loads were found to have less influence on scour depth. Scour depth increased rapidly as confluence angle increased from 15 to 75-degree and more slowly up to 120-degree. Scour depth was found to be maximum when the angle of incidence of the tributaries were symmetrical and discharge in the tributaries were equal. Scour depth decreased as the relative discharge in the tributary or sediment discharge in the tributaries increased (R.B. Rezaur *et, al.)*

After severe floods on the River Meuse in 1993 and 1995, one of the proposed measures to reduce the flood risk was dredging 120 kilometres of river bed by 3 metres. In order to gain experience first, a pilot project of 20 Km was carried out in 1996. The monitoring results show that the reduction of water levels at the upstream end of the dredged reach is as expected. In addition however, a scour hole has developed with a depth of 2 metres and a length of 1 kilometer, due to erosion of a layer of fine sediment. The rate of expansion of the scour hole after two minor floods seems to have decreased. Partly as a result of this experience, widening the river bed instead of deepening it has been chosen at a second location, where the sediment composition directly under the top layer was even finer, (Max Schropp & Ard Wolters *et, al.*)

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 Cound 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 discharge magnitudes represent a threshold for major channel changes along the reach of the river. From the study range of discharges representing the erosion threshold for the reach as a whole was recognized and three erosion classes based on erosion rate are indicated. The frequency distribution of the discharges representing lower erosion threshold and the higher erosion threshold was determined.

2.3 Methodology

The cross-sectional data, hydrographic chart, spot image, hydrological data are collected from the Morphology division of BWDB, BIWTA, SPARRSO, EGIS and Hydrology division of BWDB. The cross-sectional data and hydrographic chart which are collected are not sufficient, consistent and regular. However, these data have been analyzed and attempt has been made to develop an understanding about the siltation and erosion process in this area. Spot images are also analyzed to have idea about the bank shifting or bank erosion. The hydraulic parameters such as width, average depth, cross sectional area, mean bed level etc. are calculated from the cross sectional data with reference to the bank level.

CHAPTER THREE

3.1 The Notakhola-Aricha -Daulatdia Ferry Ghat

In 1983, a passenger facility and parking yard were built at Nagarbari Ferry Ghat under Bera Thana in Pabna District. But this Ferry Ghat was washed away by the river in 1987 due to bank erosion. Ferry Ghat at Nagarbari was kept open upto about one year even with the worse situation. After that a new Ferry Terminal and Parking Yard were constructed in 1989 at some 500 m downstream of the previous Ferry Ghat. But in the same year the Ferry Ghat had to shift about 2.5 Km downstream at Roghunathpur as a result of the big char movement towards the downstream. The Ferry Ghat at this location was kept operative by annual dredging works (Table 4.4) until 1996. Latter on big char produced at the upstream of Nagarbari becoming larger with time and shifting towards the downstream. At a certain time it blocked the channel upstream of the Ghat in such a way that, even by massive dredging it was not possible to maintain the Ferry Ghat. As a result the present Ferry Ghat is constructed at Notakhola in November' 1996 as per the decision and recommendation of the inter-ministerial meeting held on 17.05.1994 (Feasibility Report, March 1998).

3.2 Study Area

The present study area is concentrated at Notakhola at the right bank of the Jamuna, Aricha at the left bank of the Padma just downstream of the confluence and at Daulatdia at the right bank of the Padma further downstream of Aricha and the corresponding navigation route. In fact the study area is just upstream and downstream of the confluence of two major rivers the Ganges and the Jamuna, which is shown in fig 3.1. To understand the siltation problem at the study area it is important to have an idea on the characteristics of the confluencing rivers, the Ganges, the Jamuna and downstream river the Padma.

The Ganges River

The Ganges is noted for its massive discharge and huge sediment load. The continuous erosion and deposition of this river created enormous surface feature and also the sufferings for the inhabitants on its bank. The total length of the river is approximately 2600 Km from its source to fall. The source of the Ganges is at Gangotri in Uttor Khasi District of India on the southern slopes of the Himalayan range and is located at an elevation of about 7010m. The drainage area of the Ganges is approximately 977044 sq.Km upto Gualondo confluence of which approximately 67395 sq.Km (7%) lies above the Goalundo confluence and bounded by the Bhagirati-Hooghly on the west and the Ganges-Meghna in the east. The river rises from the southern flanks of the Himalayan in India and breaks through the Indian shield. Before meeting the Jamuna, the river travels about 2200 Km, draining an area of about 1,000,000 Km^2. The mean annual discharge is about 11,000 m^3/s and the bank-full discharge is about 43,000 m^3/s. the average water surface slope of the Ganges in Bangladesh is estimated by FAP24 is about $5X10^{-5}$. The average bed material size is about 0.14 mm. About 500 years ago, the river swung to the east along recent multiple faults between Rajmahal Hills and Dinajpur Shield, to enter Bangladesh at Godagari. Until then, the course had coincidence with the present Hoogly River. A hydraulic flow regime analysis of the Ganges shows that it is now in a dynamic equilibrium. However, it also shows that the sinuosity of the river is decreasing, and that the river, especially the part downstream of Hardinge Bridge, is behaving as a wandering river, changing its planform between meandering and braiding. FAP4 identified the active corridor of the Ganges, within which the risk of bank erosion is high, and also identified some embayment and nodal points along the river, in between which the river wanders. The bank erosion rate of the Ganges river is quite high, which is almost similar to the Jamuna (DELFT/DHI, 1996, Special Report No.7)

The Jamuna River

The source of the Jamuna river is at Tibet on the northern slope of the Himalayas and drains an area of bout 550,000 Km^2, extending over China, Bhutan, India, and Bangladesh. The total length is about 2,740 Km before meeting with the Ganges river at Aricha. The maximum and annual average discharge is recorded 100,000 m^3/s and 20,000 m^3/s respectively and the bankfull discharge is about 48,000 m^3/s. The slope of the river within Bangladesh decreases in the downstream direction and is $8.5X10^{-5}$ at the upstream end, and $6.5X10^{-5}$ near the confluence with the Ganges. The bed material sizes also decrease from the upstream towards the downstream part and range from 0.22 mm to 0.16 mm. Jamuna river is a braided river with a braiding index that varies spatially as well as with time. In general, the braiding index and the overall width are larger at the upstream part than further downstream, probably due to the effects of higher slope and grain sizes. The overall width of the river exhibits an increasing trend, and there is a tendency of shifting westwards, especially at the upstream part of the river within Bangladesh. The widening can be attributed to an advancing alluvial fan or to the not yet completed adaptation after the shift to its new course (DELFT/DHI, 1996 FAP24, Special Report no.7)

The Padma River

The combined flows of the Jamuna and Ganges rivers constitute the flow of the present Padma river. Before the avulsion of the Jamuna river, the flow was a continuation of the 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 bank-full discharge is about 75,000 m^3/s. The average size of the bed material is about 0.10 mm. Geomorphologically, the river is still young. A flow regime analysis by FAP4 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. FAP 9B related this phenomenon with the existence of cohesive bank material at the constricted reach. The bank erosion rate studied by ISPAN (1993) shows that the rate 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, 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, the 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.

Some of the characteristic parameters for the main rivers are summarized below

Table 3.1 Characteristic parameters of major rivers. (Source: Sobhan'1997)

	Jamuna	Ganges	Meghna	Total
Length of river (Km)	2,800	2,600	800	6,200
Length within Bangladesh (Km)	270	230	400	900
Total catchment area (Km^2)	586,000	907,00	64,000	1,554,000
Catchment area within Bangladesh (Km^2)	31,000	39,00	46,500	116,500
Highest recorded discharge (m^3/s)	100,000	76,000	19,800	
Lowest recorded discharge (m^3/s)	3,300	657	370	
Total sediment discharge (Hossain'19 92)	405 to 815 million tons	350 to 600 million tons		

CHAPTER FOUR

4.1 Data Analysis

Data collected from different organizations such as BWDB, BIWTA, SPARRSO, EGIS etc. are analyzed and discussed in this chapter.

4.2 Analysis carried out by RRI

RRI collected the satellite image data from SPARRSO and EGIS for the year 1990, 1991,1992,1993,1995 & 2000, 1993 &2000, hydrographic chart from BIWTA for the year 1990-2000, the cross sectional data from BWDB for the year 1880-81,1882-83, 1884-85, 1885-86, 1990-91, 1992-93, 1995-96 & 1998-99, dredging information for the year 1990-99 etc. Some of the consistent data hàve been analyzed and interpretations of results have been made, which is discussed in this section. In addition to these, the analysis and information obtained from the FAP study were also incorporated and discussed here for better understanding of the morphological process of the rivers at the study area.

4.2.1 Planform analysis

The Notakhola is at the right bank of the Jamuna river upstream of the Aricha confluence and the other two Ferry Ghat i.e. the Aricha and Daulatdia is in the Padma river at the downstream of the confluence. It is observed from the plan form analysis (fig.4.1-4.6) that the Notakhola Ferry Ghat experiences severe bank erosion, where as the Aricha is comparatively less. But these two Ferry Ghat is mainly located on the erodable bank for a couple of years if the main flow is analyzed. On the other hand at Daulatdia mainly deposition is observed (table 4.1). But the dredging becoming essential to maintain the navigational route between these Ferry Ghats.

The planform studied for the year 1990,1991,1992,1993,1995 & 2000 obtained from the sattelite image (fig 4.1 to 4.6) and a summary of erosion and deposition estimated thereof is shown in table 4.1 to 4.3.

Table 4.1 Erosion deposition estimated from satellite image at Notakhola.

Year	Erosion/deposition	Magnitude (m)	Remarks
1990-'91	Erosion	150	At Notakhola
	Very little deposition		Upstream and downstream
1990-'92	Erosion	300	At 850 m u/s of Notakhola
	Erosion	300	At Notakhola
	Deposition	400	At 2.5 Km d/s of Notakhola
1990-'93	Erosion	150	At Notakhola
1990-'95	Erosion	450	At 850 m u/s of Notakhola
		250	At Notakhola
		850	At 7.5 Km d/s of Notakhola
1990-2000	Erosion	600	At 850 m u/s of Notakhola
		300	At Notakhola
		2100	At 7.5 Km d/s of Notakhola

It is observed from the table 4.1 that the bank erosion is prominent compared to the amount of deposition. From 1990 to onwards there is always a tendency of bank erosion. The maximum bank erosion is observed about 2100 m compared to the 1990 bank line.

Table 4.2 Erosion/deposition estimated from the spot image (Aricha).

Year	Erosion/Deposition	Magnitude (m)	Remarks
1990-91	Little erosion	100 m	At Aricha
	No erosion	Nil	At 7 .5 Km u/s to Aricha
	No erosion	Nil	Aricha to 8.5 Km d/s
1990-92	Very little erosion	50 m	At Aricha
	No erosion	Nil	At 7.5 Km u/s to Aricha
	No erosion	Nil	Aricha to 8.5 Km d/s
1990-93	Erosion	150 m	At Aricha
	No erosion	Nil	At 7.5 Km u/s to Aricha
	No erosion	Nil	Aricha to 8.5 Km d/s
1990-95	Erosion	200 m	At Aricha
	No erosion	Nil	At 7.5 Km u/s to Aricha
	No erosion	Nil	Aricha to 8.5 Km d/s
1990-2000	Erosion	100 m	At Aricha
	No erosion	Nil	At 7.5 Km u/s to Aricha
	Erosion	500 m	Aricha to 8.5 Km d/s

The erosion or deposition at Aricha is not so indicative from the table. On the other hand from the spot image it is seen that main channel flows along the left bank, i.e. along the Aricha. In principle, there should be bank erosion, but due to the bank protection works, the bank erosion is restricted. But, some distance downstream of Aricha the bank erosion is significant, because there is no bank protection works. Big char developed very near to the Aricha can also be observed from the satellite image.

Table 4.3: Erosion/deposition estimated from satellite image (Daulatdia).

Year	Erosion/Deposition	Magnitude (m)	Remarks
1990-'91	Deposition	500	At Daulatdia
	Deposition	250	At 3 Km u/s of Daulatdia
	Deposition	900	At 3 Km d/s of Daulatdia
1990-'92	Deposition	350	At Daulatdia
	Deposition	Nil	At 3 Km u/s of Daulatdia
	Deposition	Nil	At 3 Km d/s of Daulatdia
1990-'93	Deposition	800	At Daulatdia
	Deposition	Nil	At 3 Km u/s of Daulatdia
	Deposition	1500 m	At 3 Km d/s of Daulatdia
1990-'95	Deposition	1000	At Daulatdia
	Deposition	Nil	At 3 Km u/s of Daulatdia
	Deposition	Shallow char	At 3 Km d/s of Daulatdia
1990-2000	Deposition	800	At Daulatdia
	Deposition	1200	At 3 Km u/s of Daulatdia
	Deposition	2500	At 3 Km d/s of Daulatdia

Table 4.3 shows the gradual sedimentation at Daulatdia Ghat area. This is because of the fact that, at this region, the main flow is along the left bank of the Padma. The maximum deposition estimated from the spot image plan form is about 2000 m from 1990-2000.

4.2.2 Hydrographic chart

The hydrographic chart collected from the BIWTA was analyzed and some selected sections were plotted, which is shown in figure 4.7 to 4.16. The location of the selected cross-sections is shown in the index map, Fig 3.1. But, the problem faced during the analysis of hydrographic charts is that, the soundings are not taken along the full width of the river. As a result, it is not possible to analyze the data for the estimation of erosion or siltation purposes. However, it can be visualized from the bathymetric plotting about the variation of the cross sectional geometry. Therefore, it can be stated here that the cross-sectional geometry of the river is changing randomly with time, which indicates that the river is very active and unstable.

4.2.3 Cross-section

Cross-sectional data collected from the BWDB are processed and some of the selected years are analyzed. Because the data for different sections were not available for the same year. Attempts were made to assess the amount of siltation and erosion in the study area, but due to very unstable and rapidly changing morphological nature of this region as observed from the data, the assessment will not be realistic. However, from the analysis, a qualitative idea can be achieved about the siltation and erosion of the study area. The cross sectional data plotted in different years are shown in fig 4.17-4.23 and the location of these cross sections can be seen in fig 4.24. The width, depth, cross sectional area, mean bed level were also analyzed and shown in fig 4.25, 4.26, 4.27 and 4.28 respectively. It is evident from the fig 4.26 and 4.25 that the average depth of the river at bankfull stage has a decreasing trend and in general the width of the river has increasing trend. So it can be concluded here that the river bed has been silting up and the river becoming wider. From the fig 4.28 it can also be stated that the mean bed level in the Jamuna has rising trend, on the other hand in the Padma, it is not so significant. That means, the siltation in the Jamuna riverbed is supported by the mean bed level analysis. The cross sectional area at different sections in different years are plotted and shown in fig 4.27. It is observed from the figure that cross sectional area changes in almost every locations.

4.2.4 Comparison of discharge

The discharge hydrgraph characteristics of the Ganges and Jamuna is not similar, which might have different impacts on the confluencing river, the Padma. A typical example for the discgahre hydrograph can be seen in figure 4.29. The discharge ratio in the Ganges and Jamuna is also compared and shown in figure 4.30. The following observation is made if the discharges at Jamuna and Ganges is compared.

- The rise of the Jamuna river discharge is earlier than the Ganges river. But the fall of the Ganges discharge is usually earlier than the Jamuna

- The discharge ratio (Q_{Gan}/Q_{Jam}) of the Ganges is normally below 1, except in some cases during the flood and falling season. It means that the flow in the Ganges is much smaller than in the Jamuna both for maximum, minimum and annual average flow.

- Deposition dominates during the recession of the flood in the Ganges, where as in the Jamuna the picture is more complex. Both deposition and scour occurs, and there is no real dominance of either of the two.

- So it can be mentioned here that the influence of the Jamuna on the Ganges is much larger than the influence of the Ganges on the Jamuna river. This is in line with the observations of the discharge hydrographs. The ratio Q_r is rarely larger than 1.

- Whatever is the discharge in Ganges and Jamuna, in general, the scour appears dominant in the Ganges, but in Jamuna both the erosion and deposition occurring. The dynamic behaviour upstream of the confluence is triggered by discharge differences between the two confluencing rivers.

4.2.5 Socio-economic impact due to dredging activities

It is mentioned in the earlier section that the Notakhola and Aricha are on the eroding bank and at Daulatdia it is mainly depositing for a last couple of years. The dredging works carried out for last few years are shown in the figure 4.30 and in table 4.4. This is evident from the amount of dredging mentioned in the table 4.4 that, a substantial amount of money is required each year to maintain the navigation route. Last nine years data shows that at Daulatdia the amount is maximum. The total volume of dredging for the last nine years is 49.58 Mm^3, 23.62 Mm^3 and 18.09 Mm^3 at Daulatdia, Notakhola and Aricha respectively. On the other hand these dredging spoil can be and even being used in rebuilding the land adjacent to the river banks. This is helping also for the socio-economic improvement of the people near the dredging area. These land development activities are observed at the Aricha and Daulatdia area.

4.2.6 Rapid Appraisal Survey

Environmental impact analysis has been carried out to a limited extent within the scope of the study, with a view to develop the understanding of the environmental impact with different changed condition. To achieve the goal, the Participatory Rapid Appraisal Survey has been conducted and this will reflect a quick outlook of the initial environmental condition. It is found from the Table 4.5 that, Physio-chemical components regarding the protection of bank erosion and dredging works has improved the local environmental condition to some extent. The water quality in the river and its contamination has been deteriorated due to the dredging and navigational activities. The Biological and Ecological component comprising the flood plain fish migration and river & estuarine fisheries have decreased significantly. The social and cultural components regarding the Security of homesteads and agricultural livelihoods have been improved. But the social and cultural sites have decreased significantly. From the Appraisal survey it is also found that the overall economic and operational capacity of the people under study is based on a strong economy, this might be due to the fact that the study area is a river port area.

Table 4.4 Statement of Dredging at Aricha, Daulatdia & Notakhola

Year	Name of Site	Period From To	Quantity Lac.Cum	Year wise Total. Lac. M^3 Cum	Remarks (Expenditure In lack Taka)
1991-92	1. Aricha	01.12.91 20.01.92	0.57	6.28	251.2
	2. Daulatdia	23.09.91 20.02.92	4.88		
	3. Nagerbari	15.12.91 02.01.90	0.83		
1992-93	1. Aricha	30.01.93 22.02.93	1.05	5.48	219.2
	2. Daulatdia	01.10.92 20.02.93	4.43		
	3. Nagerbari	Nil	Nil		
1993-94	1. Aricha	Nil	Nil	5.65	226.00
	2. Daulatdia	05.10.93 17.01.94	5.65		
	3. Nagerbari	Nil	Nil		
1994-95	1. Aricha	01.01.95 23.02.95	0.44	6.93	D= TK 59.2 LAC
	2. Daulatdia	12.09.94 16.01.95	5.88		M=TK.218.00 LAC
	3. Nagerbari	24.01.95 14.02.95	0.61		Total =277.20 LAC
1995-96	1. Aricha	28.11.95 08.03.96	1.77	11.31	D=155.60
	2. Daulatdia	09.09.95 09.02.96	7.43		M=371.00
	3. Nagerbari	04.11.95 08.03.96	2.11		Total-526.60 LAC
1996-97	1. Aricha	04.01.97 02.03.97	0.47	12.62	D=124.80
	2. Daulatdia	08.09.96 13.03.97	9.66		M=580.20
	3. Nagerbari	10.10.96 14.02.97	1.49		Total=705.00 LAC
1997-98	1. Aricha	13.09.97 01.03.98	8.44	25.77	D=723.60 LAC
	2. Daulatdia	30.08.97 17.02.98	11.65	Including BWDB	M=278.40 LAC BWDB=285.76 LAC
	3. Nagerbari	21.10.97 18.03.98	5.77	3.04 lac m^3	Total=12,87.76 LAC
1998-99	1. Aricha	07.01.99 04.03.99	0.43	16.03	
	2. Daulatdia	24.09.98 16.02.99	6.38	Including BWDB	
	3. Nagerbari	11.10.98 14.03.99	9.22	1.39 lac m^3	
1999-2000	1. Aricha	30.10.99 28.02.2000	4.92	17.82	16.45*38.26=629.37
	2. Daulatdia	20.09.99 27.02.2000	9.31	Including BWDB	1.37*103..97=142.43
	3. Nagerbari	11.10.99 30.01.2000	3.59	1.37 $lacM^3$	Total=12,87.76 Lac
1999-2000	Maowa	22.11.99 24.02.2000	2.54	2.54 (Including BWDB 0.81 $lacM^3$)	1.73*38.26=66.18 0.81*103.97=84.21 Total=150.39 La

NB:

*{1997-1998 BWDB DREDGER Aricha=3,03,688 M^3 Bagabari=30,169 M^3 Total = 3.34 Lac M^3 }

*{1998-1999 BWDB DREDGER Aricha = 73,506 M^3, Kazirhat =65,609 M^3 ,Surewar = 38,398 M^3 Total =1,77,504 M^3 }

*{1999-2000 BEDB DREDGER Aricha = 1,27,677 M3, Kazirhat =9773 M^3, Maowa = 80,806 M^3)

Table 4.5 Initial Environmental Assessment for Notakhola-Aricha-Daulatdia Navigation Route (Source: Field survey done by RRI research personnel)

Environmental Components	**MULTI-CRITERIA ANALYSIS VALUES**										
	+5	+4	+3	+2	+1	0	-1	-2	-3	-4	-5
PHYSICAL/CHEMICAL											
PC/1 River erosion protection					x						
PC/2 River Channel Works					x						
PC/3 Contaminant of river floods									x		
PC/4 Intervention of land loss							x				
PC/5 Reduction in Salinity						x					
PC/6 Changes in water quality							x				
BIOLOGICAL/ECOLOGICAL											
BE/1 Flood plain fish migration								x			
BE/2 Spawn/shirmp larvae capture						x					
BE/3 River & estuarine fisheries								x			
BE/4 Shirmp & fish culture						x					
BE/5 Social forestry/village groves					x						
BE/6 Plantation forests					x						
BE/7 Bio-diversity Conservation							x				
SOCIOLOGICAL/CULTURAL											
SC/1 Security of homesteads					x						
SC/2 Agricultural Livelihoods				x							
SC/3 Fishing Livelihoods							x				
SC/4 Artisanal transport							x				
SC/5 Commercial transport						x					
SC/6 Nutrition				x							
SC/7 Potable water supplies					x						
SC/8 Water related disease					x						
SC/9 Social/cultural sites							x				
ECONOMICAL/OPERATIONAL											
EO/1 Distribution of income					x						
EO/2 Rate of benefit generation					x						
EO/3 Operational complexity					x						

4.3 Study carried out by the Flood Action Plan (FAP)

The morphological study of the major rivers of Bangladesh has been carried out by the FAP study. FAP studied the morphological behavior of the Ganges, the Jamuna and the Padma as well as the confluence of these rivers. The findings of the FAP study briefly described below can help to understand the morphological process involved with the siltation phenomena along the Notakhola-Aricha-Daulatdia navigation route.

4.3.1 General morphology

The Jamuna river is characterised by its highly variable discharges. Its yearly variation ranges from 4,000 m^3/s to 68,000 m^3/s, where as the yearly average is about 20,000 m^3/s. the peak discharge occurs during the period of July-August and the lowest flows in February-March of the year. The bed configuration of the river changes drastically under different flow regimes. Deposition of sediment in one location causes deepening and scour in another location. This process is associated with the continuous wandering of the thalweg from one position to another. The process of erosion and deposition is pronounced during the high flow stages and slows down during the falling stages of discharge. The shifting characteristics of the river can be divided according to the order of the channel i.e. the shifting of the first order channel differs from the second order channel. The shifting of the first order channel of the Jamuna river is on the average 75 to 150 m per year over the past decades. The second order channel changes continuously, large channels are abandoned, and new ones are developing in a few years only. The bank erosion rate of the main channels (second order channels) is in the range of 250 to 300 m per year as common and in extreme cases, it can be more than 800 m/year (FAP24, Special Report No. 24).

The bank erosion has a dominating role in case of sediment transport through the river in addition to the upstream sediment. Bank erosion is one of the most complicated process in river morphology and even more complexity arises for the mighty river say for instance a braided river like Jamuna, where the bank erosion may vary quickly in time and space. Many factor plays a role in bank erosion, of which, 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. Bank material properties determine the cohesiveness of the bank, an important parameter for type of bank erosion. The near bank flow pattern is determined by the flow and the channel geometry. Vegetation does not play an important role in bank erosion process along the Jamuna river. Ground water flow may have an important effect on the bank erosion, especially during the recession of flood and specially in Jamuna. For sediment transport on average all the sediment that is supplied at the upstream side has to be transported in the downstream reach. The slope of the downstream river will be adjusted in such a way that on the average the flow but in particular the sediment that is supplied at the confluence can be transported. In reality the reaches upstream of a confluence are all the time adjusting but at the same time fluctuating around an average bed level. The discharge ratio between the two confluencing rivers is also an important factor for the morphological behaviour at the confluences. The more the flood hydrographs are out of phase, more pronounced the morphological changes (FAP 24, Special Report No. 24).

It can be stated here that, downstream of the confluence alternatingly aggradation and degradation occurs. This phenomena is oftenly observed in the present study area, specially at Aricha and Daulatdia. This gives rise to the generation of sand waves which travel through the downstream river. This means that during the whole year a re-distribution of the sediment has to take place in lateral direction too, otherwise there is no dynamic equilibrium (FAP 24, Final Report).

4.3.2 Historical changes in planform of the Jamuna-Ganges confluence

The combined flows of the Jamuna and Ganges rivers constitute the flow of the present Padma river. Before the avulsion of the Jamuna river, the flow was only a continuation of the Ganges river. More than about two hundred years ago the Brahmaputra river flowed through the present course of the old Brahmaputra river. Here it is worthwhile to mention that the Bengal basin is composed of recent sediment carried and deposited by the Ganges, Brahmaputra, Meghna rivers and their large number of distributaries and tributaries. The Madhupur tract is in between the present and old course of the river. The cause of the avulsion around the Madhupur tract is probably a combination of tectonic movement and either a liquefaction flow that partially blocked the old channel, an increased flood discharge, or a catastropic flood in 1787.

To have an insight of the historic development of the river, three maps are presented in figure 4.30. The oldest one is known as Rennel's map, published in 1776, the second is the Wilcox map surveyed in 1821-1834 and published in 1840. The recent map is prepared by ISPAN, 1993, from satellite images of 1991.It is evident from the Rennel's map that in the second half of the 18th century the present Jamuna river was flowing at the eastern side of the Madhupur tract and joined with the Upper Meghna river before meeting with the Bay of Bengal. But the Wilcox map clearly shows that during the period between 1767 to 1830 a new channel evolved which was carrying the major part of the discharge. The Old Brahmaputra river was still important for draining off the water. The Dhaleshwari river, one of the left bank distributaries of the Jamuna river, was significantly more prominent than it is at present.

During the past two decades the river had widened while continuing to migrate towards the west. FAP studied the changes of the average overall width and centre line migration in westward direction with respect to the 1830 centre line, which is presented in Table 4.6

Table 4.6 Average width of the Jamuna river and center line migration

Year	Average width (Km)	Westward center line migration (103m), compared to 1830 location
1830	6.2	
1914	5.5	1.9
1952	9.0	3.6
1973	8.1	4.5
1992	10.6	4.6

Neglecting the accuracy of the figures, it can be said that the average overall width of the river had increased from 6.2 Km in 1830 to 10.6 Km in 1992 and the westward migration of the center line of the river has been continuing since 1830 without showing any discontinuities. The actual bank line movement towards the west might be different from the centre line migration, because the bank line movement is the result of both the migration of the centre line and the changes of the width.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Hydrological and morphological data have been analyzed to identify the probable causes of siltation problem of the present study. The siltation problem in the Notakhola-Aricha and Daulatdia navigation route made very complicated due to the location of these three Ferry Ghats on the bank of the active river as well as near the confluence. Moreover, this type of problem investigation needs very elaborate and in-depth study, which is beyond the scope of the study. To know the physical process responsible for the problem and its effective solution is not a easy task. However, within the scope of the present study and available information collected, the following conclusions are made:

- The bank erosion problem at Notakhola is very eratic in nature and due to the planform and the main flow direction it is still at the stage of erosion prone zone. Geological factor /bank protection works some times can protect the bank from further erosion, which is not present at Notakhola. Another important point is that, the Jamuna has a tendency of shifting towards the west. This statement is supported by the historical planform changes, i.e. the bank erosion may continue as per demand of the natural process of the shifting of the river. Besides these the bank material at the Jamuna river composed of purely sand and it can't resist bank erosion during high flow velocity. On the other hand the riverbanks are collapsed due to seepage during falling stage of discharge.

- The Jamuna river bed is being silted-up and the river is widening. The silting up of the Padma river is not so indicative, but the river is widening.

- The Aricha Ferry Ghat is still on the eroding bank if it is analyzed and compared with the main flow. But the advantage is, the Ferry Ghat is to some extent protected from bank erosion due to the bank protection works at that area. As a result the bank erosion is not so dominant. Furthermore, the existence of big char very close to the Aricha Ghat is noticed.

- The Daulatdia Ferry Ghat didn't face significant erosion since last couple of years rather than deposition in this area. This can be explained that the main flow is along the left bank. But in course of time both the bank might face erosion unless it is restricted by the geological characteristics.

- The Ferry Ghat basin and most parts of the channel are situated perpendicular to the general flow for which, there exists almost no flow in the basin and channel during the dry season

- The siltation problem along the navigation route is a very acute problem, which is hardly possible to reduce at the present situation. Because these Ferry Ghat is located very close to the upstream and downstream of the largest river confluence. On the other hand the Ganges and the Jamuna carries huge sediment load in addition to the local bank erosion. Therefore, it is a natural process that siltation will occur at the falling stage of the hydrograph each year. Moreover, the discharge has a wide range of variation through out the year, which can not adjust the wide cross section more than 10 Km in the Jamuna. So the erosion and siltation is the outcome. In addition, this discharge variation from very low discharge to high discharge accumulates the other morphological problems, which makes the situation more complex. This can not be mitigated unless effective river training works are done to address the problem.

5.2 Recommendation

- The siltation problem of the Notakhola-Aricha- Daulatdia is very complicated and it is essentially required detail study to identify real causes and the way of finding out the solution. In detail study and feasibility study could be carried out say for instance as Gorai River Restoration Project.

- The river training is required to mitigate the siltation problem at the said area. The effectiveness of the required structure is very difficult to assess ahead for such a complicated problem. Therefore, the type of structure to be adopted here and its effectiveness should be studied elaborately.

- This type of morphological problem as well as the effectiveness of the required structure can be studied properly by physical modelling. RRI is the only authorized government organization to carry out the physical model study. It has long experience in carrying out the morphological problem as well as to study the effectiveness of any hydraulic structure by physical model study.

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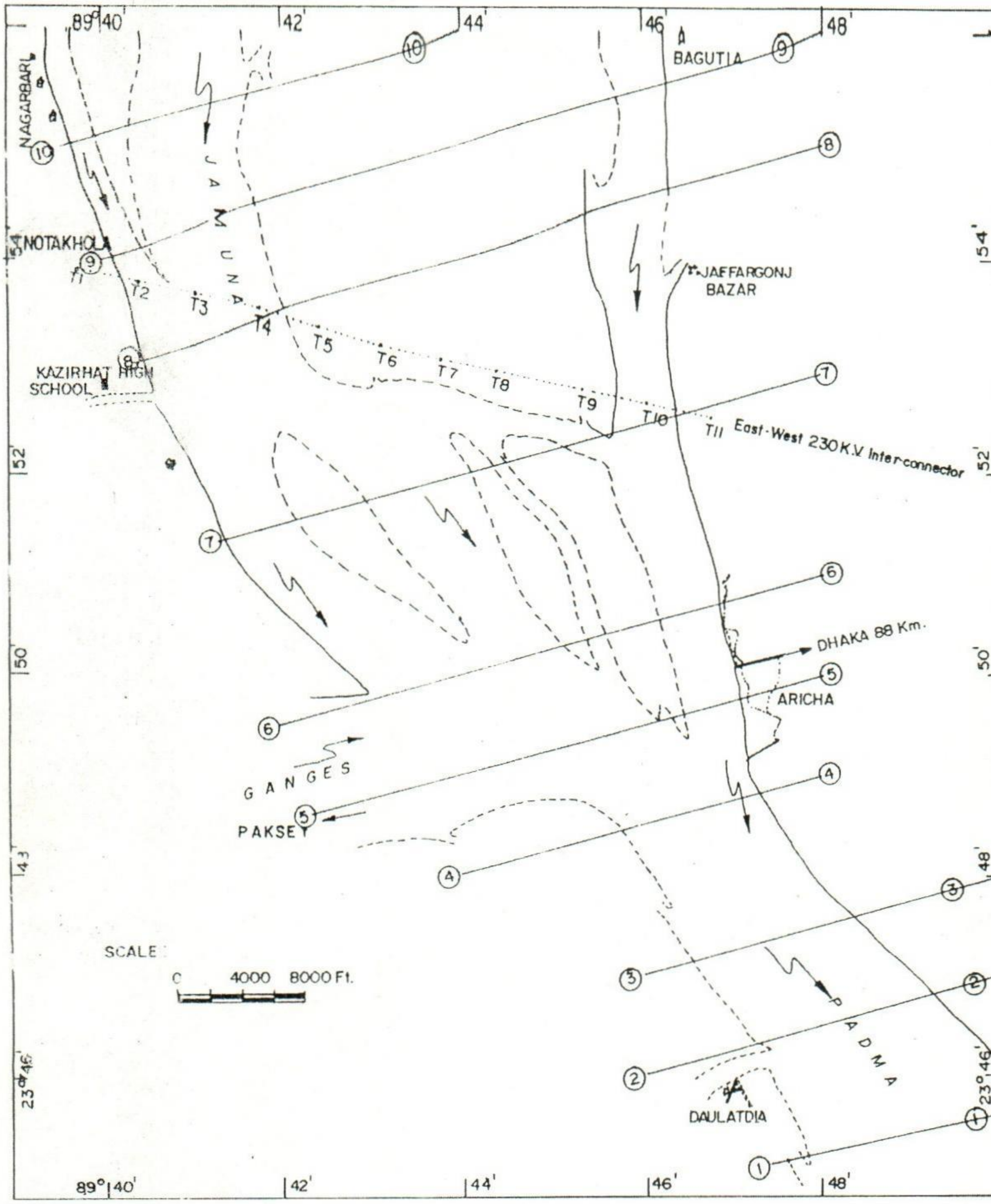


Fig 3.1 Index map of the study area (At the confluence of the Ganges and Jamuna Covering the Aricha-Natakhola-Daulatdia navigation route)

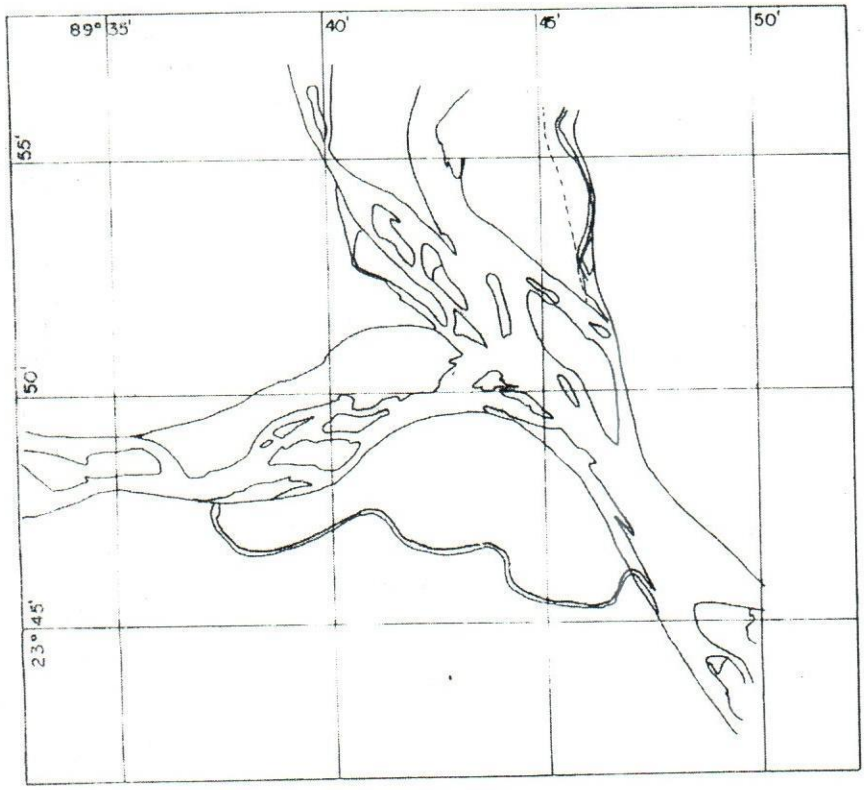


Fig 4.1 Plan form of Notakhola, Aricha and Daulatdia area (1990)

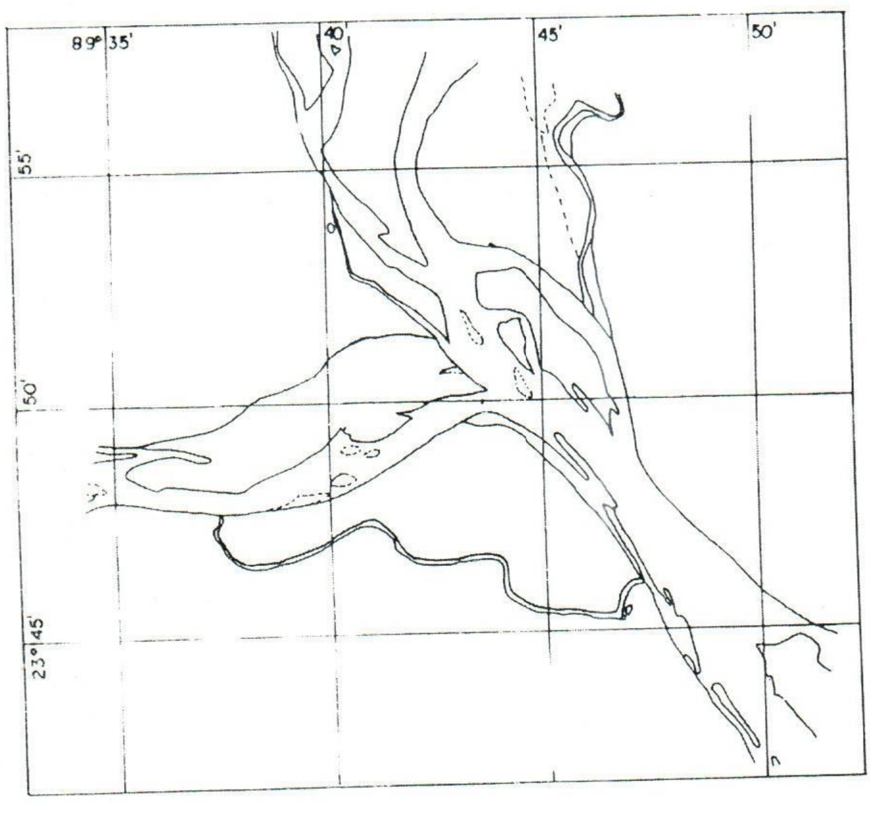


Fig 4.2 Plan form of Notakhola, Aricha and Daulatdia area 1991

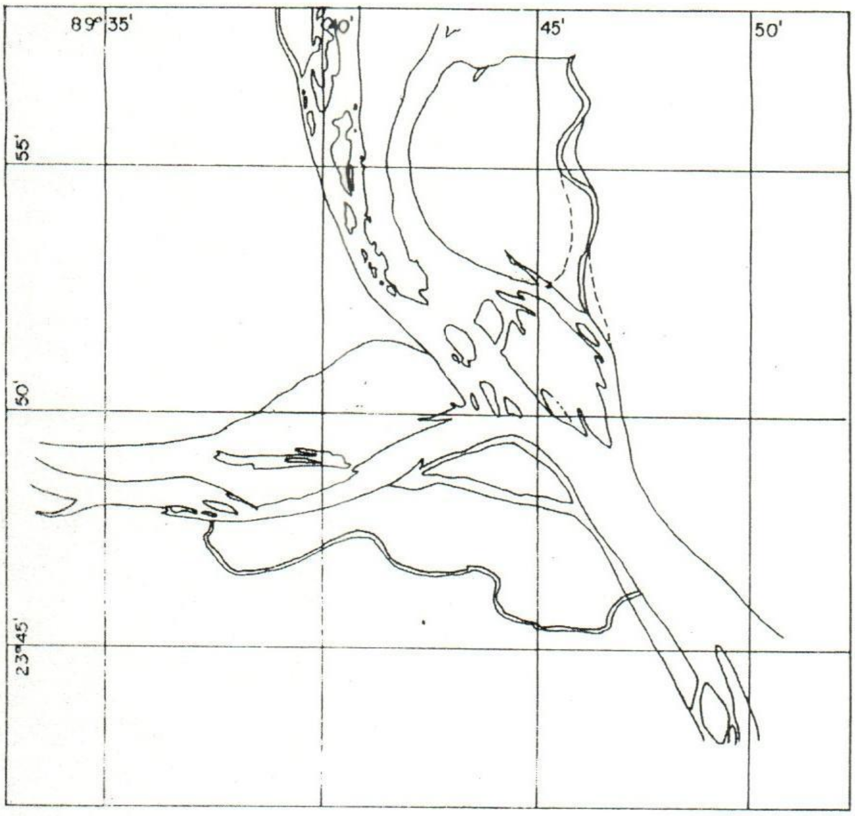


Fig 4.3 Plan form of Notakhola, Aricha and Daulatdia area 1992

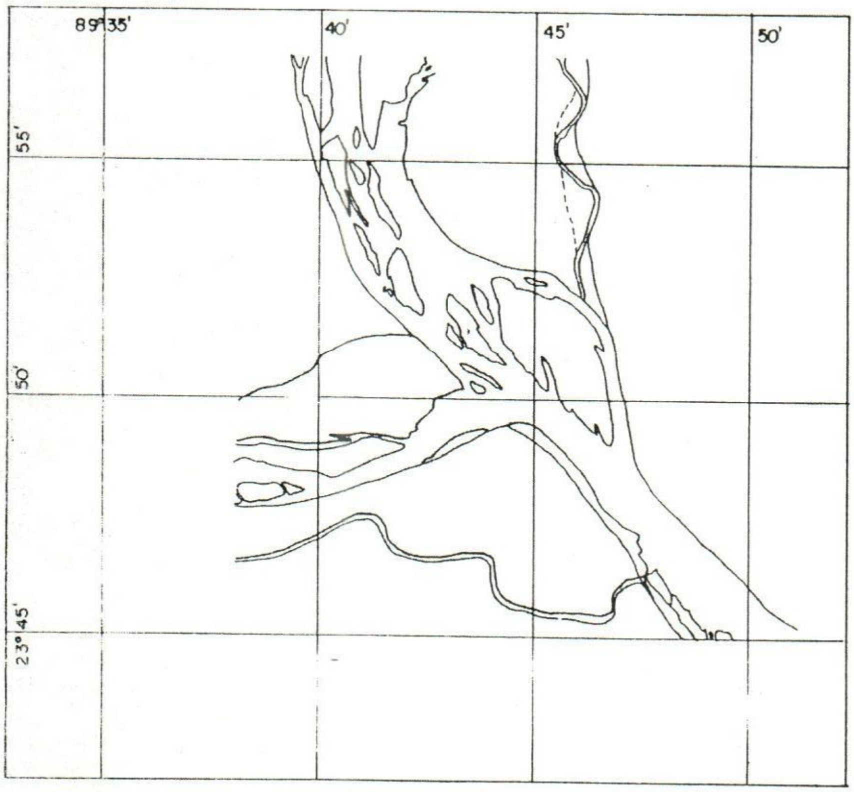


Fig 4.4 Plan form of Notakhola, Aricha and Daulatdia area 1993

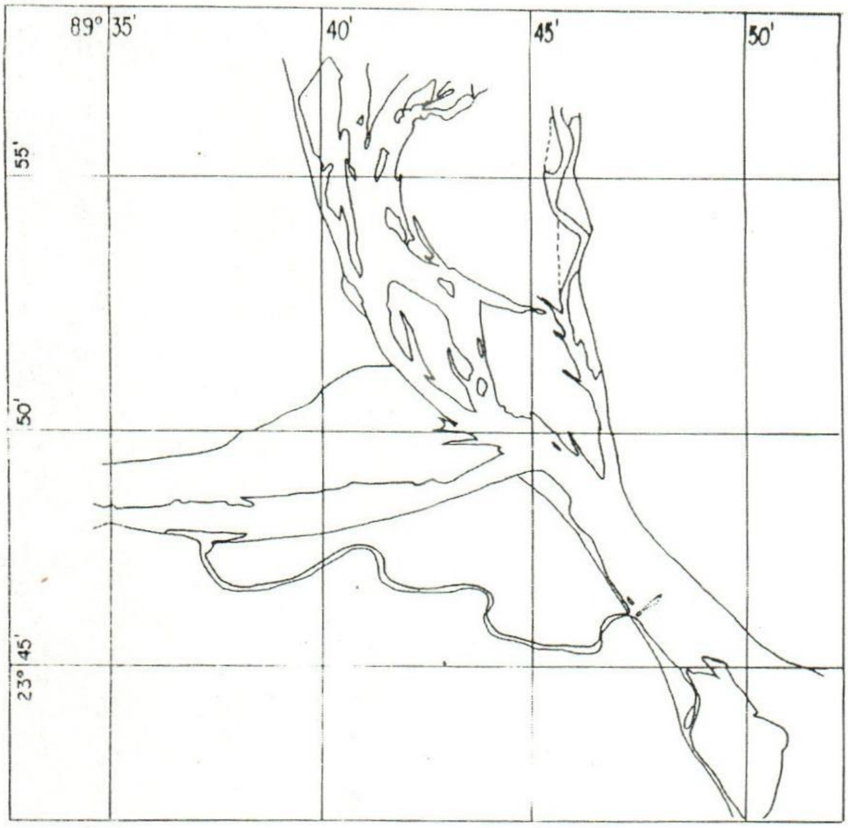


Fig: 4.5 Plan form of Notakhola, Aricha and Daulatdia area 1995

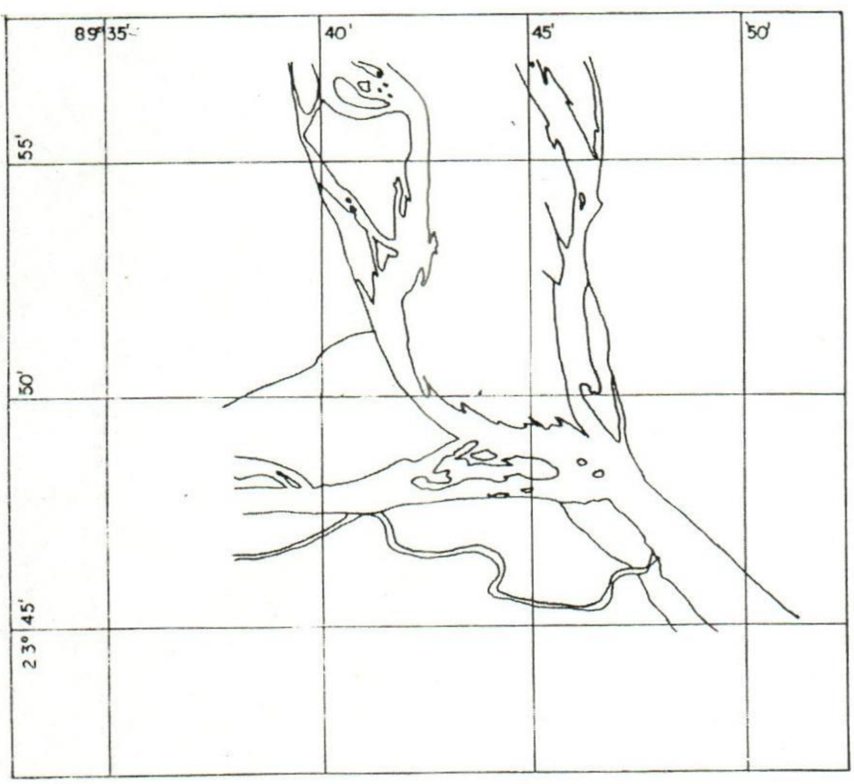


Fig 4.6 Plan form of Notakhola, Aricha and Daulatdia area 2000

Fig 4.7 Bed Profile from hydrographic chart (C/S-1 at Padma)

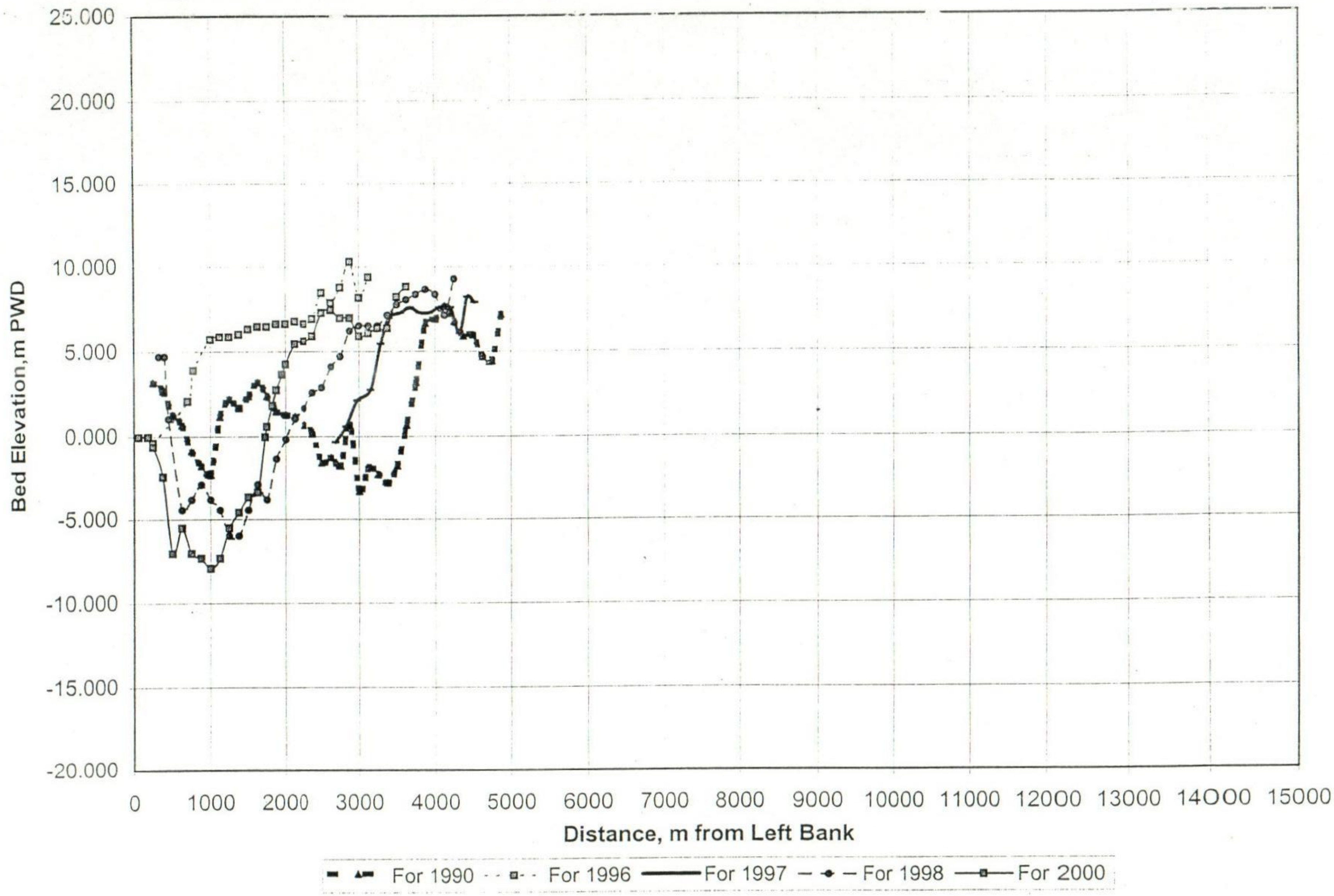


Fig 4.8 Bed Profile from hydrographic chart (C/S-7 at Padma)

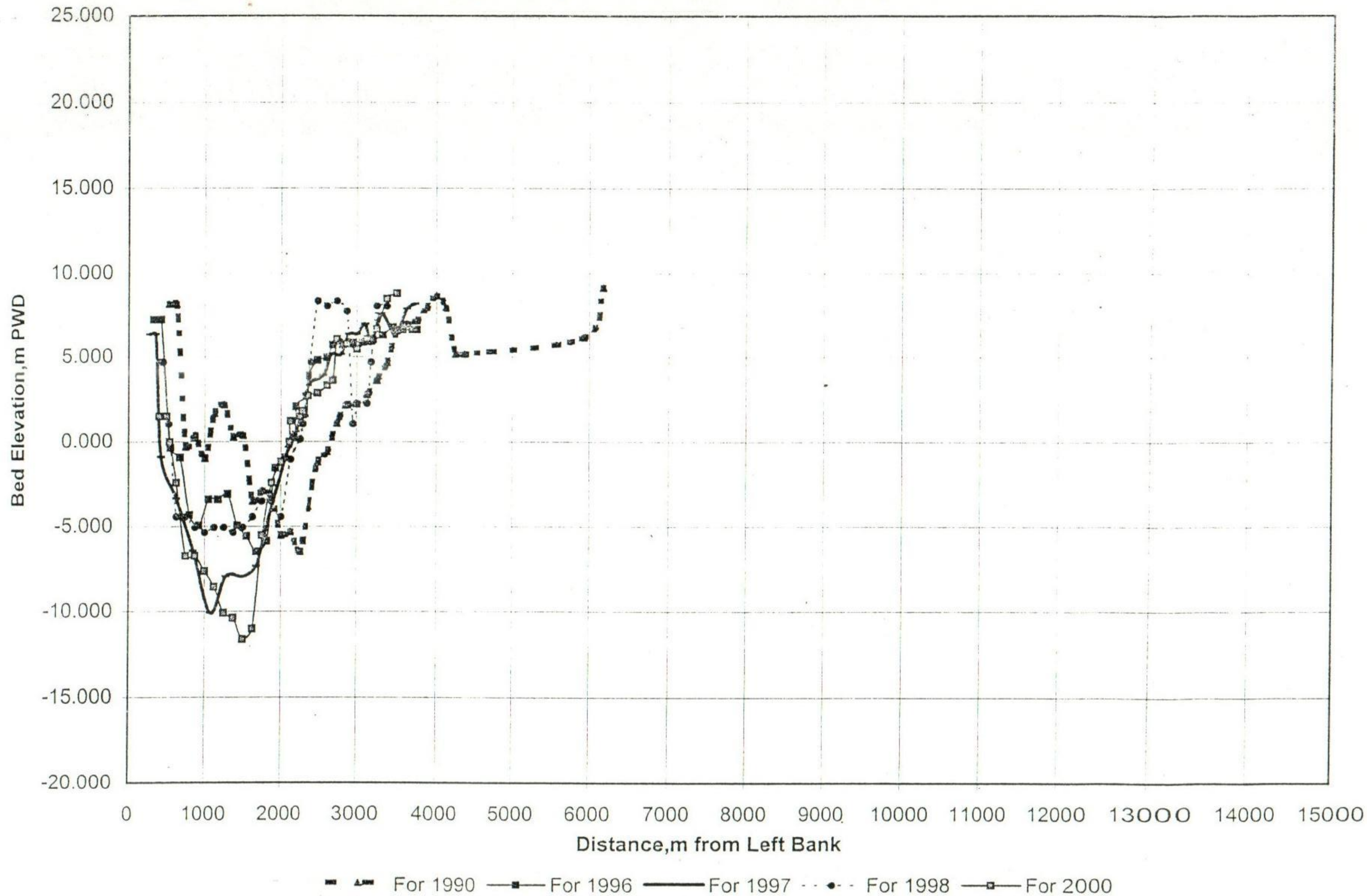


Fig 4.9 Bed Profile from hydrographic chart (C/S-3 at Padma)

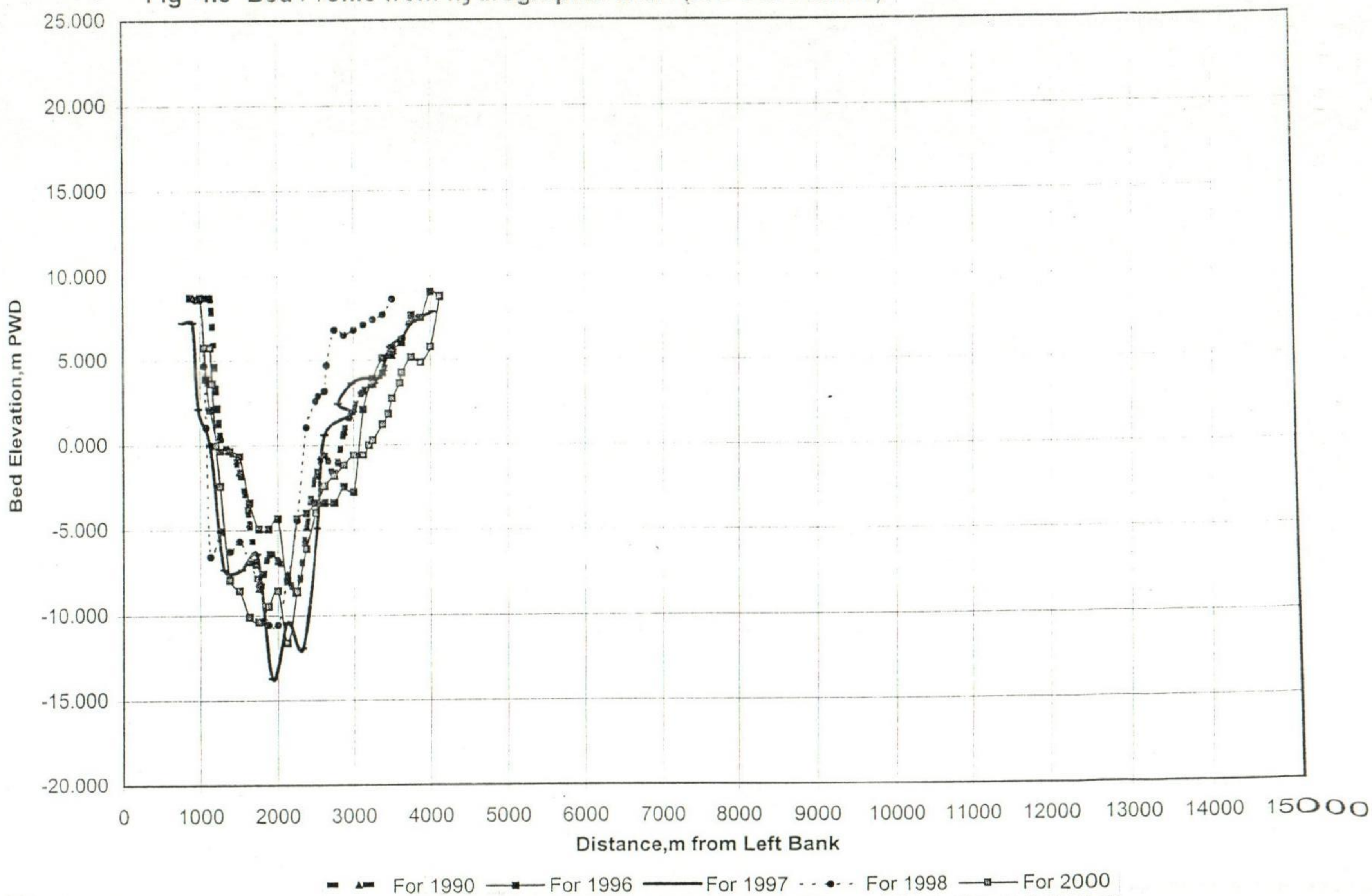


Fig 4.10 Bed Profile from hydrographic chart (C/S-4 at Padma)

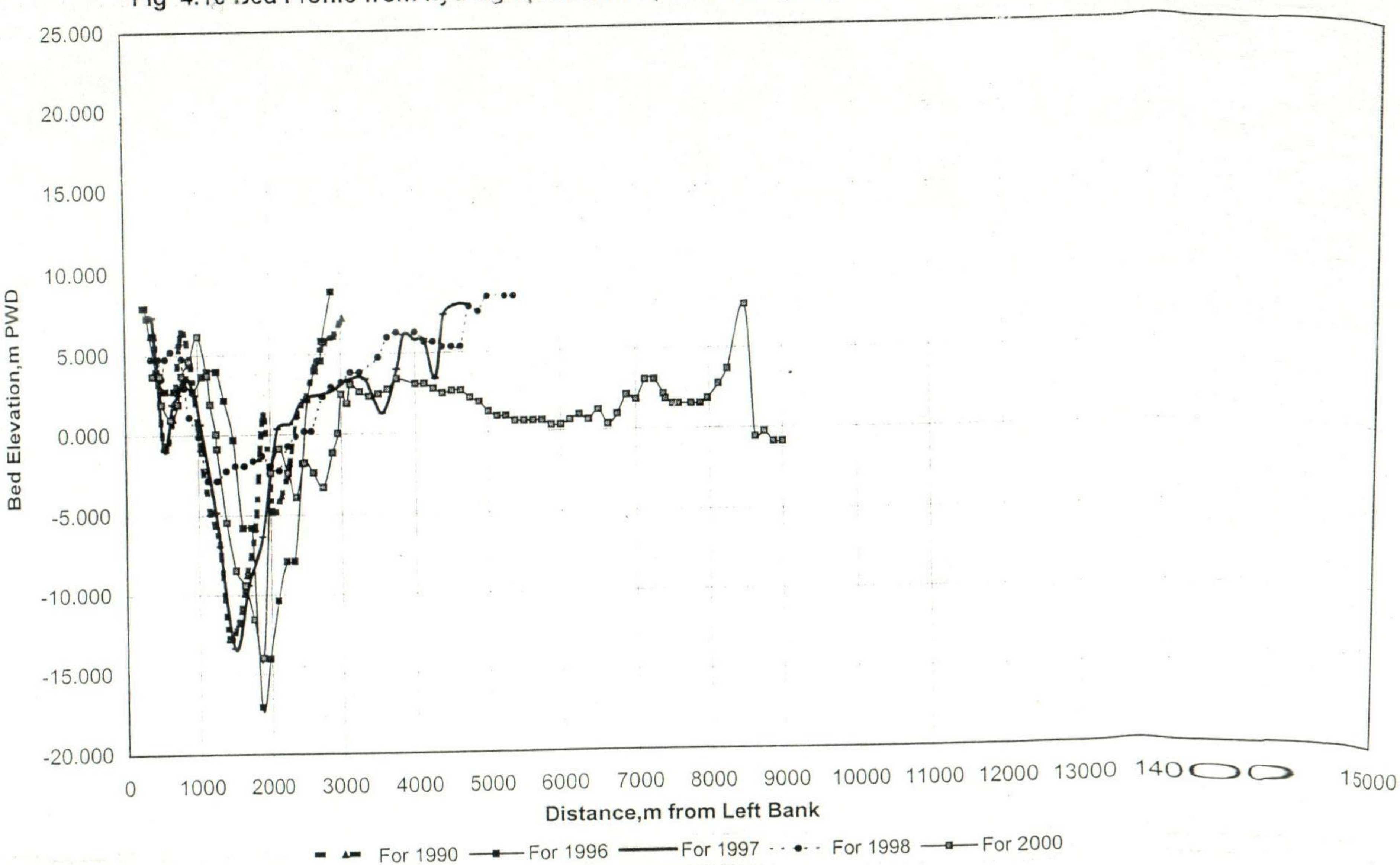


Fig 4.11 Bed Profile from hydrographic chart (C/S-5 at Confluence)

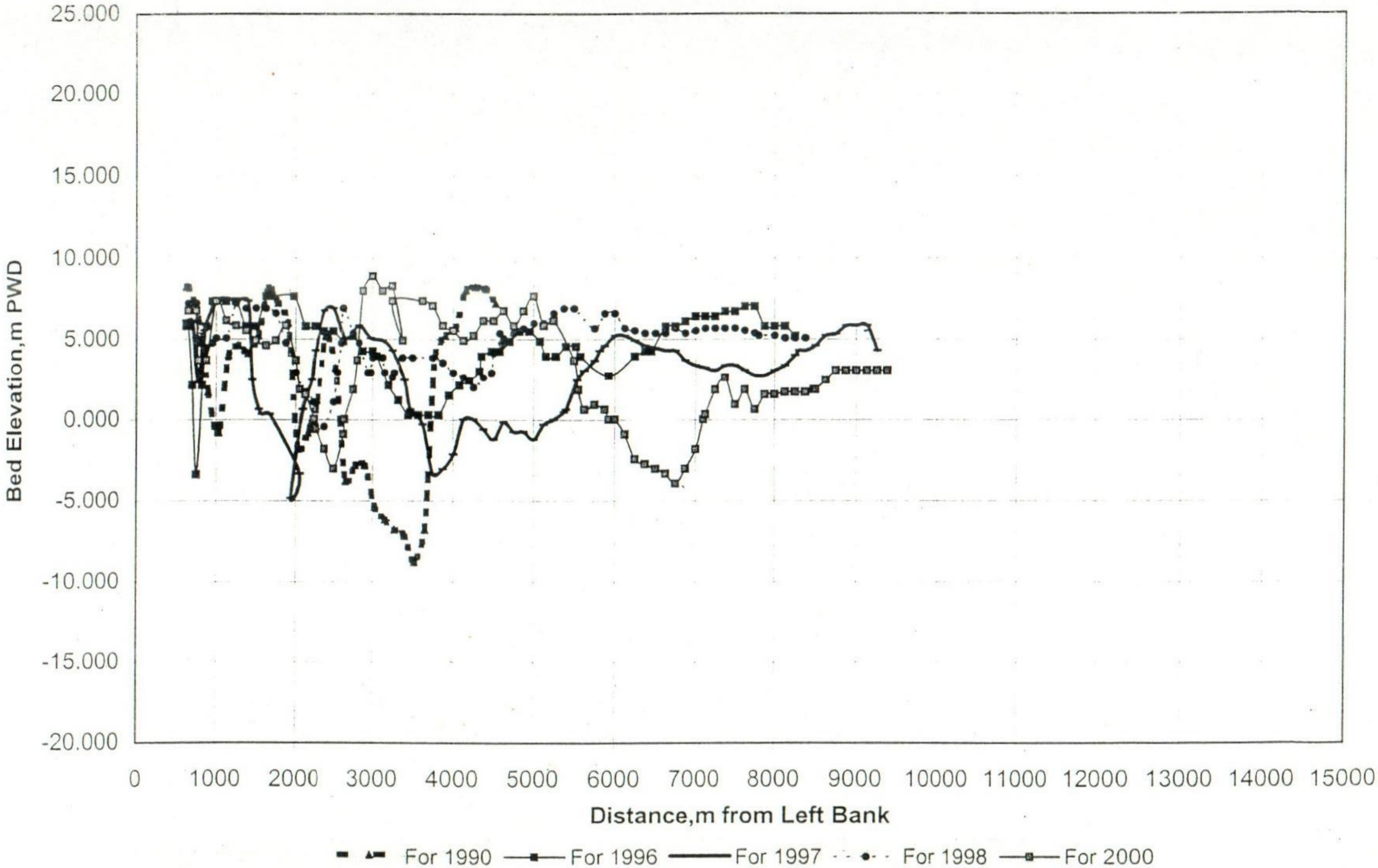


Fig 4.12 Bed Profile from hydrographic chart (C/S-6 at Confluence)

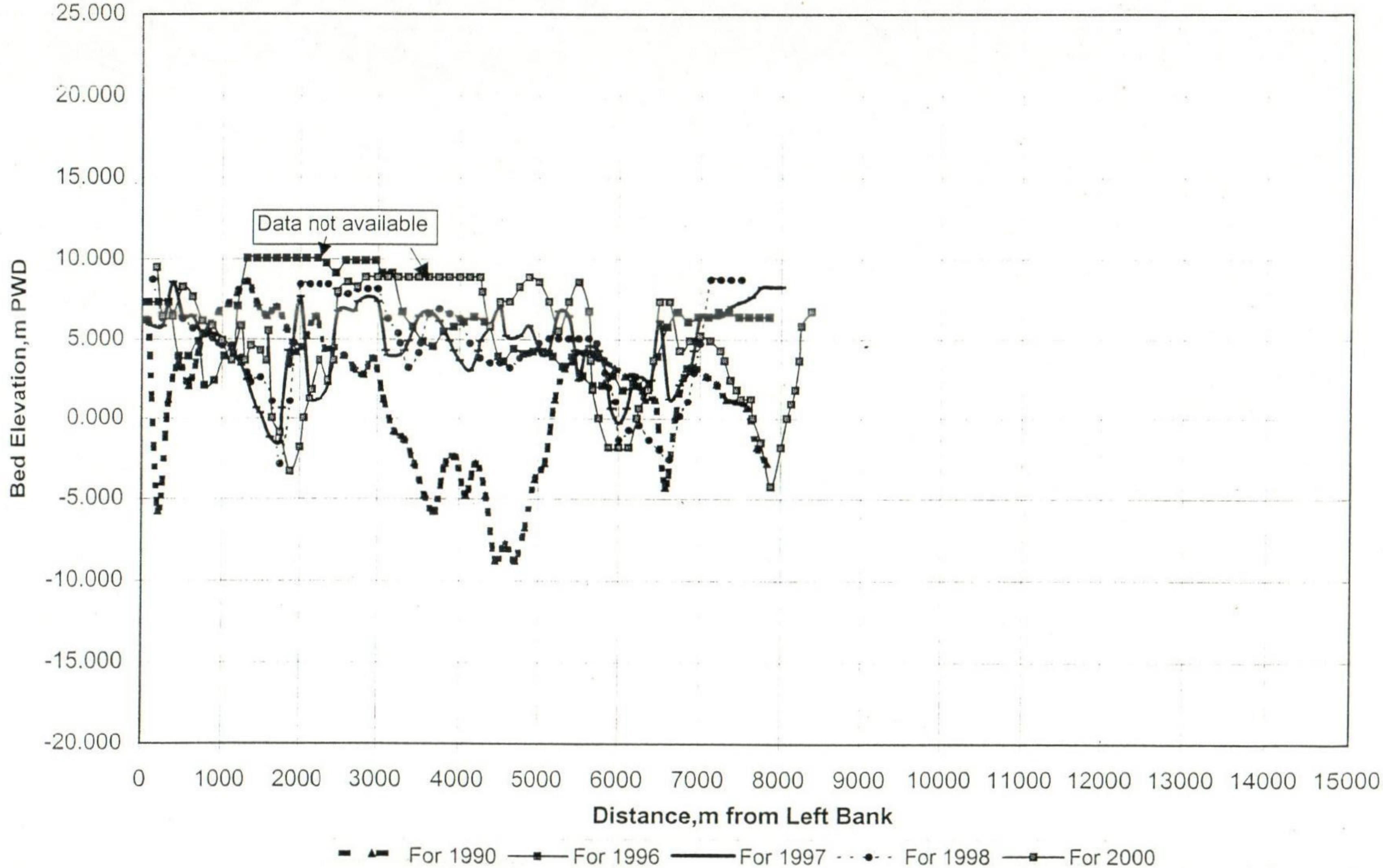


Fig 4.13 Bed Profile from hydrographic chart (C/S-7 at Jamuna)

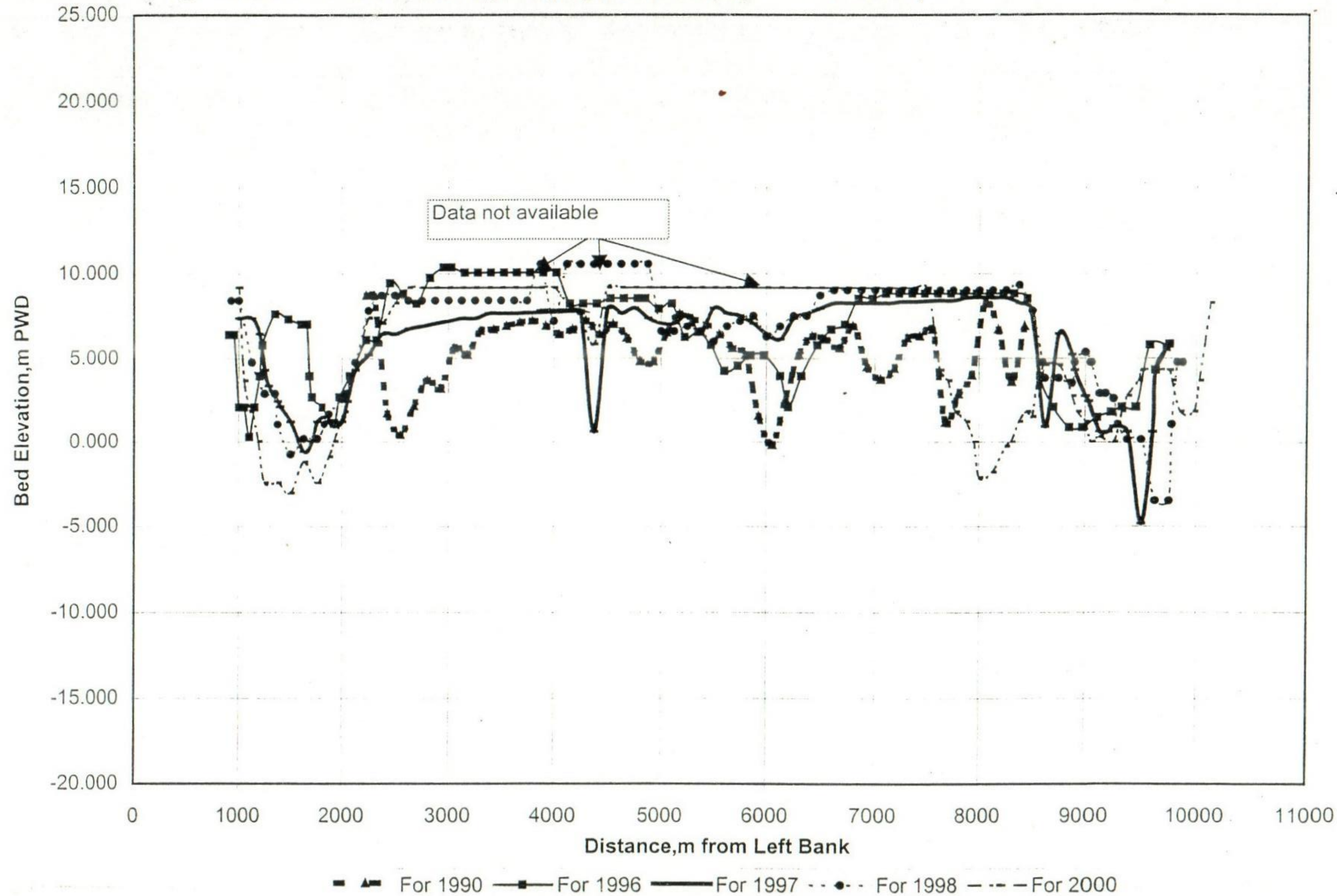


Fig 4.14 Bed Profile from hydrographic chart (C/S-8 at Jamuna)

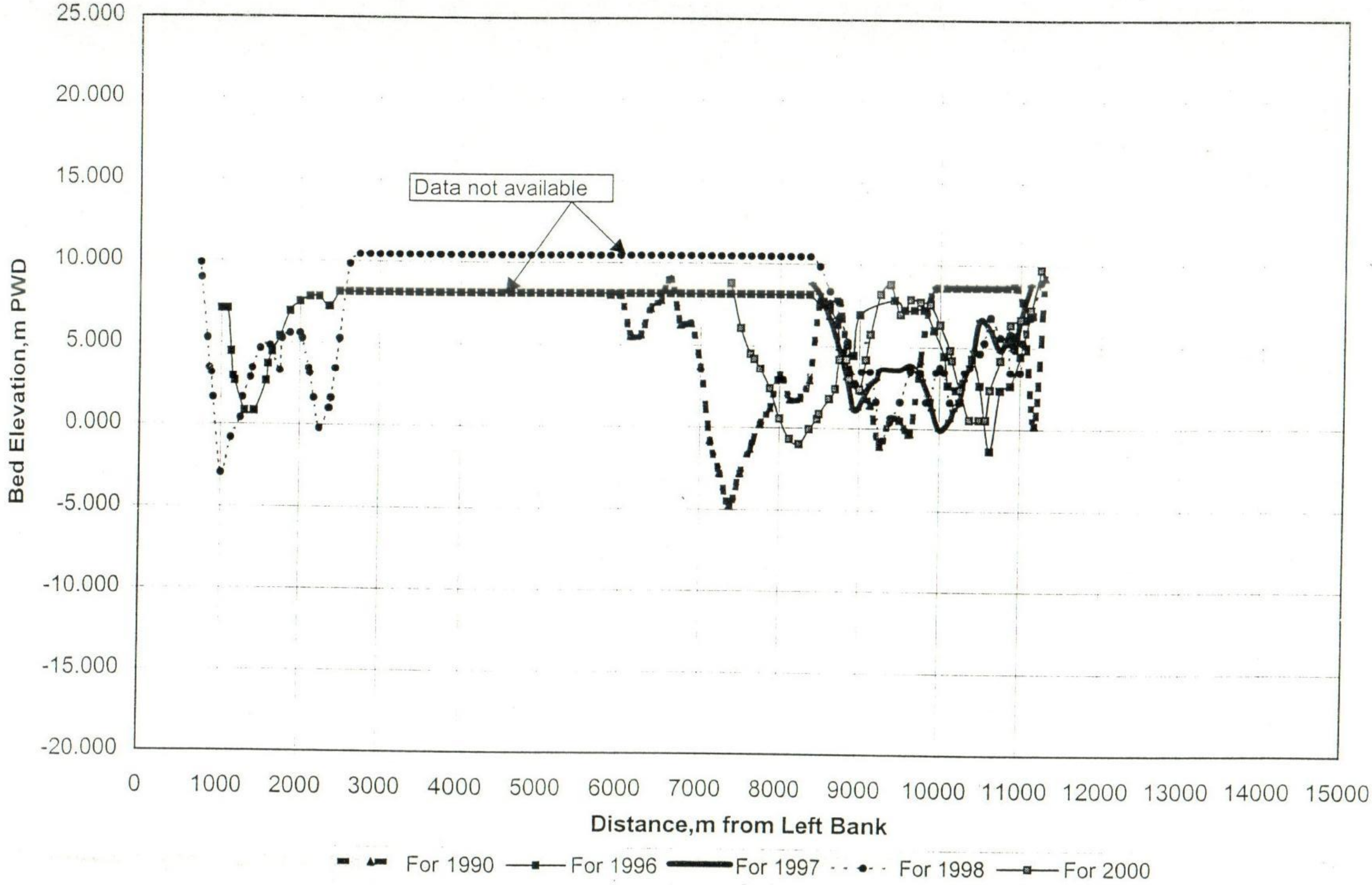


Fig 4.15 Bed Profile from hydrographic chart (C/S-9 at Jamuna)

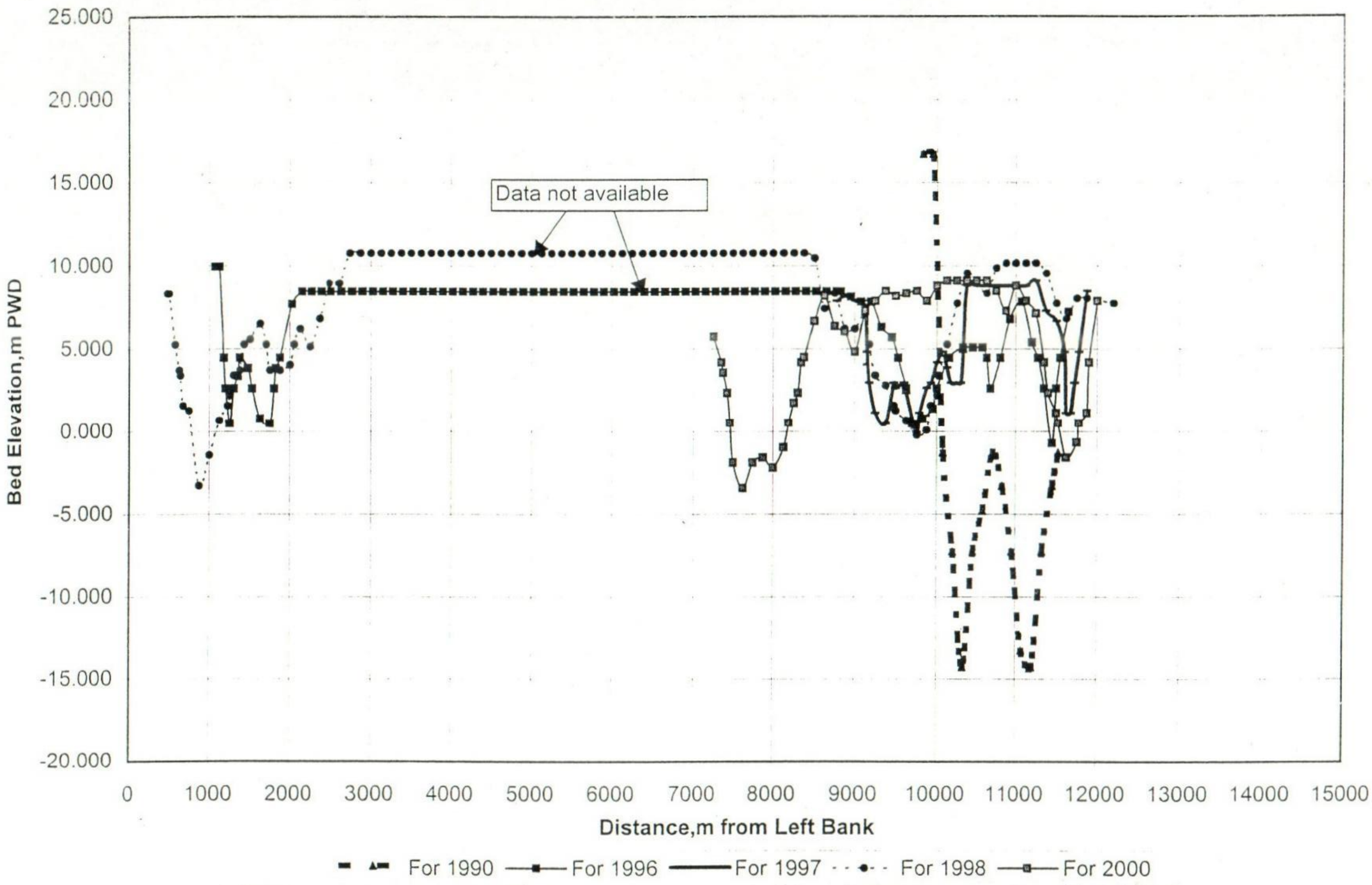


Fig 4.16 Bed Profile from hydrographic chart (C/S-7 at Jamuna)

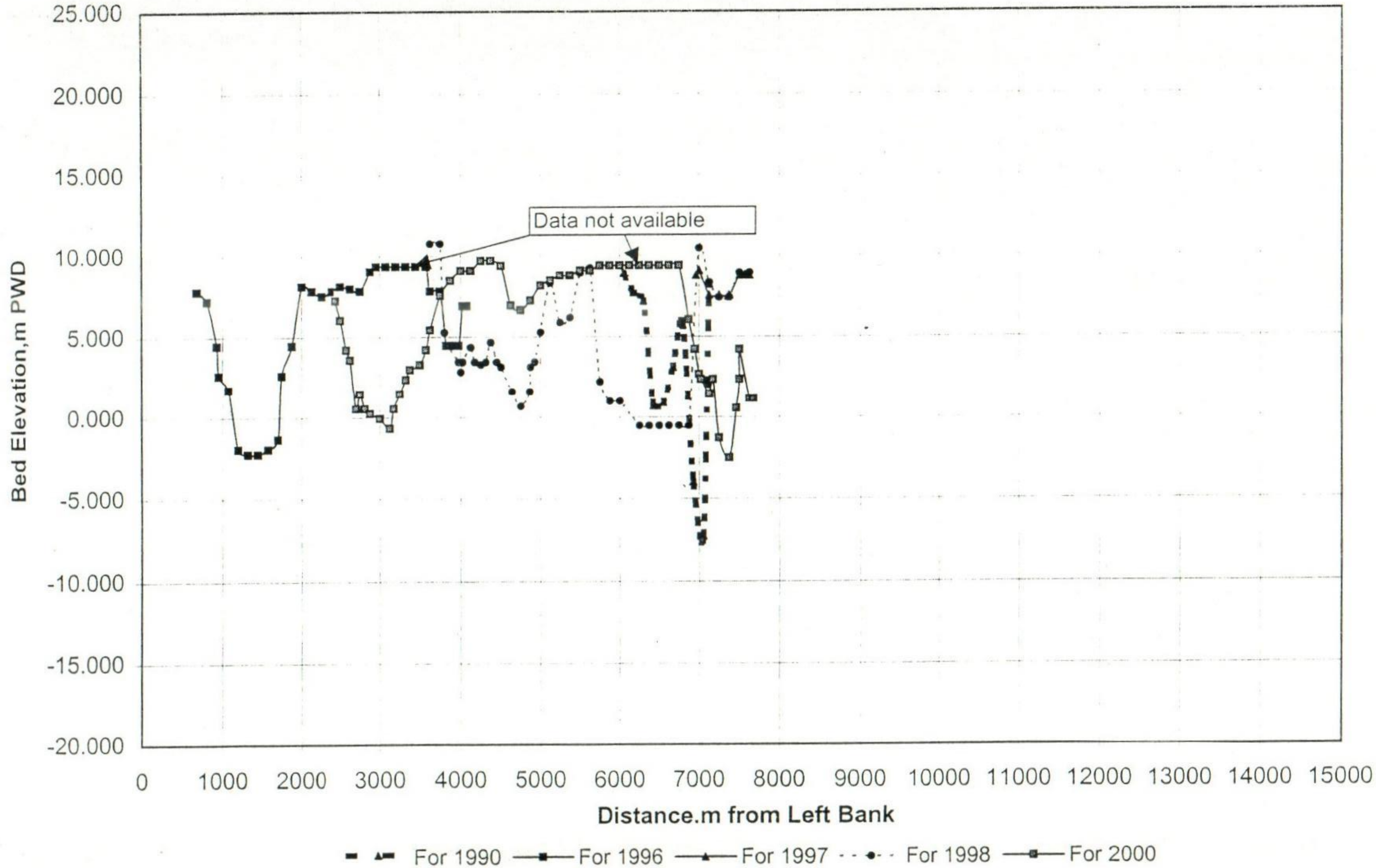


Fig 4.17 Variation of elevation over different years at Cross-section (J-0-1L)

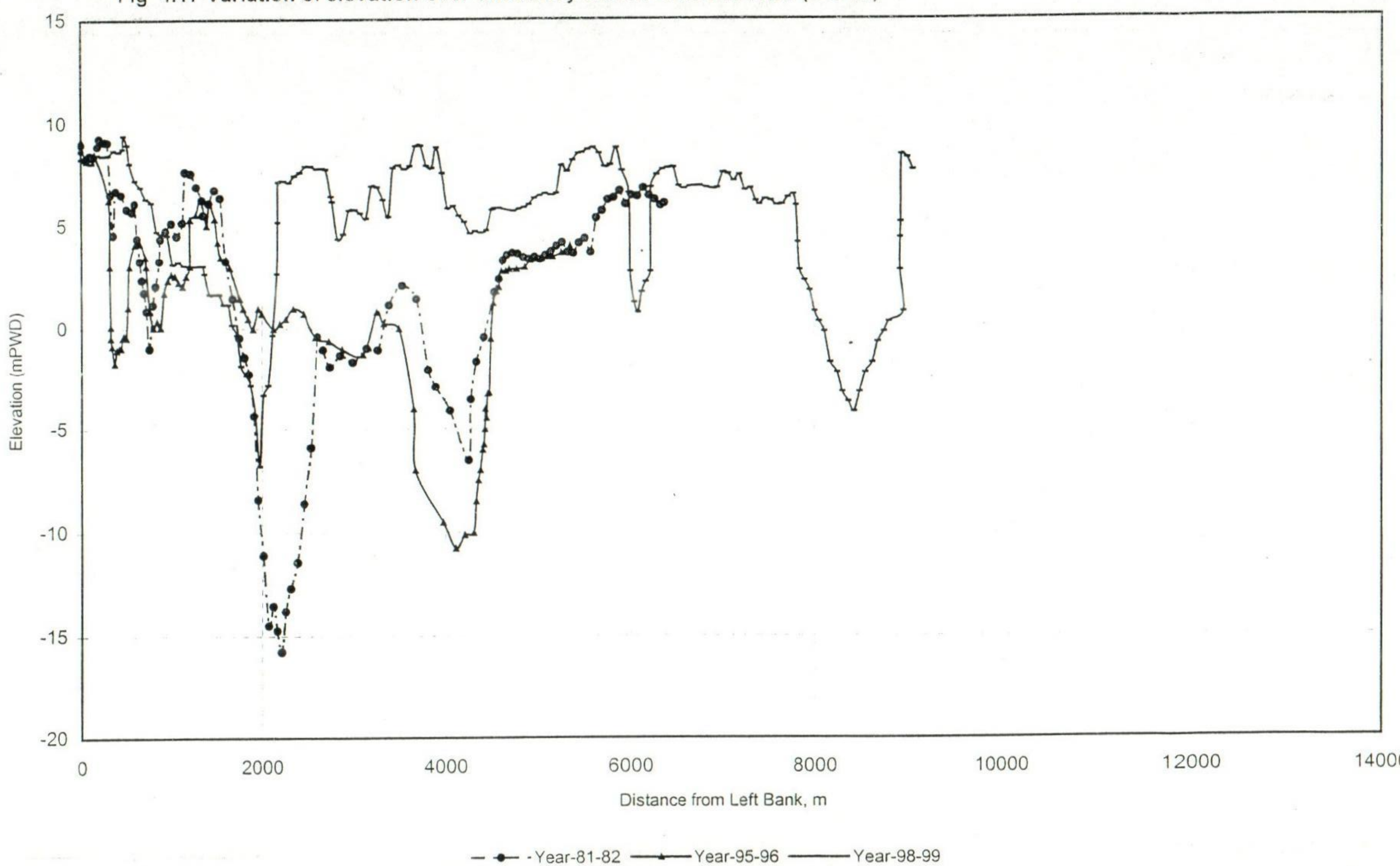


Fig. 4.18 Variation of elevation over different years at Cross-section (J-1-1 L)

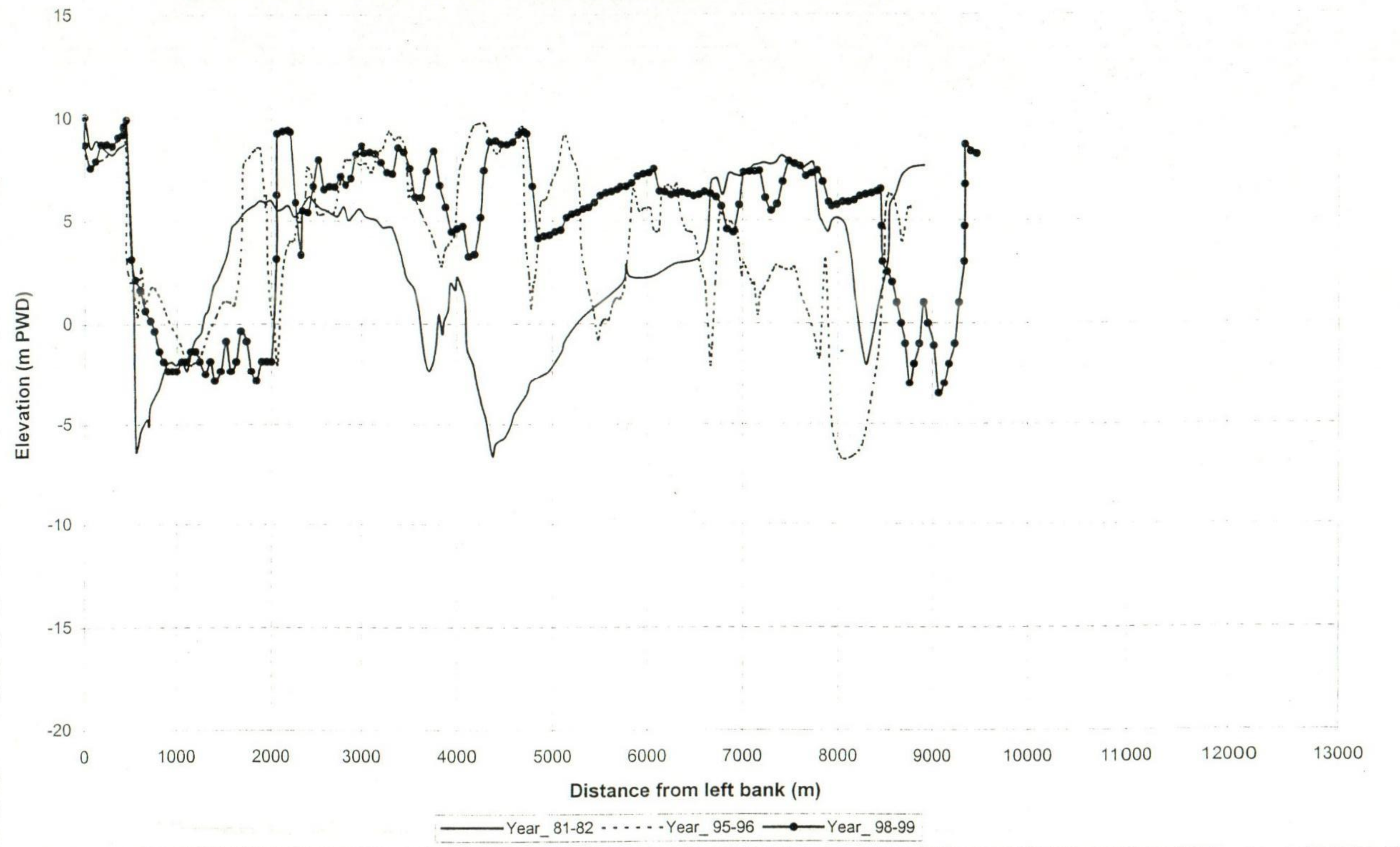


Fig. 4.19 Variation of elevation over different years at Cross-section (J-2)

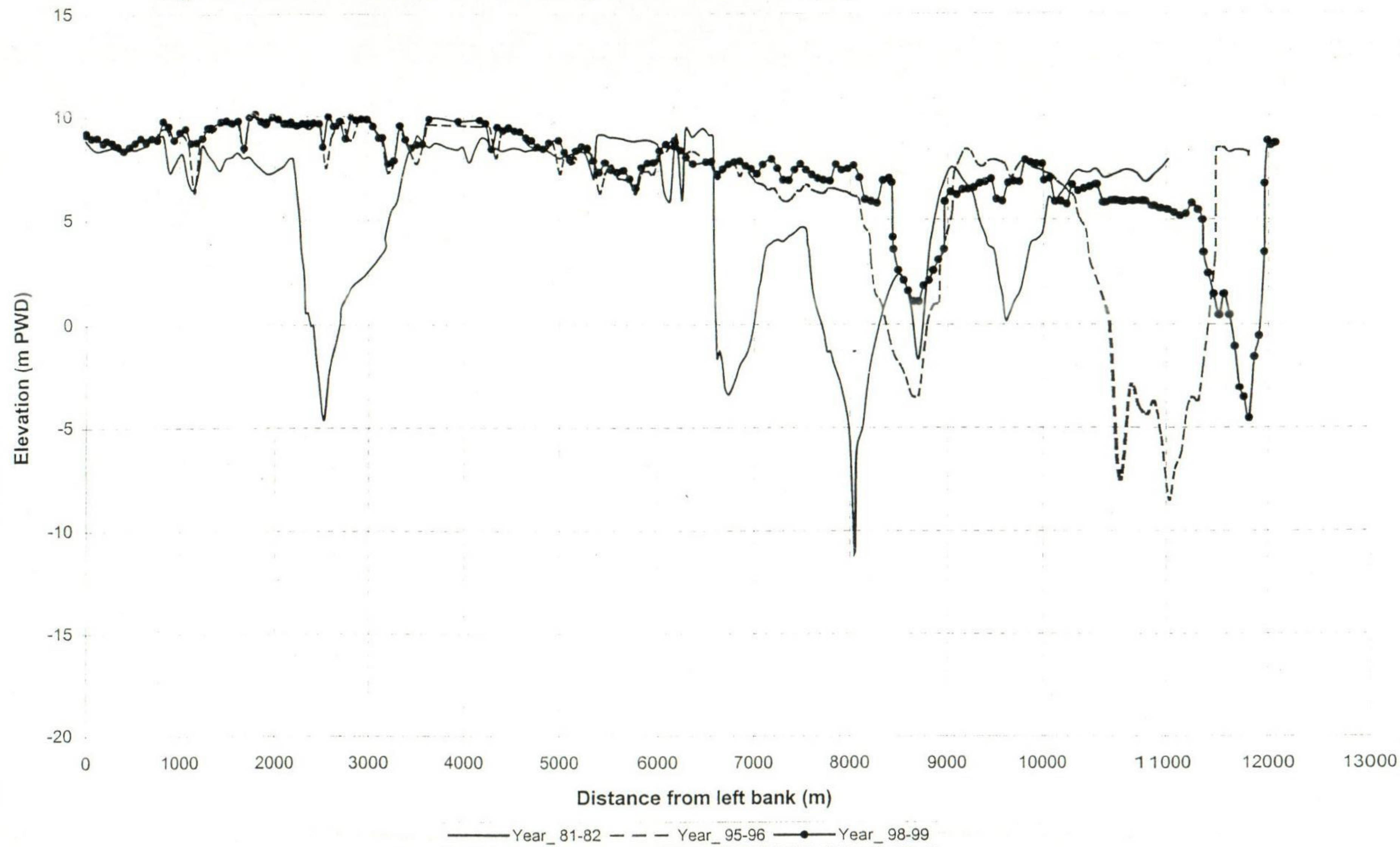


Fig. 4.20 Variation of elevation over different years at Cross-section (J-2-1 R)

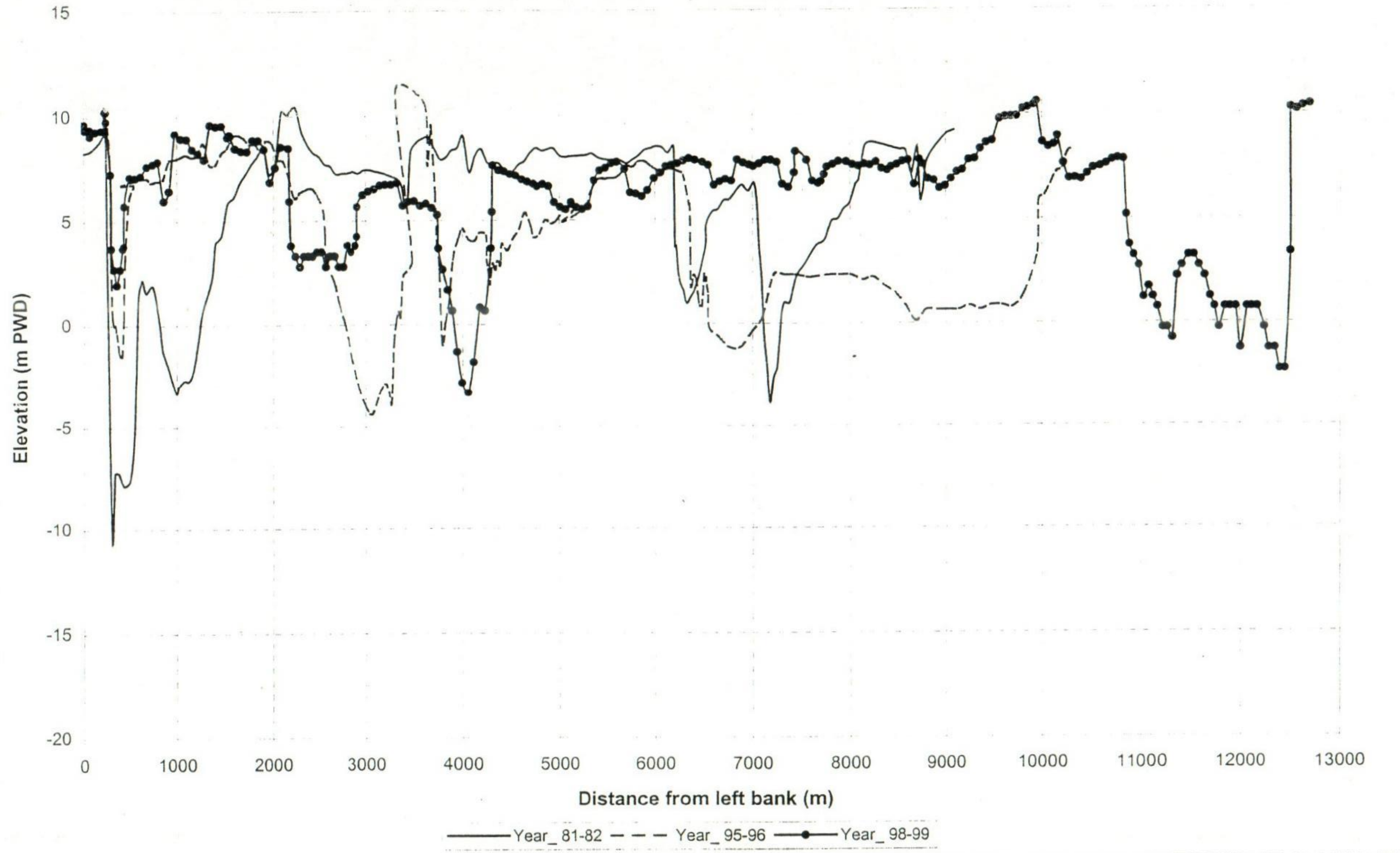


Fig. 4.21 Variation of elevation over different years at Cross-section (P-6)

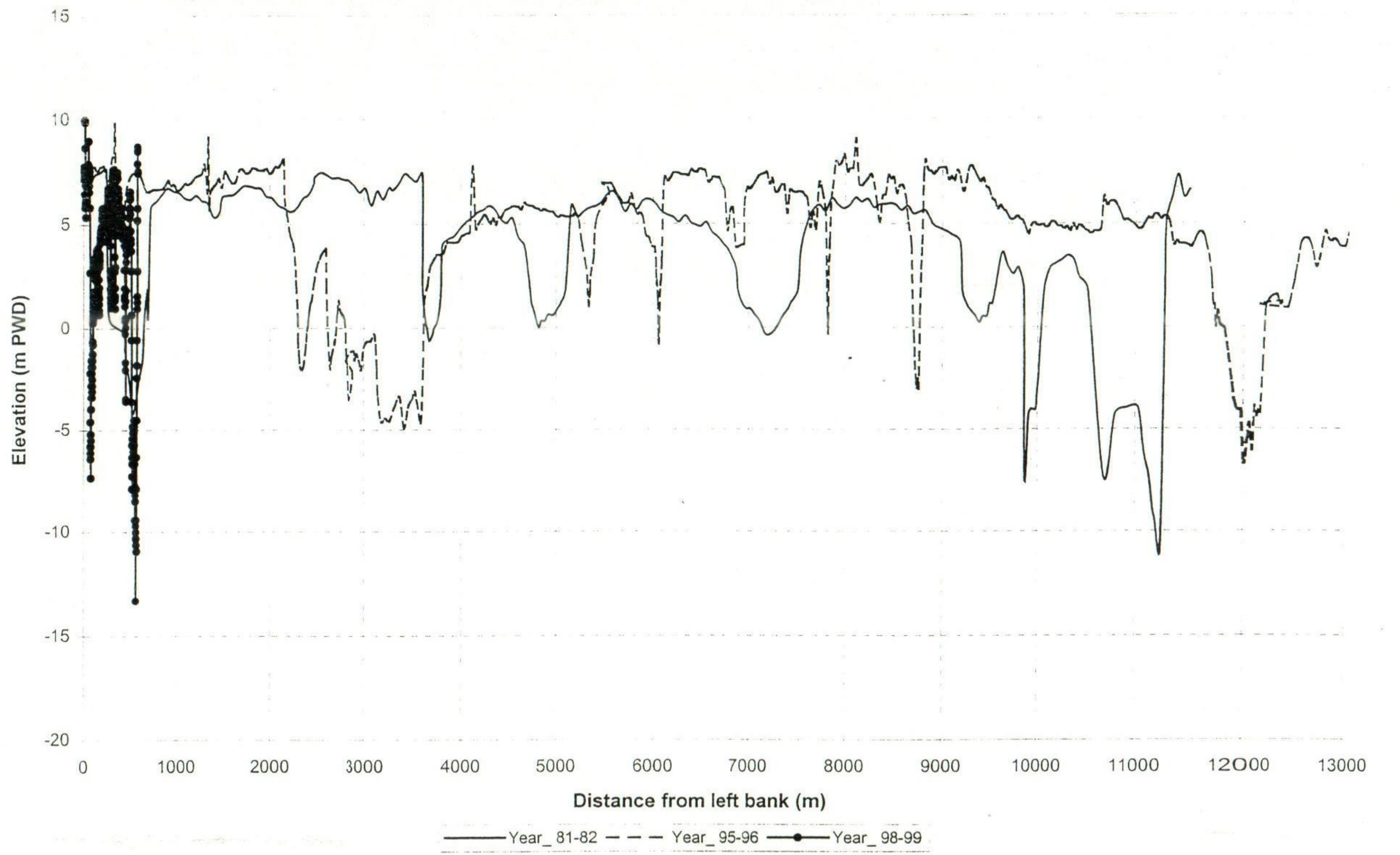


Fig. 4.22 Variation of elevation over different years at Cross-section (P-6-1)

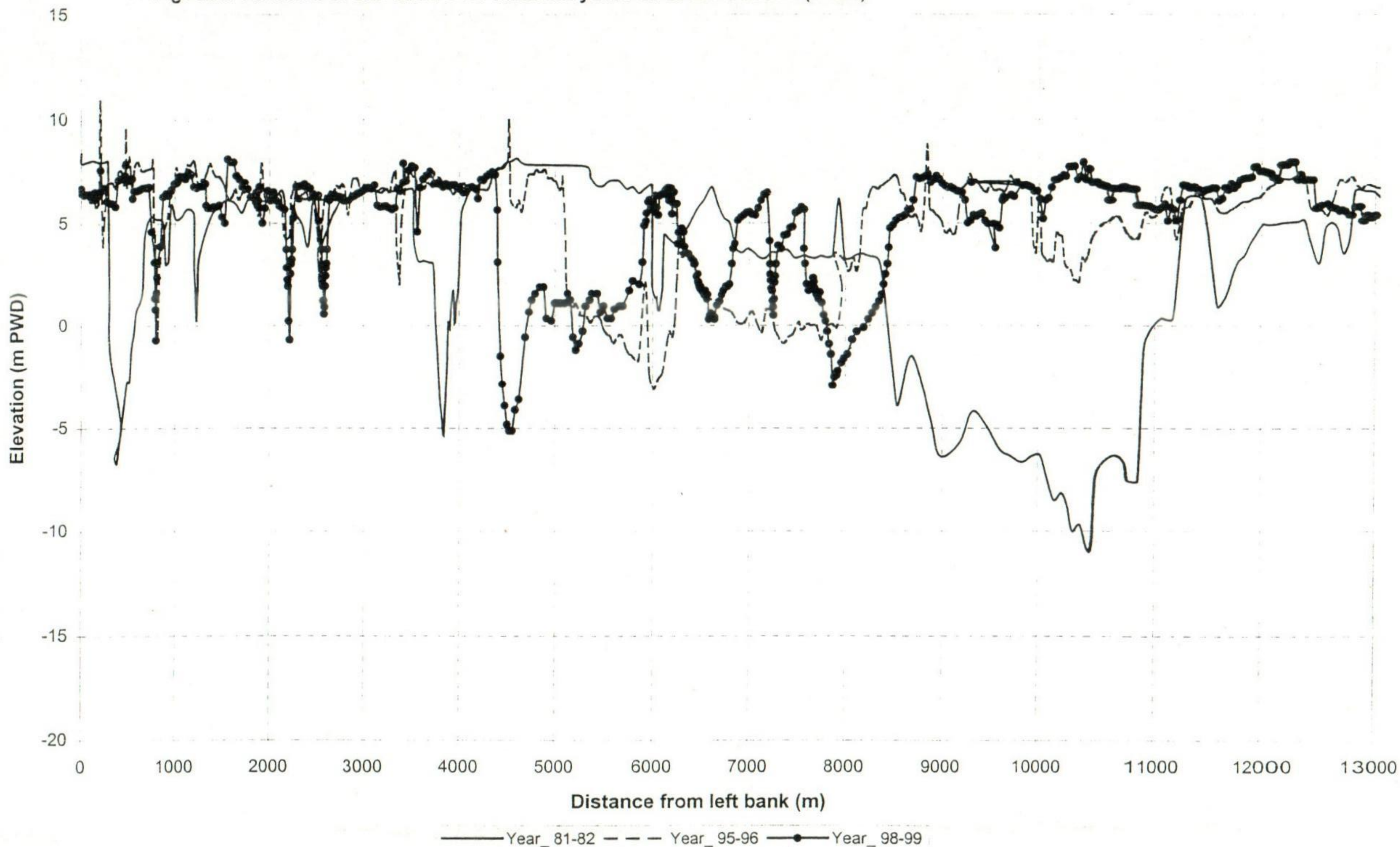
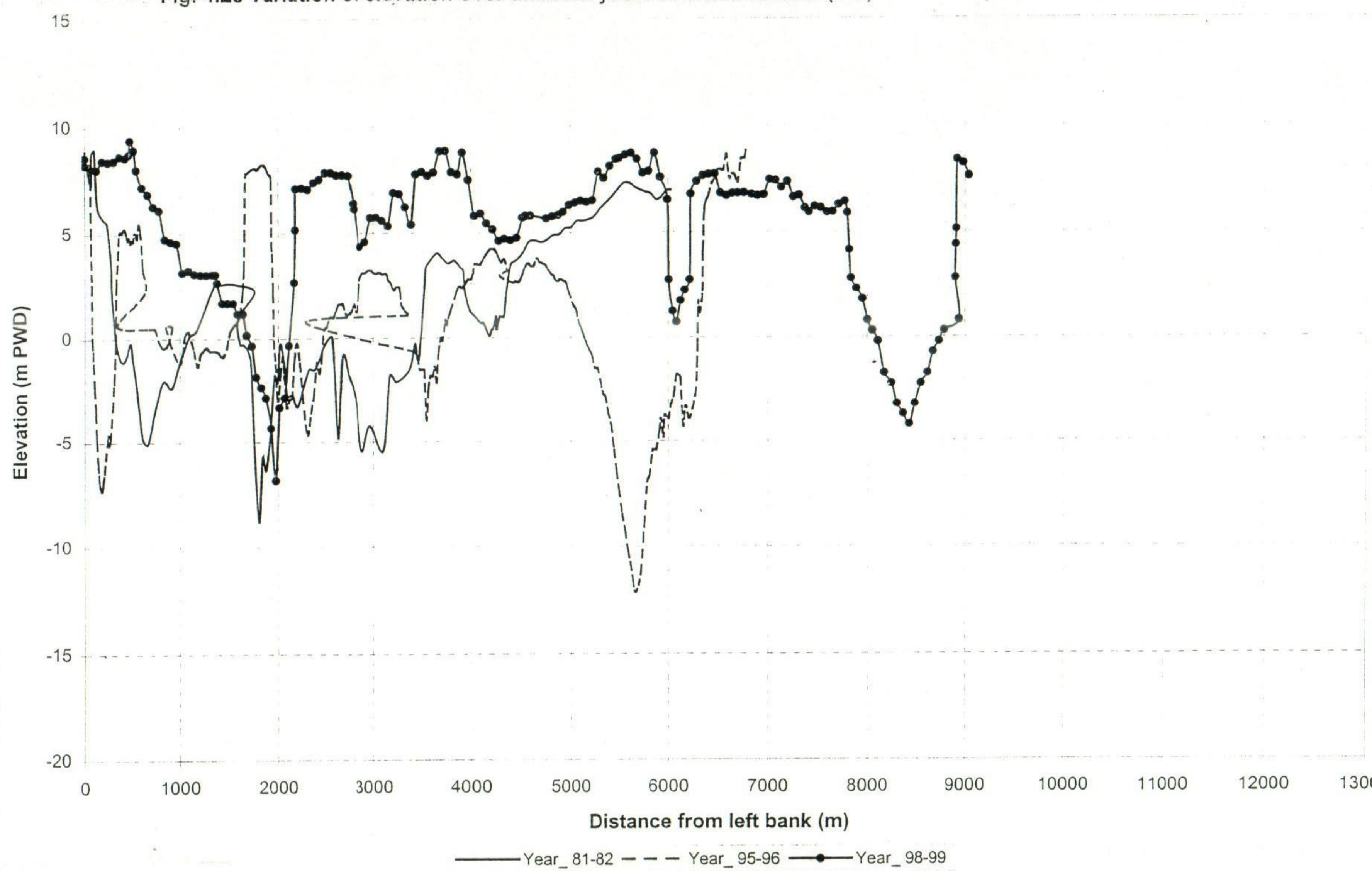


Fig. 4.23 Variation of elevation over different years at Cross-section (P-7)



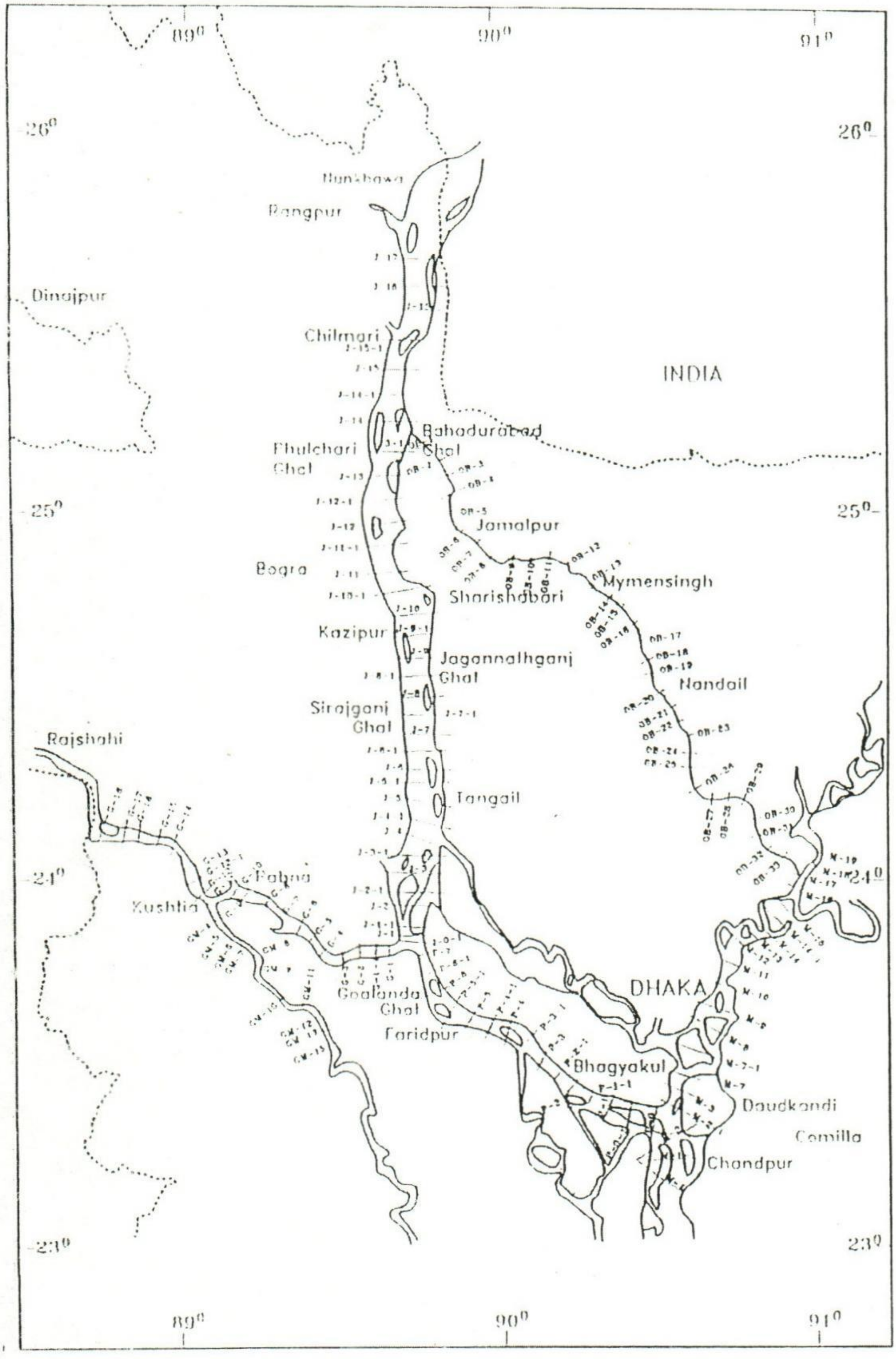


Fig 4.24 Standard BWDB cross section covering the study area (Aricha- Notakhola-Daulatdia)

Fig 4.25 Variation of Cross-sectional width

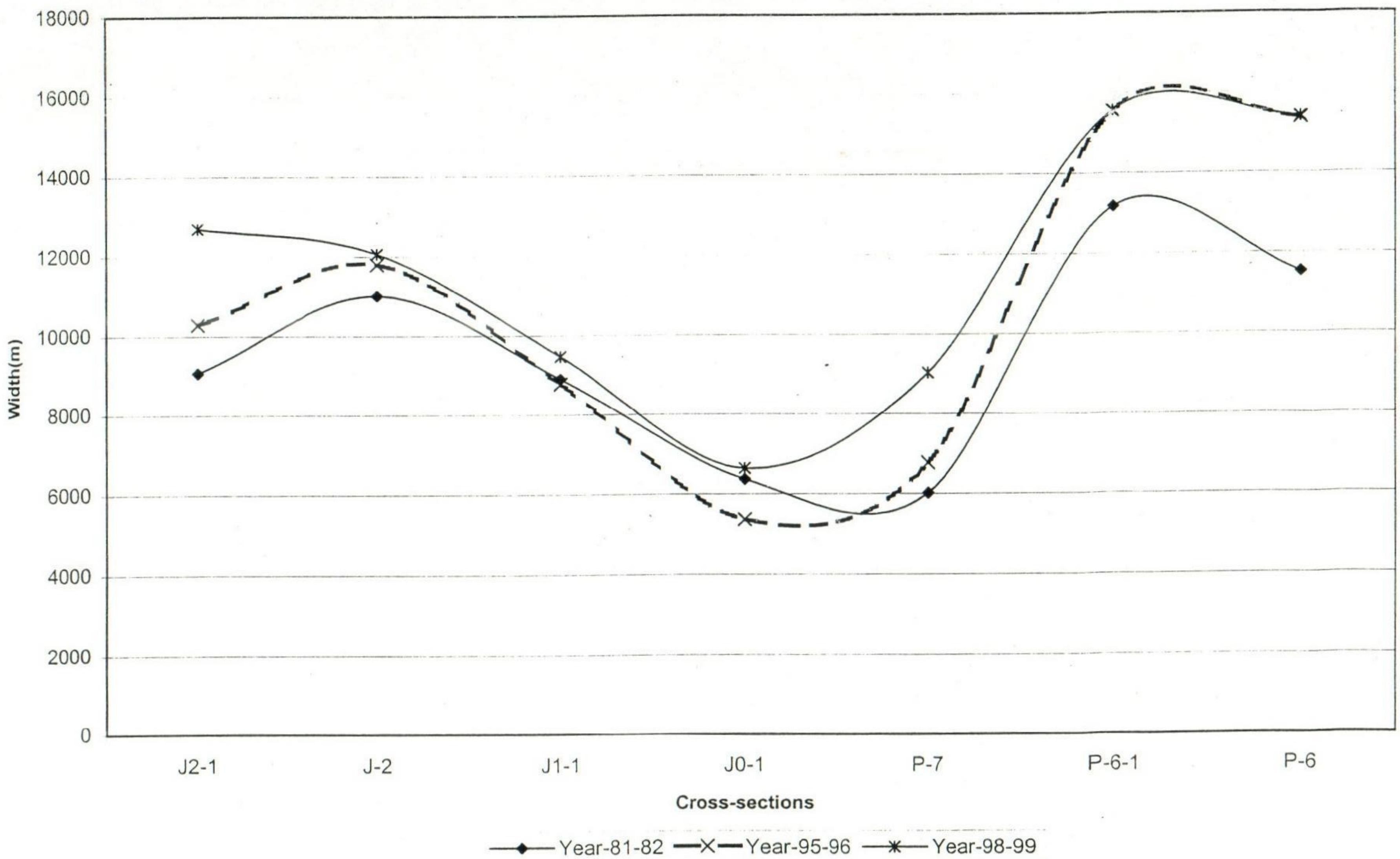


Fig 4.26 Variation of Mean Water Depth (m)

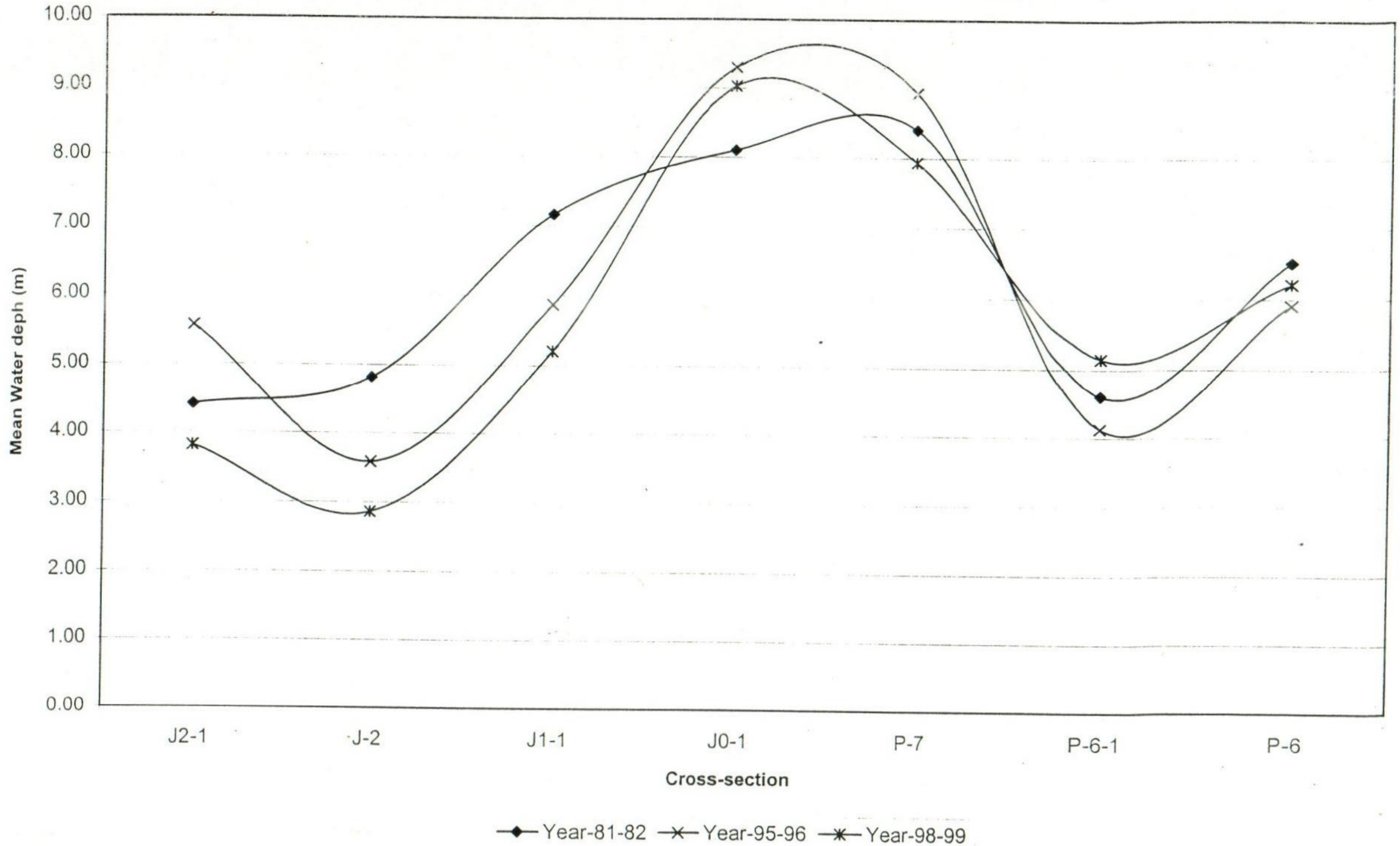


Fig 4.27 Variation of Cross sectional Area

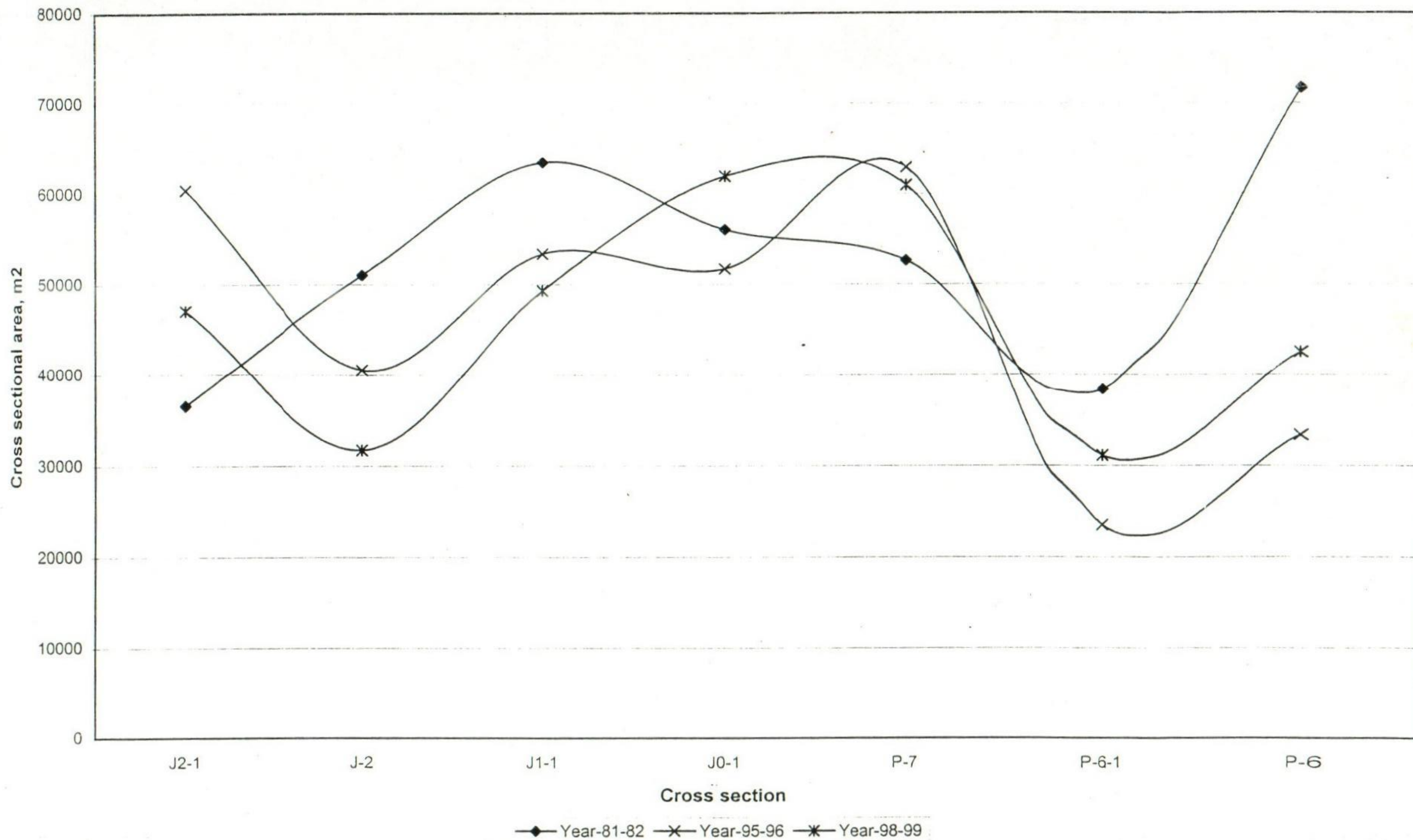
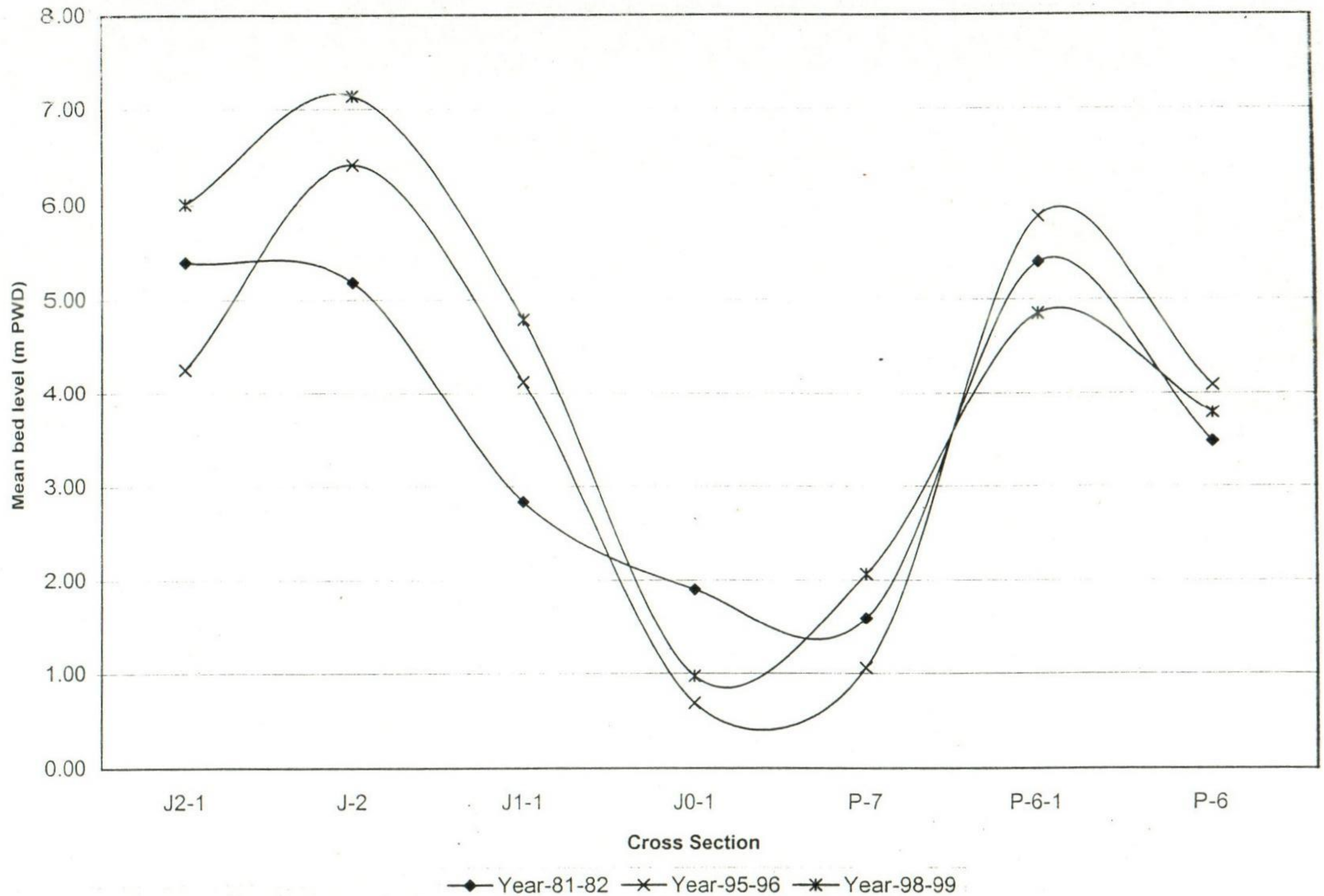


Fig 4.28 Mean bed level variation



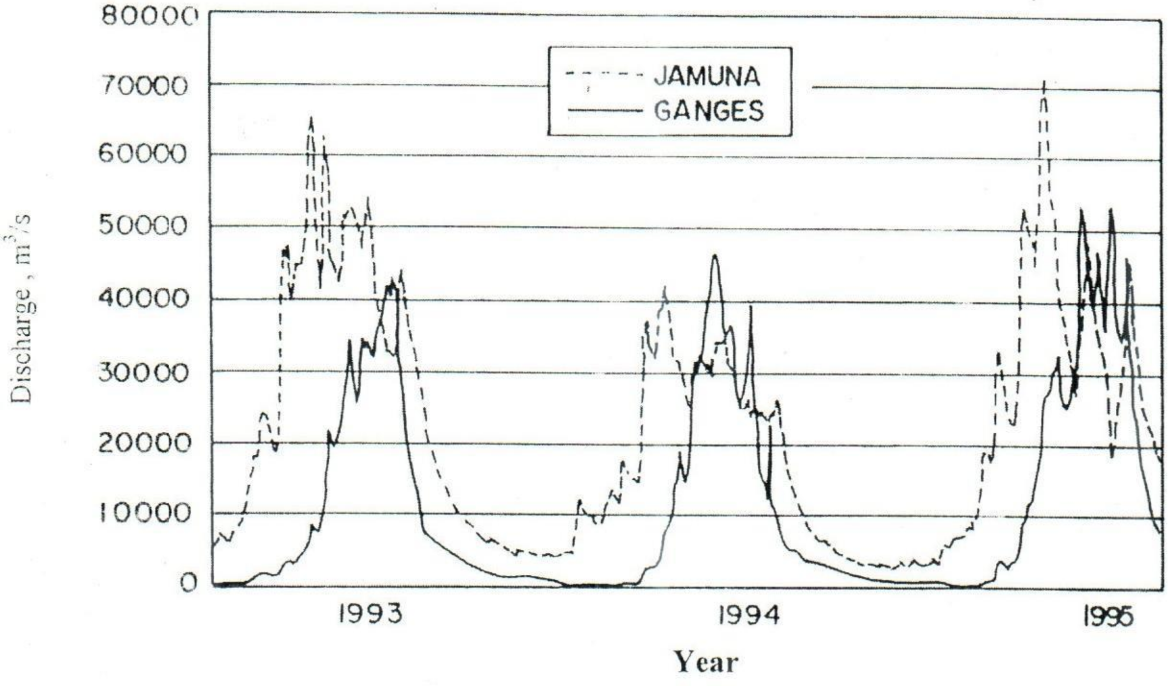


Fig 4.29 Hydrographs of the Jamuna and Ganges near the confluence (Source: FAP-24)

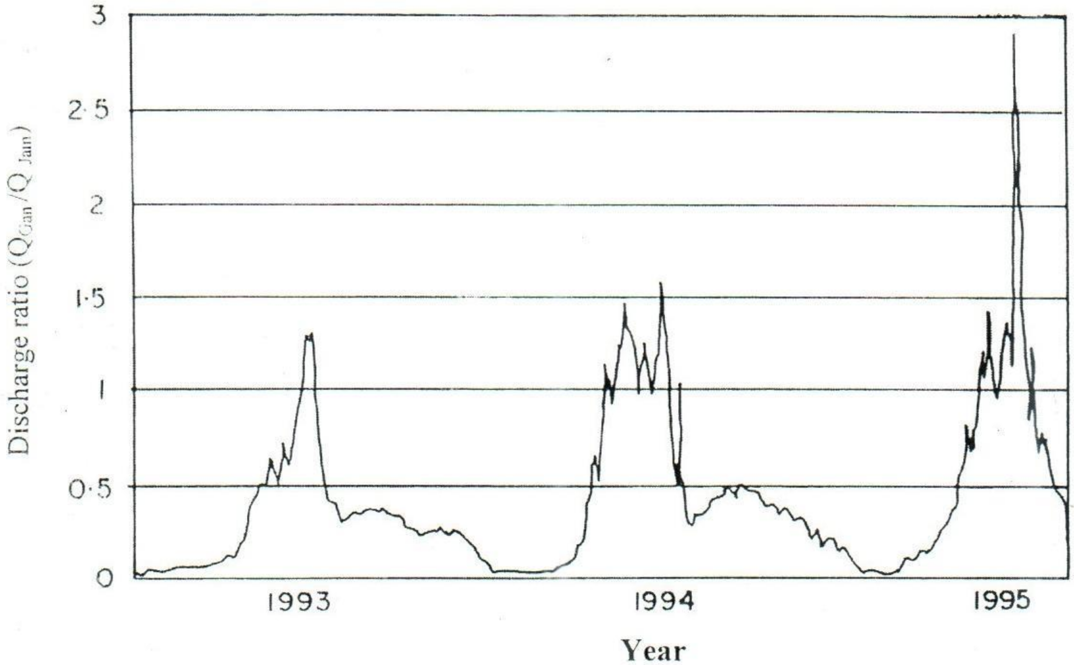


Fig 4.30 Discharge ratio for the Ganges and Jamuna near the confluence (Source: FAP-24)

Fig. 4.31 Dredging amount over the period of 1990-1999

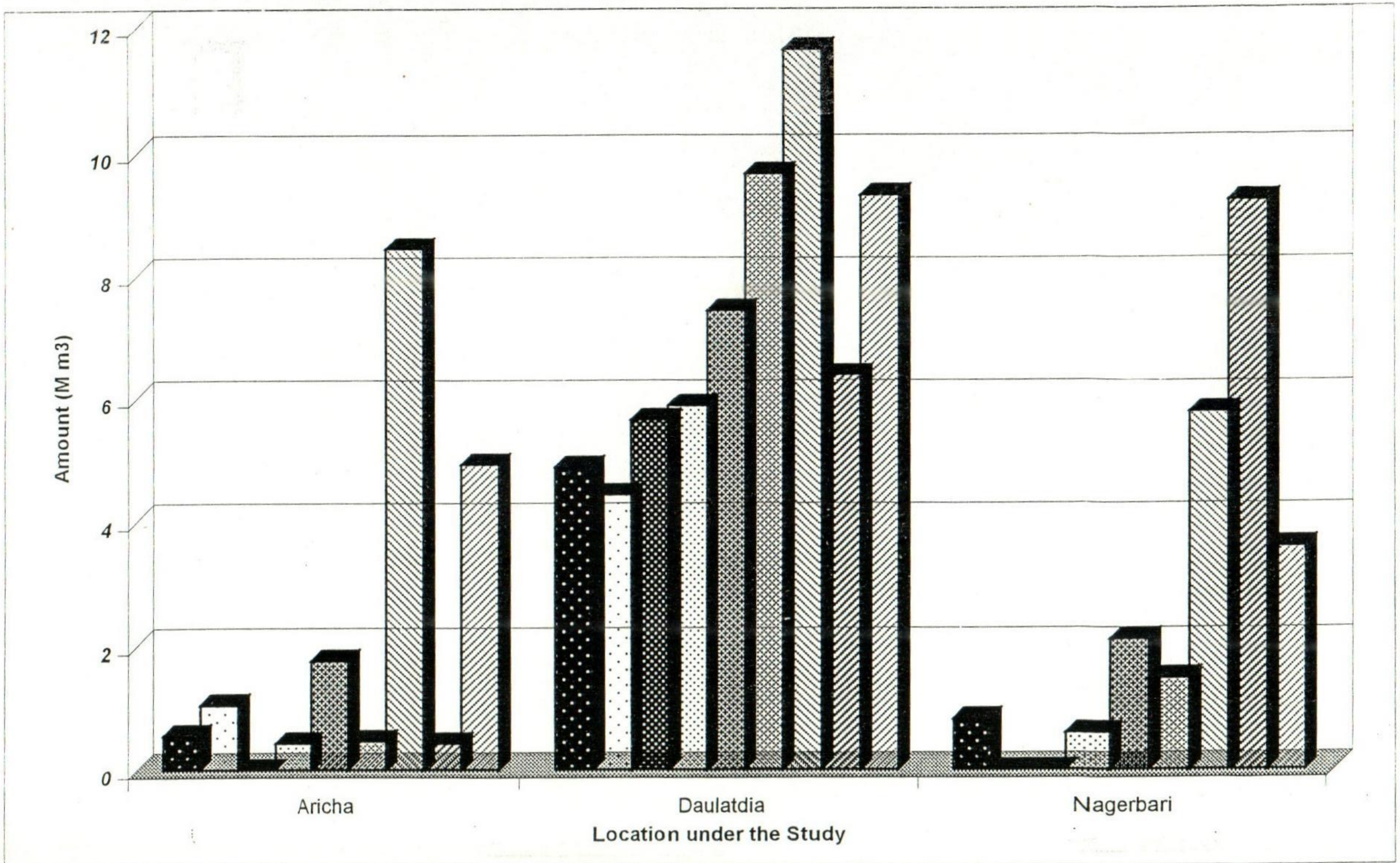
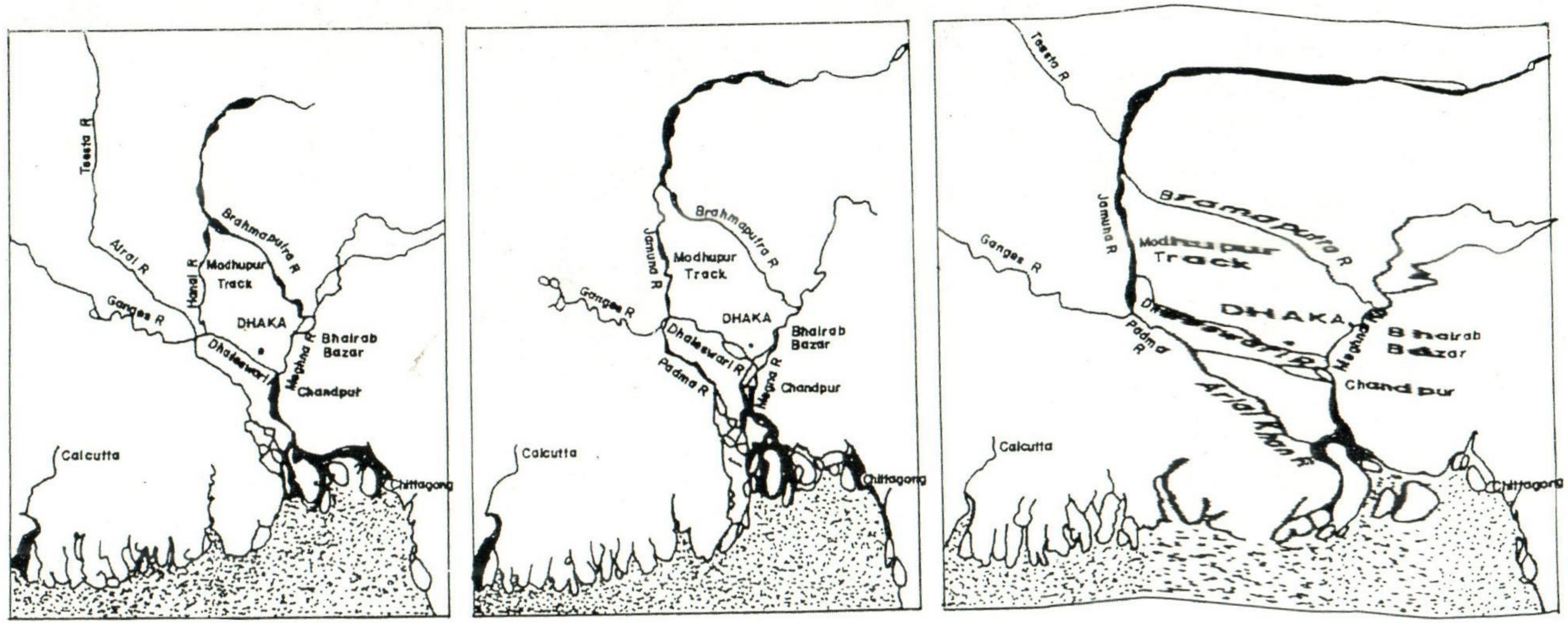


Fig 4.32 Historic map of the river system of Bangladesh (Source: FAP 24)



(After Rennel's map of 1776)

(After Wilcox map, 1840)

(ISPAN 1993)