FAP—9B

GOVERNMENT OF BANGLADESH

BANGLADESH WATER DEVELOPMENT BOARD

MEGHNA RIVER BANK PROTECTION

SHORT TERM STUDY

IDA Credit 1870BD (Part D), March 1990

FINAL REPORT

VOLUME I

MAIN REPORT

February 1992

HASKONING, Royal Dutch Consulting
Engineers and Architects

Delft Hydraulics

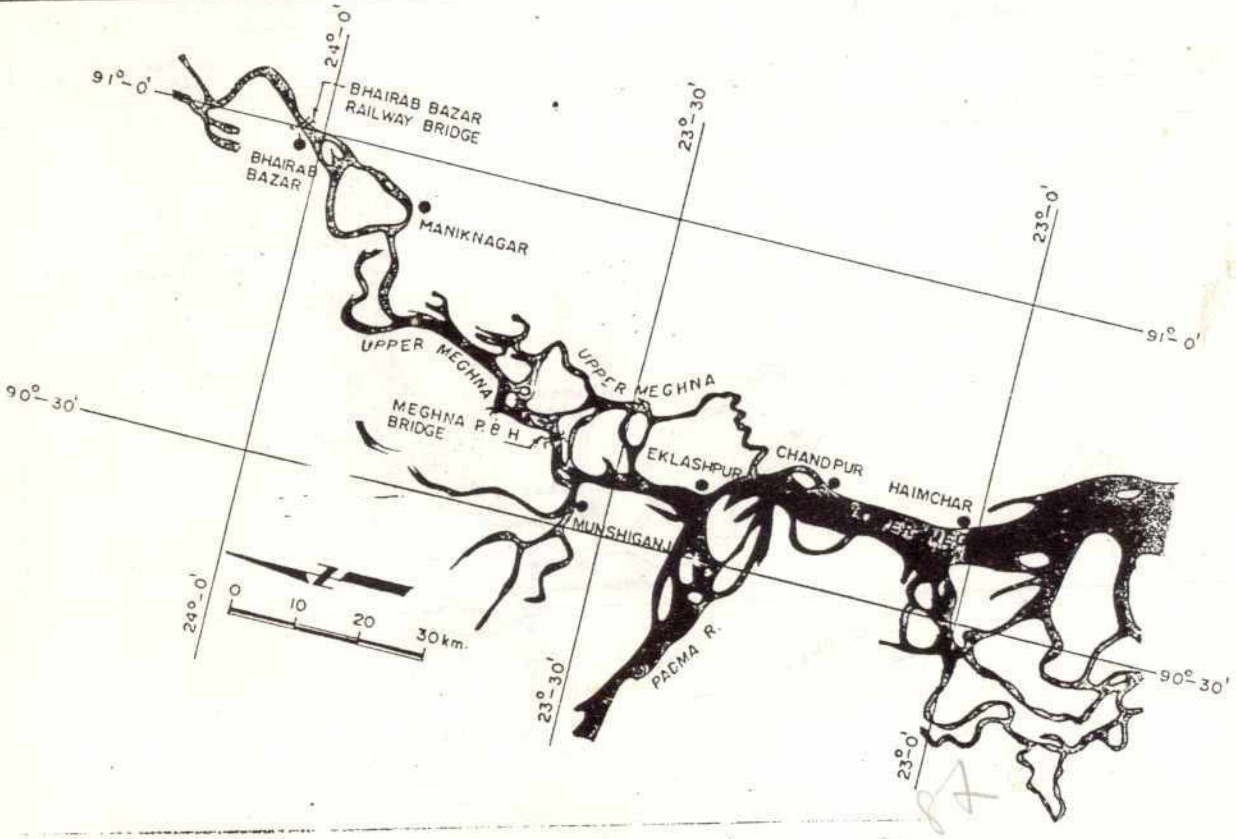
BETS, Bangladesh Engineering & Technological Services

GOVERNMENT OF BANGLADESH

BANGLADESH WATER DEVELOPMENT BOARD

MEGHNA RIVER BANK PROTECTION
SHORT TERM STUDY

IDA Credit 1870 BD (Part D), March 1990



FINAL REPORT

VOLUME I

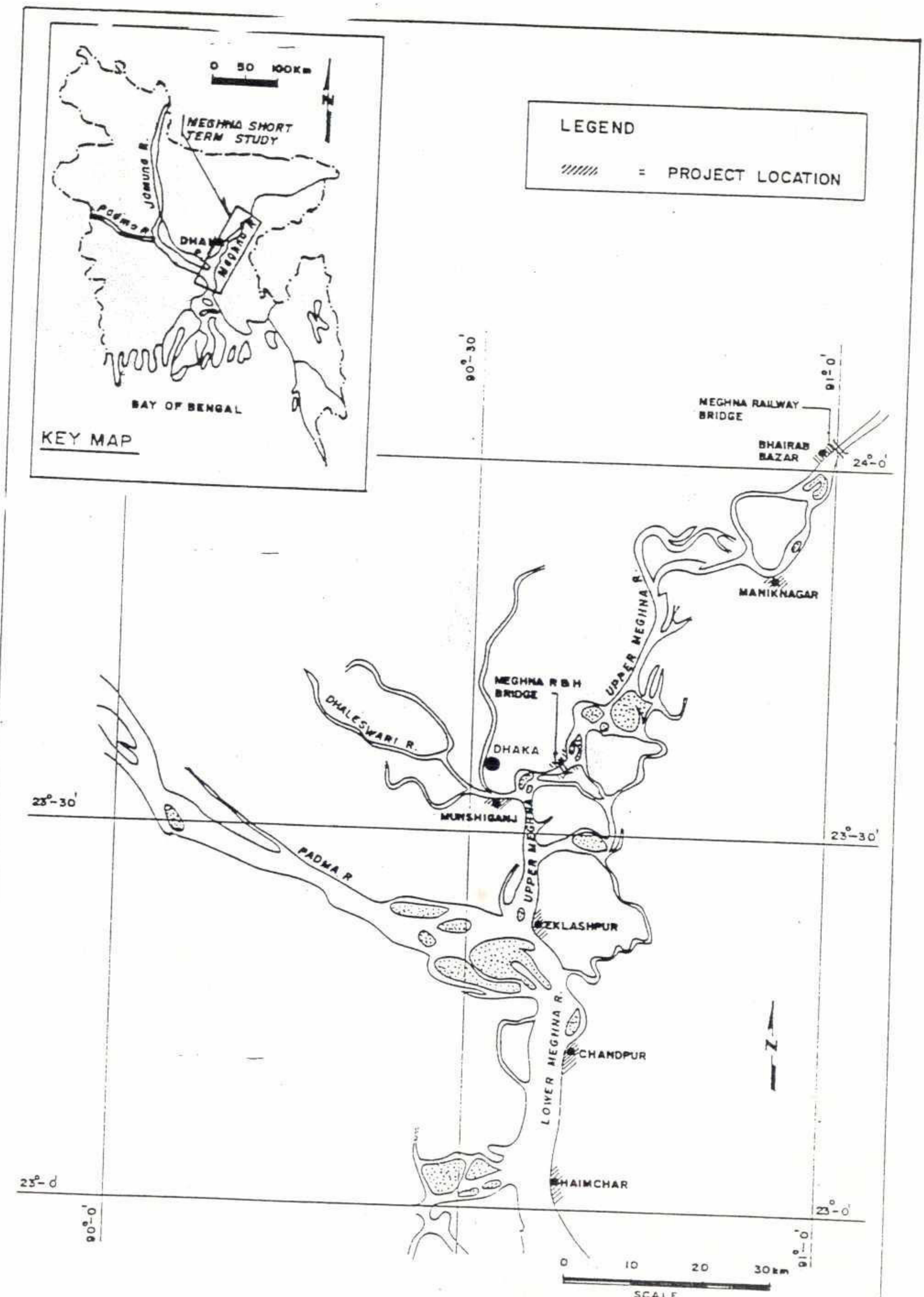
MAIN REPORT

February 1992

HASKONING. Royal Dutch Consulting
Engineers and Architects

Delft Hydraulics

BETS, Bangladesh Engineering & Technological Services



INDEX MAP SHOWING PROJECT LOCATIONS FOR THE MEGHNA SHORT TERM STUDY

PREFACE

The Meghna, one of Bangladesh' major rivers, flows through the eastern part of Bangladesh and discharges into the Bay of Bengal.

Like other rivers in Bangladesh, the Meghna erodes it banks in many points and this erosion has assumed an alarming magnitude since the severe floods of 1987 and 1988. Consequently, a number of locations requires prompt attention to prevent further damage or even events of a catastrophic nature.

This Final Report describes the surveys, studies, designs, cost estimating and economic evaluation carried out during 1990-1992 as part of the Short Term Study (FAP-9B) for Meghna Bank Protection.

The Report consists of seven volumes comprising a Main Report and nine Annexes A to I. Some Annexes are accompanied by a series of APPENDICES containing detailed information or supporting data relevant to them.

Vol I			Main Report
Vol II	Annex	A :	Hydrology
		B :	River Morphology and Geomorphology
Vol III	Annex	C :	Geotechnical Investigations
Vol IV	Annex	D :	Scale Model Studies
		E :	Mathematical Model Studies
Vol V	Annex	G :	River Bank Protection
Vol VI	Annex	F :	Economics of Protection Works
Vol VII	Annex	H :	(not used)
		I :	Environmental Impact Assessment.

d

MEGHNA RIVER BANK PROTECTION
SHORT TERM STUDY

FINAL REPORT

VOLUME I MAIN REPORT

CONTENTS

LIST OF TABLES

LIST OF FIGURES

The following sections deal with the main elements of the study.

River Morphology and Geo-morphology

3. The upper and Lower Meghna river are two completely different rivers. The lower Meghna is, in fact, the continuation of the Padma River.

4. Planform characteristics of the Upper Meghna have remained essentially the same over the last decades. the overall trend of the plan form of the Lower Meghna is different from the Upper Meghna River. In the Lower Meghna River major changes are taking place. The present morphology at the confluence of the Padma and lower Meghna Rivers is such that the width of the cross-sections increase considerably before the confluence, leading to a decrease of velocity and consequently the generation of large chars. This chars influence the course of the channels.

5. It can be stated that the overall trend of the planform of the Lower Meghna near the confluence is a continuous movement in eastern direction. This accomplished by continuous bank erosion along the bend of the Lower Meghna river in the southern direction. The location of the bank erosion varies depending on the channel pattern in the Padma River and seems to vary with a periodicity of some 15 years.

Engineering

6. After studying various alternative designs a selection was made for designs to be studied in greater detail. The selection was based on various factors including the impact of the protection works on the flow pattern, the area required to construct and maintain the protection works and cost involved.

7. Bank protection works to be constructed along the Upper Meghna are in principle similar to works constructed elsewhere in the world along meandering rivers of comparable magnitude. Bank protection works to be constructed along the Lower Meghna and more specifically at Chandpur are unique in view of the expected depth of scour holes and current velocities in this large river.

8. On all three sites bank protection in principle will consist of a revetment placed onto a geotechnically stable slope.

   The slopes will be formed by either placing (hydraulic) fill followed by slope trimming by dredgers or (at Chandpur) by placing containment bunds which are always filled with hydraulically placed sand before the next containment is constructed.

9. By means of multicriteria analysis (MCA) the following slope protection alternatives were analyzed for each case:

   - boulders or rock on geotextile;
   - concrete cement blocks placed on a filter;
   - concrete block mattresses;
   - bound or grouted aggregates;
   - wire or gabion mattresses filled with boulders; and
   - fabric mattresses filled with sand or cement.

In order to fulfil the functional requirements, quality assurance, maintenance and construction aspects, the revetment will consist of:

- above water of open stone asphalt on a geotextile;
- under water of a fascine mattress ballasted with rock or boulders depending on the site;
- at the toe of a falling apron of boulders (rock for Chandpur) without a geotextile underneath.

10. In modern design the Consultant tries to design river bank protection works having a minimum capitalized cost (less investment). It therefore is emphasized that monitoring and maintenance must be carried timely and to the required level of quality. It is suggested to consider the possibility of for instance a locally based (i.e in Chandpur or Bhairab Bazar) Meghna River Authority, founded by GOB through an ordinance.

11. The financial construction cost of the works designed for the eight priority sites is as follows:

	US $ million
- Bhairab Bazar and Railway Bridge	15.3
- Munshiganj	7.7
- Chandpur:	
(a) Short-Term	71.2
(b) Emergency	37.9
- Roads & Highways Bridge	5.2
- Maniknagar	20.5
- Eklashpur	26.5
- Haimchar	29.3

These costs are based on prices of mid-1991, the reference date for the economic study and include no customs duties or levies and no allowance for escalation in prices.

12. The construction period for the project has been assessed as:

Package I:	Chandpur Town Protection (Nutan and Puran Bazar)	27	months
Package II:	Bhairab Bazar and Railway Bridge Munshiganj Town	15	months
Package III:	Chandpur Town, Nutan Bazar, Emergency Works	13	months

CONCLUSIONS

Introduction

1. This Final Report comprises the Consultants' work in response of the revised Terms of Reference which require Consultants to submit:

- feasibility studies, detailed designs and tender documents for the priority sites:
  - Bhairab Bazar and Railway Bridge,
  - Munshiganj,
  - Chandpur
- feasibility studies and tender documents for erosion protection at the sites:
  - Chandpur (Emergency protection works),
  - Eklashpur,
  - Haimchar.
- pre-feasibility studies for erosion protection at the sites:
  - Maniknagar,
  - Roads & Highways Bridge.

2. The documents presented include:

- A main Report and eight Annexes (A to G and I), comprising the (pre-) feasibility studies and detailed designs,
- Tender documents for the aforementioned sites in five contract packages:
  - Package I: Chandpur Town.
  - Package II: Bhairab Bazar and Munshiganj.
  - Package III: Chandpur Town, Nutan Bazar, emergency works.
  - Package IV: Eklashpur.
  - Package V: Haimchar.

  Each package consists of five volumes.

Economics

13. The evaluation method has been based so far as possible on the FPCO - Guidelines for Project Assessment although other damage parameters than flooding had to be used.

In the without scenario the present day practice regarding river bank repair and maintenance activities is continued including an increase of these costs in the future.

14. The benefits of the bank protection project comprise the following aspects:

- cutbacks in maintenance and repair costs,
- reduction in loss and damage in town areas,
- reduced disruption of the economic activities,
- reduced damage of the agricultural sector,
- social benefits,
- environmental benefits,
- secondary benefits.

15. The economic feasibility (and pre-feasibility) analysis showed the following results:

	EIRR %	NPV at 12% in million Tk.
Bhairab Bazar Town and Railway Bridge	20.6	446.4
Bhairab Bazar Town only	19.9	369.7
Munshiganj Town	16.1	76.1
Chandpur Emergency Works	7.3	-992
Chandpur Town	[illegible]	-983
Eklashpur	2.8	-293.0
Haimchar	1.7	-215.9
Maniknagar	0.2	-190.6
Roads & Highways Bridge	189.9	2074.1

16. It is however, doubtful whether the presumed economic opportunity cost of capital is the appropriate criterion for an investment decision in an infrastructure of this kind.

17. Although prelimary assessment of bank protection of the Lower Meghna from Eklashpur to Haimchar gives an EIRR (6.7%) below the opportunity cost of capital, the assessed rate might be considered as acceptable for this type of infra-structural works. A more detail study is required to provide more substantiated conclusions for the river training works in the Lower Meghna.

18 Chandpur has derived its importance from its strategic location along the major river Lower Meghna. Many of its activities are related to its location near the river. Therefore, Chandpur should not be considered as an isolated threatened location, but rather as a first fixed point along a more or less fixed alignment of the Lower Padma and Lower Meghna. without Chandpur, or any other fortified (hard point) location along the Lower Meghna, it is difficult to see which mechanism would stop the historical shift of the Lower Meghna in eastward direction. Any existing infrastructure would be destroyed in the process of shifting of the river. Apart from the associated financial and economic losses, there would also be grave social consequences: many people loosing their land would not be able to acquire new land and would be bound to become landless and destitute.

Sensitivity Analysis

19. The most detrimental effect occurs when benefits decrease by 50%. In that case the EIRR decreases to 3.7% (Chandpur).

The project is also sensitive to an increase in construction cost: by a 50% increase the EIRR decreases to 4.6%.

Environmental Impact

20. For each phase of the project all possible negative environmental impacts have been identified for the various project activities. Most activities associated with river-bank protection have only **temporary, short-term or small-scale impacts**. This is due to the relatively limited area concerned. Furthermore, most impacts are associated with construction activities and not with the constructed works. The effects are therefore also limited in time. River-bank protection does not have a very intrusive nature: it strives to maintain a steady state at a certain location but does not significantly alter the riverine and estuarine ecosystems.

21. The Lower Meghna has one of the highest rural population densities in the world, and nearly all cultivable land in Bangladesh is farmed. Agriculture is the backbone of the economy. Agricultural practices are adapted to flooding: as the floods recede, submerged areas become productive land, especially for rice.

The socio-economic impact of infrastructure displacement depends on the attitude of the affected population. Information on this issue is not available, but it is expected that minimization of the inconvenience is advisable. The provision of pontoons as temporary landing facilities, and the reorganization of market facilities in the vicinity, will compensate the temporary loss of landing and market facilities at Bhairab Bazar, Munshiganj and Chandpur. It is recommended to develop a relocation scenario in cooperation with the local authorities.

22. The nature of the protection works is such, that the contractor will minimize dredging activities. The effect on flora and fauna at the dredging site can further be reduced by avoiding heavily polluted sites. If dredging elsewhere is too costly, the effects on water quality and aquatic life should be monitored.

23. It has been recommended that a long-term strategic plan be prepared for future development in the areas protected. Ideally, a monitoring programme should study the changes in water and soil quality, including the effect on aquatic organisms and fish, before the proposed works are carried out (assessment of existing situation), directly after project implementation (assessment of short-term impact), and after one year (assessment of long-term impact). The monitoring programme should run for at least a year to detect seasonal variations, and preferably several years to detect annual changes.

1. INTRODUCTION TO THE PROJECT

1.1 Background

There are three major rivers in Bangladesh; the Ganges. the Brahmaputra and the Meghna. Originating form Assam in India. the Meghna River flows through the eastern part of Bangladesh and discharges into the Bay of Bengal. The Meghna River drains an area of 77,000 km^2, of which about 46,500 km^2 is located in Bangladesh. Th[illegible] contributors to the river upstream of Bhairab Bazar are the Boulai, the Surma and the Kushiyara rivers, covering an area of 62.960 km^2. The Ganges joins the Brahmaputra near Aricha and thereafter takes the name of the Padma. The Padma joins the Meghna at Chandpur. The Lower Meghna River conveys the melt and rain water form the Ganges and Jamuna basins, combined in the Padma River, and from the Upper Meghna basin to the sea. The total catchment area is about 1,637,000 Km^2. Maximum flows can be as high as 160,000 m^3/s. The major contribution of the discharge originates from the Jamuna River (annual average 19,642 m3/s) and the Ganges River (annual average 10,874 m^3/s).

The reach of the Meghna River from Bhairab Bazar to Haimchar is about 160 km in length. Width of the river varies from 1 km to more than 10 km. The river channel is more or less well defined upstream of its confluence with the Padma and is braided in the reach downstream of Chandpur. The river is considerably deep all along and the depth ranges to 35 m in the bends. The river bed and banks consist mainly of clayey-silt which is often loosely packed and is susceptible to liquefaction at some places. Of the three major rivers, the Meghna carries relatively less sediment. The velocity of flow of the river is high during monsoon. The river banks are also subjected to heavy wave action at some points.

Like other rivers in Bangladesh, the Meghna erodes its banks in many points. Erosion at the Meghna since the severe flood of 1988 has assumed alarming proportions at the following locations which require prompt attention.

- The Railway bridge at Bhairab Bazar;
- Bhairab Bazar Township along the right bank;
- Maniknagar; along the left bank, falling within the proposed Gumti; Phase II Project;
- Meghna R & H Bridge;
- Eklashpur (near Meghna-Dhonagoda Project);
- Chandpur Town;
- Haimchar (adjacent to Chandpur Irrigation Project);

The Dhaleswari River, a tributary of Meghna, has been eroding its right bank at Munshiganj for quite some time and has threatened the existence of Munshiganj Town.

1.2. Meghna River Bank Protection -Short term Study

The study of possible bank protection works at critical locations along the Meghna river commenced officially in September 1990 when BWDB, Bangladesh Water Development Board commissioned HASKONING, Royal Dutch Consulting Engineers and Architects in association with DELFT HYDRAULICS and BETS, Bangladesh Engineering and Technological Services, to carry out the Meghna River Protection Short Term study, financed under the Credit IDA BD-1870, Part D.

The objectives of the study are:

- to provide short term measures for protection against erosion for 7 locations on the Meghna river and one location on the Dhaleswari;
- to gradually implement a coherent and phased programme of works, aiming at the control of erosion on the defined stretches of the rivers Meghna and Dhaleswari. The protection of the locations indicated above should logically fit in this programme.

The Inception Phase started in November, 1990 with the mobilisation of the Expatriate Consultants. During the Inception Phase, the inter-action between this study and Flood Action Plan (FAP) Components was identified and maintained as far as possible.

The Meghna River Bank Protection Short Term Study, is now one of the **main components** of the Flood Action Plan for Bangladesh (FAP-9B. MEGHNA LB PROTECTION PROJECT), as included in the Review Report FPCO, December, 1990.

It has been recognised that during the Inception Phase, due to the internal and international situation from November 1990 to February 1991, delays were experienced, hampering the normal development of the activities planned. Therefore, activities in the critical path of the study were delayed (i.e, hydrometric surveys, geotechnical investigations, model investigations at RRI).

Furthermore, during the first phase of the project it became more and more clear that the inclusion of the flood season survey would considerably improve the designs of the protection works which the Consultants were supposed to submit at the end of the study. In addition, strengthening of the relation with the studies of the Bangladesh Action Plan for Flood Control (FAP) would have a positive contribution to the outcome of this project. Therefore the BWDB instructed the Consultants to review and update the work plan taking note of the flood season of 1991 and the aforementioned studies of FAP.

As part of the Study a priority ranking was established. Accordingly, it was decided:

- to carry out a full feasibility study, detailed designs and prepare tender documents for bank protection works at the following locations:
  - Bhairab Bazar Township and Railway Bridge;
  - Munshiganj Town located on the Dhaleswari River;
  - Chandpur Town;
- to carry out a feasibility study and prepare tender documents for bank protection works in the following locations:
  - Eklashpur;
  - Haimchar;
- to carry out only a pre-feasibility study for bank protection works at:
  - Meghna Roads & Highways Bridge;
  - Maniknagar, part of Gumti Phase II Project.

This Final Report submitted in accordance with the (Revised) Terms of Reference comprises all (pre-) feasibility studies carried out as well as the detailed designs for bank protection works at the three locations mentioned above.

1.3 Contents of the Report

The Final Report (i.e the Feasibility Study Report) is presented in an Executive Summary, a Main Report and eight Annexes, A to G and I.

Chapter 2 of the Main Report sets out the approach to the study; Chapter 3 deals with engineering investigations, and site assessments which have been carried out to arrive at optimum bank protection designs; Chapter 4 discusses project designs.

Chapters 5 and 6 deal with risk analysis, probabilistic design, construction methods and programmes all having a direct bearing on the Project Designs. Chapter 7 presents the environmental impact assessment made. Monitoring and maintenance for the various projects proposed are considered in Chapter 9.

These projects are costed in Chapter 8. Finally, their economic feasibility is evaluated (Chapter 10).

Most of the chapters in the Main Report have one or more supporting Annexes. These Annexes are presented in six volumes (II to VII) and are listed at the beginning of this volume. Certain Annexes are accompanied by a series of Appendices containing detailed information or supporting data relevant to the corresponding Annex.

2. APPROACH TO THE STUDY

2.1 Introduction

The objectives of this Short-Term Study are, according to the Revised Terms of Reference, (May 1991):

- to provide short-term measures for protection against erosion for seven locations on the Meghna river and one location on the Dhaleswari;

- to gradually implement a coherent and phased programme of works, aimed at the control of erosion on the defined stretches of the river Meghna and Dhaleswari. The protection of the locations indicated above should logically fit in this programme.

As described in Chapter 1 of this Main Report the Inception Phase as well as the delays experienced due to reasons outside Clients' and Consultants' control resulted in a priority ranking for studies and designs to be carried out. Because of budget and time constraints it was agreed that Consultants in the first instance would concentrate on three sites. For these three priority sites not only full feasibility studies but also detailed designs and tender documents would be produced.

For two other sites only feasibility studies would be made and tender documents prepared while, finally, for two sites only pre-feasibility studies were carried out.

2.2 Scope of the Problem

The sites to be considered in the Short-term Study can be divided into two different groups: the sites along the Upper Meghna and the Dhaleswari River (Bhairab Bazar, Maniknagar, Meghna Road and Highway Bridge and Munshiganj) and the sites along the Lower Meghna (Eklashpur, Chandpur and Haimchar). The distinction between the Upper Meghna and Lower Meghna is evident.

Although having some sections with a system of various channels, the Upper Meghna can be characterized as a river mainly meandering within a rather well defined high water bed and discharges up to 20,000 m3/s. This means that bank protection works at each of the sites can be considered rather independently as long as the works fit into a more general master plan for the whole Upper Meghna.

The Lower Meghna is, in fact, the continuation of the Padma River with peak discharges of the order of 150,000 m3/s. The river system is not only characterized by a wide river bed of several kilometres in which various channels develop in combination with large propagating sand bars, but also by a gradual shifting of the whole Lower Meghna in eastward direction. This means that the erosion problems of Eklashpur, Chandpur and Haimchar originate mainly from this eastward shifting and that permanent solutions for these sites have to be considered in relation to each other. It also means that short-term bank protection works for the different sites can only be justified as part of the total river training scheme for the Lower Meghna and that short-term measures require a long term commitment.

From the above it follows that the solution of the erosion problems of the sites along the Upper Meghna and the Dhaleswari River can be looked at rather independently. The sites along the Lower Meghna, however, are dealt with as an integrated bank erosion problem of the Lower Meghna River System. In this respect a few explanatory comments should be made.

Eklashpur, Chandpur and Haimchar are situated on the left bank of the Meghna River, downstream of the confluence of the Padma (Ganges) and the Upper Meghna River. The erosion processes at the left bank are clearly related to the geomorphological development of the Padma and the Lower Meghna in combination with a severe wave attack.

The Padma River is about six times larger than the Meghna River and has shifted its course in northeast direction joining at present the Meghna River near Eklashpur instead of at Chandpur. As a consequence, the erosive force has increased at Eklashpur and may become more severe in the future. The Lower Meghna has been eroding the left bank for more than a decade, showing a gradual shifting to the East, and has engulfed a vast area of land at a very high erosion rate.

A definitive long term solution should be based on the long term geomorphological development of the river system and will require costly river training works designed in agreement with the Meghna River Long Term Strategic Plan. The World Bank advocates such long term measures for erosion protection in agreement with the results of the Meghna River Strategic Plan for which the Terms of Reference will be drafted within the framework of the present Short-term Study.

The long-term solution for Eklashpur, Chandpur and Haimchar would require the complete training of the river system downstream of the confluence at a very high expense. The investment costs have tentatively been estimated of being between 500 and 800 Crore.

For short-term measures to be effective and not only temporary, they should fit into such a long term solution. The execution of short-term measures can therefore only be effective if it is immediately associated with a commitment for the implementation of the long term river training strategic plan, for which, as stated above, studies still have to be made.

2.3 Considerations for the Short-term Study

2.3.1 Iterative Approach

Feasibility studies for infrastructural projects in general are made in order to demonstrate the technical feasibility and economic viability of a Project as well as its effects on socio-economics and environment. As part of these studies it is normal, as a first step, to collect data and to visit project sites. A second step is to carry out site investigations and other surveys and to define and carry out model testing (mathematical and physical). A third step would be the development of alternative designs followed by costing and benefit evaluation.

In the case of the three priority sites a fourth step (detailed design of selected alternative(s) and a fifth step (tender documents) have been made.

Preferably all five steps should be made consecutively. However, in practice this would mean that 18-24 months would be required. In reality only 14 months were available (incl. the two months lost due to the situation in Bangladesh in November 1990 - February 1991).

This problem was partly solved by adoption of the priority ranking of sites (Section 1.2). There was, however, still a serious budget and time constraint for this Short-Term Study of 8 (eight !) different sites along Meghna and Dhaleswari.

The only solution in such case is the iterative approach: activities which should be carried out consecutively have now been carried out parallel to each other. It implies that many assumptions had to be made which at a later date had to be corrected. Such an approach may work or it may not work. In this case it worked for a number of study features but it did not work for the scale model testing at RRI. In fact, the Consultants were still eagerly awaiting the report on these studies at the time final designs and tender documents on the basis of earlier assumptions had to be made.

2.3.2 Balanced Study Required

Another aspect of a Feasibility Study was the need to produce a balanced study. "Balanced" in this context means that all aspects whi-' ...e relevant to the Study should be studied to a degree which matches their relative importance in the Study. This implies for instance that the environmental effects must definitely be looked at but also that their importance in bank protection works does not warrant a comprehensive and detailed study. In this case an environmental impact assessment (EIA) will do.

The Study recognizes activities which are highly interrelated and dependent on each other (like geotechnical investigation and design) but also isolated activities which can wait until the designs have been completed (like EIA, monitoring and maintenance and tender documents).

2.3.3 Lack of Data

Finally, it always should be borne in mind that there is a general scarcity of reliable and comprehensive data about the river system in Bangladesh. This concerns especially the development of plan forms, geomorphology, river morphology and environmental data. Such data are also lacking on, for instance, geotechnics but here, by carrying out-site investigations, the situation can be remedied in a short period.

It must also be emphasized that for a medium size river like the Upper Meghna, a lack of data can be overcome by correlation of certain parameters with these of other similar rivers elsewhere.

Obviously, this principle can not be adhered to for the Lower Meghna. Here, not only the lack of data is very great but also this river is one of the largest (no. 3 after Amazona and Congo) in the World. This ...ct warrants a careful approach.

2.4 Data, Technical Surveys and Model Testing

2.4.1 Data and Site Visits

Apart from collection of easy accessible data in the initial (Inception) Phase the Consultants have made a great effort to collect additional data by means of site visits, surveys, and model testing.

Site visits were already made during the Reconnaissance Mission (August-September 1990). These visits provided a good introduction to the erosion problems at the various sites.

2.4.2 Surveys

It was felt that geotechnical, topographic, bathymetrical and hydrometric surveys would be required and these have subsequently been carried out in close co-operation with the Morphology Division of BWDB. These surveys served the following purposes:

- input for hydrological and morphological studies;
- provision boundary limits and bathymetry for scale model testing;
- plan of local situation and departure point for structural bank protection designs.

An important feature of the surveys was the timing of the bathymetric and hydrometric surveys.

This timing is of interest because of seasonal variations in river discharge and bed level as well as for a timely input of data for the mathematical and model testing.

2.4.3 Scale Model Testing

After review of the different bank erosion problems it was felt th[illegible] model investigations would be required as follows:

(i) For Bhairab Bazar some additional tests would be made in the distorted flow field model at RRI. The model which had been used for the study of conditions upstream of the Railway Bridge was extended in order to study possible bank protection works at Bhairab Bazar also.

(ii) For Chandpur a local scour model has been defined and constructed and used to study existing bank erosion and to propose sound short-term solutions.

(iii) For Eklashpur a local scour model was constructed in order to study the connection and the interrelationship of an eroding retreating bank with isolated bank protection works in front. The results of such a Study are also relevant to the situation at Haimchar.

2.4.4 Mathematical Model Testing

The purpose of mathematical modelling in this case was to provide boundary conditions for scale model investigations.

This mathematical modelling would be based on present (field measurement) and future bed topography. The latter in turn was arrived at through morphological analysis in combination with professional judgement.

For these mathematical model simulations a 2-dimensional depth averaged flow field model was used (see Annex E for more details).

2.5 Studies

2.5.1 Geomorphological Analysis

The geomorphological study was made to obtain a better understanding (read: sufficient for study purposes !) of the geomorphological behaviour of the Meghna River:

- to allow for the design of short-term bank protection works along the Meghna River;
- to enable the drafting of the ToR for the study to establish a Long-Term Strategic Plan.

Moreover, insight was obtained in the celerity of bank erosion processes which in turn determined whether measures would be required at short notice or not.

The analysis was only made after collection of maps, satellite images, soundings, results from earlier mentioned surveys, etc.

2.5.2 Hydrological Studies

Purpose of the hydrological studies was to determine hydrological boundary conditions for the design of the bank protection works.

These boundary conditions for each of the seven sites considered, included:

flood levels for various return periods,

- water level range along the sites during the dry season,
- maximum flow velocities near the bank protection, and
- wind speed and direction and wave data.

For further details reference is made to Section 3.7 and to Annex A.

2.5.3 Design Studies

The design studies started with the collection of topographic and bathymetric data. On the basis of the site visits alternative solutions for bank protection works were then formulated and analyzed.

In the design studies the results of geotechnical investigations, surveys, hydrological and geomorphological studies are used as a basis for the design. Moreover, features like available construction materials, design standards (deterministic or probabilistic approach) construction methods and available equipment play an important role.

The Consultants carried out separate sub-studies for each of these features. Though the bank protection works as proposed for the sites on the Upper Meghna are not unique in size and degree of difficulty to construct, such works have so far never been made in Bangladesh at such scale and based on such high quality of construction as now envisaged.

Bank protection works along the Lower Meghna and especially at Chandpur are definitely unique because of the necessity to carry out dredging and hydraulic fill operations as well as slope protection works at great depths and in high currents.

The application of the probabilistic approach in the design yields the opportunity to assess risks of failure of various alternative measures, building materials and construction methods. It also results in most cases in economical designs as over-dimensioning is avoided.

2.5.4 Environmental Impact Assessment

More and more nowadays an environmental impact assessment (EIA) has become an essential part of any study concerned with infraestructural works. Also for this Meghna short-term study an EIA has been made for all works (i.e erosion protection projects) envisaged. As will be explained in Chapter 7 it is not easy to carry out an EIA in Bangladesh as most of the information one would like to have is lacking and can not be collected in the limited study period. On the other hand the impact on the environment of the type of works envisaged is rather limited which compensates for the lack of data.

Two objectives were formulated in the Terms of Reference:

- evaluation of potential negative impacts which river bank protection may have on the environment; and
- proposition of measures to prevent, lessen or compensate the identified environmental impacts.

For further details reference is made to Chapter 7 and Annex I.

2.5.5 Monitoring and Maintenance

The T.O.R. explicitly require the Consultants to prepare a detailed description of requirements for monitoring and maintenance as well as the institutional and budgeting implications involved. For further details reference is made to Chapter 9 and to Annex G.

2.6 Socio-economic Evaluation

For an evaluation of the real benefits of the project, information on the present and future situation without project implementation will have to be compared with the situation after implementation of the various short-term bank protection works.

This means that a set of baseline data had to be collected at the start of the project. This information can be subdivided into several categories including agro-economic data, social and demographic data, data on annual recurrent operation and maintenance costs of existing embankments, annual or regularly occurring infrastructural damages and losses because of bank erosion, etc. Such information was collected from official statistical sources.

During the inception phase and afterwards, no substantial information on these subjects could be collected and analyzed. It appeared, moreover, that official statistics are generally lacking. It means that the depth to which the socio-economic analysis could be conducted was seriously limited and that a comparatively large part of the available time had to be spent in collecting basic information and making professional guesses.

Based on the site visits and the information collected, a general inventory could be made of the interests affected by the erosion problems: bridges, agricultural land, houses, godowns, shops, mills, factories, small industries, bazars, ghats, schools, government buildings, flood embankments, irrigation infrastructure, pump houses, etc. Subsequently, however, socio-economic values of these interests and the damages experienced due to erosion problems were quantified.

To estimate key information such as the value of infrastructure in the different towns, the value of irrigated and non-irrigated land at the different sites, the costs involved in maintenance and operation of the infrastructure of the irrigation districts, etc, use was made in so far as possible, of socio-economic studies already carried out by the Department of Geography of the Jahangirnagar University, Savar, Dhaka.

In agreement with the Terms of Reference and in line with the findings of the Inception Phase the costs and benefits of the short-term bank protection works will be determined in global rather than in detailed terms.

2.7 Tender Documents

The tender documents for bank protection works to be carried out at the five sites (see Section 1.2) have been drawn up on the basis of ICB (international competitive bidding) as laid down by the World Bank in its Guidelines for Procurement and in its Sample Bidding Documents for Procurement of Works (September 1985).

The Consultants were recently (1989-90) involved in the drafting of tender documents for the river training works for the Jamuna Bridge. This has enabled hem to prepare the tender documents the Meghna bank protection works in an efficient way. Especially the Specification and Bill of Quantities have been drawn up bearing in mind the nature and magnitude of the river engineering works concerned. Departure point has been the construction of these works by large international contractors specialized in hydraulic engineering and coastal works.

2.8 Terms of Reference to Establish the Meghna River Long-Term Strategic Plan

Terms of Reference have been drawn up for the Meghna River Long Term Strategic Plan, aiming at a long-term development plan within which the short-term river bank protection works will fit.

The Terms of Reference have been defined for a study which will:

(1) provide insight in the long-term natural changes in the planform of the Upper and Lower Meghna Rivers;

(2) indicate the influence of the various FAP and other previous and future projects along the Upper and Lower Meghna Rivers on the morphological behaviour of these rivers;

(3) determine the influence of river training works on the natural planform development, allowing to design an appropriate and long-term strategy for sustainable river training of the Upper and Lower Meghna Rivers;

(4) assist in providing boundary conditions for river training works to be designed along the Upper and Lower Meghna Rivers;

(5) generate the boundary conditions for the mathematical and physical model studies to be carried out to generate these and other boundary conditions;

(6) provide the morphological data required for the evaluation of alternative methods for controlling the Upper and Lower Meghna Rivers, like large scale dredging, floating vanes, etc. using the results of FAP 22 as far as available during the period of the assessment;

(7) identify long-term measures against river bank erosion, their relative priority and their technical and economic feasibility;

(8) identify river training schemes suitable for the permanent protection of the river banks;

(9) prepare an implementation schedule for a phased implementation of such training schemes and other measures to be taken;

(10) prepare cost estimates for implementation and maintenance of the long term strategic plan.

As the short-term study has demonstrated the importance of the morphological processes in the Padma River for the bank erosion and scour processes in the Lower Meghna River, it is imperative to include the analysis of the morphological processes in the Padma River downstream of Mawa into the present study. The results of the morphological study will be used for the design of the river training works on a probabilistic basis. Hence the results of the morphological study should reflect the stochastic behaviour of the different phenomena like bank erosion and scour to allow such a probabilistic approach.

The terms of reference are not included in this Report and will be submitted separately.

ଓ2

3. ENGINEERING INVESTIGATIONS AND SITE ASSESSMENTS

3.1 General

The data collection, site investigations, surveys, analysis and desk studies carried out as part of the engineering feasibility Study and for preparation of detailed designs and tender documents for bank protection works at selected locations had largely to be undertaken as parallel activities, although mostly interrelated with each other.

These various activities . . eported in detail in the Annexes A, B and C to this Main Report and are summarized briefly in this Chapter to assist an overall appreciation and understanding of the interrelationships.

3.2 Geology

The project area is located on the eastern flank of the Indian Platform, in the transition (or hinge) zone between the continental shelf and the Bengal Basin. The Meghna flows across this zone towards the Bengal Basin on deep sediments which overlie pre-cambrian basement rock, The basin is bounded by the Dauki fault in the north, and the Tripura folded belt in the east. Both features are part of the orogenic belt of the Himalayas, with continuing tectonic movements causing severe earthquakes in the region. Regional tectonics are believed to determine the course of many rivers in Bangladesh.

The entire project area lies within the delta that has been formed by the deposition of sediments carried by the Meghna (7 sites) and Dhaleswari (Munshiganj). There is only minor topographical relief within the project area.

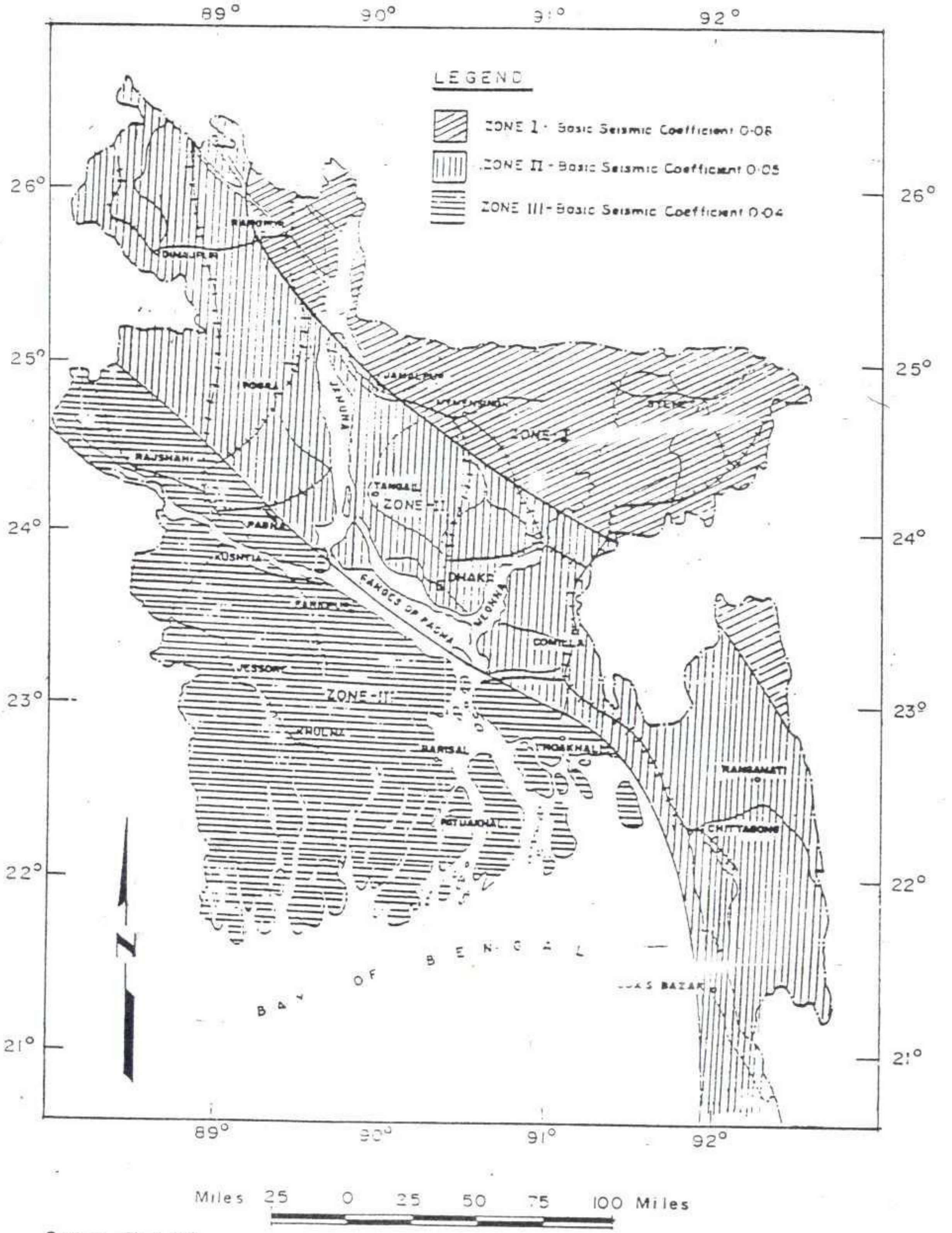
The top layer in the project area is made up of fluvial deposits of recent to sub-recent origin. Very fine textured soils comprise the bulk portion of the project area while the remainder is moderately fine, with a high silt content and a mica admixture as prominent features.

3.3 Seismicity

The Bengal Basin is located in a seismically very active region. This clearly has a major influence on the design of the proposed river bank protection works.

The seismic events affecting Bangladesh were studied by a Committee of Experts on Earthquake Hazard Minimisation which published a report entitled "Seismic Zone Map of Bangladesh and Outline of a Code for Earthquake Resistant Design of Structures" the Committee recommended Bangladesh to be Sub-divided into three zones I, II and III (Fig. 3.1).

The project area is situated in Zones II & III,. These zones were classified with basic horizontal seismic coefficients of 0.05 and 0.04 respectively. Considering source distance of major earthquakes of the past, being well over 100 km from any of the sites, a value of 0.05 as the basic horizontal seismic coefficient for slope stability will be adopted.



Source : Ref. 20

ZONES OF SEISMICITY IN BANGLADESH	FIGURE 3.1

৩৪

3.4 Geotechnical data

3.4.1 General

During the initial stages of the project study, geotechnical data were collected from various organizations for the Meghna River Study. These data related to projects executed by BWDB, R & H Directorate, Bangladesh Railway etc., as part of development activities, investigations and feasibility studies. These data were evaluated to allow specifications to be drawn up for additional in-depth investigations in support of this study.

Conclusions of the Inception Report gave priority to 4 out of 8 locations for an in-depth geotechnical evaluation. These locations are at Bhairab Bazar Railway Bridge, Bhairab Bazar Town, Munshiganj and Chandpur.

The site investigation comprised sinking of 8 bore holes (2 bore holes per site, depths of 20-30m), in conjunction with sampling and Standard Penetration Testing. Extracted undisturbed and disturbed samples were tested in the laboratory for strength properties, classification, granulometry and chemical composition.

Stand pipe piezometers were installed, to monitor ground water level movements in relation to river levels.

Additional site information was derived from the visual inspection of the endangered sites and the analysis of topographic and bathymetric surveys, in order to ascertain the nature of the events taking place. This information served to better identify the failure mechanisms taking place and enabled definition of geotechnical design criteria.

The overall assessment and choice of design parameters, to allow slope stability analyses to be carried out, was supplemented by data concerning the geological features and earthquake criteria attributed to the project area.

Detailed analyses and review of data are presented in Annex C, Geotechnical Investigations.

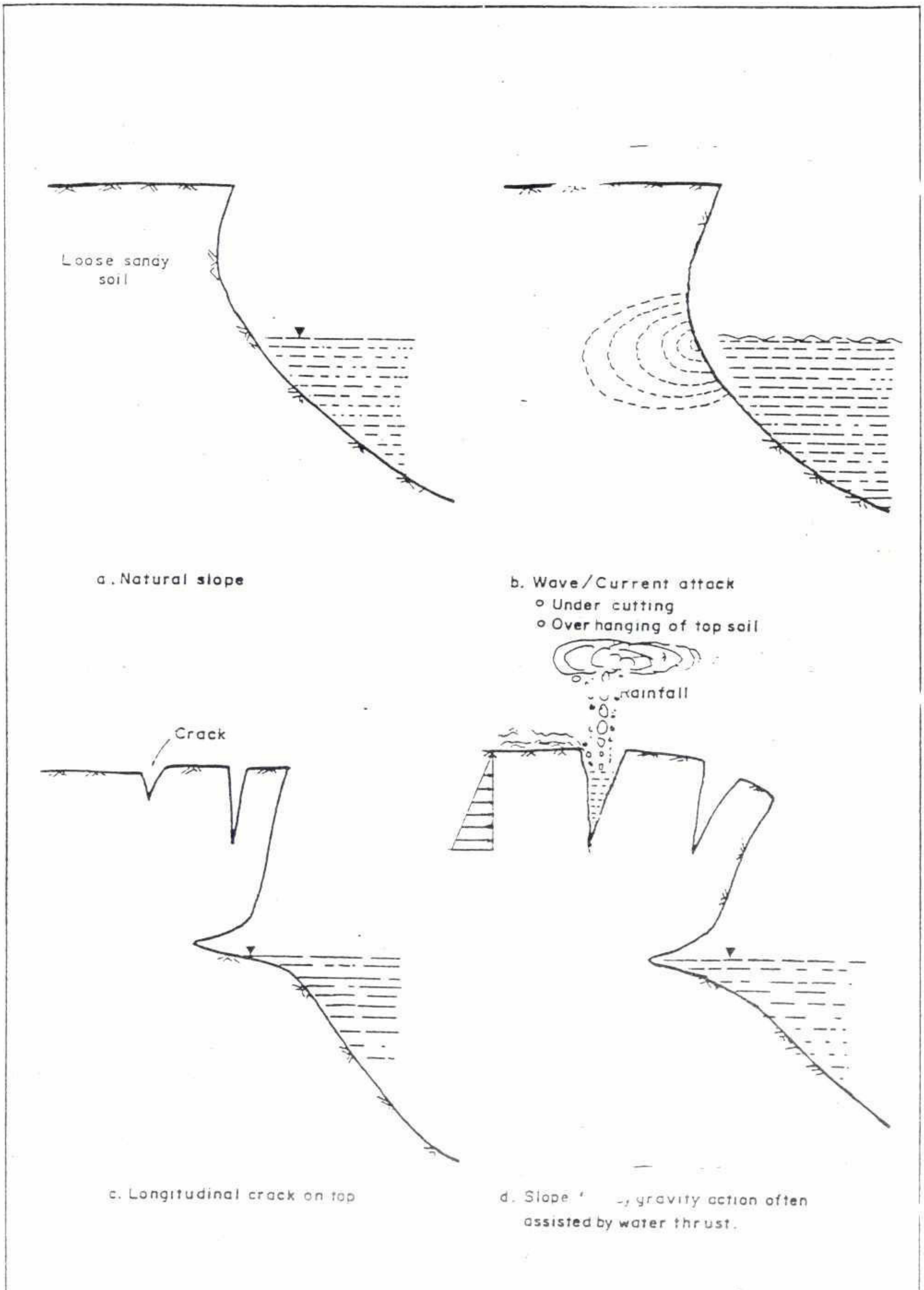
3.4.2 Slope stability considerations

It has been recognized that exposed slopes, mainly developed at the outer bends of the river bed, are most prone to the effects of the erosive action of currents. Wave attack may further aggravate the erosion of surface layers.

The visible effects of receding river banks, however, mainly originate in the events taking place below water level. Here alternating effects of inwardly and outwardly directed water flow perpendicular to the slope surface, in conjunction with the erosive action of the current, contribute to temporary stability and unbalance respectively (Fig. 3.2).

The latter phenomenon creates conditions of oversteep slopes and critical conditions where slope angles of 1:1.5 and 1:1 can just be sustained. Applying slope protection, without changing slope angles, will only suppress some of the erosion phenomena, while the slope itself will remain in a critical state, i.e. having a safety factor of n = 1. This overall slope stability behaviour is being referred to as macro slope stability.

Remedial works, pursuing long lasting protection, should cater for flattening of slope angles and reduction of the effects of alternating flow patterns as well as for wave attack. The reduction of the slope angle will result in a reduction of the developed shear stresses, as origin of slope stability, with regard to the ultimate shear resistance, which parameters have been derived from laboratory tests. The ratio between those two shear stress parameters is denoted as the "safety factor".



GEOTECHNICAL FAILURE MECHANISM | FIGURE 3.2

Slope protection will serve to control the effects of currents, wave attack and alternating flow patterns, to ensure that an overall stable slope angle will remain intact. This slope stability condition is being referred to as micro slope stability.

Stable slopes can be defined, via introduction of a safety factor, by limiting the magnitude of the developed shear stress during a permanent loading condition. When allowing for the effects of e.g. earthquake loading, as an incidental short term event, some elasto-plastic deformations are regarded acceptable. This means that a lower factor of safety can be accepted. Safety factors and loading conditions reflecting international design recommendations are presented in the next paragraph.

Safety factors have to be taken into account for the overall slope and structural elements forming part of that slope, i.e. the slope protection and underlying layers. The effect of earthquake loading, causing the slope to move in relation to its base, will mainly result in displacements of the whole slope body. The slope protection will form an integral part of this body. Consequently, no seismic loading needs to be allowed for when designing the slope protection.

Slope stability analyses will have to satisfy the following safety factors:

n = 1.5 : for permanent loading (including effects of ground water flow), governing macro and micro-stability;

n = 1.1 : when allowing for the effect of earthquake loading as well but for macro-stability only.

The encountered layering per location served, when possible, to establish the likely course of failure. Consequently, specific layering may affect details of remedial works as well. It can be concluded that:

(i) The consistency of layering in general warrants the conclusion that the engineering characteristics of present sites have been explored sufficiently;

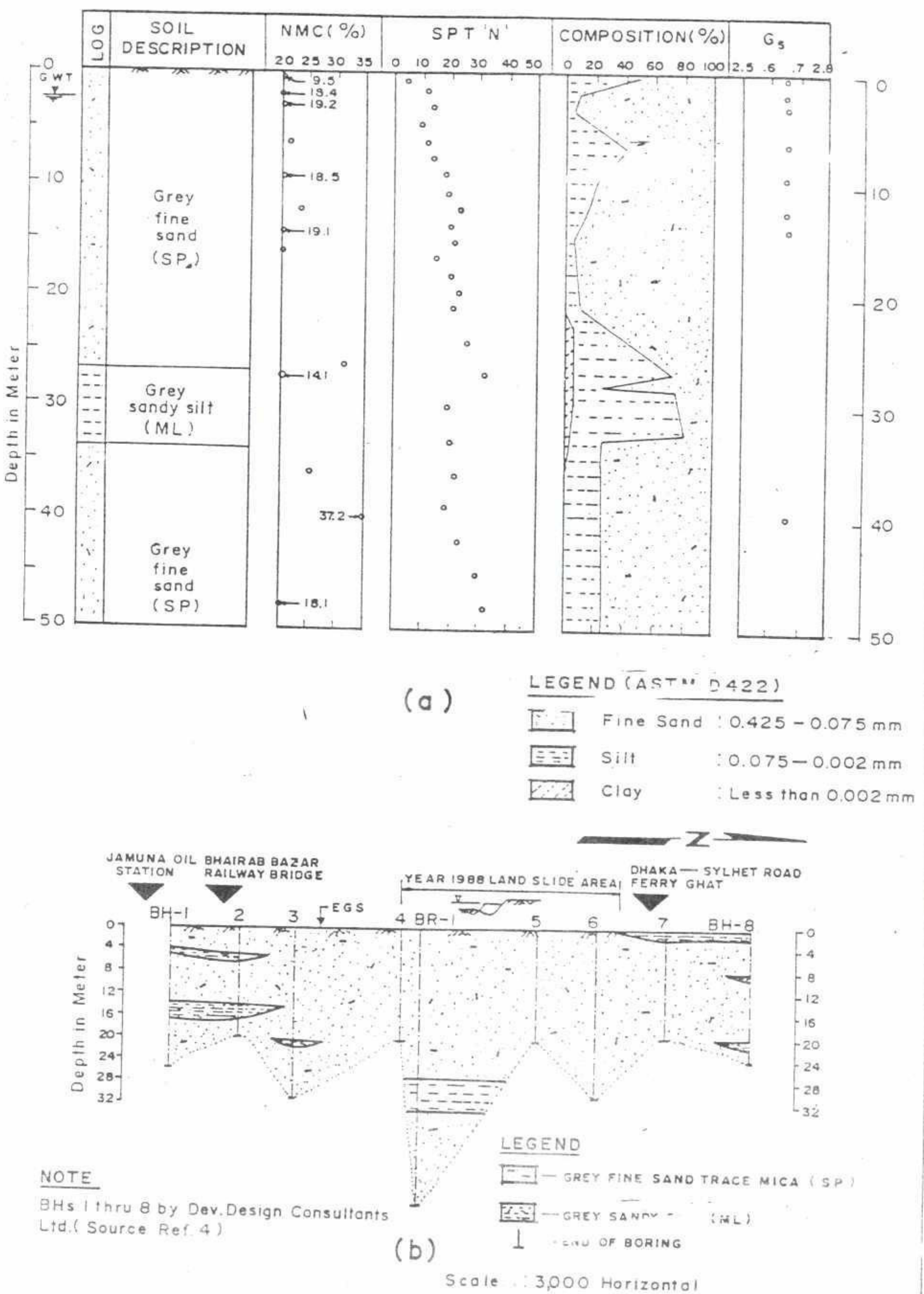
(ii) The evidence of 3 distinct layers within a stretch of 120km allows general design parameters to be established for each of them.

The layer designation, neither defining sequence nor thickness, is presented below. Based on bore logs and laboratory tests layers can be classified accordingly (Fig. 3.3 and 3.4).

Table 3.1 - LAYER DESIGNATION FOR MICACEOUS SAND AND SILT

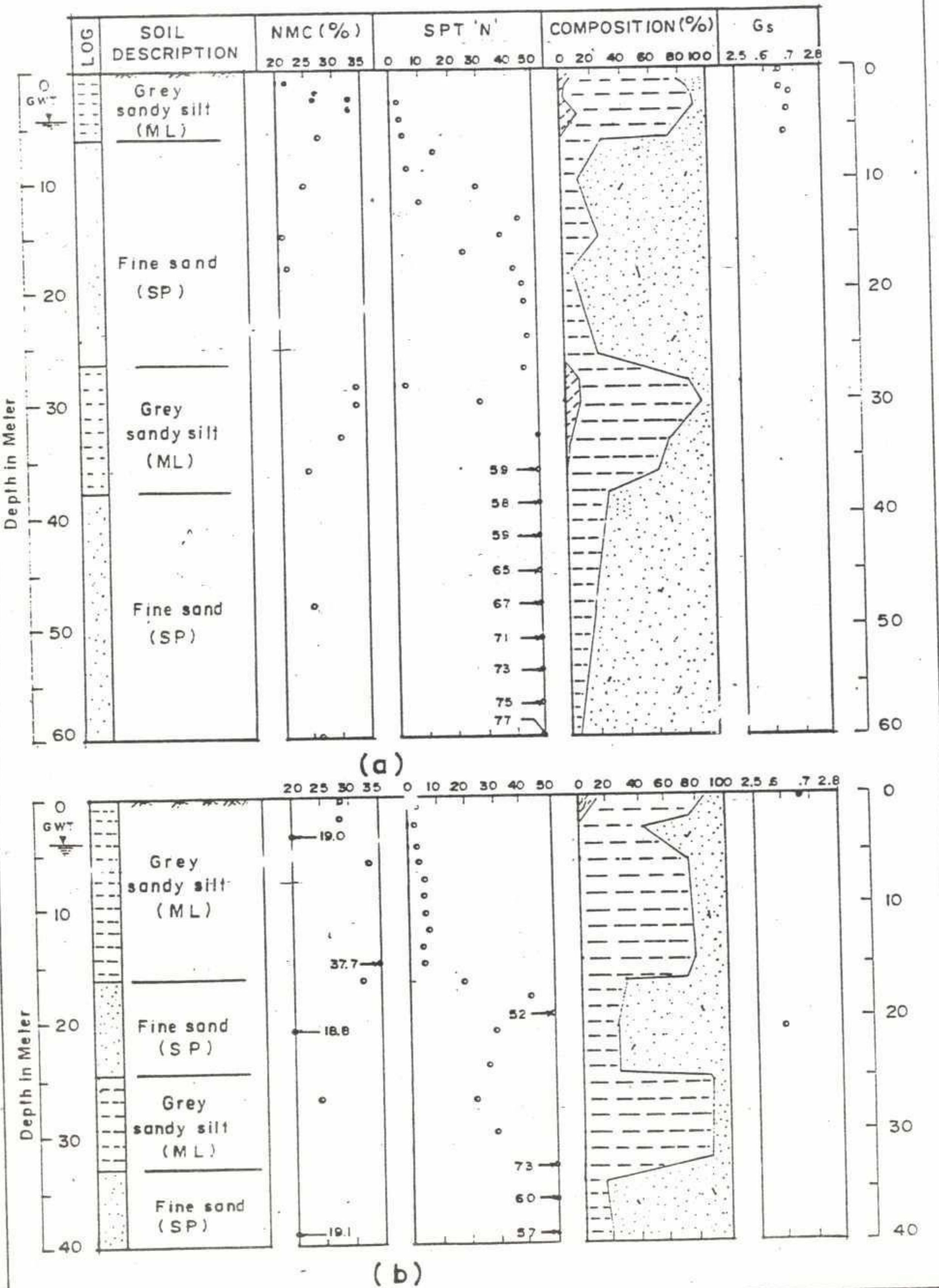
Layer	Description	Composition (%)		
		fines.	silt	clay
I	FINE SAND, with silt	60-95	5-40	-
II	SILT, with f. sand and clay	5-40	60-80	2-10
III	SILT, with f. sand and clay	5-10	70-80	10-20

There is a general trend for the layers to be more silty in the upper layers (10 - 15m) and to be more sandy at greater depth. One boring near Munshiganj shows the presence of a distinct clayey silt layer (III) to a depth of approx. 30m. A similar, more isolated layer, has also been encountered at Bhairab Bazar, at the location of the bank slide.



TEST RESULT BHAIRAB BAZAR (a) AND STRATIGRAPHY THROUGH SITE (b)

FIGURE 3.3



a) TEST RESULTS FROM CH-1 AT CHANDPUR b) TEST RESULT FROM CH-2 AT CHANDPUR	FIGURE NO. 3.4

3.5 Geomorphology

In the past (i.e. before 1780) the Brahmaputra River joined the Meghna at Bhairab Bazar, so the Meghna carried also the discharge of the Brahmaputra. The actual discharge is therefore less than before the major avulsion of the Brahmaputra.

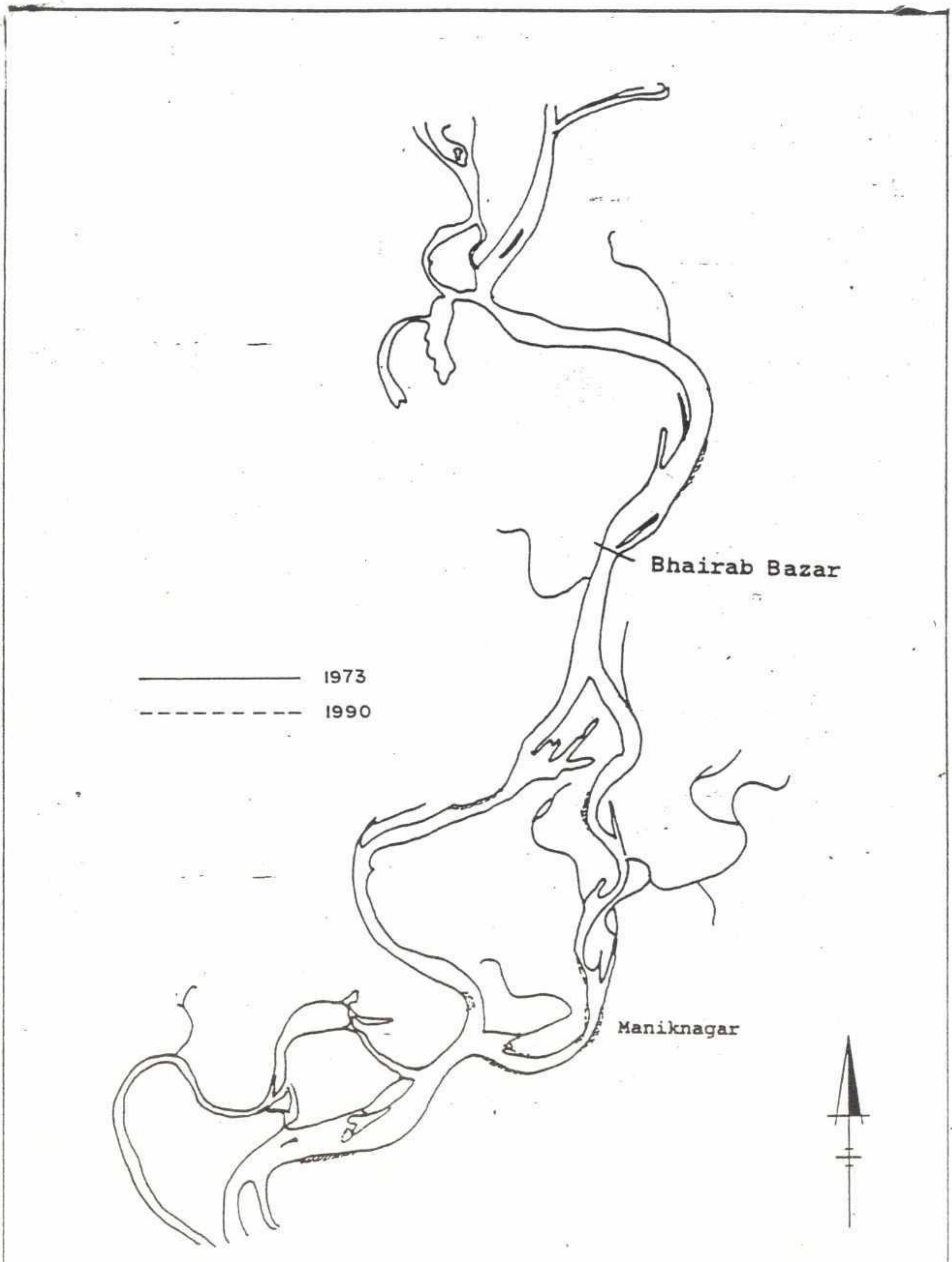
In this respect it should be pointed out that the Upper and the Lower Meghna river are two completely different rivers. In the past, when the Brahmaputra River still followed its old (Old Brahmaputra River) course, the Lower Meghna River could be viewed as the downstream reach of the Upper Meghna River. This was the more so, because the Ganges River at that time had a different outlet to the Bay of Bengal. Nowadays, however, the Upper Meghna is just a smaller tributary to the Ganges/Jamuna-Padma-Lower Meghna Rivers system. Hence, very often in this Report, the Upper and the Lower Meghna have been treated separately. Even more, for an understanding of the processes in the Lower Meghna one should include an analysis of the river processes in the Padma River, rather than consider the Upper Meghna in this respect. This explains why often the lower reach of the Padma River has been included in the analysis too.

The Upper Meghna flows through probably, structurally, the most active part of the Bengal Basin, notably the Sylhet depression. This Sylhet basin has subsided about 10 metres within the last several hundred years. This subsidence may be a combination of compaction together with tectonic activity (related to the major fault system bounding the northern side of the area). Together with the compaction and the tectonic activity another factor affects the drainage of the Sylhet area. This deeply flooded area is in fact an area which is inundated by the backwaters of the Ganges and the Jamuna. Because of the high water levels in these rivers, the floods from the Sylhet area do not have sufficient slope to be rapidly evacuated to the bay of Bengal. This "impeded drainage" causes the floodwaters to accumulate in the deeply flooded area, causing silting up, and so create an enormous basin which only gradually drains into the Meghna. The prevailing morphological action in this upper catchment area is sedimentation rather than erosion.

An interesting fact of the Upper Meghna is that branches of the river which are relatively unimportant in the sense that they carry little water in comparison with the main channel, not seem to change over the years as shown in Figure 3.5. For example at a certain point one sees many channels. Only one channel carries a great deal of the total conveyance. The relative importance of this channel is great. The other, relative unimportant, channels do not seem to be filled up with sediment in a period of 8 years, although one expects that the velocity in these small channels will not be high. The depth of these small channels is about 2 m. and seems to stay about 2 m.

The Lower Meghna is, in fact, the continuation of the Padma River with peak discharges in the order of 150.000 m3/s. The river system is characterized by a wide river bed of several kilometres in which various channels develop in combination with large propagating sand bars (locally called chars). Going downstream, the Padma increases its width just before the confluence with the upper Meghna. Together with this increase in width, the dimensions of the chars in the floodplain of the Padma increase. The Upper Meghna can be considered as a tributary of the Padma. The stages along the Lower Meghna are subject to tidal influence. During low flows in the Lower Meghna River the tidal range near the confluence with the Upper Meghna is about 0.4 m.

To get a clear view of the morphological changes of the Lower Meghna the satellite "thick" images of the available years were compared with each other. To do this the different images have to be on the same scale and water levels have to be approximately equal. Applying the procedure described in Annex B Section B.3.4, ensured that these conditions were approximately fulfilled.



Comparison .. pıanform from satellite images of 1973 and 1990	Figure 3.5

In this study the available ("historical") data were collected and some surveys were done to do additional measurements. The collected data consisted of maps, satellite images, soundings, sediment transport data in addition to the hydrological data. Additional measurements were carried out during surveys in February and September of 1991. During these surveys mainly soundings were made for use in the physical and mathematical modelling, but these data were also useful for the present Study as they provided quite detailed information. Also bed samples were taken during these surveys and the samples were analyzed at RRI (River Research Institute in Faridpur). Due to a number of reasons this data collection phase extended to September 1991.

Satellite images did not reveal significant changes. Changes which were visible on the different images were very small, too small to ascribe them to erosion or sedimentation processes rather than differences in scale of the different satellite images. Erosion of the river bank does occur at the Upper Meghna, but is so small that studies on the basis of the available data reveal no clear picture of the extent of erosion and sedimentation.

3.6 River Morphology

The technical study of the river morphology was required to improve the understanding of riverine processes in Bangladesh' major rivers in general and in the Meghna River in particular.

Two main issues have a direct bearing on the design of the proposed bank protection projects :

- future planform development of the river at and near the various bank protection sites.
- maximum scour that may occur at the foundation level of the bank protection works.

Though some major bridges and bank protection works have been constructed in the past on the Meghna River the designs for these works were in general not based on extensive surveys and measurements.

This is understandable as :

- data collection in developing countries does not always have high priority and is usually carried out over a short period only as part of a study for a specific project;
- data collection on a large river especially when it is a very wide river with various channels in combination with large propagating sand bars as the Lower Meghna is particularly cumbersome, difficult and expensive.

Because of time and budget constraints is was not possible for this Short-Term Study to organise and execute an elaborate programme of surveys and measurements. If that had been possible a better understanding of scour development (specially at Chandpur) and planform development would have resulted. Nevertheless, Consultants are satisfied that sufficient data have been collected and analyzed to allow forecasting of riverine processes (partly as a consequence of implementation of proposed bank protection works) with a reasonable degree of accuracy.

Possible overall trends of the planform changes of the Upper Meghna River were studied on the basis of maps, satellite images and BWDB cross-sections. Satellite images are available since 1973, whereas the available BWDB cross-sections cover only the last 10 years. Only the maps cover a much longer period, but the large time intervals between the maps and their inaccuracy make the interpretation more difficult.

Use was made of all the available information, notably old maps, satellite images, BWDB soundings, BIWTA sounding charts and other information. Also quite extensively use was made of the results of a study carried out fairly recently by Galay (1980), which attempted to analyze the changes in the Lower Meghna River too.

Comparison of the available **maps** reveals definite changes. When the course of the Upper Meghna in 1960 is compared with the course in 1776, the decrease in size of the river channel is clearly visible Furthermore it can be noticed that the number of parallel channels has decreased significantly. Nevertheless the present Upper Meghna course is approximately corresponding with previous Brahmaputra channels. This is slightly amazing as it was noted that in a braided river like the Jamuna River the channel pattern changes quickly while it is not certain that the major avulsion of the Brahmaputra River occurred in a very short time and immediately after the preparation of Rennell's map. Therefore some doubt is present as to the foregoing conclusion. Furthermore it should be realized that the comparison between these two maps is not reliable as a result of the limited accuracy of the Rennell's map (not being based on aerial photography).

Comparison of the other available maps (1860, 1953 and 1960) does reveal changes in the Upper Meghna course (see Annex B Figure B.5.2). Near the confluence Dhaleswari - Upper Meghna the some major changes can be identified clearly:

(1) In the Dhaleswari River upstream of the confluence with the Lakhya River the evolution of a cutoff can be followed: between 1860 and 1953 the bend radius of the bend just upstream of the Lakhya junction decreases, resulting in a cut off; in 1960 the old channel has been abandoned.

(2) The bends of the channel just upstream of the Dhaleswari - Upper Meghna confluence become more pronounced, as the bend radii become smaller.

Other changes have also occurred but the accuracy of the maps does not allow to draw definitive conclusions. Analysis of the available **cross-sections** showed that planform properties and location of the river banks have not changed much. Four cross sections are analyzed in a more extensive way. In one of the cross sections, (M#14), a shifting of the 50 % conveyance point was significant. This shifting, however, was not of a systematic nature: the 50 % conveyance point moved in either of the two possible directions (to the right or to the left bank). Other available cross-sections were also analyzed and it appeared that location, width and depth remained the same (Figure 3.6).

For easy reference the following observations regarding the channel and bar system in the Padma/Meghna River system are repeated here:

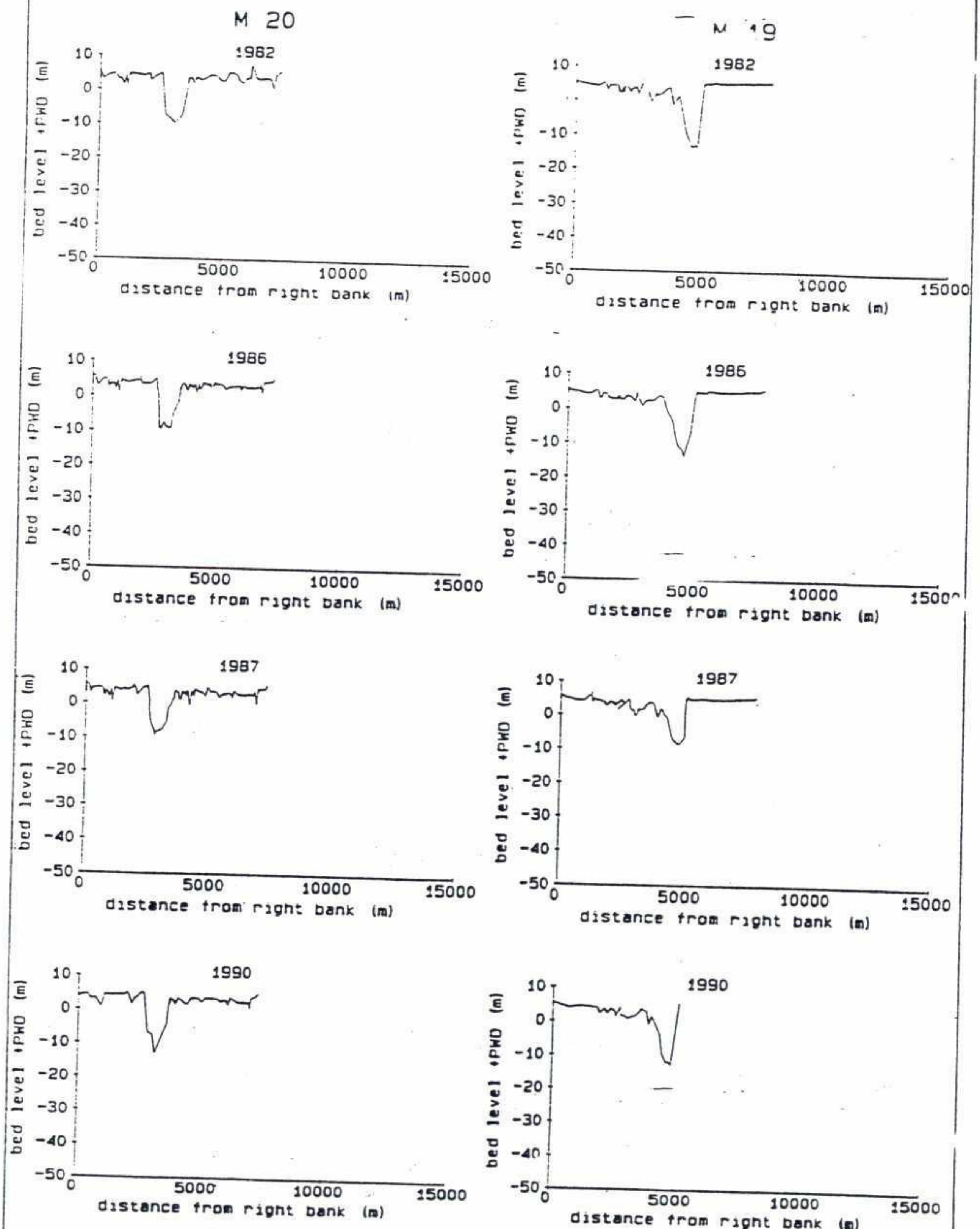
- Plan form characteristics of the Upper Meghna have remained essentially the same over the last decades. Special mention should be made of the confluence of Dhaleswari and Upper Meghna. Here the Dhaleswari shows a tendency of gradual widening during the last 15 years.

  The overall trend of the planform movement of the Lower Meghna River is different from the Upper Meghna River, where changes of the planform are minor only, in the Lower Meghna River major changes are taking place.

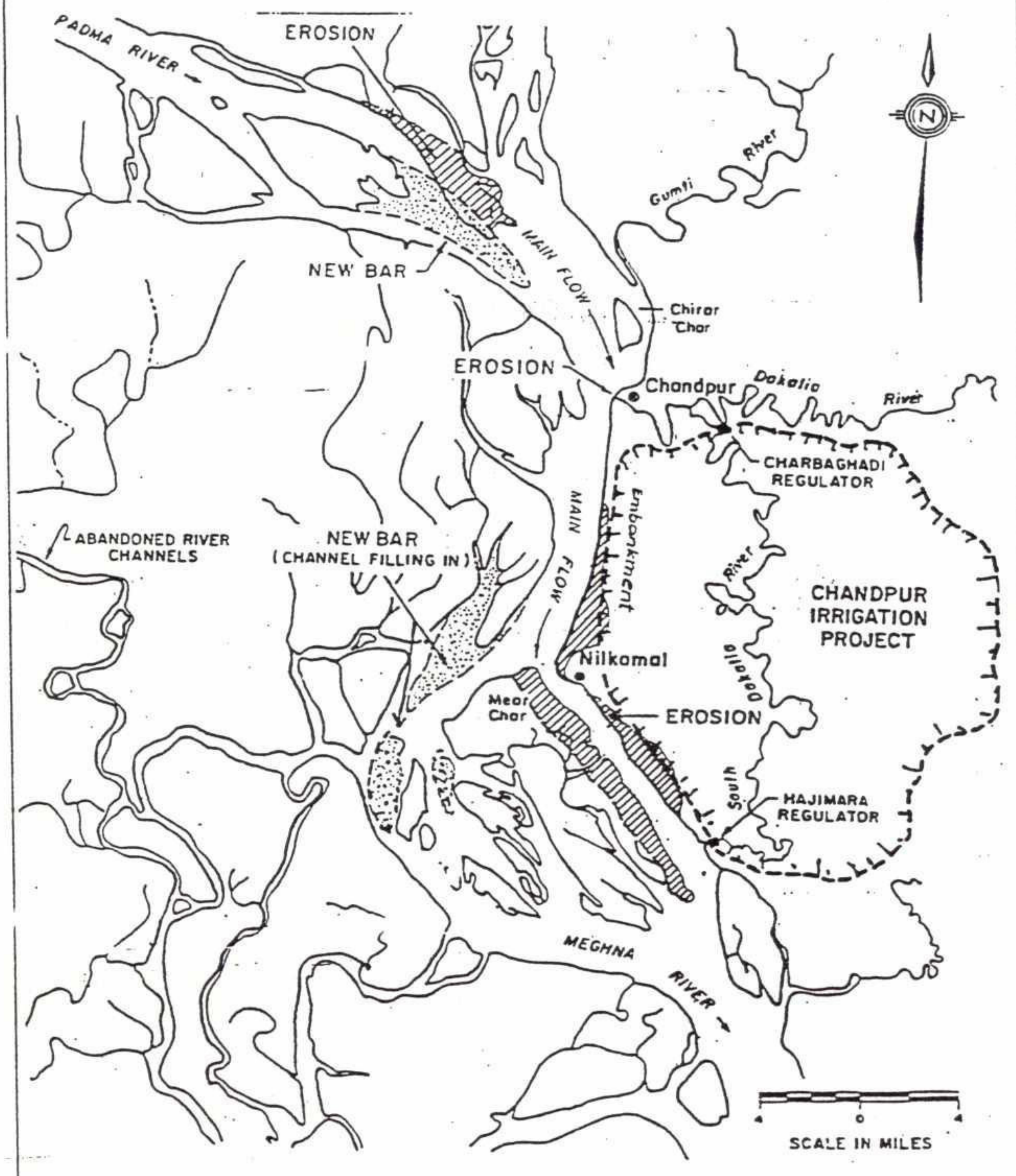
  The present morphology at the confluence of the Padma and Lower Meghna Rivers is such that the width of the cross-sections increases considerably before the confluence, leading to a decrease of stream velocity and consequently the generation of large chars. These chars influence the course of the channels. Erosion on the upstream end and sedimentation on the downstream end of the chars result in the downstream movement of the chars through the Padma River, into the direction of the confluence. Figure 3.7 shows the major changes due to the flood 1974 (Coulay 1980)

Because it was found that these bank line changes are closely related to the movement of the system of channels and bars in the combined Padma/Lower Meghna system, the whole system from Mawa along the Padma River down to Haimchar in the South was considered.

At the confluence the three rivers (the Padma, Upper Meghna and Lower Meghna Rivers) are determining the conditions. The discharge of the Upper Meghna River is relatively small in comparison to the other rivers, but its influence is not negligible. Chars entering the mouth of the Upper Meghna



Measured cross-sections M#20 and M#19 for the years 1982, 1986, 1987 and 1990	Figure 3.6



Major changes in the Lower Meghna River due to the 1974 flood (Galay, 1980)	Figure 3.7

River are being eroded by this river. In other words, a char in the Padma River can not block the Upper Meghna, hence there will always be a northern channel. This in contrast to what happens at the southern side, where a char can block the southern channel. This forces the river to convey the total discharge through one channel, which is located at the northern side and causes erosion near Eklashpur. Upstream of this char another char usually develops at the northern side, forcing the channel to flow more to the south and thus eroding the char which is present at the southern side of the floodplain. This process is going on until a cutoff takes place. The width of the channel at Chandpur is decreasing as a result of sedimentation on the right bank of the river, and the Lower Meghna River is becoming deeper.

From the above combined analysis of satellite images, old maps, soundings and cross sections the following conclusions may be drawn:

(1) chars migrate in the Padma River until they reach the [illegible] downstream the confluence, then the migration stops, and the char is being eroded;

(2) the position of a char, upstream of the confluence, is being taken in by the next char within a period of some 15 years;

(3) there has been a considerable amount of erosion at the left bank of the Padma and the Lower Meghna between 1952 and 1990:

- the erosion at the left bank near Eklashpur amounts about 3.25 km,
- the erosion at the left bank near Chandpur amounts about 2.75 km.

(4) in the period 1952-1990 the erosion of the left bank near Eklashpur has not been constant: in certain years erosion is not noticeable, while in other years the erosion rate is very large;

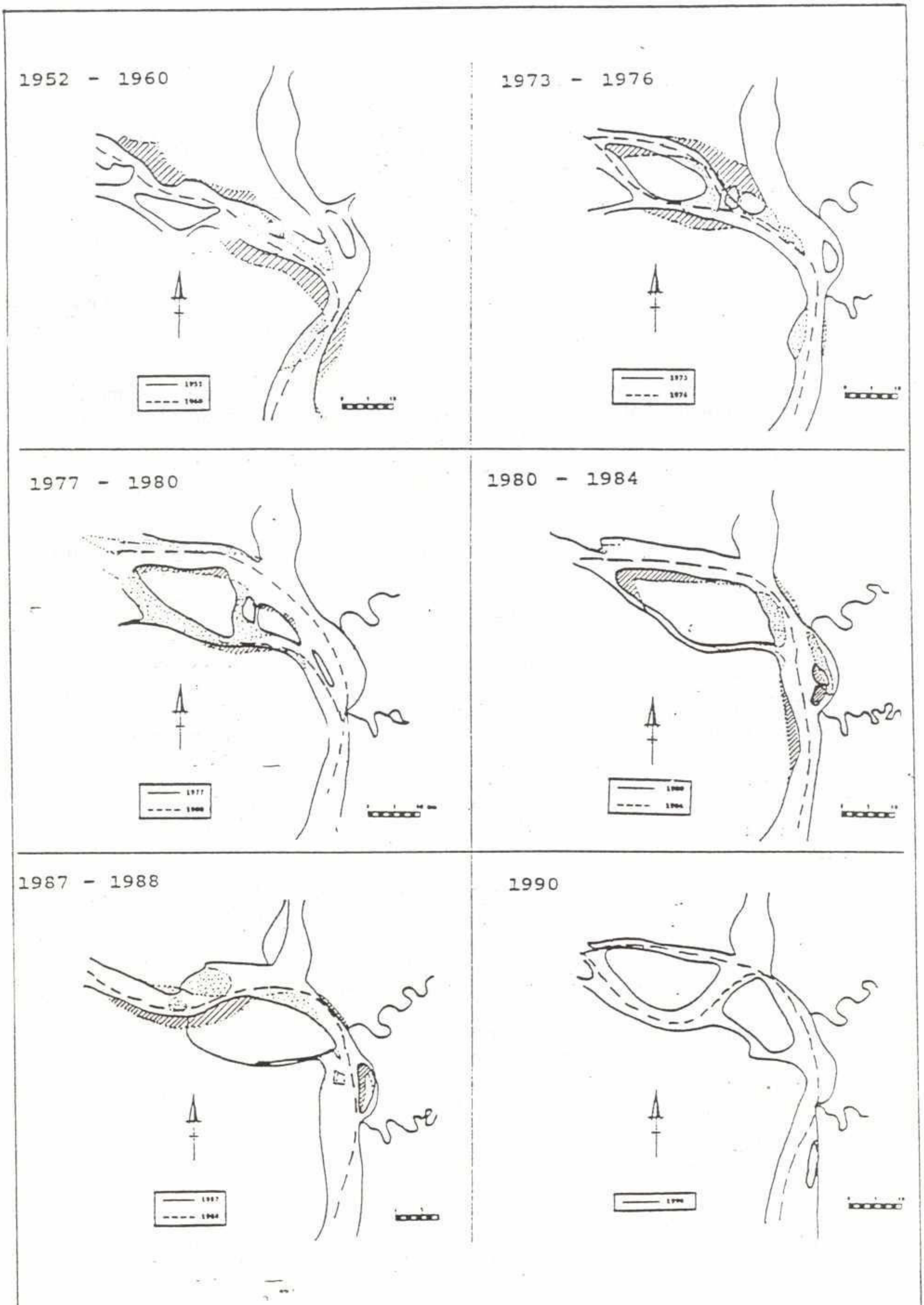
(5) the width and depth of the channel at Chandpur are correlated to and depend on the number of channels upstream and their angle of approach;

(6) the banks of the lowest reach of the Upper Meghna remain at the same location, no horizontal erosion is noticeable between 1982 and 1990;

(7) due to stabilization of the left bank at Chandpur after [illegible] erosion is noticeable on the available satellite images;

(8) erosion in vertical direction has continued after 1980, as was deduced from the comparison of the cross-sections at the Chandpur site.

Concluding it can be stated that the overall trend of the planform of the Lower Meghna near the confluence of the Padma River with the Upper Meghna River is a continuous movement in eastern direction. This is accomplished by continuous bank erosion along the long bend of the Lower Meghna river in southern direction. The location of the bank erosion varies depending on the channel pattern in the Padma River and seems to vary with a periodicity of some 15 years. It may well be that the cutoff of the channel south of Chandpur is the way the Lower Meghna River is trying to cope with the continuous movement of the upper reach in eastern direction. The changes of the upstream channel of Chandpur are presented in a simplified form in Figure 3.8.



Changes in the planform near the confluence of the Padma and the Upper Meghna River	Figure 3.8

3.6.1 Scour Process

Local phenomena (like bends, confluences, constrictions, etc.) may cause large scour depths in alluvial rivers. These scour holes may threaten the bank protection works already present or to be constructed in the future. This Chapter analyses the various types of scour that occur in the Upper Meghna and the Lower Meghna Rivers. The main purpose of this analysis is to provide tools to estimate the maximum scour depth for the different proposed bank protection works. The tools can be used to generate design conditions. The results of the present analysis, in combination with predictions of the future planform of the river near the sites to be protected, will be used to generate these design boundary conditions in Annex G.

A distinction can be made between general scour and scour that occurs more locally. **General scour** is the reaction of the river on changes in its boundary conditions, like aggradation or degradation owing to accelerated soil erosion, sea level rise, cutoffs of bends etc.

- General scour (i.e. lowering of the bed level due to changes and developments in the catchment) will most probably only occur on a limited scale. Based on experience obtained with a large 1-dimensional model for the Jamuna Bridge Phase II Studies the Consultants estimate for the Upper and Lower Meghna an overall negligible effect and some aggradation respectively (Fig. 3.9).

Table 3.2 POSSIBLE GENERAL SCOUR (AGGRADATION) AS CAUSED BY OUTWARD CONTROLS

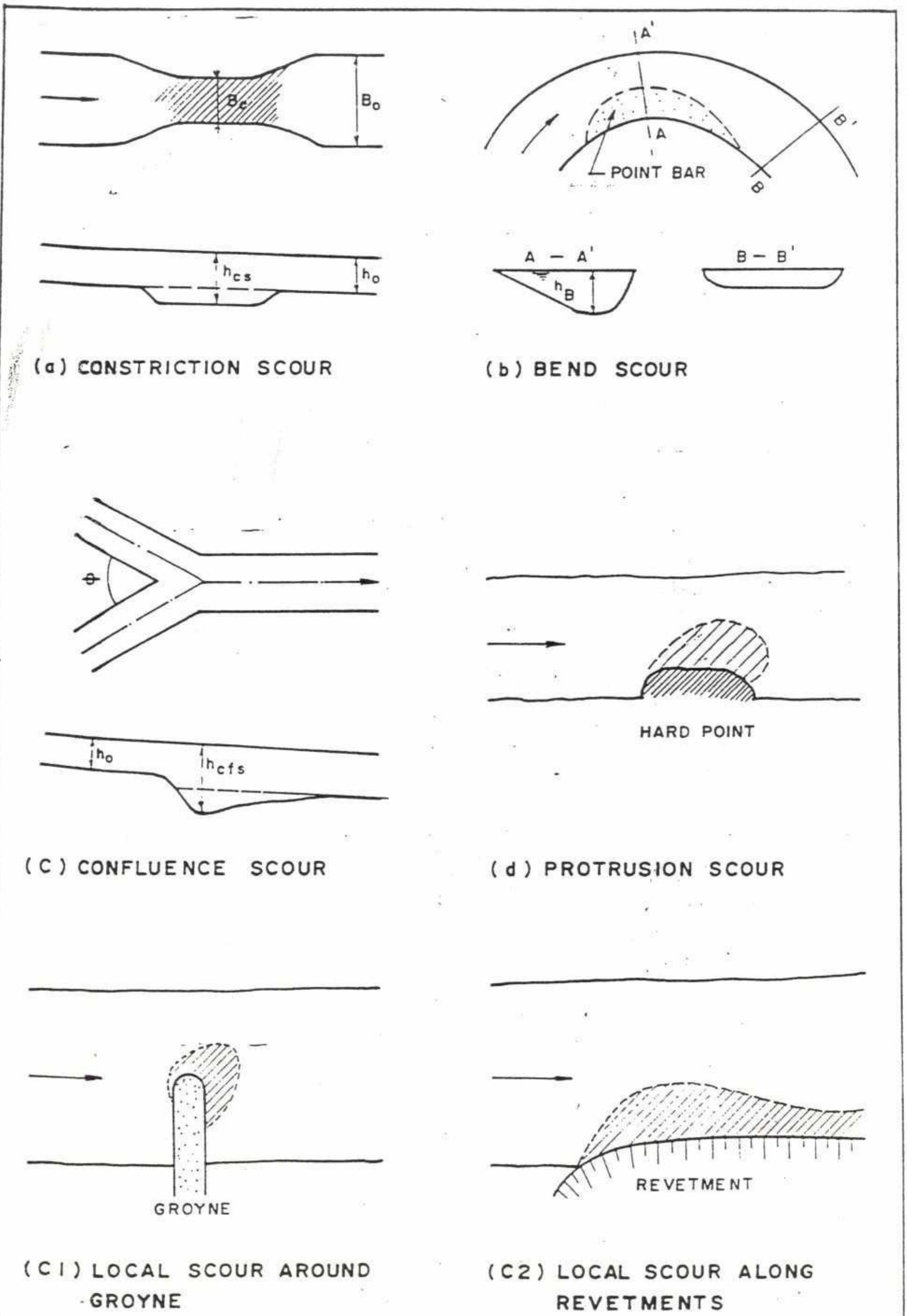
Possible cause	Effect on	
	Upper Meghna	Lower Meghna
Shifting of Brahmaputra R.	possible aggradation	no effect
Sinking away of Hoar area	scour	negligible effect
Accelerated soil erosion	no effect	no effect
Flood embankments	possibly scour	possibly scour
Sea level rise	aggradation	aggradation
Diversion of water	slight aggradation	negligible effect

Constriction scour occurs if the width of an alluvial river is constricted over a substantial length. This may inter alia be caused by bank protection works. The effect of the constriction will be that the depth increases and usually the slope in the constricted river reach decreases. Equations developed earlier for the Jamuna River can also be used to calculate constriction scour in the Upper Meghna. For Bhairab Bazar this type of scour will be in the order of 2.5 m.

Outer bend scour is the type of scour that develops in the outer part of river bends. On the basis of soundings made in the recent past it could be concluded that in the Upper Meghna River this type of scour is approximately 2 times smaller than would follow form the theory. For Bhairab Bazar 27.5 m was found.

Confluence scour in general is less important for bank protection works as it usually occurs away from river banks.

Protrusion scour is due to protrusions causing major scour holes. Chandpur, on the Lower Meghna is only example of such protrusion scour but because of its magnitude here, its effect is extreme. Near Chandpur the deepest scour holes are found upstream of the protrusion. This distinguishes protrusion scour also from local scour, the latter normally being found downstream of structures. For Chandpur 60.0 (m -PWD) was found as a combination of outer bend scour and protrusion scour.



DIFFERENT TYPES OF SCOUR	FIGURE 3.9

Bed form scour is related to the possibility of deep troughs being formed downstream of the crests of bed forms. Field observations learnt that bed forms are almost absent on Upper and Lower Meghna or disappear during floods. For the Upper and Lower Meghna this type of scour can be neglected.

Local scour is the scour caused by man-made structures. In bank protection works local scour near groynes, guide bunds, protrusions and along revetments is of interest.
At Bhairab Bazar this type of scour in combination with the other types will give a total scour in the order of 42 m.

Before making an estimate of the future conditions at the Chandpur site, it seems appropriate to review the local conditions and to provide some data on measured scour depths in the past. Chandpur is located where the Dhakatia River enters into the Lower Meghna River. The part of Chandpur North of the confluence is called Nutan Bazar, while the Southern part near the river is called Puran Bazar. The different components of the total scour observed at Chandpur were analyzed, and an overview is provided in Table 3.3. From this Table it can be concluded that the mechanisms that cause scour are not constant in time, but that over the years the total scour depth is composed of the different types of scour in different proportions. At Chandpur, by combining outer bend scour and protrusion scour the local scour, during a 1:100 years flood is expected to be about 63 m - PWD.

TABLE B.3.3 TYPES OF SCOUR ACTIVE AT CHANDPUR OVER THE YEARS

Year	Types of scour active [1])										
	Nutan Bazar					Puran Bazar					
	GS	BS	CFS	PS	LS	GS	CS	BS	CFS	PS	LS
1964	small	no	no	yes	no	small	no	no	no	no	yes
1968	small	yes	no	yes	no	mall	no	no	no	no	yes
1970	small	yes	no	yes	no	small	no	no	no	no	yes
1971	small	no	no	no	no	small	no	no	no	no	?
1975	small	yes	yes	yes	no	small	no	no	no	no	yes
1976	small	yes	no	yes	no	small	no	no	no	no	yes
1977	small	yes	no	no	no	small	no	no	yes	no	yes
1983	small	yes	no	yes	yes	small	no	no	no	no	yes
1984	small	no	no	yes	no	small	no	no	no	no	yes
1986	small	yes	no	yes	no	small	no	no	no	no	yes
1989	small	no	no	yes	no	small	yes	no	no	no	yes
1990	small	no	yes	yes	no	small	yes	no	yes	no	yes
1991	small	no	yes	yes	no	small	yes	no	yes	no	yes

Explanation of abbreviations:
GS = general scour
CS = constriction scour
BS = outer bend scour
CFS = confluence scour
PS = protrusion scour
LS = local scour

8 ~~?~~

3.7 Hydrology

Knowledge of the hydrology of the Meghna river and its catchment is essential for the development of designs. Parameters like :

- Flood levels having return periods upto 100 years;
- water level range;
- hydraulic head difference across the bank protection;
- maximum flow velocities near the bank protection;

are determined for each of the selected sites.

These parameters in turn are used to calculate :

- scour depths in front of the bank protection works;
- size of units to be used for revetments or groynes;
- flood levels and duration curves for water levels and discharges in relation to construction periods (Fig. 3.10 and 3.11)
- top level of bank protection works.

In Table 3.3 flood levels at the protection sites for 50 and 100 years return periods are given.

Table 3.3 FLOOD LEVELS AT THE PROTECTION SITES FOR 50 AND 100 YEARS RETURN PERIODS

Site	Chainage	Return Period			
		50 years		100 years	
	km	u/s	d/s	u/s	d/s
Bhairab Bazar	7.5 - 9.0	7.66	7.62	7.83	7.79
Maniknagar	31.0 - 37.0	7.22	7.10	7.39	7.27
Meghna R & H Bridge	88.0 - 88.0	6.42	6.42	6.59	6.59
Munshiganj (Dhaleswari)	8.0 - 4.0	6.41	6.32	6.60	6.51
Eklashpur	114.0 - 123.0	5.80	5.58	5.93	5.69
Chandpur	134.0 - 137.0	5.31	5.25	5.40	5.32
Haimchar	147.0 - 154.5	5.02	4.86	5.09	4.91

All levels are in m+PWD

Table 3.4 presents the standard low (SLW) and standard high (SHW) water levels for the various sites.

Table 3.4 STANDARD LOW AND STANDARD HIGH WATER LEVELS AND 95 AND 5% EXCEEDANCE LEVELS EXTREMES

Station Name	Code	SLW	SHW	95 %	5 %
Bhairab Bazar	273	0.71	8.57	1.16 (1.31)	7.44 (6.50)
Nabinagar	298	0.65	7.63	1.09	7.08
Narsingdi	1650	0.62	7.11	0.88	6.71
Baidyar Bazar	275	0.59	6.49	0.92	6.12
Meghna ferry ghat	275.5	0.73	6.34	1.03 (1.22)	5.96 (5.38)
Satnal	276	0.55	6.04	0.90	5.60
Chandpur	1640	0.19	5.16	0.55 (1.02)	4.59 (4.22)
Nilkamal	277.3	0.73	4.79	0.95	4.09

For detailed information on flow velocities under different circumstances reference is made to Annex A.

3.8 Climatology

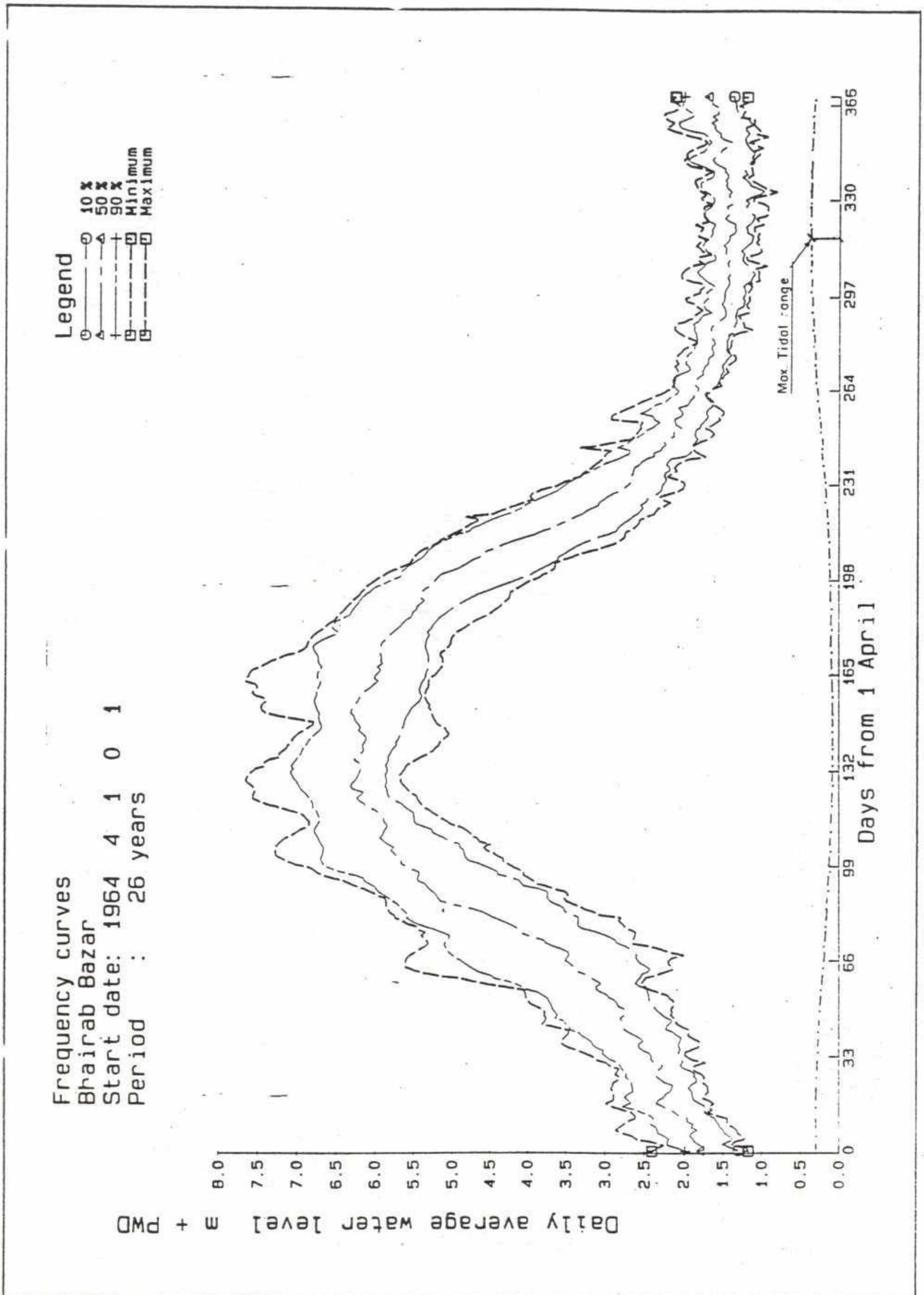
3.8.1 Wind

In Bangladesh two wind systems generate extreme high wind velocities leading to the design wind speeds for the determination of design waves:

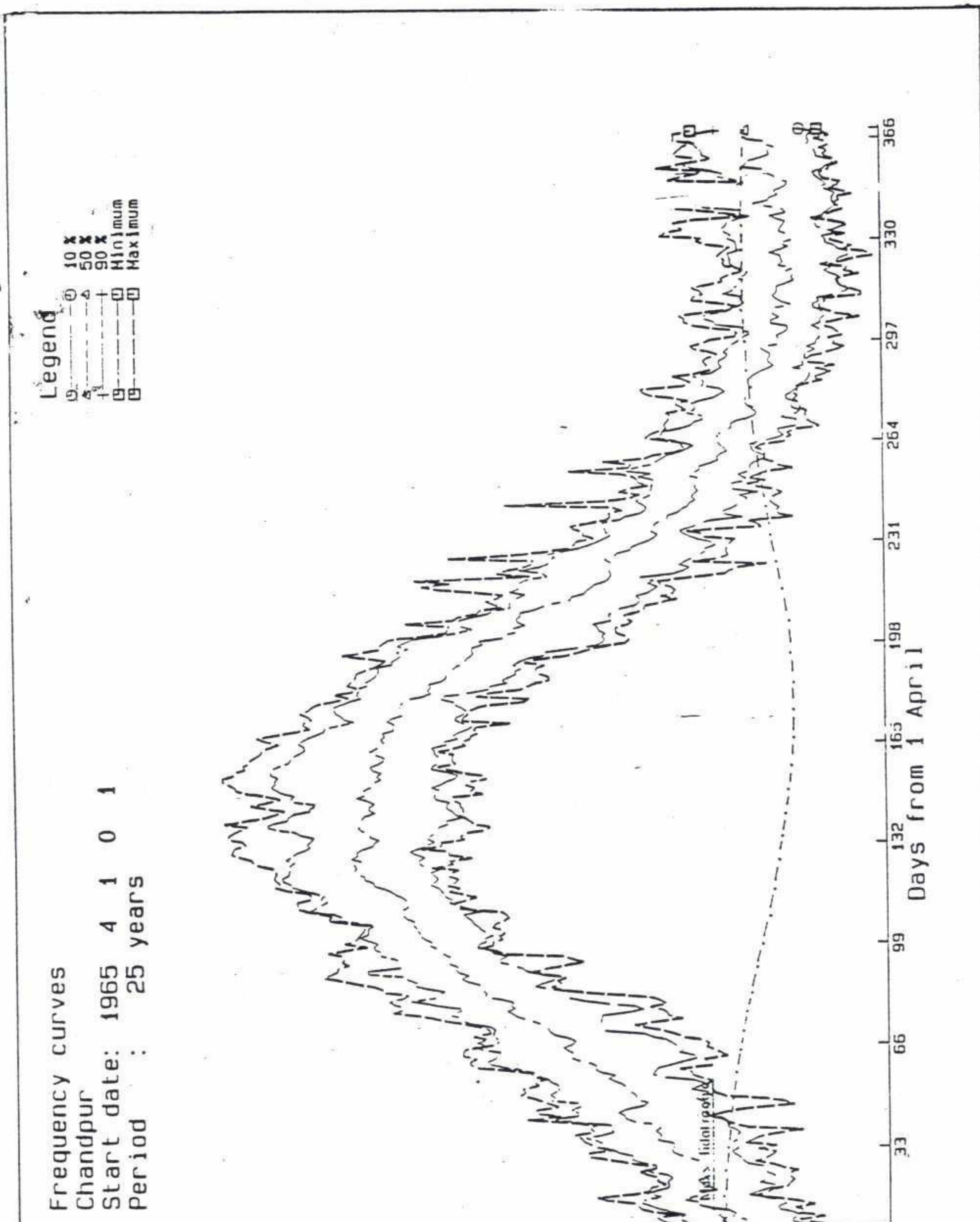
- 'Nor-Wester' thunderstorm squalls, and
- cyclones

High wind speeds in Bangladesh are most commonly associated with the 'Nor-Wester' thunderstorm squalls, generally occurring within the season April - June, though also possible between March and September. The classic pattern is a rapid rise in speed accompanied by a swing in direction, followed by a progressive decay over about half an hour. There is, however, a range of variation; the higher speeds are probably associated with shorter durations. However, more complex events, particularly at the lower speed levels, do also occur.

Very high winds may also occur as a result of the incursion inland of tropical cyclones from the Bay of Bengal, although these are rare events. Cyclonic storms occur in the [illegible] and post monsoon period (i.e. April-May and October-November), with a general direction of the tracks South-East to South. The average number of cyclones affecting any part of Bangladesh is about three in any ten-year period, and each such cyclone will only cause very high winds over a small fraction of this area.



FREQUENCY CURVE BHAIRAB BAZAR | FIGURE 3.10



FREQUENCY CURVES DAILY AVERAGE WATER LEVELS AT CHANDPUR PERIOD 1965-1989	FIGURE 3.11

3.8.2 Climate

Bangladesh has a typical tropical monsoon climate. Three basic types of weather can be distinguished:

- the cool season form November till February;
- the hot season from March till May and;
- the rainy season from June till September.

The rainfall varies from 20 mm/month to 900 mm/month. The maximum rainfall occurs in the months of July and August.

The maximum temperature values vary from 25°C upto 33°C whereas the minimum values vary between 15°C and 25°C. The relative humidity varies between 75 % and 90 %.

3.9 Topographical and Hydrographic Surveys

The project sites along the Upper Meghna en Lower Meghna have been the subject of mapping during both the dry and flood season of 1991.

Up to date mapping of ground surface and river channels is essential for:

- a good understanding of hydrological and morphological processes and likely changes following construction of the protection;
- the selection of horizontal alignments of protection works and river training works;
- lay out of protection works and river training works;
- bed topography for both physical and mathematical modelling;
- costing of the works at the various project sites.

During the period January 1991 .... August 1991 the following surveys have been undertaken and data collected:

- topographic surveys (longitudinal profiles, cross sections) of the alignment of approaches and existing protection works and the existing infrastructure at Bhairab Bazar, Munshiganj and Chandpur;
- hydrographic surveys to asses the various morphological phenomena including bed sampling, velocity measurements and the preparation of cross sections for Upper Meghna, Bhairab Bazar, and Lower Meghna, from Mawa to Haimchar. Surveys have been carried out during the dry season, January to February 1991 and during the flood season, August 1991.
- Landsat and SPOT imageries for the Upper and Lower Meghna. These were used for the Geomorphological Study and various other design purposes.

No separate Annex has been dedicated to the aforementioned surveys as the results have been used throughout the project for technical studies. These studies are reported upon in the Annexes and the surveys as such do not warrant specific separate reporting.

3.10 Local Materials

3.10.1 General

In view of the magnitude of the proposed bank protection works no detailed investigations were required to assess the availability in terms of quality and quantity of local construction materials. In this respect it should also be noted that the Consultants took part in the extensive materials survey carried out in relation to the design and future construction of the Jamuna Multipurpose Bridge. They are therefore well aware of the nature and availability of local construction materials.

Below, some comments are made about the local materials of which significant quantities will be required for the envisaged bank protection works.

Other local materials like bricks, bullah, reed, bamboo, jute sticks after extraction of the fibres, jute (gunny) bags, rope will be required as well but they do not require specific attention in the context of this Feasibility Report.

3.10.2 Sand

Delivery of sand for the production of concrete will not be a problem. Often a mixture of 'local' sand and Sylhet sand is used to arrive at the proper grading.

All sand in Bangladesh has a rather high mica content, while often a high percentage of fines (diameter less than 0.063 mm) is present.

3.10.3 Boulders

Boulders are widely available in Sylhet and, to a lesser extent, in the Rangpur area. Most of the supply is likely to come from Sylhet, where boulder collection is a seasonal activity. Experience in the past has learnt that when orders are timely placed a quantity of 100,000 m3 of boulders can be delivered to site in approximately 6 months, but not without certain problems. Such large orders do disturb the market equilibrium and force prices upward. Boulders can be used for protection of both the upper and lower parts of the slope (single boulders, gabion mattresses, sack gabions).

3.10.4 Cement

Cement is available from sources in Bangladesh. The quantity of this cement is limited, however. Cement would be necessary for production of concrete blocks or cement blocks

3.10.5 Rock

The only places were suitable rock is found at (near) surface level is in the Chittagong Hill Tracts and West Bengal; but problems may occur with supply and transport. The existing infrastructure and security situation will probably make it difficult to obtain large quantities of rock in a short time from this area; the only way is to import it from, for instance, India or Malaysia or neighbouring countries. Rock from India would have to be transported by train. From Malaysia, from existing quarries, the required gradings could easily be obtained and transported by barge to Bangladesh.

3.10.6 Bitumen

Bitumen is produced in Chittagong (East Refineries) and can be used for the production of open stone asphalt.

4. PROJECT DESIGNS

4.1 General

The sites which have been considered in this Short-Term Study can be divided into two groups, those along Upper Meghna and Dhaleswari and those along the Lower Meghna:

Upper Meghna and Dhaleswari	-	Bhairab Bazar *)
	-	Maniknagar
	-	Meghna Roads and Highways Bridge
	-	Munshiganj *)
Lower Meghna	-	Eklashpur
	-	Chandpur *)
	-	Haimchar

*) priority sites

Although the Upper Meghna has some stretches with a system of various channels it still can be characterized as a mainly meandering river having a rather well defined high water bed and having peak discharges up to 20,000 m^3/s.

The Lower Meghna conveys the discharges of Upper Meghna and Padma. Peak discharges are in the order of 170,000 m^3/s and the erosion processes along its left bank (where the three aforementioned sites are situated) are related to geo-morphological development of both Padma and Upper Meghna but also to wave attack.

Bank protection works at sites along the Upper Meghna will not have a significant impact on the river regime as a whole. The situation is, however, different along the Lower Meghna. Here, the river has been eroding the left bank for more than a decade which has resulted in a gradual shifting of this bank to the east. As a consequence thereof erosion forces are considerable at all three sites mentioned above. Any successful effort to stop erosion at one or more sites will have an effect, either positive or negative, on the erosion pattern and magnitude upstream and downstream of this (these) site(s). As already stated in Chapter 2, in the absence of a Long Term Strategic Plan for bank protection along the Lower Meghna such effects will have to be accepted if the sites have to be protected in the very near future.

As explained in Chapter 1 detailed designs for bank protection works have been prepared for three priority sites only (marked in the table above with an asterisk). For the other 4 sites feasibility level or pre-feasibility level designs were made. Accordingly, in this Chapter more design details are presented for the three priority sites than for the others.

The locations of all seven sites are shown on the map preceding this report.

4.2 Design Alternatives

4.2.1 Approach

The general design approach has been elaborated upon in Chapter 2. As part of this approach alternative solutions for bank protection works at the various sites have to be generated, evaluated and a preliminary selection made. Subsequently, the selected alternatives are considered in greater detail and dimensioned on the basis of known constraints (boundary limits), design loading, construction materials etc.

In this Section the alternative solutions which in principle are available for bank protection works at individual sites are discussed and a first selection made.

4.2.2 Bhairab Bazar

At Bhairab Bazar protection works are required for Bhairab Bazar Town (right bank) and for the Railway Bridge which crosses the Upper Meghna at this location, just upstream of the Town (Fig. 4.1). Deep scouring near the right bank both upstream and downstream of the Railway Bridge has resulted in steep (instable) underwater slopes and bank slides.

Recently, Bangladesh Railway has carried out protection works to prevent development of unacceptable scour holes near the bridge piers.

Any solution considered should basically satisfy two criteria:

- to prevent geotechnical instability of land areas near Bhairab Bazar Town and Ferry Ghat;

- to prevent development of scour holes near the piers of the Railway Bridge.

Consequently, seven alternative solutions were formulated which can be summarized as follows:

(1) maintain present conditions;

(2) overall revetment along existing (right) bank and between piers;

(3) ditto but along an advanced right bank and between piers;

(4) groyne u/s Railway Bridge;

(5) series of groynes u/s Railway Bridge;

(6) short groyne u/s Railway Bridge, sill between piers, guide bund along bank u/s of bridge;

(7) bed protection at Railway Bridge, sill between piers and guide bund as (6).

The basic difference between a revetment (alternatives 1, 2, 3) and groynes is that by constructing a revetment one accepts scour and high current velocities immediately in front of the revetment at the right bank while a groyne or groynes will divert the flow from the attacked bank and thus preclude erosion due to high currents and scour. However, a groyne (or groynes) create a problem somewhere else (here at the piers of the Railway Bridge and at the left bank) which in turn requires new protection measures (bank protection, sill).

After due consideration, taking into account the results of scale model testing, it was decided to select alternatives (2) and (3) for further elaboration.

4.2.3 Maniknagar

In the case of Maniknagar (Fig. 4.2) the erosion along 16 km length of a large outer river bend threaten to encroach onto the future alignment for the flood embankment. The latter would be part of the Gumti Phase II, Irrigation Project. At present the (left) bank line is at a distance of 300 m of the (future) embankment and the average annual erosion, though different from place to place, may well have reached the alignment within the next decade.

Four alternative "solutions" have been considered:

(1) maintain bank line in outer bend by protection works i.e. either a continuous revetment or a series of groynes;

(2) deviate the river flow from the left bank by creating a channel along the right bank;

(3) construct the projected flood embankment for Gumti Phase II Project at a retired alignment;

(4) after due consideration alternative (2) was rejected as it would hamper navigation. It was also considered that alternative (3) would require more detailed study or studies as part of Gumti Phase II designs. Consequently, only alternatives (2) and (4) were retained as solutions to be studied at pre-feasibility level

4.2.4 Meghna Roads and Highways Bridge

The left bank abutment of the R&H Bridge is located at an eroding bend (Fig. 4.3). Erosion during the last five years amounted to 40-50 m p.a. This erosion is due to shifting of the main channel to the left bank.

Moreover, construction of the Bridge together with flow concentration has led to constriction scour in the river bed under the Bridge. A deep scour hole now located left of the former ferry ghat approaches piers numbers 8 and 9 which in due course may endanger the Bridge' integrity.

Possible protection works may result either in a short term or in a long term solution of the erosion problems.

Short term in this connection means protection of the bridge' substructure (piers, abutments) without trying to control the river flow.

Alternative solutions in this respect are:

(1) bed protection around the piers by means of stone dumping;

(2) extended bank protection at left abutment by placing sheetpiles; concrete filled mattresses and gabion dumping.

Long term solutions would imply river training i.e. preventing further erosion u/s and d/s of the Bridge which erosion could be followed by outflanking.

Within the context of this Short Term Study only pre-feasibility designs will be prepared for long-term solution as it is felt that short-term measures are (still) the responsibility of the bridge contractor.

In this respect the following alternative solutions were reviewed:

(1) protection of ferry ghat and vortex areas;

(2) ditto but also groyne of 200 m length upstream of Bridge;

(3) spurdyke which guides the flow lines.

4.2.5 Munshiganj

Munshiganj Town is situated at the right bank of the Dhaleswari river near its confluence with the Upper Meghna.

The situation is in so far different from sites discussed in the preceding sections that at Munshiganj (a) erosion occurs at both banks and (b) this erosion is due to wave attack during high river stages and not to bank parts sliding into deeply scoured river channels (Fig. 4.4). There is in fact a foreshore in front of the river bank. Consequently, for any proposed protection measures the purpose should be:

(i) to prevent development of scour in front of foreshore,

(ii) to prevent erosion due to wave attack.

Based on the principle of an overall revetment three alternative solutions were formulated:

(i) a design based on BWDB designs;

(ii) protection of foreshore at existing bank line;

(iii) protection on re-constructed embankment.

Finally, a combination of alternatives (2) and (3) was selected for the final de... As much as possible the existing embankment is used and by means of cut and fill a suitable slope is created on to which the revetment can be made.

4.2.6 Eklashpur

Eklashpur is situated at the left bank of the Lower Meghna, near the confluence of Padma and Meghna (Fig. 4.5). Erosion has gone on for more than a decade and is due both to current and wave action.

Because of the local impact of both Padma and Meghna rivers the geo-morphological situation is complex and without an in-depth overall study of the geo-morphology of the Padma and Meghna rivers it is impossible to forecast with reasonable accuracy what will happen during the next decades. To overcome this problem a range of alternative solutions was defined which show an increasing degree of intervention in the existing erosion and flow pattern.

In all cases the aim is to prevent local collapse of the flood embankment surrounding the Meghna Dhonagoda Irrigation Project.

The alternative solutions considered are:

(1) protection of existing embankment by means of a deeply founded revetment;

(2) construction of a retired embankment, for the time bein... ...ut revetment;

(3) a banana shaped guide bund protecting a bank li... stretch in addition to the stretch of river bank defended according to BWDB design;

(4) a groyne placed under an angle with the embankment' axis (length 600 m, location 2 km u/s of Eklashpur).

The selection finally made was apart from cost and other considerations based as extensive scale model testing carried out (Annex D).

4.2.7 Chandpur

The Chandpur township consisting of Puran Bazar and Nutan Bazar is located at the left bank of the Lower Meghna (Fig. 4.6). The town is bisected by the Dakatia river.

The left bank of the Meghna u/s and d/s of Chandpur has been eroding continuously for the past 20 years. Emergency works have been carried out in the past and are being carried out today to protect Chandpur against the erosive forces of the L wer Meghna.

These emergency works had thr... ...gs in common:

- the designs were not to the standard required for this very difficult situation;
- construction was not carried out in such manner that the under water protection could fulfill its task;
- construction elements were placed on eroding, oversteep and, thus, unstable slopes.

The conclusions as well as the reasons behind it are presented in greater detail in Annex G, Section G.2.2.3.1. Here it suffices to state that the emergency measures so far have had a very limited life time.

Any design and construction concept for a durable protection of Chandpur Town should be based on the following principles:

- slopes must be stable under various conditions;
- protective elements and corresponding filter layers must be able to withstand erosive forces of currents and, to a lesser degree, wave attack;
- provision must be made for scour depths in excess of the river depth prevailing at the time of construction;
- construction mu... .. according to the designs made by using the right kind of equipment, approved and suitable working methods and quality control.

The oversteep underwater slopes, the remains of various protective layers placed haphazardly in the past as well as the expected future increase in scour depth preclude the implementation of a simple cheap solution.

These considerations as well as many others (see Annex G, Section G.2.2.3.1) have prompted the Consultants to analyze the following alternative solutions for a durable protection of Chandpur Town:

(1) protective layers on existing slopes improving on present slope angles by cut and fill;

(2) advanced protection concept which involves the construction of a new bank line, at some distance from the present bank line at Nutan Bazar, or Puran Bazar or both;

(3) series of 2 groynes in front of Nutan Bazar;

(4) groyne u/s of Chandpur;

(5) submerged sand sausages placed in upstream direction u/s of Chandpur.

Some of these solutions (e.g. (4), (5)) can be considered as long term solutions having a "regional" effect. The other solutions are of ...ocal nature, do not require additional comprehensive river studies and can be implemented in the near future. As it was felt that Chandpur is most benefitted by a quick solution alternative (2) i.e. advanced protection of Nutan Bazar was selected for further elaboration. This protection will also protect Puran Bazar against scour.

In addition at Puran Bazar in any case measures have to be taken against wave attack.

After the aforementioned alternative solutions had been formulated the Consultants were asked to consider also "emergency measures" for Chandpur Town. In fact this would concern measures whcih could be implemented within one dry season (1991-1992). The various aspects involved in such measures are discussed in Chapter G.3 of Annex G in greater detail. M... details in this Main Report can be found in Section 4.5.7.

4.2.8 Haimchar

Haimchar is situated about 20 km south of Chandpur Town at the left bank of the Lower Meghna (Fig. 4.7). The river width is approx. 10 km and since 1929 ongoing erosion of the left bank has been reported. At present the rate of erosion is about 200 m p.a. This has led to the construction of retired flood embankments protecting the Chandpur Irrigation Project. Not only scour but also wave attack is causing the erosion.

The following alternative solutions have been formulated:

(1) a revetment protecting the existing bank;

(2) a retired embankment protected by a deeply founded revetment;

(3) groynes u/s of Haimchar which should deviate the flow from Haimchar.

Considerations for further selection will be presented in Section 4.5.8.

4.3 Design Data

4.3.1 General

The design data required for the design of the bank protection works have been established on the basis of:

(i) field observations and measurements;

(ii) analyses of same as presented in Annexes A, B and C;

(iii) physical and mathematical modelling (Annexes D, E).

Part of the design data was already presented in Chapter 3, other significant design data are presented below in order to give an impression of the scope of the problems. For complete information reference is made to the relevant Annexes.

4.3.2 Hydrologic Data

Water levels for various return periods were already tabled in Section 3.7. Discharges and current velocities are presented in Tables 4.1 and 4.2.

Table 4.1: DISCHARGES UPPER AND LOWER MEGHNA (in m3/s)

Return period (years)	Upper Meghna			Lower Meghna
	Bhairab Bazar	Maniknagar	R&H Bridge	
10	16,500	*)	*)	137,000
25	18,000	*)	*)	151,000
50	19,200	19,700	19,700	161,800
100	20,300	20,[illegible]00	20,900	172,250

*) values not determined.

Table 4.2: MAXIMUM CURRENT VELOCITIES ON UPPER AND LOWER MEGHNA (m/s)

Return period (years)	Upper Meghna				Lower Meghna		
	Bhairab Bazar	Manik-nagar	Munshi-ganj	R&H Bridge	Chand-pur	Eklash-pur	Haim-char
10	1.46	*)	*)	*)	2.52	*)	*)
25	1.57	*)	*)	*)	2.76	*)	*)
50	1.67	1.26	1.74	1.31	2.93	*)	*)
100	1.75	1.32	1.84	1.36	3.10	1.90	1.90

*) values not determined.

4.3.3 Geotechnical Data and Characteristics

In Section 3.4 the composition of three distinct layers has already been given (Table 3.1).

From Annex C design data are summarized below concerning shear strength, piezometric head differences, permeability and grain sizes.

(a) Shear strength parameters

Triaxial tests, consolidated-undrained, were carried out to establish shear strength parameters. Anisotropic consolidation (K = 0.44), allowing for the prevailing normally consolidated in-situ stress conditions, was adopted for specimen preparation. Taking into account that slope stability analysis must be based on long term behaviour shear strength parameters were selected. The results are presented in Table 4.3.

Table 4.3: SHEAR STRENGTH PARAMETERS FOR LONG TERM LOADING

Layer	Description	ϕ'(°)	c'(kN/m²)
I	Fine sand, with silt	27	-
II	Silt, with sand & some clay	25	-
III	Silt, with clay & some sand	20	10

The separate analysis of the stability of the protective layer, assumed to be infinite, should take due account of the composition of underlying layers:

- when coarse backfill has been used an angle of internal friction of $\phi' = 30°$ is used, otherwise an angle of internal friction of 25° should be adhered to,

  when geotextile is installed, having a frictional resistance most likely not exceeding 25°, this layer may become a slope angle governing construction element.

(b) Piezometric head difference and ground water gradient in slope

Based on the readings during the month of April 1991 the following approximate differences between piezometric head and river level have been monitored:

- Bhairab Bazar H = 3.5 m
- Meghna R&H Bridge H = 3.5 m
- Munshiganj H = 2.75 m

The differences in piezometric heads will result in the development of outwardly directed ground water flow, defined via its gradient.

In a natural "critical" unprotected slope the gradient perpendicular to the slope "i" may become 1 at the free water level, causing collapse of the layers above.

In a design slope (1:3.5) with open protection, such as boulders, gradients will be reduced dramatically. The design gradient will be on average 0.04.

(c) Permeability

The following characteristic values have been derived:

	K soil in 10^{-5} m/s
Bhairab Bazar	3.51
Munshiganj	3.49
R&H Bridge	0.016
Chandpur-Nutan Bazar	0.060
Chandpur-Puran Bazar	0.016

(d) Grain sizes

The following characteristic values of D_{90} from borings were determined:

	D_{90} in 10^{-6} m (μm)
Bhairab Bazar	60
Munshiganj	40
R&H Bridge	80
Chandpur	90

4.3.4 Waves

Waves at the site would either be generated by wind or by ships. Data on wind waves were not available. Based on wind data from the meteorological stations Dhaka and Chandpur, predictions of the wind waves have been made. Waves generated by ships have also been considered.

The data were retrieved from the Hydrological Study, Annex A. The available data comprise monthly maximum wind speed data of the stations Comilla and Dhaka.

For wave attack a dominant wind direction of NE has been considered with a duration of 15 minutes. Wind velocities are listed in Table 4.4. For the fetch length it is considered that maximum wind velocities will occur from April till June, hence the fetch length in that case will be 2,000 m for sites on the Upper Meghna and 7,000 m for sites on the Lower Meghna. For the water depth average value of 10 to 30 m are selected. With Bretschneiders formula for wave generation a significant wave height has been calculated for various return periods (Tables 4.4 and 4.5).

Table 4.4: WIND AND WAVE CHARACTERISTICS UPPER MEGHNA

Return period (years)	Wind velocity (m/s)	Significant wave heights H_s (m)	Wave period T_p (s)
1	15.20	0.54	2.68
10	20.40	0.76	3.12
100	25.60	0.98	3.51

Table 4.5: WIND AND WAVE CHARACTERISTICS LOWER MEGHNA (CHANDPUR)

Return period (years)	Wind velocity (m/s)	Significant wave heights H_s (m)	Wave period T_p (s)
1	8	0.42	2.55
10	16	0.96	3.71
100	20	1.25	4.18

For completeness sake it is recalled that ship traffic on the Upper and Lower Meghna may induce wave action. However, these waves will not be higher than 0.50 m and are of minor importance if compared to wind induced waves.

4.4 Design Considerations and Parameters

4.4.1 Study Objectives

As elaborated upon in Chapter 2 the objectives of the Study are:

(i) to provide short term measures for protection against erosion at seven locations along Upper and Lower Meghna and one location on the Dhaleswari;

(ii) to gradually implement erosion control on the rivers Meghna and Dhaleswari (i.e. river training).

4.4.2 Causes of Erosion

Bank erosion is caused by one or more of the following reasons:

- scour near the exposed bank resulting in an oversteep geotechnically unstable bank slope which in turn will lead to slides; (in many cases the slides are prompted by rapidly falling water levels in the rivers which lead to ground water flows increasing the instability);
- wave attack;
- removal of soil particles from the underwater bank slope by high currents.

4.4.3 Protection Measures

In principle there are two methods to prevent erosion of the exposed bank:

- to accept the "environmental" loads (scour, waves, currents) and to protect the bank against these attacks by introducing gentle slopes lined with erosion resistant material;
- to divert the major part of the aforementioned attack from the exposed bank by means of groynes or other measures; the attack in this context is mainly the attack caused by shifting river channels. It is obvious that such groynes will themselves be subject to the environmental loads.

It will depend on the magnitude of the bank protection works (i.e. length of bank line protected, shape and length of guide bund, length and number of groynes) whether one may speak of a local measure or of river training.

The local measure will only protect the site concerned (for instance Bhairab Bazar Township) but in the long term may (note: not necessarily <u>will</u>) lead to further erosion upstream and downstream of the protected site and even to outflanking. However, this measure is clearly in line with objective (i) as given above.

River training is a more comprehensive way of keeping erosion at bay: In this case not only the attacked site is protected against further erosion but also the area u/s and d/s of this location and in the long term the river will not shift its banks or outflank the protection works.

River training is obviously in line with objective (ii) but especially on the Lower Meghna it will require much more study before the required expensive works can be defined and designed.

Summarizing, the designs presented will be mainly short-term measures having a local impact only. They may either be based on acceptance of the local attack and will then counter this attack (revetment, lining of the bank, guide bund) or on diversion of the scour-inducing river-channel (groyne(s)).

4.4.4 Modelling of the Meghna River

Apart from site investigations and assessment (Chapter 3) and design data (Chapter 4, Section 4.3) the various alternative solutions for different locations as formulated in Section 4.2 of this Chapter must be based on results of mathematical and/or physical (scale) model testing.

The mathematical modelling carried out within the context of this Study (reported upon in Annex E) provided the boundary limits for the scale modelling. Upstream boundaries of the 2-D mathematical model have been located at Mawa and Nilkamal. In general, the procedure for schematization implies the determination of the model boundaries. The modelled area was exceptionally large (about 70 km in length from Mawa to Haimchar) for this kind of 2D-hydrodynamic model simulations. Boundary conditions, consequently, could have no effect on the computed flow fields in the areas covered by the physical scale models. The upstream boundaries were on purpose located at Mawa and Satnal, where the rivers forms only one channel; hence, avoiding the need to specify a detailed flow direction and distribution at this location. Nevertheless, a flow distribution according to the Chézy-equation was imposed as upstream boundary condition. Flow distribution in the Padma immediately downstream of Mawa did not adjust substantially, and the imposed boundary condition was therefore accepted. From geo-morphological considerations, the worst case (future development) was selected for schematization of the river channel in the 2-D ... The boundary layout and bed topography is shown in Figure 4.1.

The scale models have been constructed and tested in the River Research Institute in Faridpur. The scale modelling should provide the following data:

- magnitude of local scour due to the presence of a hydraulic structure (revetment, groynes, guide bund);
- maximum current velocities near the structure;
- technical (i.e. river engineering) feasibility of a proposed solution as well as its morphological consequences (if any).

Various possible alternatives for river bank protection as well as for the location (layout), underwater slope, alignment of the protection works, etc, were tested in the physical hydraulic models. Scale modelling was carried out for three locations:

- Bhairab Bazar
- Chandpur
- Eklashpur

The scale ratio, distortion factor and the dimension of the models are mentionned in Annex D and Appendix D/1.

For Bhairab Bazar a distorted scale model was constructed to study the flow field from 3 km upstream of the Railway Bridge near Bhairab Bazar up to 2 km downstream of this Railway Bridge. Three alternative solutions to reduce the bank erosion at Bhairab Bazar town along the right bank of the Upper Meghna River were studied. These alternatives are: a continuous bank protection downstream of the Railway Bridge along the right bank, a sill between the first three piers of the railway bridge and a groyne, which is located upstream of the railway bridge along the right bank. In addition, some tentative measurements of the scour depths were analyzed. The results have been used in dimensioning the various alternative designs.

In order to study the local scour process in front of Chandpur, a part of the Lower Meghna River near Chandpur with a length of about 5 km and a width of about 1.5 km was modelled at a length scale of 1 in 150. The non-distorted scale model has one main upstream inflow boundary, a small inflow boundary representing the flow over the char along the left bank upstream of Chandpur, a small inflow from the Dakatia river and one outflow boundary some kilometres downstream of Chandpur.

For Eklashpur, a part of the Lower Meghna River from the confluence of the Padma River with the Upper Meghna River to a few kilometres downstream of Eklashpur and a width of about 1.5 km was modelled at a length scale of 1 in 150. The non-distorted model has either three or four inflow boundaries and one outflow boundary with different tailgates. The discharge distribution along the inflow boundaries was obtained from the mathematical model study.

4.4.5 Other Design Considerations

Apart from "environmental" loads and boundary conditions like scour, waves and current velocities and the impact of proposed hydraulic structures on the flow pattern and morphology, the design should take into account such issues as:

- site specific constraints;
- risk analysis and related probabilities of failure of the site specific protection works as a whole and of its components;
- origin, characteristics, availability and cost of construction materials;
- required technology and equipment needed to construct the protection works;
- construction issues like season, length of construction period, working areas and quality control.

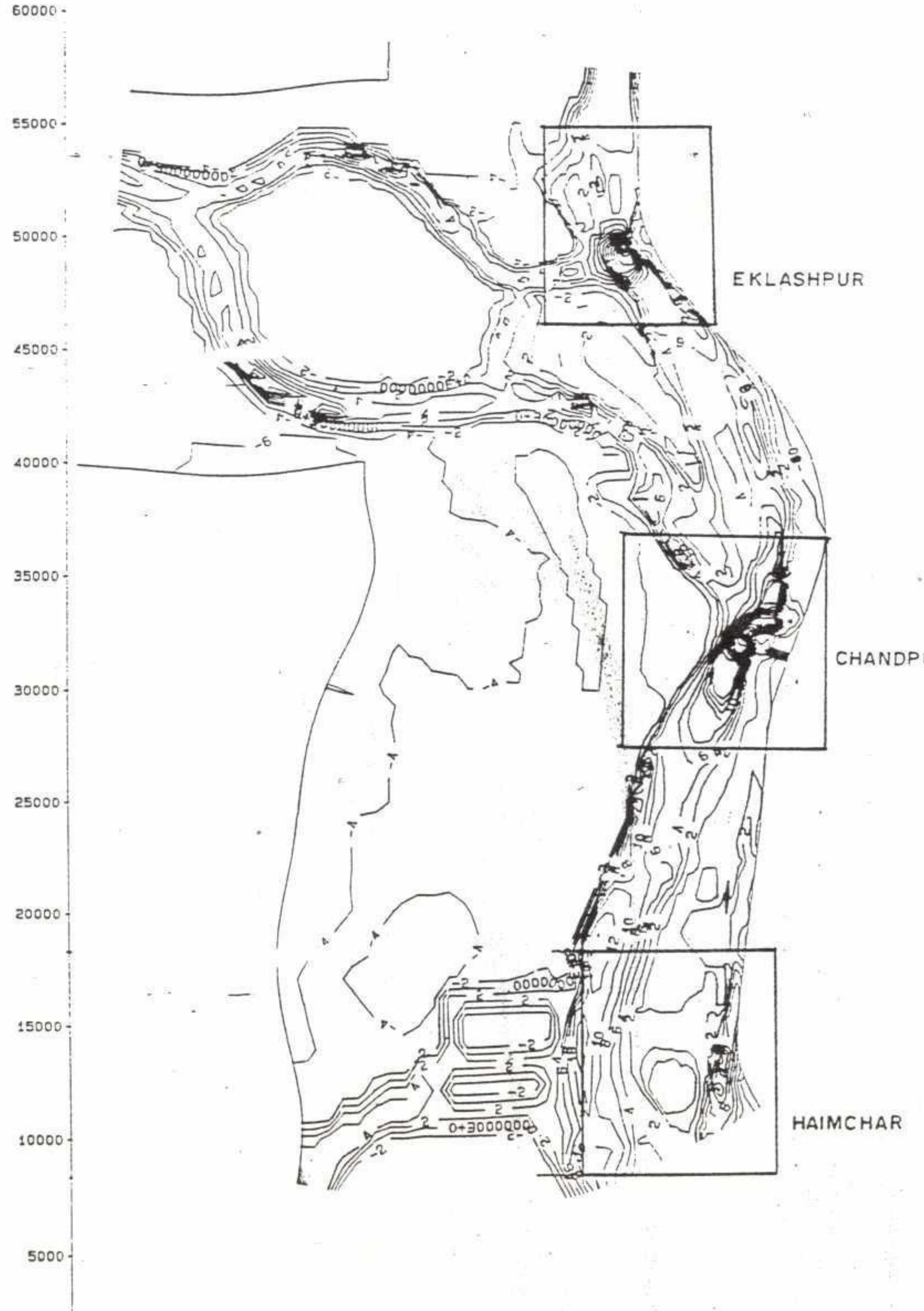
Site specific considerations and constraints have already partly been discussed for the various sites in Section 4.2 of this Chapter. Additional considerations (if any) will be tabled in relation to the design in the relevant sub-sections of Section 4.5.

The risk analysis and related failure probabilities will be the subject of a separate chapter as its application is a relatively new feature in river engineering projects.

The origin, characteristics, availability and cost of construction materials is an input for the selection of materials to be incorporated in the design. The selection in turn is also determined by the technology applied and the equipment needed to construct the protection. Both these items, technology as well as equipment, are determined not only by the environmental loads but also by site specific considerations. The need to use a certain technology and to make use of certain large modern equipment will on the one hand determine the selection criteria to be applied for pre-selection of contractors and on the other satisfy the conditions of a minimum degree of quality control.

Finally, all these features have a bearing on the construction period (length) and the season during which work is possible as well as on the extent of working areas required.

49



2- D MATHEMTICAL MODEL BOUNDARY LAYOUT AND BED TOPOGRAPY	FIGURE 4.1

Obviously, not each solution to protect a particular site against erosion satisfies non-quantifiable criteria in the same way.

By introducing the concept of multi criteria analysis (MCA) for final selection of a project design for Bhairab Bazar, a basis for final selection other than in monetary terms is presented. Such an analysis has also been considered for other sites but ultimately were not required as the selection process in those cases was rther straight forward.

4.5 Designs for Protection Works at Selected Sites

4.5.1 General

Bearing in mind all data and considerations presented in the foregoing Chapters and in the Sections of this Chapter designs will now be discussed for the alternative solutions selected for further consideration in Section 4.2 of this Chapter.

4.5.2 Bhairab Bazar

(a) Alternatives

In Section 4.2.2 it was stated that after due consideration two alternatives, out of seven presented, were selected for further elaboration:

(2) overall protection along existing (right) bank,

(3) ditto, but now along advanced bank.

"Advanced" in this respect means fill placing on the existing slopes. On the sloping part of this fill a revetment will be placed. This will provide adequate working space during construction, it will enable a smooth bank line to be constructed and, finally, it will add a valuable reclaimed area to the township at large.

(b) Scour depth

The choice of these alternatives for further elaboration implies that maximum scour to be expected in front of the new 1,689 m long bank line is a major point of departure for the design.

In Annexes B, D and G to this Report it is demonstrated that scour will be composed of:

- constriction scour ' 28. m
- bend scour 27. m
- local scour 15. m

The local scour seems to be dominant over all other forms of scour. However, the extent of local scour is to a certain degree dependent on the initial depth which in turn depends on the two other forms of scour. For a deterministic design the value of 42 m below water level (at a 1:100 years flood) can be accepted. This is a depth of 33.19 m - PWD. A scour depth determined in a probabilistic manner will be given in Chapter 5.

(c) Geometry of bank protection

Fill is placed in front of the existing protection by hydraulic means or otherwise. During the construction season current velocities will be low (in the order of 0.2 m/s). The aim is to have slopes after fill placing which are as steep as possible (1:7 is expected). It is however also possible to construct successively a number of containment bunds (Fig. 4.8) and fill the compartments with dredged sand.

After trimming of the fill to a slope of 1:3:5 the revetments can be placed.

In the case of alternative (2) the elevation of the top of the bank protection will be between 2 m + PWD and 7.5 m + PWD. The advanced bank protection (alternative (3)) has an elevation of 7.80 m + PWD i.e. the level of 1:100 years flood.

(d) Design parameters

For the design of the bank protection important design parameters are current velocity, wave-height, geotechnical characteristics and stability of the fill mass.

The current velocity used in the design of the revetment has been determined in the scale model test (Annex E) for a 1:100 year flood. This implies a discharge of 22,000 m^3/s and a current velocity (in the vertical over the bank) of 1.95 m/s. For the wave height a value of 0.98 m was calculated (Table 4.4) (frequency 1:100 years).

Extensive slope stability analysis (Annex C) showed for a 1:3.5 slope at Bhairab Bazar safety values of 1.55 and 1.14. The latter is found when seismic activity is taken into account. Minimum acceptable values were 1.50 and 1.10 respectively. The selected slope angle of 1:3.5 does also meet the micro-stability requirements. Stability of an infinite slope will be governed by an angle of internal friction of $\phi' = 27°$.

(e) Slope protection alternatives

For the protection of a soil mass one may select either a "closed" or an "open" revetment. Because of rapidly falling water levels in the river causing ground water flow towards the river, a closed revetment is not preferred. Therefore only "open" structures will be considered.

The Consultants have carried out an extensive review of possible open revetment structures. In this review a distinction was made between:

- protection above water,
- protection under water: sloping part,
- protection under water: falling apron section.

By means of a multi-criteria analysis (MCA) the following slope protection alternatives were analyzed for each case:

- boulders or rock on geotextile;
- concrete cement blocks placed on a filter;
- concrete block mattresses;
- bound or grouted aggregates;
- wire or gabion mattresses filled with boulders;
- fabric mattresses filled with sand or cement.

The MCA was based on four criteria:

- functional requirements;
- quality assurance
- maintenance
- construction aspects

For protection above water it was found that open stone asphalt was best suited to withstand wave attack and that it also satisfied the other criteria provided certain conditions (e.g. an experienced contractor) were met.

For protection under water boulders on a fascine mattress was selected.

Finally, for the falling apron section: boulders having a proper grading without underlying geotextile would be applied.

For all details on the MCA reference is made to Section G.1.5.2 of Annex G to this Report as well as to Appendix G/1.

(f) Dimensioning of revetment elements

In first instance dimensioning of revetment elements has been based on a deterministic design method. Later on a probabilistic design method will be applied to optimize the designs (Chapter 5).

The formulas used have been developed in the the Netherlands after extensive research, model and prototype tests and applied in the large Delta Project and Rotterdam's Harbour Europoort. More recently they have been used for the design of the river training works for the proposed Jamuna Bridge.

Dimensioning of revetment elements above water must be based on currents as well as on wave attack while dimensioning of under water revetment elements can be solely based on current velocities.

Based on the deterministic design method the following dimensions resulted:

- open stone asphalt from 3 m + PWD up to 7.80 m + PWD (top) having a layer thickness of 0.15 m on a filter of synthetic woven fabric.
- boulders from 3 m + PWD down to (on average) 25m-PWD having a D_{50} = 0.15 m and a layer thickness of 0.30 m. The boulders are dumped on a fascine mattress consisting of a composite geotextile with a framework of bamboo poles and reed fascines (note that this type of mattresses was successfully applied in Bangladesh for the Feni Dam closure in 1985).

At the toe of the slope revetment a falling apron is applied to anticipate future scour to the calculated maximum depth.

The principle of the falling apron is well known in the sub-continent and it was successfully applied at the Hardinge Bridge. It will also be applied in the river training works for the Jamuna Bridge. For this falling apron a grading of boulders has to be selected which contains a sufficient quantity of rock suitable to individually resist the current forces.

For more details on the above reference is made to Annex G of this Report.

The two alternative designs developed are presented on Figs. 4.9 and 4.10.

92

4.5.3 Maniknagar

In Section 4.2.3 it was concluded that only two alternative solutions out of four solutions formulated warranted further consideration with the context of this Short Term Study:

(1) maintain bank line in outer bend by protection works i.e. either a continuous revetment or a series of groynes;

(4) do nothing in the near future.

For (1) pre-feasibility level designs have been made (see Figure G.1.5.7 in Annex G).

However, bearing in mind that (i) the erosion rate is reach the embankment of the Dhonagoda Irrigation Project only after, say, 45 years and (ii) the low value of the benefits, the Consultants propose to do nothing in the near future at Maniknagar.

4.5.4 Meghna Roads and Highways Bridge

In Section 4.2.4 it was suggested that short term solutions required to project the bridge press, its abutments and approaches are the responsibility of the bridge contractor.

Three alternative long-term solutions were suggested:

(1) protection of ferry ghat and vortex areas;

(2) ditto but also groyne of 200 m length upstream of Bridge;

(3) spurdyke which guides the flow lines.

Though the effects on the flow lines of a groyne and a spurdyke are hard to predict without further detailed study it must also be realized that protective measures are urgently required for the Meghna Roads & Highways Bridge. On the basis of (i) more favourable cost and (ii) the future geo-morphological development (Annex B) the alternative of the spurdyke consisting of sand cement stone was selected.

The core of sand cement stone will be protected by an armour layer of concrete blocks. The layer thickness of (D=0.25) m cubes will be 0.50 m. Also here a falling apron will be required as the scour depth could be 10 m in relation to the actual depth of 20 m (see Annex B for further details).

4.5.5 Munshiganj

(a) Selected alternative

In Section 4.2.5 it was stated that after due consideration a combination of alternatives (2) and (3) was selected. This means in practice that as much as possible the existing embankment is used and by means of cut and fill a suitable slope is created on to which the revetment is placed (Fig. 4.11).

(b) Boundary limits

The boundary limits are practically the same as for Bhairab Bazar. It implies that scour depth, current velocities, geotechnical considerations and wave attack are the same as for Bhairab Bazar (see Section 4.5.2).

(c) Design of revetment

On the basis of (b) above it was decided to have a revetment design for Munshiganj which is equal to that of Bhairab Bazar. Local topographic/bathymetric features may be slightly different but these do not change the calculations performed earlier for Bhairab Bazar.

4.5.6 Eklashpur

(a) Alternatives

In Section 4.2.6 four alternative solutions were presented which show an increasing degree of intervention in the existing erosion and flow pattern:

(1) protection of existing embankment by means of a deeply founded revetment;

(2) construction of a retired embankment, for the time being without revetment;

(3) a banana shaped guide bund protecting a bank line stretch in addition to the stretch of river bank defended according to BWDB design;

(4) a groyne placed under an angle with the embankment' axis (length 600 m, location 2 km u/s of Eklashpur).

After design drawings were made for the various alternatives (Annex G, Figures G.2.5.3, G.2.5.4) preliminary cost estimates have been prepared taking into account that phasing of construction is possible.

It was felt that Eklashpur is most benefitted by a solution that can be implemented relatively quick and is, of course, economically feasible. Accordingly alternative (1) was selected for further elaboration.

(b) Design and dimensioning

As the maximum current velocity (1.9 m/s according to physical model tests, see Annex D) and the maximum scour depths to be expected (10 m according to the aforementioned tests) at Eklashpur are similar to those at Bhairab Bazar the same structural design of the revetment could be applied for Eklashpur. The only difference with Bhairab Bazar is a heavier wave attack. Therefore the open stone asphalt layer in the zone of wave attack will have a thickness of 0.20 m at Eklashpur.

It is possible to construct the protection works partly in the dry by excavating a trench. For further details reference is made to Figures G.2.5.5 and G.2.5.6 of Annex G.

The protection as being carried out by BWDB is improved upon by extending the lower part by a boulder mattress and a falling apron section.

4.5.7 Chandpur

(a) Alternative selected

In Section 4.2.7 various alternative solutions to protect Chandpur against erosion by wave attack and current attack were discussed. An advanced protection of Nutan Bazar was selected for further elaboration. In addition it was stated that this protection will also protect Puran Bazar against scour, though to a lesser extent, and that this last location in any case needed a protection against wave attack.

As already mentioned in Section 4.2.7 GOB felt the need for a design of emergency works at Chandpur. Emergency designs for the protection of the most critical areas are, however, generally not the result of an optimisation of functional requirements, costs and benefits.

As discussed in Section 4.2.7 the Consultants had already selected and designed short term measures for the protection of Chandpur. Consequently, the most convenient approach for the lay-out of the emergency designs, was to design a structure which is part of the proposed short term measures and which can be integrated into the lay-out of the short term measures.

(b) Scour depth

Scour depths to be expected in front of a bank protection at Chandpur are unique in the sense that there are only a few river banks in the world which border channels having a scour depth of 69 m (63 m -PWD). This figure is the combined result of two types of scour: outer bend scour and protrusion scour. More details are presented in Annexes B, D and G.

(c) Geometry of bank protection

Protection of Nutan Bazar will be by means of a banana shaped (in plan) bank protection which provides a 25 m wide berm. This berm has its top at 5.40 m + PWD (water level 1:100 years flood 5.38 m + PWD).

Emergency works at the same location would be similar in geometry but much shorter in developed length as the emergency works would mainly protect the Mosque and the Railway Station at Nutan Bazar. Figures 4.13 and 4.14 show the proposed protection works at Nutan Bazar and the emergency works respectively.

Other considerations are similar as to those presented for Bhairab Bazar (Section 4.5.2, paragraph (c)).

(d) Design Parameters

Current velocities follow from the scale model testing (Annex D) carried out for various alternative solutions at Chandpur. The maximum flow velocities found for the advanced protection in front of Nutan Bazar:

at Nutan Bazar	3.5 m/s
at Puran Bazar	1.5 m/s

Because of the protection works at Nutan Bazar the current is diverted from the Puran Bazar Bank which explains the lower value found for the current velocity.

Extensive slope stability calculations (Annex C) showed for a 1:3.5 slope at Chandpur safety values of 1.68 - 1.76 and 1.22 - 1.27 depending on the location. Requirements (safety factors) were 1.5 and 1.1 respectively. The lower values take seismic activity into account. Also here a slope of 1:3.5 does satisfy micro-stability requirements and the angle of internal friction is $\varphi' = 27°$ for stability of an infinite slope.

(e) Slope protection alternatives

The considerations about open and closed type revetments as given for Bhairab Bazar (Section 4.5.2 paragraph (e)) apply also here. Also slope protection alternatives and criteria tested in a MCA and as given for Bhairab Bazar do apply. The situation at Chandpur is however different from that at Bhairab Bazar: greater scour depth, large current velocities, greater exposure to wave attack. Consequently, the MCA shows that rock is to be preferred for the revetment rather than boulders:

- protection above water: stone asphalt on a geotextile;

- protection under water: rock on a fascine mattress;

- falling apron: rock having a proper grading without underlying geotextile.

For further details reference is made to Section G.2.5.3.2 of Annex G of this Report.

(f) Dimensioning of revetment elements

Also here firstly a deterministic design method has been applied. The outcome of the calculation was as follows:

- open stone asphalt from 2.50 m + PWD up to 5.40 m + PWD (top) having a layer thickness of 0.20 m on a filter of synthetic woven fabric;

- rock from 2.50 m + PWD down to an average bed level of [illegible] PWD having a D_{50} = 0.35 m and a layer thickness of 0.70 m. The rock is placed onto a fascine mattress by using special stone placing equipment. Composition of fascine mattress is similar to that proposed for Bhairab Bazar.

At the toe of the slope revetment a falling apron is applied.

For further details reference is made to Annex G and to Fig. 4.12.

4.5.8 Haimchar

In Section 4.2.8 three alternative solutions were selected for further consideration for bank protection at Haimchar:

(1) a revetment protecting the existing bank;

(2) a retired embankment protected by a deeply founded revetment;

(3) groynes u/s of Haimchar which should deviate the flow from Haimchar.

The situation is in so far similar to that at Eklashpur that also here construction of works can be phased. After due consideration it was concluded that a combination of alternatives (1) and (2) is most beneficial for Haimchar.

Design, dimensioning and construction methods of the protection works are similar to those envisaged for Eklashpur but at Haimchar future scour depths will be 13 m -PWD in the present geo-morphological situation.

As this situation is, however, expected to improve in future i.e. the erosion proves will decreased a scour depths at 10 m -PWD was taken for the design of the falling apron (to be placed in the drawing as for Eklashpur at the bottom of a trench at 7 m -PWD).

Other boundary conditions like flow velocities (1.9 m/s) and wave height (1.25 m) are the same as for Haimchar.

For lay-out and a typical cross-section reference is made to Annex G, Figures G.2.5.15 and G.2.5.16.

4.6 Analysis and Final Selection of Project Designs for Bhairab Bazar

4.6.1 General

For the sites of Bhairab Bazar two alternative designs were selected for further elaboration. As the details of the design and its estimated construction costs and benefits are now known it is possible to make the final selection.

As stated on Section 4.4.5 such selection is only necessary for Bhairab Bazar. For the other sites only one design was selected for further elaboration.

4.6.2 Bhairab Bazar

It is recalled that two alternative solutions were identified as suitable for short term protection works at Bhairab Bazar.

These alternatives were:

(2) overall protection along existing right bank and between bridge piers;

(3) ditto, but same works now advanced in order to create a smooth bank line and a reclaimed area immediately behind the bank line.

Selection must take place on the basis of quantifiable (costs, benefits) as well as on non-quantifiable effects. The latter concern structural, construction, environmental and social aspects.[1]

When such a diversity of effects has to be judged it is difficult to make an objective choice.

By carrying out a multi criteria analysis (MCA) it is possible to obtain more insight in the relative importance of individual effects for each alternative. For the technique to be applied in making a MCA reference is made to Annex G, Section G.1.8 and Appendix G/1. Here, only the two tables (4.6 and 4.7) for alternatives (2) and (3) respectively are presented in order to show: what primary and secondary criteria have been used (columns 1, 3), the weightings of primary and secondary criteria (columns 2, 4 respectively), the suitability in points (column 5) and the final score (column 6).

1 Reference is made in this respect to the foregoing Sections of this Chapter as well as to Chapters 8 and 10 respectively.

Table 4.6 CALCULATION OF SCORE FOR ALTERNATIVE I, BHAIRAB BAZAR

Primary criteria	Z (%)	Secondary criteria	X (%)	Y	W
Flexibility	24	Settlements	20	2	9.60
		Scour	40	2	19.20
		Geotechnical	40	1	9.60
Durability	20	Erosion	40	3	24.00
		Climate	30	2	12.00
		Chemicals	15	3	9.00
		Biologic	15	2	6.00
Construction	18	Duration	40	2	14.40
		Availability	20	0	0.00
		Quality control	40	1	7.20
Maintenance	13	Monitoring	40	1	5.20
		Duration	20	2	5.20
		Replacement	40	1	5.20
Environment	12	Pollution	40	2	9.60
		Impact	50	1	6.00
		geometry/colour	10	1	1.20
Human Factors	13	Vandalism	10	2	2.60
		Social impact	60	0	0.00
		Mishaps	30	1	3.90
TOTAL					149.90

where:
X = weight of secondary criteria in %
Y = suitability of alternative in points
- Y=0 satisfies requirements almost not at all, to poorly
- Y=1 satisfies requirements poorly to sufficiently
- Y=2 satisfies requirements sufficiently to reasonably
- Y=3 satisfies requirements reasonably to well

Z = weight of primary criteria in %

Table 4.7 CALCULATION OF SCORE FOR ALTERNATIVE II, BHAIRAB BAZAR

Primary criteria	Z (%)	Secondary criteria	X (%)	Y	W
Flexibility	24	Settlements	20	2	9.60
		Scour	40	2	19.20
		Geotechnical	40	3	28.80
Durability	20	Erosion	40	3	24.00
		Climate	30	2	12.00
		Chemicals	15	3	9.00
		Biologic	15	2	6.00
Construction	18	Duration	40	3	21.60
		Availability	20	3	10.80
		Quality control	40	3	21.60
Maintenance	13	Monitoring	40	2	10.40
		Duration	20	2	5.20
		Replacement	40	2	10.40
Environment	12	Pollution	40	2	9.60
		Impact	50	2	12.00
		geometry/colour	10	1	1.20
Human Factors	13	Vandalism	10	2	2.60
		Social impact	60	3	23.40
		Mishaps	30	1	3.90
TOTAL					241.30

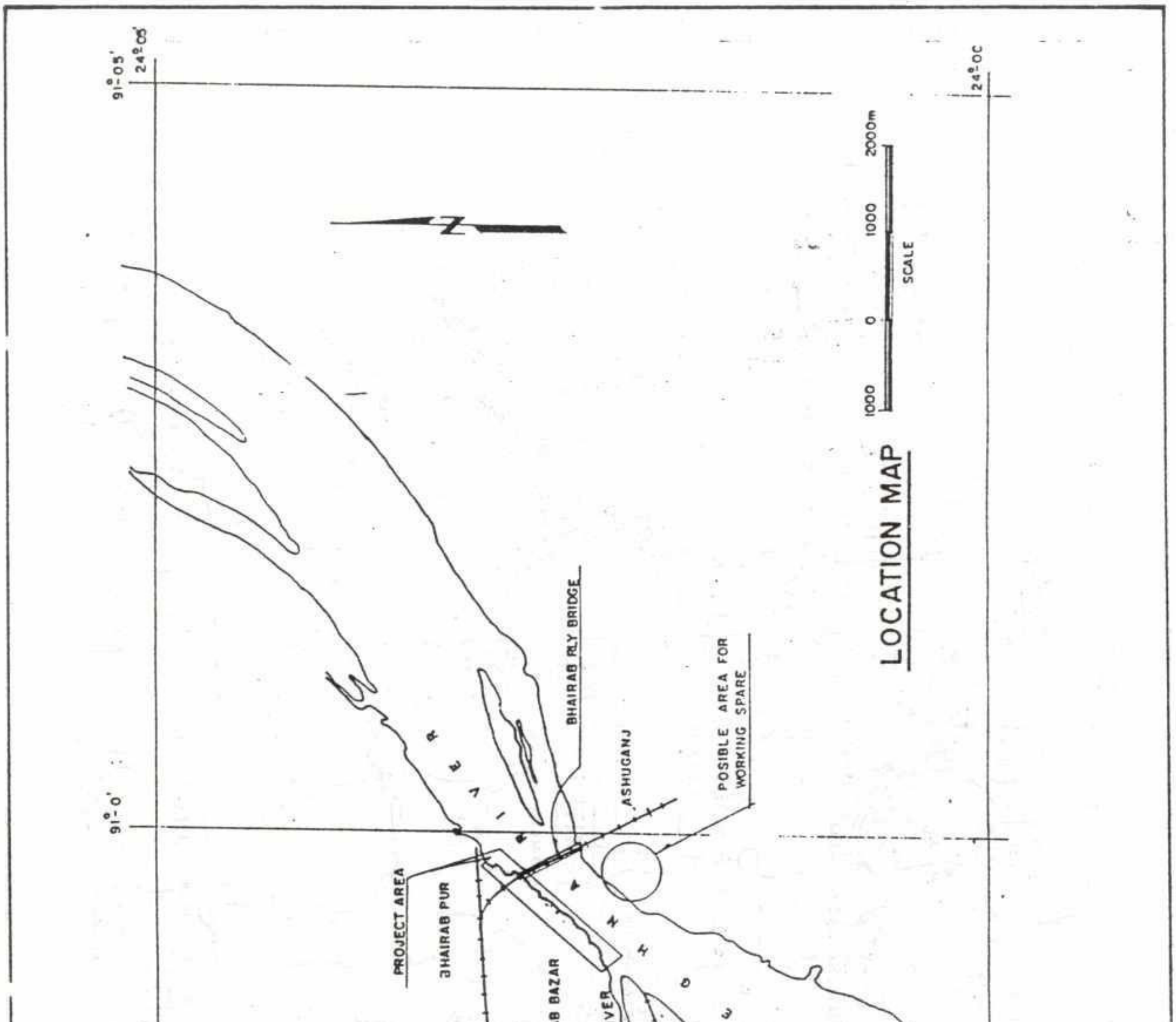
where:
X = weight of secondary criteria in %
Y = suitability of alternative in points
- Y=0 satisfies requirements almost not at all, to poorly
- Y=1 satisfies requirements poorly to sufficiently
- Y=2 satisfies requirements sufficiently to reasonably
- Y=3 satisfies requirements reasonably to well

Z = weight of primary criteria in %

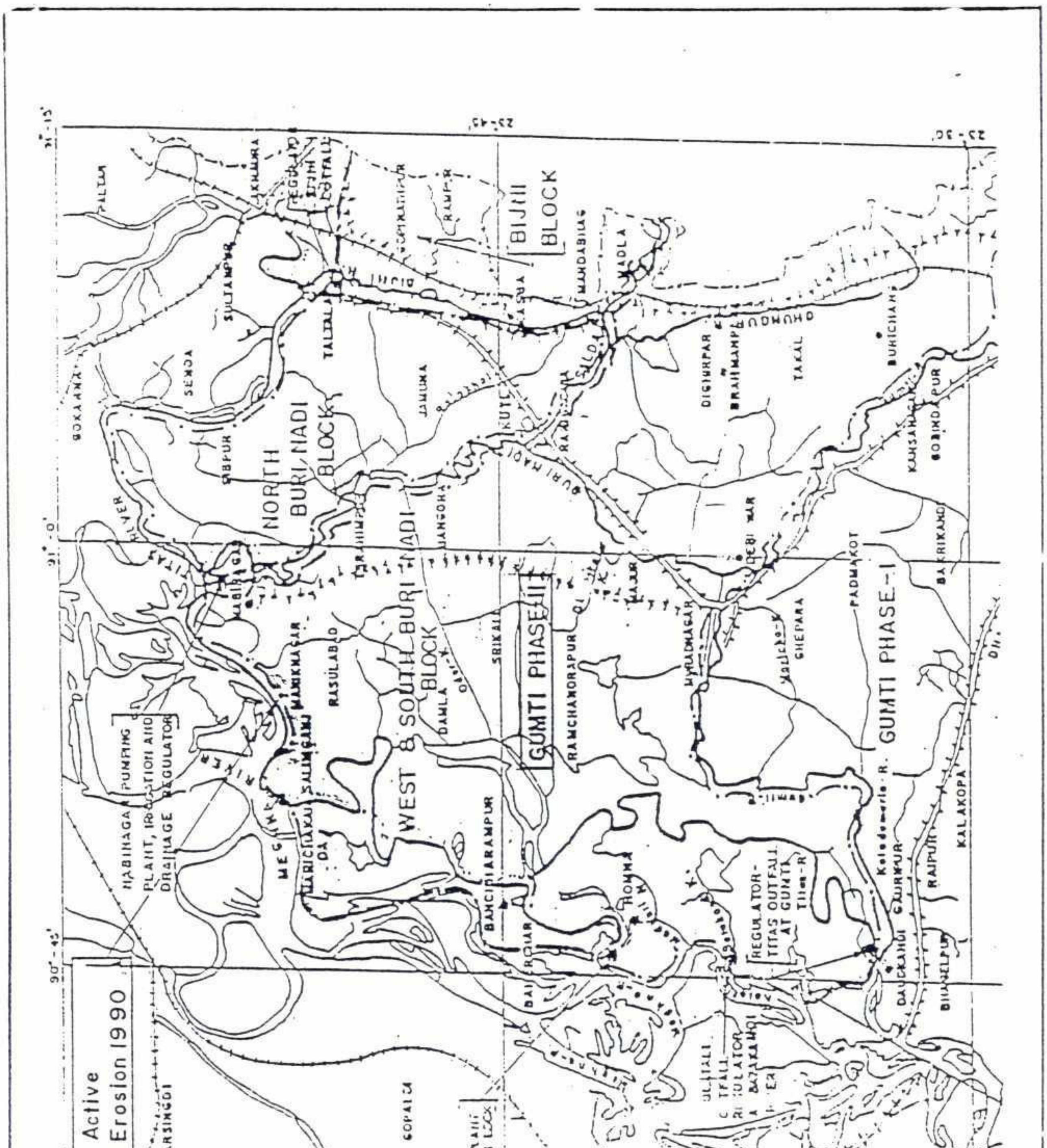
The final result is shown in Table 4.8.

Table 4.8: **FINAL SELECTION SOLUTION FOR BHAIRAB BAZAR ON BASIS OF MCA, COST AND BENEFITS**

Alternative	MCA Score	Cost in million US$	Benefit in million US$	IRR cost	MCA / [illegible]	MCA x
(2) "normal" bank protection		149.9	13.9		10.8	
(3) advanced bank protection		241.3	15.7		15.4	

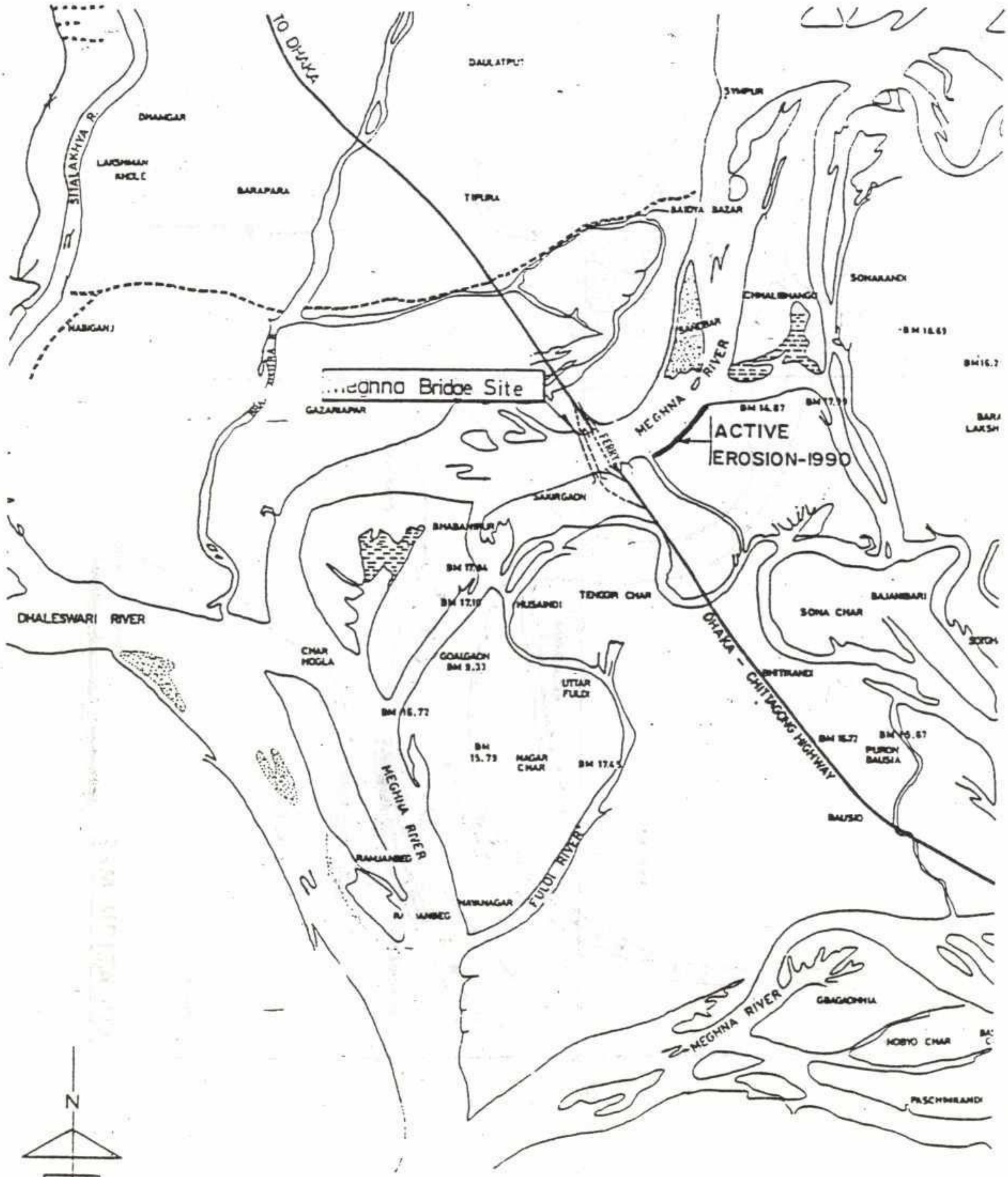


LAYOUT PLAN BHAIRAB BAZAR	FIGURE 4.2



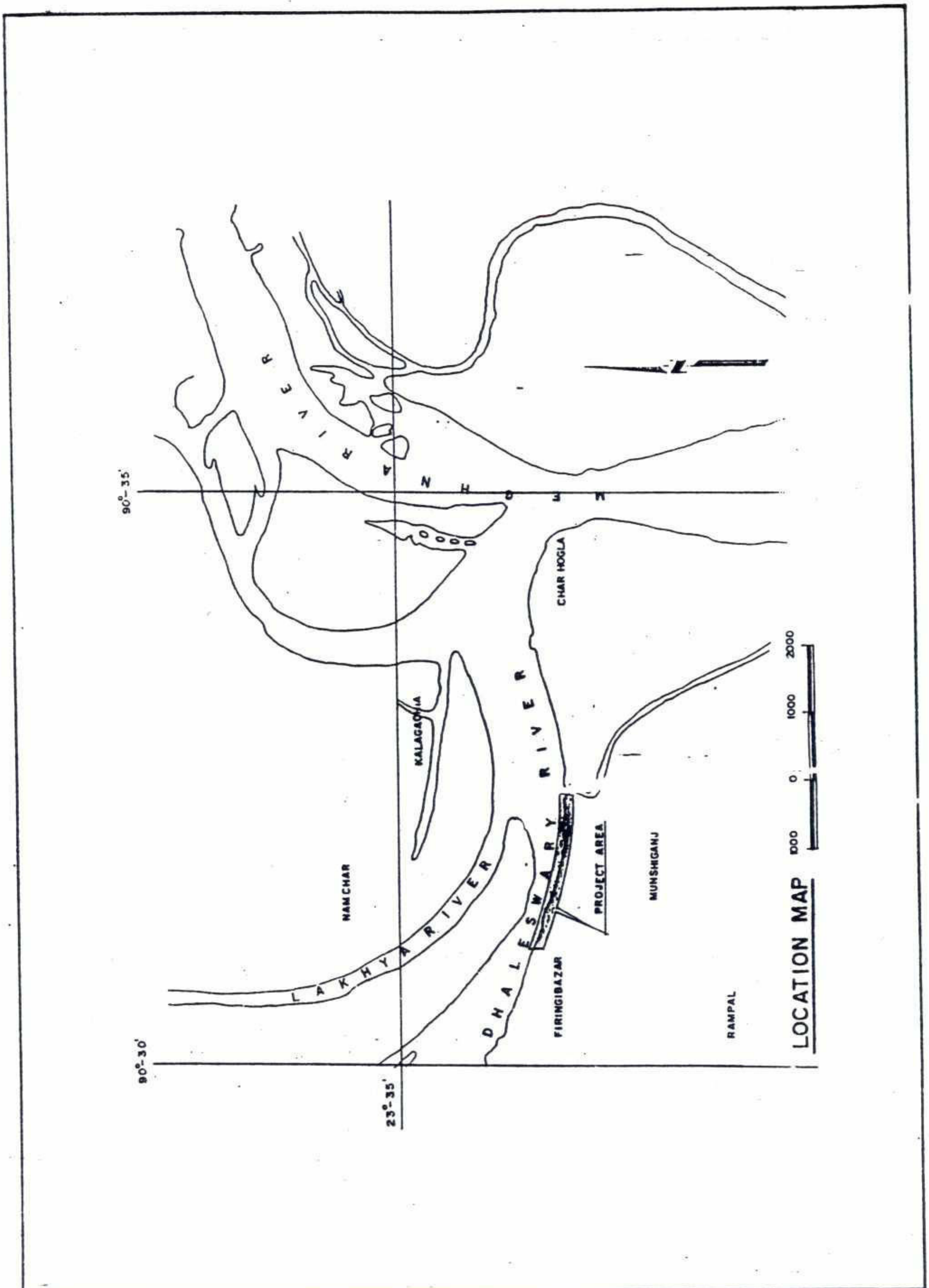
LAYOUT PLAN MANIKNAGAR

FIGURE NO. 4.3

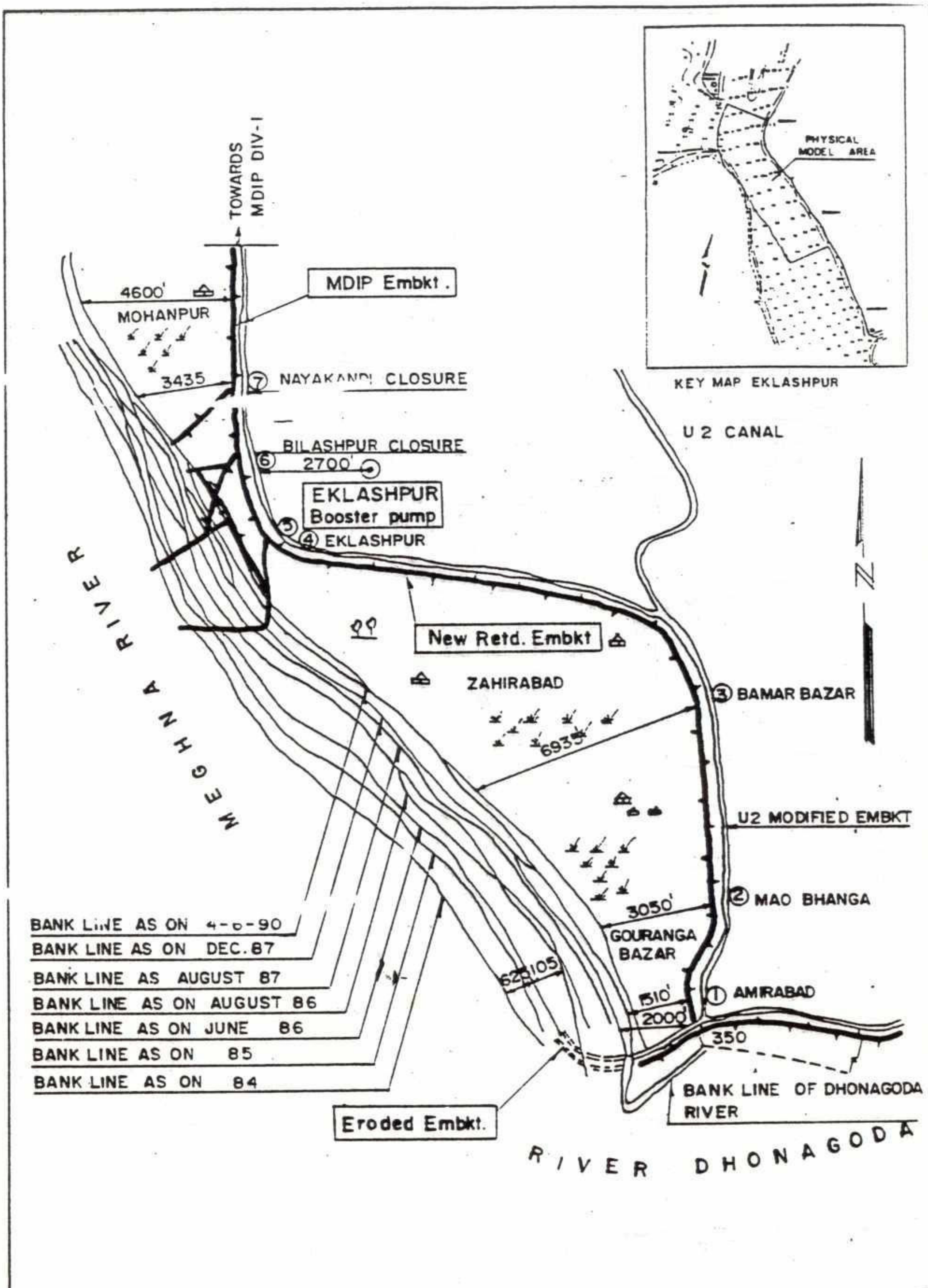


LAYOUT PLAN R & H BRIDGE

FIGURE NO. 4.4

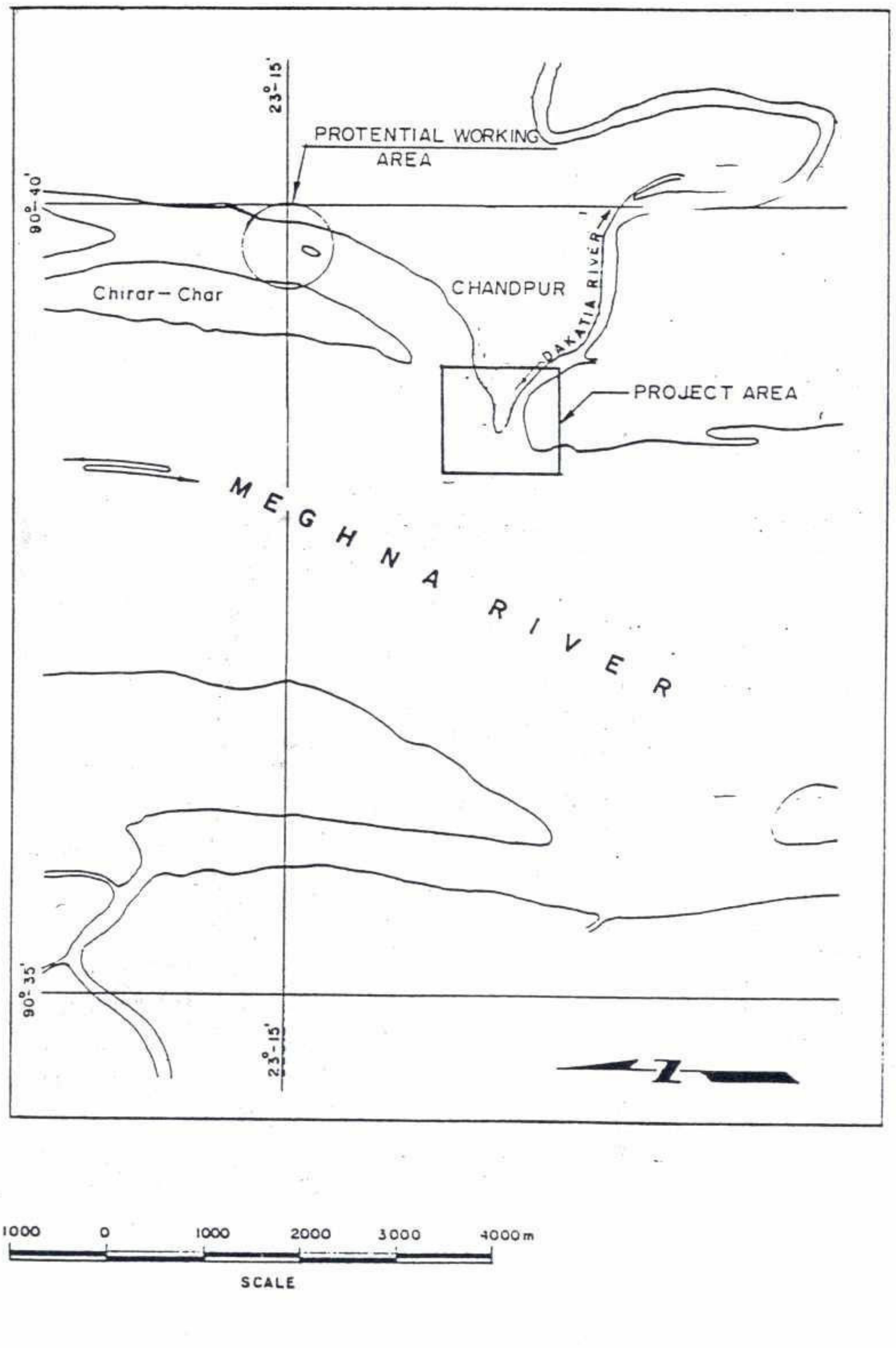


LAYOUT PLAN MUNSHIGANJ	FIGURE 4.5



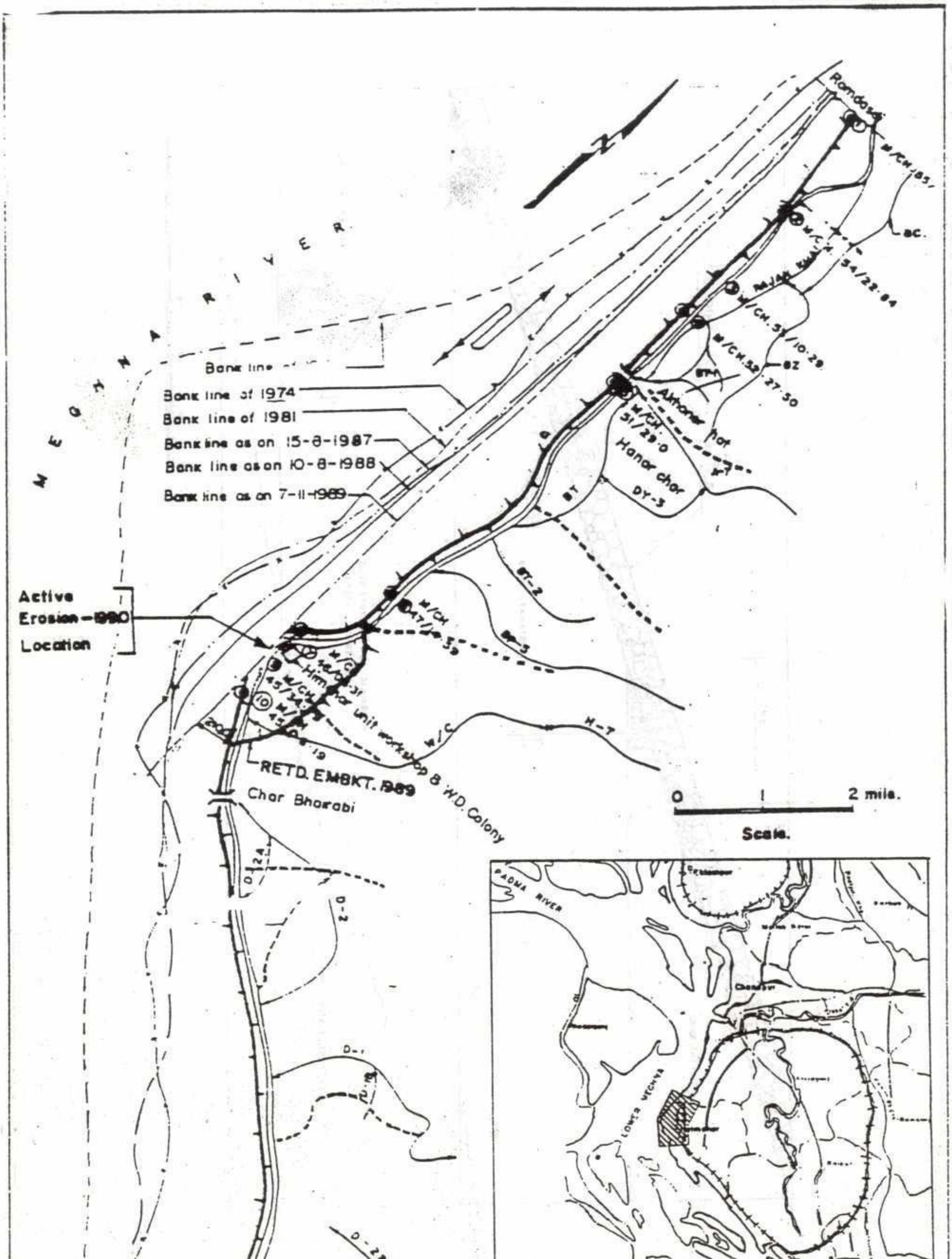
LAYOUT PLAN EKLASHPUR

FIGURE 4.6



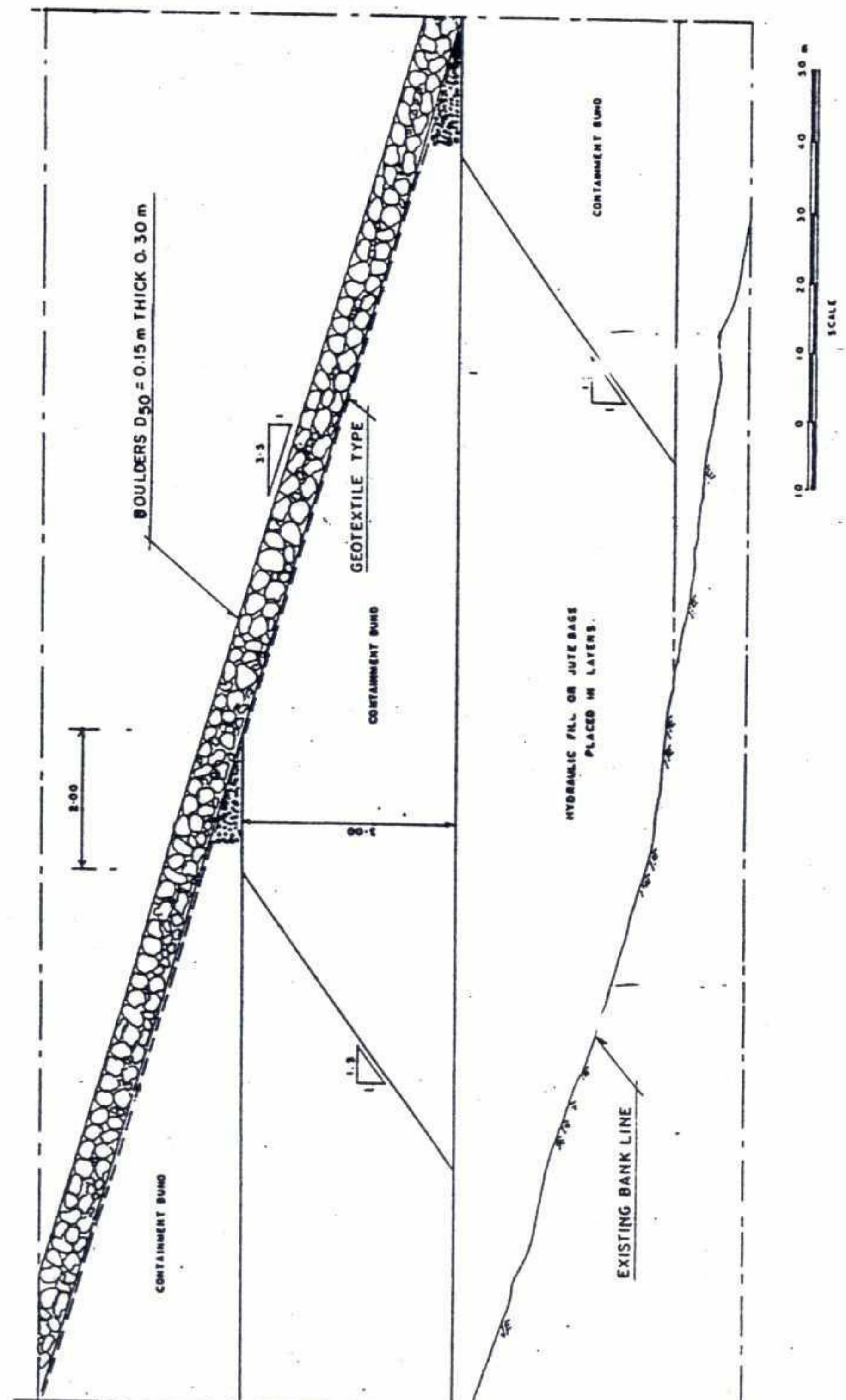
LAYOUT PLAN CHANDPUR TOWN

FIGURE 4.7



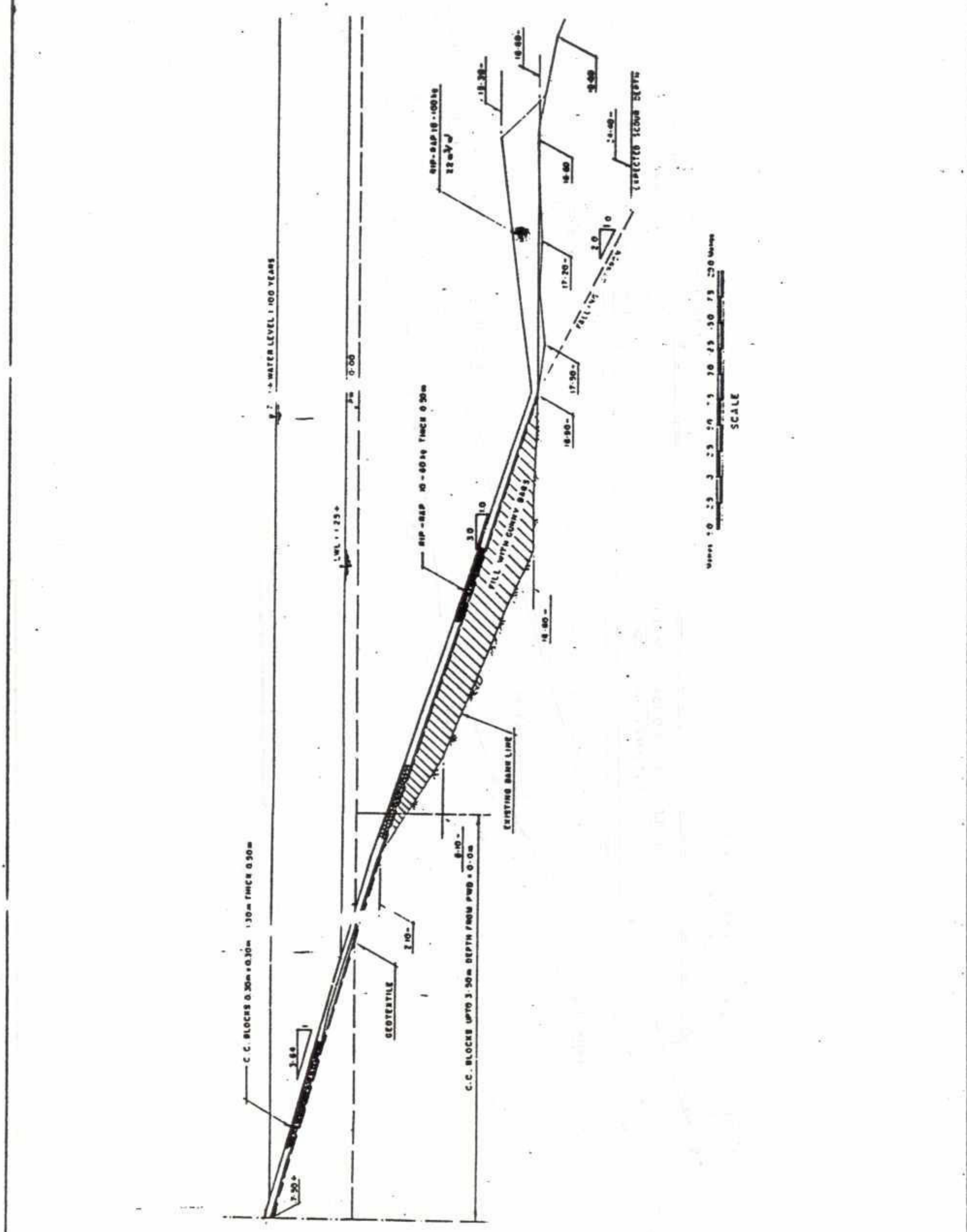
LAYOUT PLAN HAIMCHAR

FIGURE 4.8



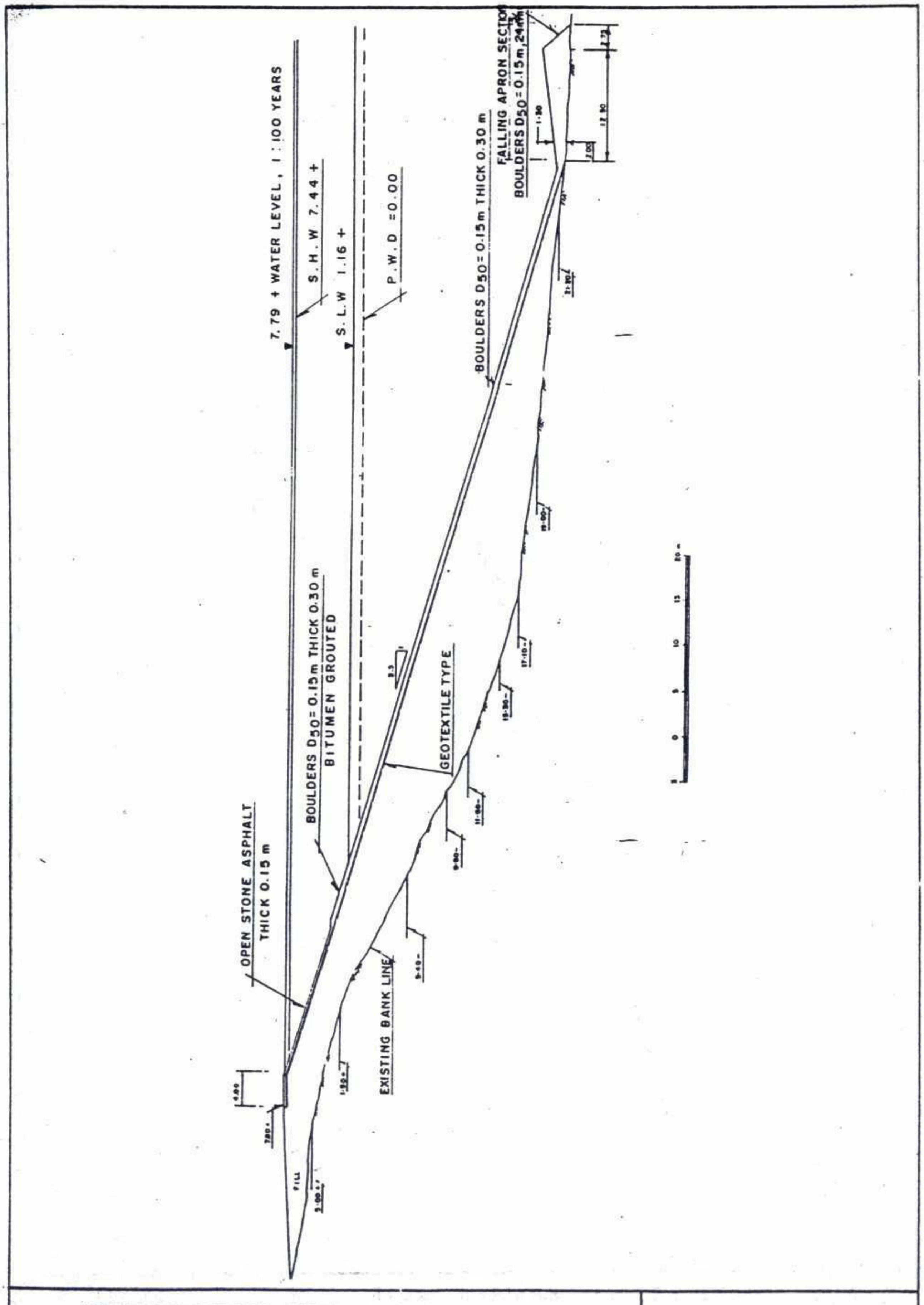
CONTAINMENT BUNDS

FIGURE 4.9



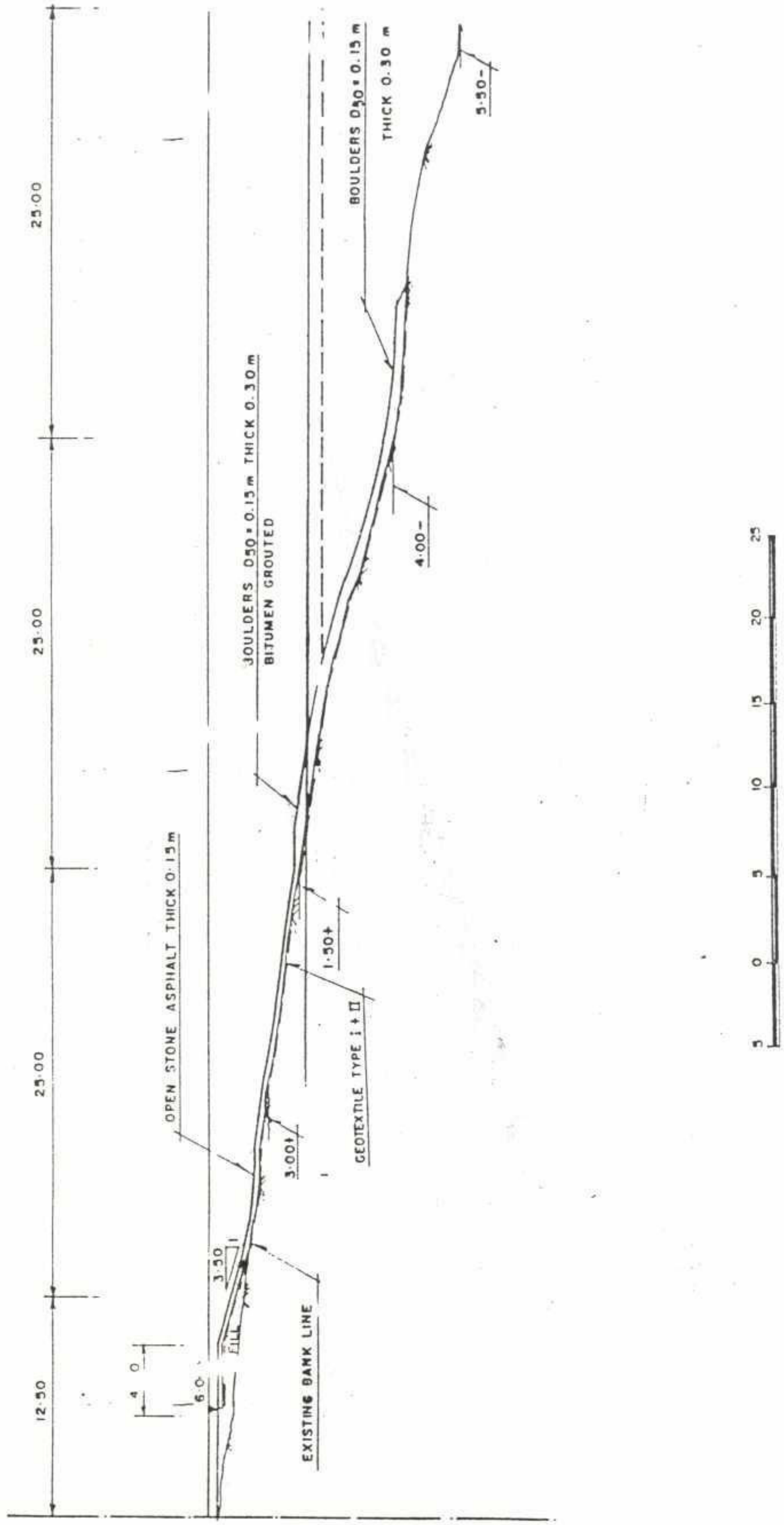
TYPICAL CROSS SECTION BHAIRAB BAZAR
(PROTECTION ON EXISTING SLOPE)

FIGURE 4.10

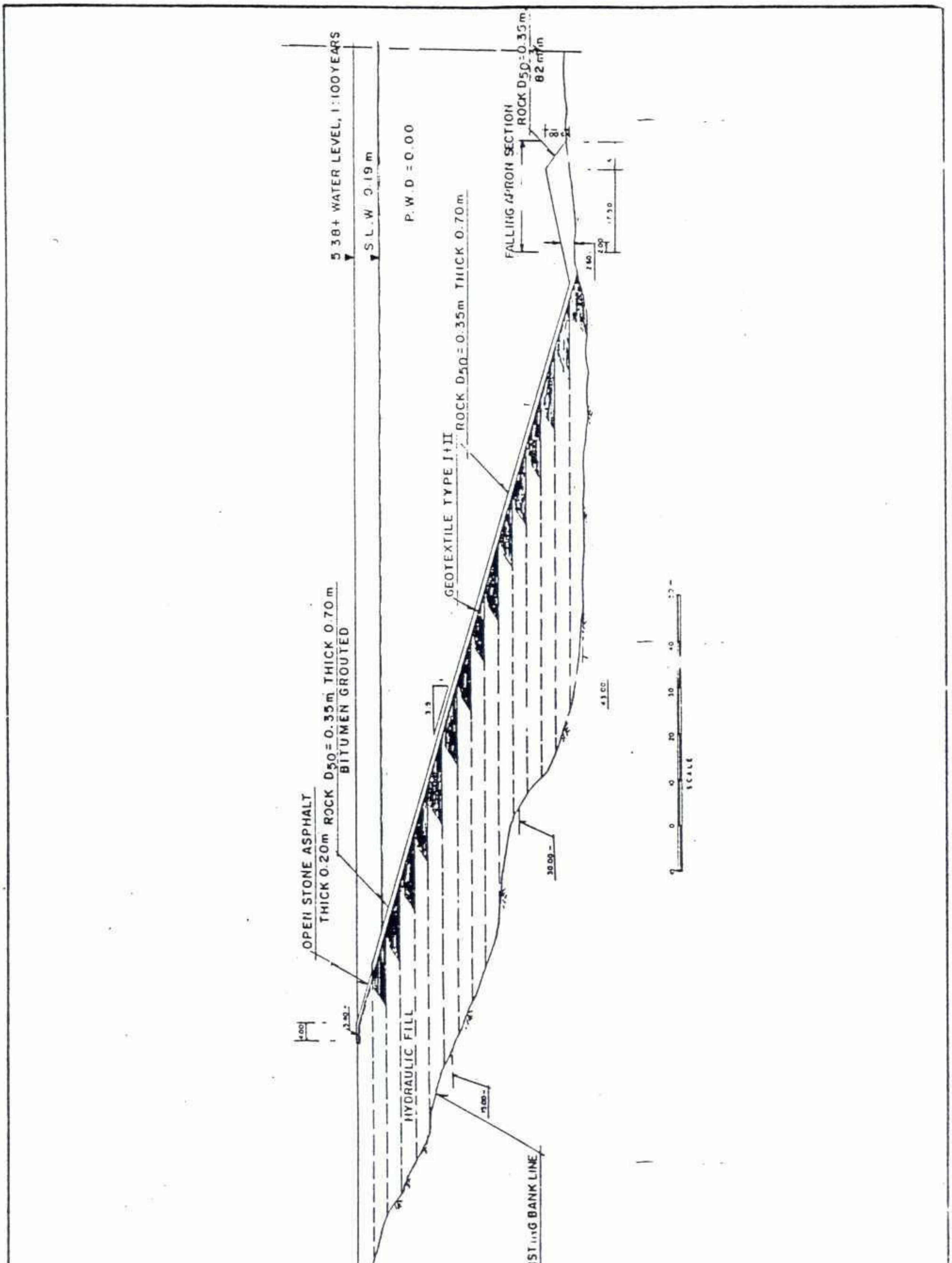


TYPICAL CROSS SECTION BHAIRAB BAZAR
(ADVANCED PROTECTION)

FIGURE 4.11



TYPICAL CROSS SECTION MUNSHIGANJ	FIGURE 4.12



TYPICAL CROSS SECTION CHANDPUR	FIGURE 4.13

5. RISK ANALYSIS AND PROBABILISTIC DESIGN

5.1 General

Until recently civil and hydraulic engineering projects were designed on a purely deterministic basis. This meant that a certain safety factor was applied, a design load selected without regard to the economic consequences of these choices or to the possibilities of failure which existed. In many cases this meant that a structure was over designed in one aspect and was therefore too costly but also that it had a good chance to collapse because another aspect (e.g. lack of maintenance) was neglected.

This omission was first felt in the offshore industry and by the designers of airplanes and space craft. It was then that risk analysis and related probabilistic design methods were introduced.

Following the successful application in offshore projects and commercial aviation the risk analysis was introduced in the Netherlands in large hydraulic engineering projects, i.e. the multi billion Eastern Scneldt Storm Surge Barrier.

It should be emphasized that introduction was only possible because of high capacity computers and related software becoming available in the seventies.

The procedures and calculation methods developed in the Netherlands for risk analysis and probabilistic design of hydraulic engineering projects were for the first time applied at a large scale in Bangladesh for the design of the river training works for the Jamuna Bridge.

Also for the bank protection works at three priority sites along the Meghna River a risk analysis has been carried out.

As the application of this method is not yet standard a general introduction is presented below followed by some figures as calculated for the bank protection works. Details on the risk analysis performed can be found in Annex G, Sections G.1.5.4 and G.2.5.5.

5.2 Introduction into the Risk Analysis of Bank Protection Works

5.2.1 Objectives and Definitions

The objections of the risk analysis are:

- to define an acceptable probability of failure of the bank protection;
- to identify and quantify the hazards of the bank protection;
- to integrate the design of the bank protections into other infrastructural works.

The three main elements in a risk analysis are hazard, mechanism and consequences. A risk analysis starts with an inventory of the hazards and mechanisms. A mechanism is defined as the manner in which the structure responds to a hazard as shown in the following scheme.

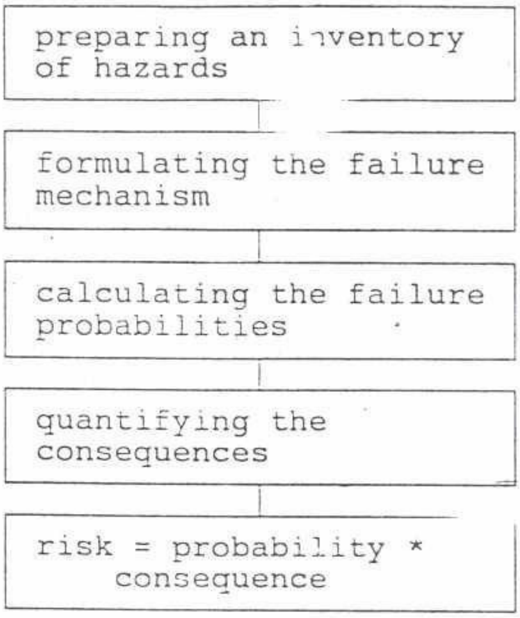


Figure 5.1 Elements of risk analysis

A combination of hazards and mechanisms leads, with a particular probability, to failure or collapse of the structure or of its components parts.

Finally, the consequences of failure or collapse must be considered. In the event of failure of a bank protection as a whole,the relevant damage characteristics, structural damage and duration of load must be estimated. The probability of failure multiplied by the damage or loss constitutes the risk. For an optimal design it is essential to weigh the risk against the cost of constructing a heavier structure.

5.2.2 Failure Modes

Bank protection along the Meghna River is constructed to protect the population and the economic values against floods and shifts of the alignment of the river. Absolute safety is in principle impossible to realize. Therefore it is much better to speak about the probability of failure of a certain protection system. In Table 5.1 some possible modes of failure have been listed. All possible causes of failure have to be analyzed and consequences determined. The so-called fault tree is a good tool for this purpose.

Table 5.1 POSSIBLE CAUSES OF FAILURE OF BANK PROTECTION

Possible failures to be analysed
Bank instability
Toe scour
Transition between parts or systems
over topping
excessive movement of armour under current attack
excessive movement of armour under wave attack
settlement
loss of sub layer material through armour
loss of subsoil through geotextile filter
loss of grouting or binder materials
deterioration of geotextile filters
failure of cables
failure of pins or other connections
abrasion
corrosion of wire
chemical action
bed lowering by dredging or maintenance
plant growth
cattle
vandalism

An overall fault tree for a bank protection is presented in Figure 5.2. In the following the design will be restricted to the following failure modes, which will be analyzed thereafter:

- geotechnical failure
  - micro instability
  - macro instability
- failure of the slope protection
  - instability of top layers
  - instability of filter layers

The risk analysis is based on the fault tree presented in Figure 5.3. The specific sites of Bhairab Bazar and Munshiganj have been considered when this fault tree was prepared.

The fault tree is an essential part of the probabilistic design Approach which, as a rule, can only be applied quantitatively at the design stage. The said fault tree is a scheme in which events and their consequences, or errors and their causes, which contribute to the failure, are arranged clearly.

5.2.3 Acceptable Probability of Failure

An acceptable probability of failure for bank protection works is determined on the basis of Fig. 5.2. The graph displayed in this figure shows generally accepted risk levels for various structures and activities.

In view of the type of protection, magnitude of loads, cost of repair works and commercial interests involved an acceptable failure probability has been determined:

- for bank protection works at both Bhairab Bazar and Munshiganj: 0.5×10^{-3};
- for bank protection works at Chandpur: 0.25×10^{-3}.

On this basis failure probabilities can then be distributed over the various branches (i.e. events/consequences or errors/causes) of the fault trees (Figures 5.3 and 5.4).

This will not be discussed in detail. Two examples may suffice:

- in slope stability calculations it was found that the safety factor is quite high if a slope 1:3.5 is applied. Therefore the probability of failure will be quite low: 0.125×10^{-3};

- for maintenance (or better: lack of maintenance) howe..., i.e. failure to monitor and maintain sound engineering judgement results in a high probability of failure: 2.0×10^{-1}.

  Obviously such a high probability can only be counter acted upon by introducing a low probability of failure for the chance that the erosion protection layer fails or local slope damage occurs (see Fault tree, Fig. 5.3).

5.3 Probabilistic Calculations

5.3.1 General

No details will be presented here about the probabilistic calculations in which for instance Gumbel extreme value type distribution or Gauss distributions are used as well as other related parameters and methods common to statistical calculations.

Calculations by means of the probabilistic design methods can be found in Annex G Sections G.1.5.5 and G.2.5.6 and also in Appendices G/4 and G/5.

Three design loads have been used for testing (by means of the probabilistic method) the probability of failure of the protective layer designed earlier (see for instance Section 4.5.2 (f) of Chapter 4). These are:

- scour depth
- current attack
- wave attack

5.3.2 Probabilistic Calculations for Bhairab Bazar and Munshiganj

For Bhairab Bazar and Munshiganj, Tables 5.2, 5.3 and 5.4 present the results for scour, current attack and wave attack respectively.

It is shown that for:

- a scour depth of low,
- the design slope,
- slope diameter selected, and
- layer thickness of stone asphalt (0.15 m)

the probability a scour depth of 10 m, the design slopes, stone diameter selected and layer thickness of stone asphalt of 0.15 m the probability of failure is nowhere higher than the acceptable ones following from the fault tree.

Table 5.2 RESULTS PROBABILISTIC CALCULATIONS EXPECTED SCOUR DEPTHS

Scour level referred to initial bed level (m)	Probability of failure (-)	Acceptable probability of failure (-)
-10.00	9.39 10-2	1.20 10-1

Table 5.3 RESULTS OF PROBABILISTIC CALCULATIONS FOR CURRENT ATTACK AT BHAIRAB BAZAR

Section	Slope	μ(D50) (m)	σ(D50) (m)	Probability of failure (1/year)	Acceptable probability of failure (1/year)
Falling apron	1:2	0.12	0.012	1.49*10-2	3.12*10-2
Lower part	1:3.5	0.06	0.006	2.42*10-2	3.12*10-2
Upper part	1:3.5	0.06	0.006	5.33*10-3	6.25*10-3

Table 5.4 RESULTS PROBABILISTIC CALCULATIONS WAVES (OPEN STONE ASPHALT)

Slope	μ(D50) (m)	σ(D50) (m)	Probability of failure (1/year)	[1]Acceptable probability of failure (1/year)
1:3.5	0.15	0.015	1.05*10-1	1.5*10-1

5.3.3 Probabilistic Calculations for Chandpur

Similar calculations were done for the bank protection works designed for Chandpur. Tables 5.5, 5.6 and 5.7 refer.

Table 5.5 RESULTS PROBABILISTIC CALCULATIONS EXPECTED SCOUR DEPTHS

Scour level referred to initial bed level (m)	Probability of failure (-)	Acceptable probability of failure (-)
-15.00	1.0*10-2	6.00 10-2

[1] *The value presented is [illegible] from the one presented in the fault tree. A commonly used criteria for wave attack at open stone asphalt is 1.5*10-1.*

Table 5.6 RESULTS OF PROBABILISTIC CALCULATIONS RESISTANCE AGAINST CURRENT ATTACK

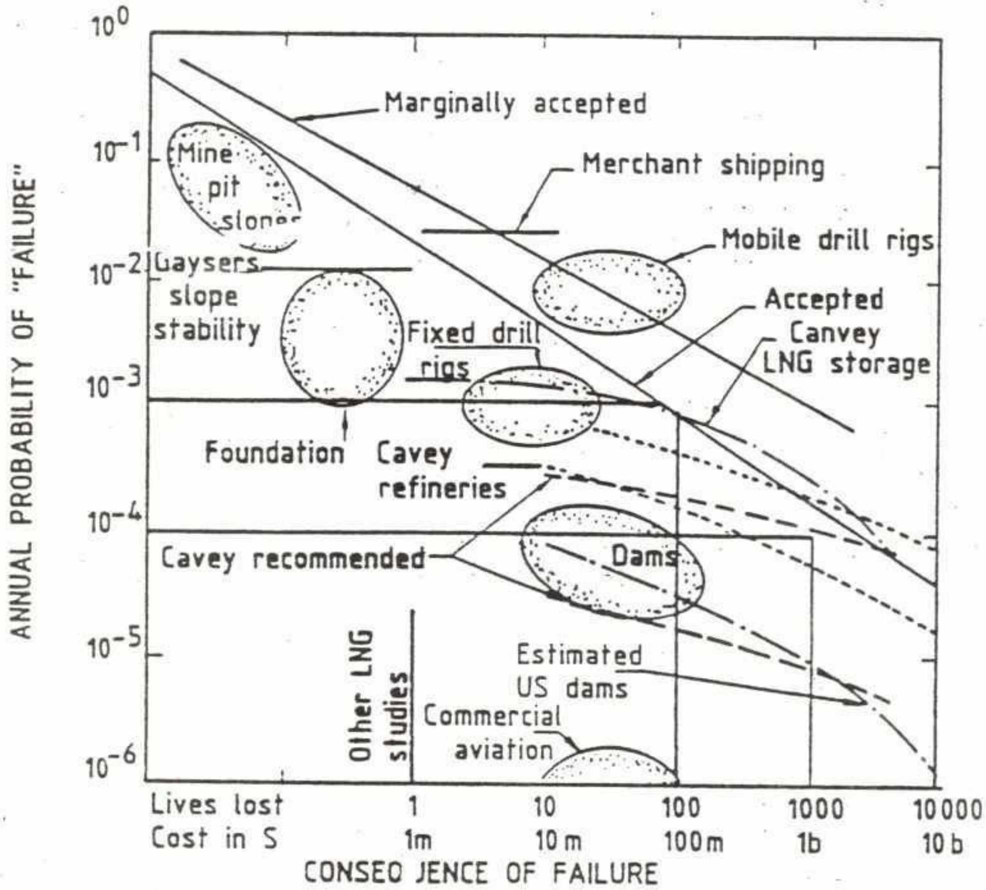
Section	Slope	μ(D50) (m)	σ(D50) (m)	Probability of failure (1/year)	Acceptable probability of failure (1/year)
Falling apron	1:2	0.35	0.035	8.0*10-3	1.56*10-2
Lower part	1:3.5	0.35	0.035	8.9*10-3	1.56*10-2
Upper part	1:3.5	0.35	0.035	1.5*10-3	3.13*10-3

Table 5.7 RESULTS PROBABILISTIC CALCULATIONS WAVES (OPEN STONE ASPHALT)

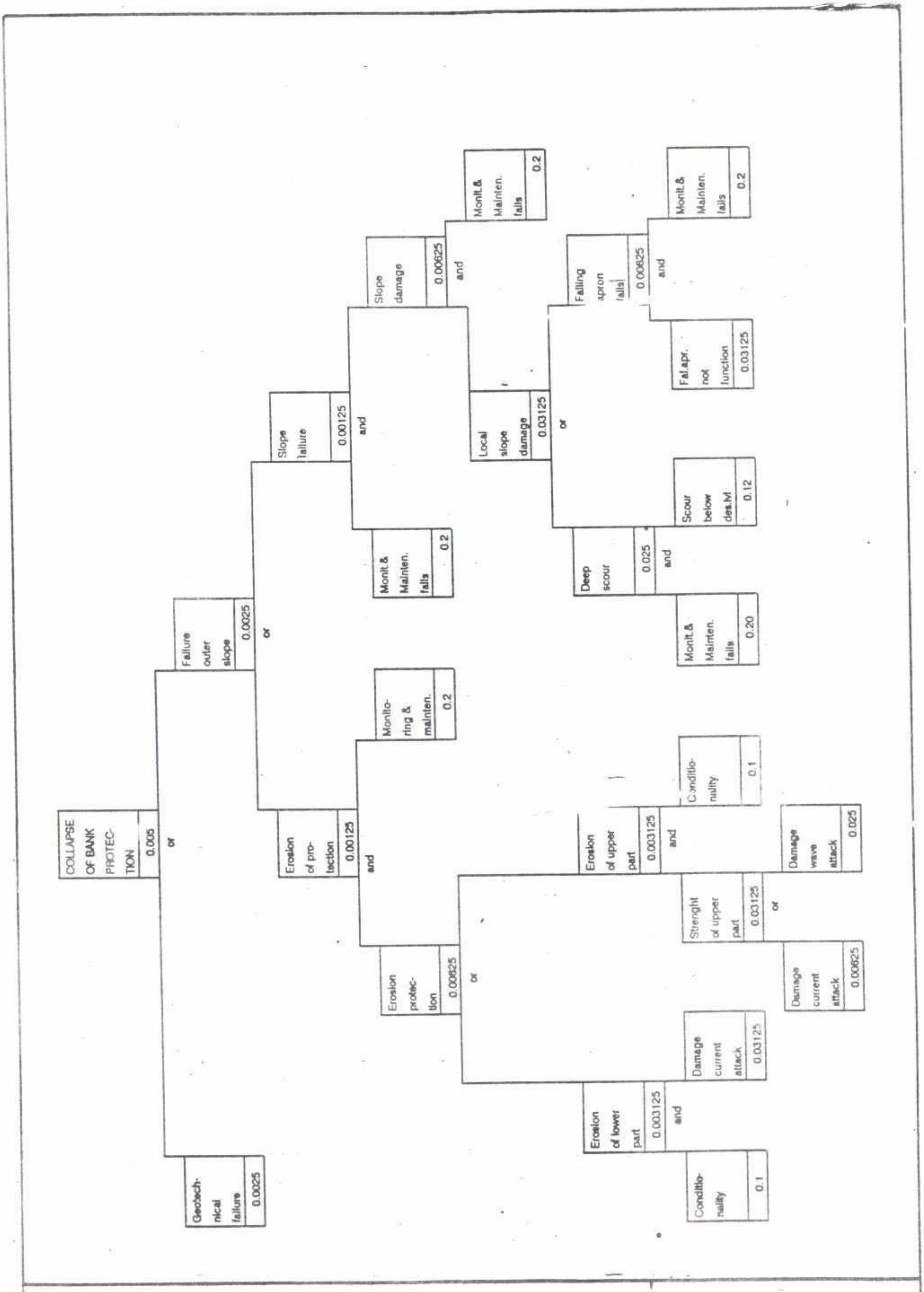
Slope	μ(D50) (m)	σ(D50) (m)	Probability of failure (1/year)	[2]Acceptable probability of failure (1/year)
1:3.5	0.20	0.020	8.75*10-2	1.5*10-1

[2] *The value presented is different from the one presented in the fault tree. A commonly used criteria for wave attack at open stone asphalt is 1.5*10-1*

29

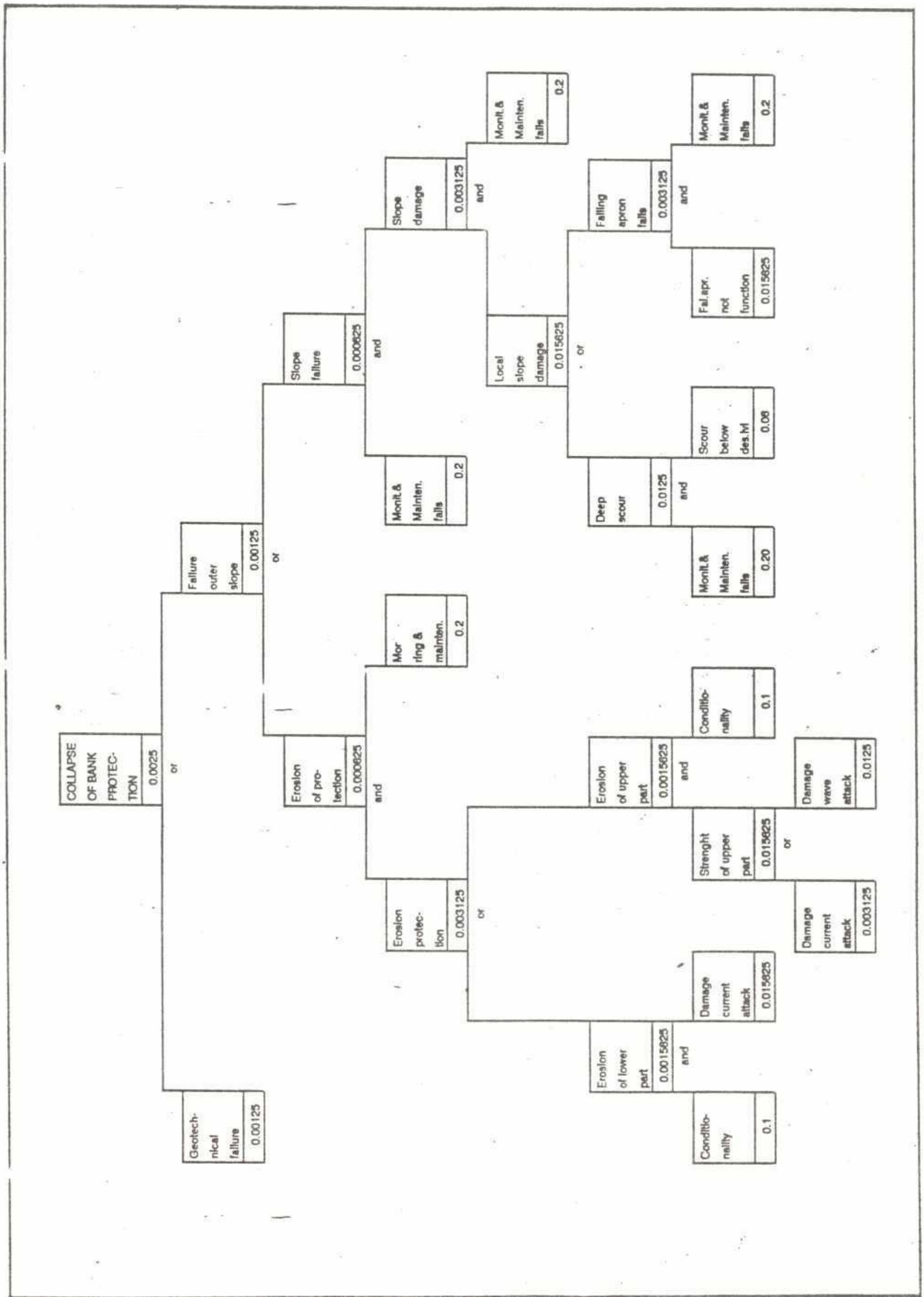


CRITERIA FOR FAILURE PROBABILITIES	FIGURE 5.2



FAULT TREE FOR BHAIRAB BAZAR

FIGURE 5.3



FAULT TREE CHANDPUR

FIGURE 5.4

6. CONSTRUCTION METHODS AND PROGRAMME

6.1 General

It is a known and accepted fact that the mighty rivers in Bangladesh in most cases during the past have continued their morphological processes without being hindered by the works of mankind.

Only in a few cases (major bridges, a few towns) mankind has been able to more or less successfully train a river at a local scale

Thanks to more detailed knowledge obtained recently about the morphological processes in Bangladesh' rivers, development of advanced design methods in the Netherlands and, last but not least, modern construction methods and equipment developed in offshore construction it is now possible to resist bank erosion by Bangladesh' mighty rivers.

Morphology and design have been discussed in other chapters and, in more detail, in various Annexes.

The importance of construction methods and related programmes for the proposed bank protection works along Upper and Lower Meghna is emphasized by dedicating a separate chapter to it.

6.2 Protection Works along Upper Meghna

6.2.1 Experience Required

The sites along the Upper Meghna for which final designs have been prepared are: Bhairab Bazar and Munshiganj. Two vital elements in the construction of new embankments or revetments at these sites are: dredging and protection of slopes under water. The works have more in common: both should be carried out in a relatively short time, mainly around the dry season. Preparations should be made in the time preceding the dry season.

The inter-relation betw... ...e various construction activities is very critical. For instance the re-dredging of a slope at Bhairab Bazar should be followed immediately by the installation of slope protection mattresses. It is obvious that such a project can only successfully be completed by contractors who not only have experience with all the elements of the work, but also have the capability to plan and coordinate all those elements.

There are no contractors in Bangladesh who have all the resources and experience to complete the works on their own, even when they would join forces. It is therefore inevitable that the works will be executed under the responsibility and control of a foreign contractor with ample working experience in similar works and with adequate equipment at hand or at his disposal.

Yet for the designs of the new embankments and slope protection works every effort has been made to use as much local resources as possible. Also Bangladeshi contractors will have ample opportunity to participate in the construction works, mainly in the capacity of suppliers and sub-contractors.

6.2.2 Dredging and reclamation

(a) Bhairab Bazar

To store his materials and to prepare slope protection mattresses, the Contractor requires an adequate work area. Inspection of the site has revealed that there are no suitable areas available at the right bank. On the other hand there appe... ...e space at the left bank, just upstream of an area not so long ago reclaimed for Petro Bangla. The Contractor's work area would have to be reclaimed with hydraulic fill from the river. Filling can be done using a cutter suction dredger.

The soil for the advanced protection at Bhairab is foreseen as hydr... This fi... be placed by a cutter suction dredger, or by a small trailing suction hopper dredger. The under water slope of the hydraulic fill might not be steeper than 1:7, which is too ge tle for the slope protection (too large an area to be protected) and would reduce the cross sectional area of the Upper Meghna too much. Therefore the underwater slopes will have to be re-dredged, as short as possible prior to the placing of the fascine mattresses. Only a well controlled cutter suction dredger is suitable for shaping the under water slopes. As it is very costly to mobilise two different dredgers for the relatively small quantity of dredging work, it is likely that the contractor will also use a cutter suction dredger for the other dredging activities.

(b) Munshiganj

For Munshiganj there are few options other than to obtain the required quantity of earth fill by dredging. In view of the relatively high level of river bed adjacent to the bank, the fill may have to be placed initially in one or more soil storage areas, from where it can be transported to its final destination using dry earth moving equipment. In this case the need to re-dredge too gentle slopes, which would result from under water disposal of dredged soil, can be avoided, thus also avoiding the need to have a dredger on site for a very long time.

6.2.3 Slope protection mattresses

Generally, slope protection mattresses consist of a geotextile fabric with a cover of boulders. For bringing the geotextile in place it will be necessary to prepare mattresses ... launching ramp. Bamboo fascines have to be fixed to the geotextile to arrive at sufficient buoyancy (necessary during transport) and flexibility, without folding, etc. during the sinking of the mattress. Experience with the Feni River Closure Dam has learned that the sinking can successfully be carried out making use of almost exclusively local resources, including labour, provided the management thereof is very strong.

6.2.4 Falling apron

Boulders for the falling apron can be applied using the same equipment and labour resources which will be required for the dumping of boulders on the slope protection mattresses.

6.2.5 Open stone asphalt

Open stone asphalt is a material which has probably not been used before in Bangladesh. Yet it can be made using fairly standard asphalt production plant, which is probably available in Bangladesh, and almost exclusively local materials. The skills of making the upper part of revetments using this material can probably be transferred to Bangladeshi contractors in the course of the project.

6.2.6 Containment bunds

Construction of an "advanced" protection in front of, for instance ...ab Bazar and Chandpur, making use of hydraulically placed fill under water, and using a "safe" slope gradient of 1:3.5 may lead to post-construction settlements in case of liquefaction caused by an earthquake. Attention should be given to this phenomenon in the risk analysis (see Annex G). Should liquefaction occur then this may theoretically lead to a mass flow. However case histories of mass flows, particularly in the Netherlands (where loosely packed fine sands abound in the southern provinces), indicate that such mass flows only occur when steep slopes (say 1:1.5) over a substantial height are present along the length of an earth structure, like a dike or dam. The proposed slope gradient for the Meghna project (1:3.5) would appear to be sufficiently conservative in this respect.

For the construction, under water, of the containment bunds, highly sophisticated equipment will be required. Two types of floating equipment come hereby to mind: a stone dumper with highly controlled sideways dumping or a work-ship equipped with a fall pipe; the end of the fall pipe may need to be provided with a remotely controlled vehicle. Yet use of such equipment may be the only acceptable possibility to achieve the required accuracy and to minimize the use of granular material. Use of less accurate equipment can easily lead to a substantially larger quantity of coarse material being required.

For placing of the bulk of the hydraulic fill use can be made of a cutter suction dredger or a self trailing suction hopper dredger. In the latter case a small cutter suction dredger will still be required to place hydraulic fill in the upper part of the new embankment, unless the hopper dredger would be provided with a facility to pump fill material ashore.

6.3 Protection Works along Lower Meghna

6.3.1 Chandpur Protection Works

The proposed protection works at Chandpur are rather unique. To the Consultant's knowledge no reclamation and subsequent protection works have ever been carried out in a riverine environment in which such large depths and high current velocities occur. However the current velocities are not always high: during the low flow season the Lower Meghna is predominantly a tidal river. Current reversal occurs to a point upstream of Chandpur. So by definition four times every day there will be a slack water period which can, and should, be used for making fast progress with the works. Moreover the maximum current velocities in the dry season do not exceed 0.5 m/s near Chandpur.

Reclamation of the advanced protection will have to be done using containment bunds, behind which the hydraulic fill has to be placed. The whole operation can only be carried out in stages. The thickness of each layer will probably be about 3m, in order to reduce the quantity of coarse granular material required for the construction of the containment bunds. This height should however not be prescribed in the contract; it will only be used for cost estimating purposes.

In view of the large quantities of materials involved for the containment bunds, the rock on the fascine mattresses and in the falling apron, and the relatively short construction window (say from November till May) almost all materials will have to be produced and stockpiled near the works site. As no sufficiently large area is available in or around Chandpur, it is envisaged that the contractor creates his own work area by reclaiming it from the river.

The reclamation of the contractor's work area and the stockpiling of materials will probably take the better part of a year, which has been reflected in the tentative work programme as indicated in Figure 6.2.

6.3.2 Containment bunds

The containment bunds have only one function: to contain the hydraulic fill which would otherwise flow out at a too gentle gradient. Re-dredging at such depths is not considered to be a viable option. The achieve its purpose the material of the containment bund should be coarse granular material. Basically many materials could satisfy the performance requirements, like rock, boulders, bricks, etc. Most of such materials will be rather costly. A cheaper solution may be found when using sand cement blocks.

While this material is probably not very durable, this is not a problem: after the construction of the protective revetments (fascine mattress with rock) a certain degree of disintegration is acceptable.

Sand cement blocks are perceived to be made from dredged sand, mixed with cement. A possible production method may include the use of equipment which is normally used for cement stabilisation in road construction. After mixing a layer of say 0.3m and a degree of hardening the mix can be cut and after complete hardening the then formed blocks could be removed from the underground with a wheel-loader or similar equipment. After removal the next layer can be treated in a similar fashion by the mixing equipment.

The contractor should however be free to select his own type of materials for the containment bunds which satisfy the requirements.

For placing the sand cement blocks, or other materials, in the containment bunds, ships or pontoons equipped with a fall pipe will be required. At the end of the fall pipe a so-called "remotely operated vehicle" is attached, which "holds" the end of the fall pipe into position. Other methods, like the use of a stone dump barge, will probably not lead to a sufficient accuracy in view of the large water depths.

Fall pipe ships are frequently used in the offshore industry for covering of pipe lines on the seabed with rock. The depth at which such fall pipes are used is up to 100m. For Chandpur the use of a ship would appear to be too costly. Instead one or more pontoons with a fall pipe may be used. The supply of rock to the funnel of the fall pipe could be by towed barges, which are loaded at the work area cum stockyard.

6.3.3 Dredging and reclamation

In order to reduce losses of fill during placing as much as possible, it is attractive to use the coarsest possible sand, though at Chandpur one is not likely to find sand with D_{50} > .25 mm. The best source may be many kilometres from Chandpur. As there is no need for later re-dredging it is opportune to assume that a trailing suction hopper dredger, with self discharging provisions, is used, rather than a suction or cutter suction dredger. A trailing hopper dredger also diminishes hindrance to navigation on the Lower Meghna.

6.3.4 Fascine mattresses with rock

The slope protection mattresses consist of a geotextile fabric with a cover of rock. In view of the absence of a sufficient quantity of large sized boulders in Bangladesh, rock has been proposed. Other alternatives, like the use of concrete blocks, have extensively been researched for the Jamuna Bridge project, but a cover of rock had advantages, including costs, over other alternatives. For estimating purposes it will be assumed that rock will be imported from Malaysia, where a multitude of suitable quarries exist from where the rock could be obtained. Other sources of rock need however not be excluded.

For bringing the geotextile in place it will be necessary to prepare mattresses on a launching ramp. Bamboo fascines have to be fixed to the geotextile to arrive at sufficient buoyancy (necessary during transport) and flexibility, without folding, etc. during the sinking of the mattress. Contrary to the river bank protection works at Bhairab Bazar and Munshiganj, for mattress sinking operations in Chandpur, sophisticated equipment and positioning methods are indispensable. The use of computer controlled stone dumping barges is likely to lead to the desired result. If necessary this can be combined with fall pipe equipment should it appear that certain sections of the mattresses had not received a sufficient cover.

The same equipment can be used for the placing of rock in the falling aprons.

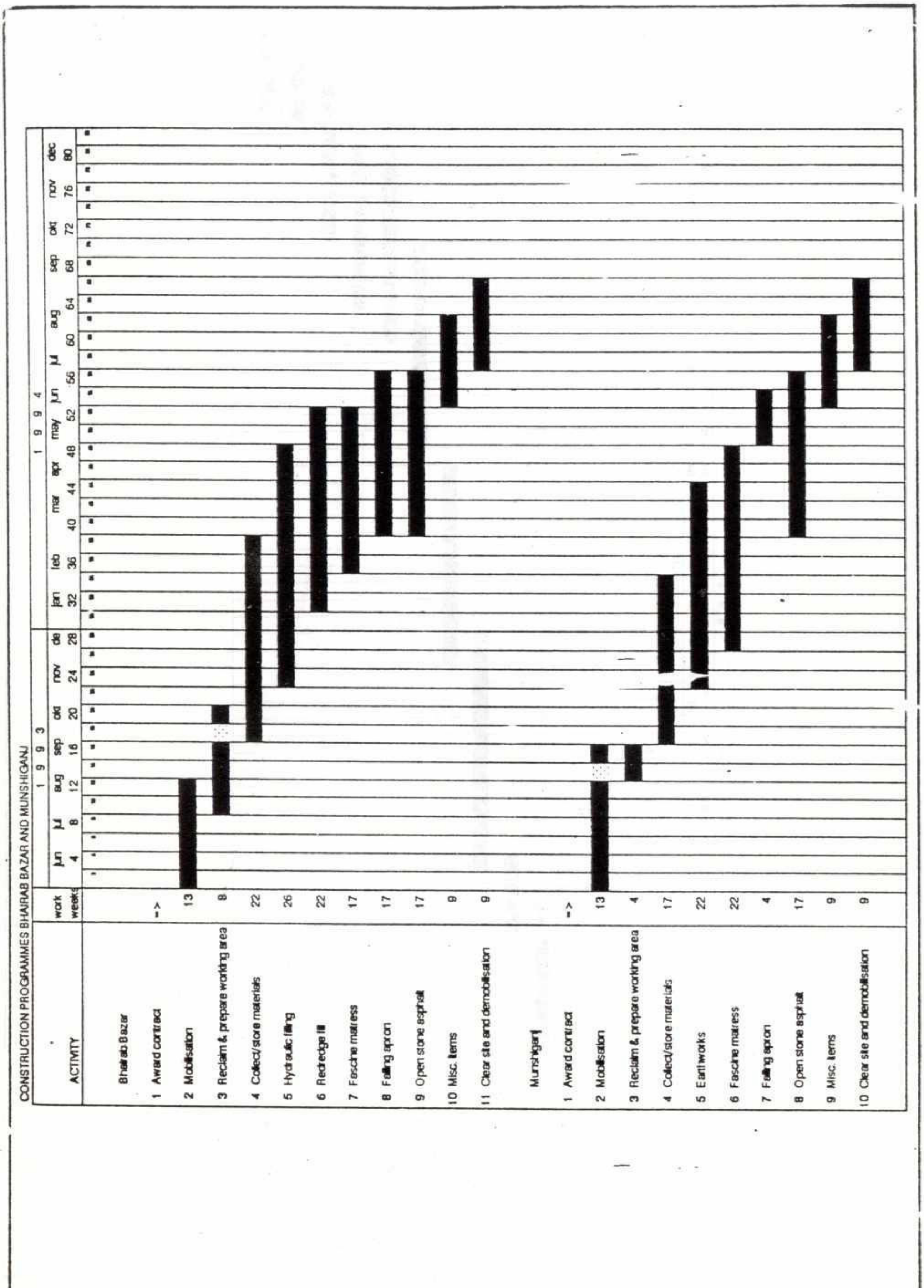
6.4 Construction Schedules

Construction schedules for the bank protection works at the three priority sites are presented in the form of barcharts:

- Fig 6.1 Construction Programmes for Bhairab Bazar and Munshiganj;
- Fig 6.2 Construction programme Chandpur, Nutan Bazar.

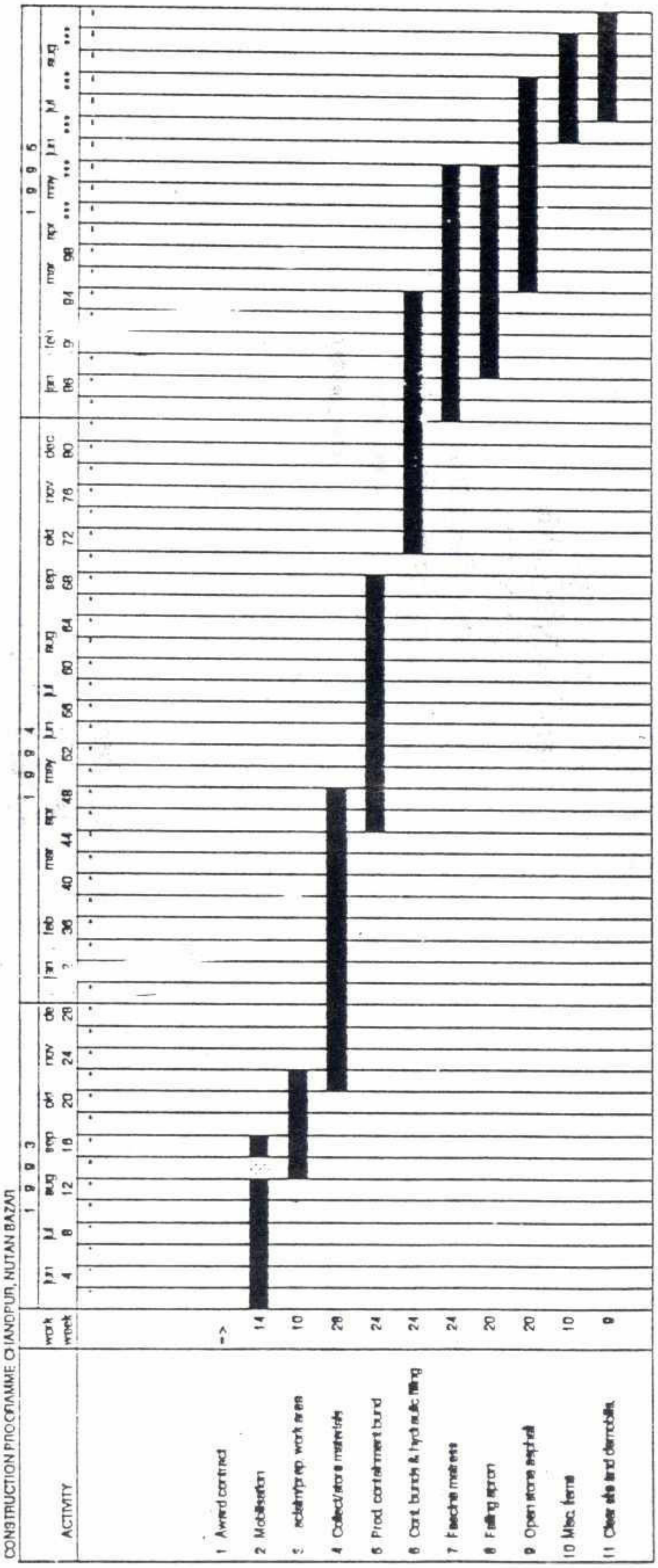
the construction programmes are based on a contract award by (at the earliest) June 1993. Fill placing, re-dredging and placing fascine mattresses shall take place during the dry season. The construction of the works at Bhairab Bazar and Munshiganj will be part of one contract. These works will have a duration of 15 months and those for Chandpur (Nutan Bazar and Puran Bazar) of 27 months.

Construction of Emergency Works at Chandpur Nutan Bazar should start already by May 1992 if the works have to be complete before the 1993 flood season. A duration of these works of 13 months has been foreseen (Annex G, Figure G.3.7.1).



CONSTRUCTION PROGRAM BHAIRAB BAZAR AND MUNSHIGANJ

FIGURE NO. 6·1



CONSTRUCTION PROGRAM NUTAN BAZAR

FIGURE NO. 6·2

7. ENVIRONMENTAL IMPACT ASSESSMENT

7.1 Introduction

The Government of Bangladesh and the World Bank are concerned about the effects the proposed Meghna river-bank protection works would have on the environment and therefore requested the preparation of an Environmental Impact Assessment. The present environmental assessment was conducted in accordance with the World Bank Operational Directive 4.00, Annex A: Environmental Assessment (1989), and the draft Guidelines for Environmental Impact Assessment of the Bangladesh Flood Action Plan (1991).

Environmental assessment is a flexible procedure which may vary in scope, depth and analytical techniques, depending on the project. The detail and sophistication of the study should be in proportion with the expected impacts. The scope of the present Environmental Impact Assessment is limited. Two objectives were formulated in the Terms of Reference:

- evaluation of potential negative impacts which river-bank protection may have on the environment; and
- proposition of measures which prevent, lessen, or compensate the identified environmental impacts.

7.2 Study methodology

The Study has been conducted on the basis of a work plan consisting of four phases:

In order to obtain a concise report which covers all significant environmental issues, a four-phased work plan has been adopted:

Phase 1: Analysis of the proposed project activities.

Phase 2: Description of the existing environment and autonomous development relevant to the project.

Phase 3: Evaluation of potentially negative environmental impacts.

Phase 4: Recommendation of preventive, mitigative or compensatory measures.

The necessary information was obtained from a number of sources:

- interim report and technical documents on project design;
- site visits to the project locations and other areas which may be affected by the project;
- environmental and socio-economic survey of the project locations;
- consultation of Bangladeshi officials and project experts;
- review of literature on existing environmental conditions, possible environmental impacts of the project activities, and alternatives for mitigation.

7.3 Physical Environment

7.3.1 General

Apart from climate, topography, geology, geo-morphology and hydrology which are discussed elsewhere in this Report the following parameters are of interest.

7.3.2 Water quality

The water and sediment quality of the Meghna depends on it's pollution load and the fate of the chemicals in the aquatic environment. Data on the Meghna concerning pollution load and transport and transformation mechanisms are unavailable at present.

Industrial pollution is rather localized in Bangladesh: industry is primarily concentrated in five centres, but small-scale industry is found in most towns. Chromium, cadmium and mercury are highly toxic wastes discharged by tanneries and paint factories. Boats and oil terminals cause pollution with oil and oil products. Drainage from irrigated areas may contain residues of agro-chemicals. Vector eradication programmes pollute with pesticides. The Ganges, the most polluted river of India, also contributes to water pollution in Bangladesh.

Organic pollution is expected to be largest near the towns and industrial plants where domestic and agro-industrial wastes are often discharged untreated. The biological oxygen demand (BOD) changes according to site and season.

The self-purification capacity of the Meghna is quite large, especially in the monsoon season. Due to the fast flow and large quantity of water discharged, pollutants are quickly transported and diluted. Water quality varies seasonally: as river flows are drastically reduced during the dry season, the concentration of pollutants increases.

Many pollutants bind with the finest fraction of suspended sediments, and are deposited with the sediment further downstream. However, contamination decreases closer to sea due to mobilization and mixing with clean sea sediments. Pollutants are also retained in the interstitial water of the sediment. Through chemical exchange or re-suspension, these pollutants may re-enter the aquatic ecosystem.

Some pollutants are taken up in the food-chain and subsequently broken down to other chemical compounds and/or stored. Storage in aquatic organisms may lead to bioaccumulation, depending on the type of pollutant and organisms. Examples are heavy metal salts and halogenated hydrocarbons (pesticides).

The remaining pollutants decompose, e.g. under influence of light, or are eventually transferred to a sink (e.g. ocean).

7.3.3 Flora and Fauna

During the rainy season, half of Bangladesh can be considered a wetland. This includes the Meghna and tributaries, and their cultivated floodplain with shallow freshwater lakes and marshes.

The floral composition of the floodplains bordering the Meghna is relatively uniform, with a seasonal variation in dominant species. The natural aquatic vegetation has for the most part been replaced with cultivated species, as the Meghna is bordered by extensively cultivated floodplains. The former wetland forests have been almost completely destroyed. The Lower Meghna flows between many uninhabited permanent and temporary islands having some remaining swamp vegetation, but in the project area most are cultivated. Detailed data on the composition of the aquatic ecosystem in the Meghna are lacking.

The wetlands support a variety of wildlife. The fish and prawn fauna are discussed in 7.4.4. Wetland species in the Meghna include:

- amphibia: several species of frogs, some endangered;

- reptiles, such as the Gharial (<u>Gavialis</u> <u>gangeticus</u>: endangered, some individuals in the Lower Meghna), two endangered monitor lizards species (<u>Varanus</u> <u>bengalis</u> and <u>V.</u> <u>flaviscence</u>), various turtle and tortoise species, and six species of freshwater snakes;

- mammals include the Ganges River Dolphin (<u>Platanista</u> <u>gangeticus</u>), other dolphins and whales which visit irregularly, and two otter species.

Bangladesh harbours a wide variety of resident and migratory wetland bird species. Migratory birds generally visit in the period September to March. Of the recorded about 150 species of waterfowl in Bangladesh, almost 80 are regularly spotted. In a census of the Lower Meghna waterfowl, 38 species were identified, including seven rare or endangered species. The populations in Bangladesh decline due to agricultural development, urbanisation, industrialisation, etc. Large numbers are eaten by the local population.

Detailed data on the bottom flora and fauna are lacking. The river bed is not a very rich ecosystem as a result of the continuou[illegible] of sediments, smothering sedentary bottom dwellers, and lack of light.

7.4 Cultural environment

7.4.1 Land-use

About 80% of land in Bangladesh is farmed: infrastructure in towns and villages occupies relatively very little land and the pressure on the land is high due to the exceptionally dense population. The average farm size is quite small, under 1 hectare, and half of the population is landless. Many of these have lost their land in the past due to river-bank erosion.

Optimal use of water resources for agriculture presents a major problem in Bangladesh. Excessive flooding limits agricultural development and damages crops, livestock and infrastructure. In the dry season, the amount of water for irrigation is limited.

Land and large water bodies are often owned by the government. The margins of waters are leased by the government for rice cultivation on an annual basis. Private low-lying areas are almost exclusively used for rice cultivation, while potatoes and other vegetables are grown on the higher lands near the villages.

The main activities in the floodpl[illegible] fishing and rice cultivation which are both discussed below.

7.4.2 Agriculture

Agriculture is the backbone of the economy: it provides employment for 60% of the population, accounts for 45% of the Gross National Product and 60% of merchandise exports (World Bank, 1990).

The alluvial soils in the project area are low in nitrogen and phosphate, rich in calcium, magnesium and potassium, and alkaline (pH 7.0-8.5). They are enriched with heavy silt deposits by overbank flooding of the Meghna. Agricultural practices are adapted to flooding: submerged areas become productive land as the floods recede. The principal crops in the floodplains are rice, jute, beans, and lentils. The commonest fruits and vegetables are papaya, pineapple, potatoes, and cabbage.

Rice is the main crop, grown on about 80% of the cropped area. Bangladesh is both the largest producer and one of the largest importers of rice in the world. The yield of rice per ha is relatively low, indicating a limited application of modern technology.

High yielding varieties are grown on the about three million ha of irrigated lands (1987). About 5% of the total area planted is treated with pesticides, mainly on high yielding varieties. This accounts for 90 % of pesticides used, almost all insecticides. The total usage was about 3,700 metric tons per year in 1986-1987 (Hamid, 1991). The project area contains the Meghna-Dhonagoda and Chandpur irrigation projects in which pesticides presumably are used, but detailed data on the type of pesticides used in the project area and it's catchment areas are lacking.

The distribution of fertilizer in Bangladesh was about 2,000,000 metric tons in 1988-89. About three quarters of this is used for rice production, predominantly for high yielding varieties in irrigated rice culture.

Jute and jute-based products supply most of the export earnings. It is a main floodplain crop and accounts for 5% of cropped area. It is predominantly grown during the monsoon season.

Livestock production is relatively unimportant in the project area. Cattle and buffalo play an important role as draft animals. Livestock breeding is hampered by the lack of grassland: they graze in the wetlands during the dry season.

7.4.3 Water-use

The elaborate network of rivers and canals provides a major transport and communication system. Steamers and launches are the cheapest, often quickest, and most comfortable means of transport. All project sites are served by water transport means.

Chandpur is an inland river port and a stop on the Dhaka-Chittagong route. Munshiganj is a stop on the Dhaka-Chandpur route. Bhairab Bazar is a main river port connected with Narayanganj. Because a minimum depth is required for year-round navigation these routes are periodically dredged at shoals.

A major use of water is irrigation, as it offers opportunities to increase agricultural production. The extensive wetlands, in particular the rivers, provide a year-round source of water.

The domestic water supply within the municipalities is generally poor. A considerable number of people has access to river water only for bathing, washing, drinking water, etc. The same river is also used for domestic and industrial waste disposal.

7.4.4 Fishery

Fish is a staple food in Bangladesh, providing 80% of the per capita animal protein in the daily diet (Ali, 1990). Even though fishery is mostly artisanal, it is the second most important economic activity: Bangladesh exports fish and fish products. Fishery provides full-time employment for an estimated 2 million people. About three-quarters of rural households fishes occasionally.

River fishing is practised under a governmental lease/auction system: the lease holder may sub-lease sections or collect rent from fishermen. Indiscriminate harvesting of fish and prawn is induced by this system, and leads increasingly to overfishing.

260 species of freshwater fish and 20 species of freshwater prawn have been identified, but the catches in the rivers are dominated by hilsa and a variety of major carp and freshwater prawn species. River fishing takes place most of the year but peaks in the cold season, between November and February. Only hilsa catches a peak during the monsoon season.

Hilsa represents about 40% of the total catch. It is sensitive to water quality and only found in relatively clean water. The adult hilsa migrates between the sea and spawning grounds in the estuary. The juveniles disperse upstream from the estuary to the nurseries. The Lower Meghna is a very important nursery ground and accounts for about 70% of the total fish catch, which amounts to 62,000 ton (1988).

Giant freshwater prawn (Macrobrachium rosenbergii) breeds in the estuary, after which the juveniles migrate upstream and into their nursery in the floodplain by crawling. Prawn accounts for 3% of the annual Meghna catch.

The major carps are Rohu (Labeo rohita), Catla (Catla catla), and Mrigal (Cirrhinus mrigala). They breed and spawn in the clear, oxygenated water of the hilly areas (e.g. Sylhet and Assam). Both adults and juveniles then disperse downstream over the floodplain. They present less than 1% of the annual catch of the Meghna.

7.4.5 Socio-economic features

The Lower Meghna has one of the highest population pressures in Bangladesh, which is already the most densely populated rural country in the world. The population density was estimated at 576 persons per square kilometre in 1990. The high annual population growth rate (2.4 in 1989) is a major constraint to development.

80% of the population lives below the poverty line. Their socio-economic situation is characterized by a low income, increasing landlessness, illiteracy, malnutrition, vulnerability to natural disasters and dependency on foreign capital, imported food and raw materials.

Rural employment is found largely in agriculture and fisheries. In the towns, employment is mostly found as paid worker, followed by unskilled labourer and then entrepreneur. Wages are often supplemented by agricultural and fishery activities.

The mostly small-scale industrial sector in Bangladesh is at a low level of development. Industries are sited preferentially both near the towns and along waterways. In the project area they are concentrated in the Dhaka and Narayanganj area.

The major industry is jute twine and carpet backing, which produces large quantities of organic waste. Leather tanneries are one of the main sources of pollution, discharging the extremely toxic hexavalent chromium in the Buriganga near Dhaka. Heavy industry is centred mainly around Tongi north of Dhaka. Chemical industries include paper and pulp industries, fertilizer factories, and distilleries.

Intermediate and light manufacturing is scattered across the country. Most industries discharge wastes without treatment into open water: the Zia Fertilizer Factory near Bhairab Bazar is one of the exceptions. Data on the pollution load from industries in the project area are lacking.

Table 7.1 **OVERVIEW OF INDUSTRIAL ACTIVITIES IN THE PROJECT AREAS**

Type of Industry	BB	Mn	RH	Mg	Ep	Cp	Hc
Textile, Apparel and Leather	8			11		3	
Chemical Industry	9					1	
Food, Beverages and Tobacco	65			42		91	
Machinery and Equipment	37						
Paper and Paper Products	11						
Metal Industry							
Non-metallic and Mineral Products	8					21	
Wood and Wood Products	6			6		2	1
Others (Handicrafts etc.)	9	2		9	1	31	1
Total	151	2	- 0	?[1]	1	149	2

Sources: Site visits, and literature on two sites:
BB: 'Bhairab Past and Present' Bhairab Municipality, 1990.
Cp: Chandpur Chamber of Commerce and Industries, 1991.

The towns in the project area have open drains which discharge into the river. The sewage systems are often limited in size, and poorly constructed and maintained. Water often accumulates in the drains due to congestion. Solid waste is collected regularly, but the capacity is often insufficient. Surplus waste piles up and is washed into the river by the rains. Waste in rural settlements is disposed of indiscriminately. Drainage is sometimes impeded by the existing river-bank protection works.

Housing in the rural project areas often consists of huts constructed with natural materials. After erosion of houses at Eklashpur and Haimchar, large numbers of the local population have taken shelter on the embankments. Municipal housing is mostly constructed by using bricks, but squatters in huts occupy the eroded banks at Chandpur. The market stalls in Bhairab Bazar are also constructed with natural materials.

7.5 Autonomous development

7.5.1 General

This Section on the autonomous development describes the future without project situation, taking into account proposed and anticipated future developments.

The Government has declared 1990 "Year of Environment", and 1991-1999 "Decade of Environment". The presently small Department of Environment will expand considerably in the near future. It's capacity is strengthened for national environmental monitoring, pollution control and environmental management, including Environmental Impact Assessment. A revised law, the Bangladesh Environment Preservation Ordinance, National Environmental Quality Standards, and Guidelines for EIA of flood control are in the making.

The number of industries will increase in future, with comparatively more emphasis on non-agro-industrial activities. Environmental degradation from discharge of industrial and domestic wastes will diminish if they are collected and treated adequately. One of the objectives of the Industrial Policy 1991 is to control environmental pollution by forcing industries to take adequate precautionary measures. The

[1] For Munshiganj, data are available only on industry in the erosion-prone zone. Source: consultant's survey.

Department of Environment is identifying polluting industries in a nation-wide survey. The "National Environmental Monitoring and Pollution Control Project" runs from 1989-1992.

An increase in agricultural production is necessary to make Bangladesh self-sufficient. Intensified use of the existing lands is the main solution. An increase in irrigation, high yielding varieties, pesticide and fertilizer use is expected. The planned monitoring of pesticides and the ban on harmful agro-chemicals will, however, not decrease the impact significantly.

Fisheries production will continue to decrease steadily due to the reduction, modification and degradation of the aquatic environment, and because of overfishing. E.g. the lateral fish migration into the inundated floodplain is hampered by extensive flood control and drainage projects, leading to a decline of floodplain fisheries. Therefore, the Government of Bangladesh plans to enhance aquaculture activities.

7.5.2 Project-related activities

At present, various activities are undertaken or planned to protect the river-banks at most sites. In the without project situation these activities will continue, as most do not present a long-term solution to river-bank erosion.

In the long-term, river-bank protection may be followed by river training, which aims to stabilize river morphological patterns. This has significant socio-economic benefits, as the risk of loss of infrastructure, life and property due to river-bank erosion is minimized. River training works will more or less stabilize the main morphological development, but shifting of minor channels and chars will probably not be influenced to a large extent. Therefore, the overall effect on the riverine and estuarine environment is limited.

Plans for flood control, such as the Flood Action Plan, will lead to construction of more embankments and increase the need for river-bank protection and river training. This will have far-reaching effects on the natural environment, due to the interference with natural flooding patterns.

Dredging for navigation purposes will continue, as the sediment load of the rivers will not decrease.

7.6 Environmental Impacts

7.6.1 General

The emphasis of an environmental impact assessment lies on the identification of negative effects of a project because unprecedented adverse impacts decrease the success of a project in economic, social and environmental terms. Therefore, EIA identifies negative impacts at an early stage to enable incorporation of mitigative measures in the project design, and evaluation of environmental costs and overall project benefits by decision-makers.

Beneficial impacts are usually not assessed in detail as they are often the objective of a project and do not require mitigation. In this case, the aim of protection of eroding river-banks at the selected sites is to safeguard municipal infrastructure and agricultural lands. This has significant socio-economic benefits: among others, employment opportunities are secured and created; transport is assured; risk of loss of life and property is decreased; and erosion of agricultural lands is reduced, preventing increased landlessness.

A major constraint for the present environmental impact assessment is the general lack of quantitative or qualitative data on the environment of the Meghna, in particular of the aquatic ecosystem. This forces a qualitative assessment of the proposed project.

A second constraint is that in the present environmental study for two sites pre-feasibility and for two others only feasibility studies were conducted. No final decision has been made for these four sites as to which alternative will be ultimately selected for construction. Thus, the description of environmental impacts concentrates on the proposed protection works at Bhairab Bazar, Munshiganj and Chandpur.

7.6.2 Possible impacts

The possible impacts are discussed in chronological order for all project sites. Only where necessary are impacts specified per location. Table 7.2 presents an overview of possible environmental impacts and potentially significant effects.

7.6.2.1 General impacts

The use of mechanized equipment in all phases of the project will temporarily have some negative effects: air pollution from exhaust fumes, soil and water pollution from oil spills, noise and vibration, and accident risks. The impact is short-term, but the extent depends on the equipment used and its physical condition.

Table 7.2 **OVERVIEW OF MAIN EFFECTS OF PROPOSED PROJECTS ACTIVITIES**

Activities	Possible effects	Significant effects
General 1 equipment 2 labour force	1 pollution, accidents 2 pollution, social impacts	1 - 2 socioeconomic benefit
Pre-construction 1 land clearing 2 infrastructure displacement 3 dredging 4 work areas 5 construction material	1 loss of land 2 social impacts 3 ecosystem change, pollution, transport disruption 4 loss of land, impeded drainage, pollution 5 pollution	1 - 2 potential adverse social impact if unplanned 3 potential adverse impact if the dredged sand is heavily polluted 4 - 5 -
Construction 1 hydraulic fill 2 slope re-dredging	1 pollution, transport disruption 2 pollution, transport disruption	1 - 2 -
Post-construction 1 river-bank protection 2 wrap-up	1 ecosystem change, loss of land 2 pollution	1 socioeconomic benefits 2 -

Most of the labour force (up to an estimated 500 - 1000 people per site) will be recruited locally, presenting an economic benefit. Import of labourers requires the establishment of labour camps, which may have short-term adverse environmental and socio-economic impacts. Labour camps may cause water and soil pollution with domestic wastes, an increase in infectious disease incidence, and disruption of social, cultural and economic patterns. The impact is short-term, the extent of the impact depends largely on the planning and management of the camps.

7.6.2.2 **Pre-construction phase**

(a) Site preparation

Land must be cleared for lab... ...mps, work areas and project sites. In Bhairab Bazar, Munshiganj and Chandpur this leads to a loss of land used for draw-down agriculture. In the rural areas, land clearing may lead to a loss of agricultural lands or natural vegetation and thus fauna habitat. The effect is negligible due to the relatively small area needed for working space.

To enable earth filling, the landing facilities for the oil terminal, launch and cargo ghats in Bhairab Bazar will temporarily have to be shifted. Of the about 70 market stalls along the waterfront, some may have to be relocated temporarily. The ferry ghat at Munshiganj and loading/unloading operations at the cold stores and industries must be moved temporarily. At Chandpur, unloading at the fish market and use of the launch ghat may be hampered. These temporary relocations may cause resistance by the local population and are potentially significant impacts (see Section I.4.3.1).

(b) Dredging

Dredging will temporarily alter the river bed but, due to sediment transport, the dredged material is quickly replaced. The dredging also destroys the sedentary aquatic life at the site, but the bottom flora and fauna is relatively poor. The effect is short-term: the chemical and physical characteristics of the dredged site remain the same and it will rapidly be recolonized after the operations are finished.

The increased turbidity due to dredging in the Lower Meghna has negligible environmental impacts, as the natural sediment load of the river is relat...ely high. The Dhaleswari at Munshiganj receives water from the Jamuna River, and therefore presumably has rather high sediment loads, which minimizes the effect of increased turbidity. Indigeno... ...quatic life is adapted to these conditions. The Upper Meghna, howeve..., has a low se...ent load. Increased turbidity will have short-term effects on aquatic life as the penetration of light is reduced locally.

Spawning and migration of the major fish and shrimps species will not be affected by increased sedimentation (Figure I.2.4). Dredging will mostly take place in the dry season, when most species do not spawn. The giant freshwater prawn does spawn, but is not affected as it spawns in brackish water in the estuary. Hilsa and giant freshwater prawn migrate in the dry season, but only in the Lower Meghna where dredging is relatively insignificant. Dredging in the wet season will be limited: some is necessary to reclaim land at Chandpur and Bhairab Bazar. This may theoretically affect fish migration, e.g. at Bhairab Bazar, spawning and juvenile migration of major carps. However, migration of fish species will in general not be hampered as the rivers are very wide, especially in the monsoon season.

As dredged material is predominantly anaerobic, suspension of these sediments may temporarily lower dissolved oxygen levels at the dredging site. The dissolved oxygen content varies during the year and differs from site to site. It will especially be low near drainage sites of agro-industries. If areas with a low dissolved oxygen content are dredged, the dissolved oxygen levels may fall to a level which is lethal to fish. The respiration of sedentary organisms near the dredging site may temporarily be affected, but mobile organisms such as fish can avoid the disturbed area. Detailed data on the conditions of the soil and the dissolved oxygen levels of the water are not available at present, but the information available indicates that the decrease in water quality might significantly affect fish (see Section I.4.3.2).

Dredging releases pollutants from sediment and interstitial water into the already polluted water. Much will be deposited downstream by (re)suspended sediments. High levels of industrial or agro-chemical wastes do probably not occur in the project area. The effect of resuspension of pollutants depends largely on the selected site, as industrial pollution is rather localized. The impact may be significant if the dredged material is heavily polluted (see Section 7.6.3).

Dredging activities may hinder navigation, depending on the selected site and the planning of activities.

(c) Work areas

If land is reclaimed in Bhairab Bazar and Chandpur, this leads to a loss of land used for draw-down agriculture. The area, however, is of little importance as a seasonal bird and fisheries habitat because larger and undisturbed areas are available in the vicinity. The effect is negligible because the amount of land needed is very small.

Reclaimed land, storage facilities and access roads may impede surface water drainage if not properly planned and executed.

Disposal of discarded construction materials may cause some pollution. The extent of the effect depends largely on the execution of the activities, but should be minor under normal circumstances.

(d) Construction materials

The quantity of construction materials required, such as boulders, is quite large. The transport of material by boat may cause water and air pollution, and hindrance to navigation. The transport of soil by road at Munshiganj may cause air pollution. The transfer and storage of material at the work space may cause pollution due to dust. However, the necessary quantity of material and related transport and transfer activities do probably not significantly differ from the without project scenario when river-bank protection activities must be conducted regularly.

The use of open stone asphalt and bitumen has only very limited environmental impacts. Preparation of asphalt and bitumen causes some short-term air pollution. After incorporation into the works, asphalt and bitumen wear very slightly from daily use, but the effect is insignificant as it is a very long-term decomposition process in a large volume of water. Open stone asphalt is widely used elsewhere where stringent environmental regulations are maintained.

The slow decomposition of bamboo and reed will not detectably deoxygenate the water. The use of geotextile is not anticipated to have adverse effects: the material has passed the stringent Dutch environmental regulations and is widely used. Construction of containment bunds with cement, sand, gravel and water will temporarily cause some air pollution with dust.

7.6.2.3 Construction phase

(a) Hydraulic fill

The existing flora and fauna is disturbed and sedentary organisms are smothered by hydraulic fill. The effect is negligible as the extent of habitat destroyed is very small. Moreover, the existing flora and fauna is relatively poor, and is already locally affected by water pollution near the towns.

A temporary decrease in water quality may occur if the hydraulic fill is polluted. The effect depends on the pollution load of the dredged material. The present river-bank soils near the towns are likely to be more contaminated than the dredged material due to local drainage of domestic and industrial water. Theoretically, clean hydraulic fill may adsorb/absorb more pollutants than the former river-bank material, thus decreasing water pollution temporarily.

Hydraulic fill transported by truck may temporarily hinder road transport at Munshiganj, if not adequately planned.

(b) Slope re-dredging

At Bhairab Bazar, a temporary decrease in water quality may occur if the hydraulic fill is polluted. The effect depends on the pollution load of the re-dredged material.

Re-dredging activities may hinder navigation, depending on the selected site and the planning of activities.

7.6.2.4 Post-construction phase

(a) River-bank protection

In Maniknagar and Haimchar, the river-bank material is changed from fine sand to boulders, bamboo, and reed. The river-banks of the other sites have already been strengthened with boulders, bricks, or cement blocks. The stones covered with algae and some aquatic vegetation attract certain types of fish and discourage others. As the area to be protected is quite small in comparison to the total length of river-bank, the overall effect will be insignificant.

River-bank protection with revetments does not change erosion patterns downstream. The advanced revetments decrease the width of the river, and increase the flow velocities in the outer bend up to about 5% of high discharges. The constriction may theoretically cause a limited backwater effect upstream and a diminished overbank flow downstream. The effects of constriction are marginal as the rivers are very wide.

(b) Wrap-up

Demolition of storage facilities, labour camps and reclaimed areas may temporarily cause some air, water and soil pollution.

7.6.3 Potentially significant effects

In the following section background information is presented for a further assessment of the extent of the impacts identified as potentially significant.

7.6.3.1 Infrastructure displacement

River-bank protection will provide significant socio-economic benefits to the population of Bhairab Bazar, Munshiganj and Chandpur. However, it will also give some temporary inconvenience to activities along the waterfront:

- In Bhairab Bazar, landing facilities for the oil terminal, launch and cargo ghats will have to shift temporarily. Several market stalls may have to be re-located temporarily to enable earth filling.
- The ferry ghat at Munshiganj will be moved temporarily; loading/unloading operations at the cold store and industries will temporarily have to be shifted.

At Chandpur, unloading at the fish market near the railway station will have to be shifted.

The provision of alternative landing facilities will modify the effect to a great extent.

These displacements may cause resistance by the local population. Cooperation of the local population is necessary: vandalism or other forms of resistance may damage the newly constructed protection or delay the construction schedule.

The risk of public resistance is at present not clear. The affected population faces short-term costs versus long-term benefits, such as protection from river-bank erosion, and extension of the market on the advanced revetment. Therefore, if the inconveniences are limited due to proper re-location planning, the project will probably be perceived as beneficial to the local population's interests and the socio-economic effect will be minimal.

7.6.3.2 Water quality deterioration

The extent of the impact of dredging depends on the pollution load of the dredged material. Two types of pollution may be involved: organic pollution and toxic chemicals. The soil and water quality of the Meghna has not been quantified, but some assumptions can be made:

- Upstream of Bhairab Bazar there are a few pollution sources (pulp and paper industry, agro-chemicals used for tea), but the concentration of their pollutants will be insignificant when they reach the town. The waste water of the Zia fertilizer factory is treated before discharge. Organic pollution from agro-industries and domestic wastes is likely along the waterfront, but hydraulic fill will not be dredged nearby. Further downstream, the dissolved oxygen content will be higher, as the discharge from the Old Brahmaputra dilutes the pollution.

  Pollution by toxic chemicals is not considerable. Only pollution from the Jamuna Oil Terminal poses a small risk if material is dredged downstream, above the confluence with the Old Brahmaputra.

- Munshiganj accommodates a considerable number of agro-industries. Furthermore, the Dhaleswari receives water from the Dhaka and Narayanganj industrial areas, and the Dhaka sewerage system. Organic pollution lowers the dissolved oxygen content. A very low dissolved oxygen content, combined with dredging of anaerobic sediments, may locally affect respiration of aquatic life, leading to fish kill in extreme cases. The extent of the impact depends on the water and soil quality at the dredging site.

  The Dhaleswari receives the waters of the Buriganga, which is polluted with chromium from the tanneries near Dhaka. The concentration of pollutants will have decreased considerably when it reaches Munshiganj due to the mechanisms elaborated upon in Section I.2.3.5. The town itself contributes mostly organic effluent from domestic and agro-industrial wastes. Therefore, the soil of the Dhaleswari is not expected to be heavily polluted with toxic chemicals.

  At Chandpur, some sand will be dredged locally to reclaim land on Chirar Char, north of the town. The major part will be dredged elsewhere. The three main sources of pollution in the area are discharges from the Ganges and the Dhaleswari, and industrial and municipal waste discharged by Chandpur. Pollution from the Ganges and Dhaleswari are diluted by the large flows of the Meghna and Brahmaputra (Jamuna). As Chandpur has mainly small-scale agro-industry, the soils in the vicinity will not be heavily polluted.

Concluding, there is a small risk of dredging material being polluted with toxic chemicals at Munshiganj. The pollution during the construction period is not expected to be significant.

As dredged material is predominantly anaerobic, suspension of these sediments may temporarily lower dissolved oxygen levels at the dredging site. The dissolved oxygen content of the Meghna is unknown, but might especially be low near drainage sites of agro-industries. There is a small risk of fish kill if anaerobic material is dredged in water with a low dissolved oxygen content. Detailed data on the conditions of the soil and the dissolved oxygen levels of the water are not available at present, but the information available indicates that only dredging downstream of the agro-industry in Munshiganj poses a risk. The effect is estimated to be minor as it is localized and short-term.

7.7 Mitigation Options

7.7.1 Introduction

Mitigation may include avoiding, minimizing, rectifying, reducing, eliminating or compensating impacts. In the EIA, the emphasis lies on significant and easily mitigatable negative impacts.

Several mitigative measures have already been incorporated in the project design: the permeable river-bank protection works do not impede drainage; the tender documents specify that outlets for municipal drains will be constructed to prevent congestion; and dredging will mostly take place during the low flow period. After land reclamation, erosion control measures will be taken. The nature of the contract is such that the contractor will limit dredging or reclamation activities as far as possible. After completion of the project, the contractor will be required to convert the work space to it's original state, as far as possible.

7.7.2 Mitigation

Two river-bank protection activities are identified with potentially significant adverse impacts, namely infrastructure displacement and dredging of polluted soil, but the extent of their impact can not be quantified at present (see Section I.4.3). A major component of their mitigation is the more detailed study of the extent of the impact.

Care must be taken that execution of the mitigative measures proposed is proportional to the impact. For example, if pollution levels are low at dredging sites, it is not required to monitor them.

Table 7.3 presents an overview of the proposed mitigation options.

7.7.2.1 General

(a) Equipment

The air pollution from exhaust fumes, soil and water pollution from oil spills, and noise and vibration can be minimized with 'clean technology': this implies a minimal pollution generation or end-of-pipe pollution control measures. The contractor may be required to incorporate these measures to comply with Bangladeshi pollution standards. Accident risks can be reduced by enforcing safety regulations during construction.

(b) Labour force

Provision of adequate housing, waste disposal facilities, and medical care will minimize the environmental and social impacts.

220

Table 7.3 **OVERVIEW OF MITIGATION OPTIONS**

Activities	Mitigation options
General 1 equipment 2 labour force	1 pollution control measures 2 adequate housing and sanitary facilities, safety measures
Pre-construction 1 land clearing 2 infrastructure displacement 3 dredging 4 work areas 5 construction materials	1 site selection 2 temporary relocation, pontoons, planning 3 site selection, water and sediment quality assessment, pollution control measures, coordination 4 site selection, drainage planning, pollution control measures 5 none
Construction 1 hydraulic fill 2 slope re-dredging	1 pollution control measures, coordination 2 water and sediment quality analysis, pollution control measures, coordination
Post-construction 1 river-bank protection 2 wrap-up	1 planning 2 pollution control measures, planning

7.7.2.2 Pre-construction phase

(a) Land clearing

The loss of land and wildlife habitat can be minimized by careful site selection, avoiding environmentally sensitive areas, and by limiting the extent of area to be cleared.

(b) Infrastructure displacement

The provision of pontoons as temporary landing facilities, and the reorganization of market facilities in the vicinity will compensate the temporary loss of landing and market facilities at Bhairab Bazar, Munshiganj and Chandpur. It is recommended to develop a re-location scenario in cooperation with the local authorities.

(c) Dredging

The effect on flora and fauna at dredging sites can be minimized by avoiding polluted sites. An assessment of the environmental quality and composition of the soil at the dredging sites is recommended. If it is heavily polluted, dredging can take place at a less polluted site. If this is not possible, the effects on aquatic life should be monitored.

Interference with navigation, and road transport at Munshiganj, can be minimized by developing transport scenarios in cooperation with transport authorities.

(d) Work areas

At Bhairab Bazar, the effect of loss of land and fauna habitat can be minimized by using already reclaimed land in the vicinity. Drainage impediment can be avoided by constructing outlets.

Pollution during construction and operation can be minimized by the correct disposal of waste and pollution control measures.

(e) Construction materials

Both the quantity of materials used and the need for transport and transfer to work space and project sites can not be mitigated easily.

7.7.2.3 **Construction phase**

(a) Hydraulic fill

An assessment of the environmental quality and composition of the sediment at the project site is recommended.

Interference with navigation, and road transport at Munshiganj, can be minimized by developing transport scenarios in cooperation with transport authorities.

(b) Slope re-dredging

Interference with water and road transport can be minimized by developing transport scenarios in cooperation with transport authorities.

7.7.2.4 **Post-construction phase**

(a) River-bank protection

After completion of construction activities, the effects of river-bank protection are insignificant, and mitigation is not required.

(b) Wrap-up

Pollution can be minimized by adequate planning of demolition activities and incorporation of pollution control measures.

8. COST ESTIMATES

8.1 Introduction

Estimates of cost have been prepared for the construction and maintenance of the works and are summarized in Tables 8.1 to 8.3. They have been formulated for use both in comparisons of design or layout alternatives and for the economic analysis of the project.

The method by which the estimates have been prepared is that which would be adopted by an international contractor. This technique has enabled estimates to be based on probable construction methods and equipment selection. Costing for all principal construction operations was established after agreement on methods and plant with the design engineers. This was followed by derivation and costing of the required quantities of all permanent and temporary materials and labour resources. Full account has been taken of the effect of seasonal influences and the remoteness of some sites on construction activities.

The cost of each of the project designs has been estimated independently, always provided that Bhairab Bazar and Munshiganj are combined in one contract package. The construction schedules for the Works at each of these sites have however been derived taking account of the interdependence of the various activities.

The resource analyses which are presented in Tables 8.1 to 8.3 form the detailed basis for the economic appraisal.

The feasibility study cost estimates have been based on prices of mid 1991.

8.2 Basic Data

An important starting point for the feasibility estimates was the availability and detailed knowledge of the data collected during the period 1986-1988 for the Jamuna Phase I and II Studies and subsequently for the Project Cost Estimate for this Jamuna Bridge (June 1990, updated October 1991).

A review of those estimates was carried out in October 1991 to determine their applicability for the Meghna bank protection projects, and also to determine those areas in which further attention would most effectively improve the accuracy of the estimates.

As a result, emphasis has been on the collection of data relating to the following aspects:

- dredging: characteristics, outputs, reclamation, charter rates, quantities, seasonal influences;
- access channels to sites: routes from Chalna and Chittagong, depth and width requirements, seasonal variations, volumes;
- use of dredged material in guide bunds, groynes and bank protection works;
- research into sources of suitable boulders and rock for revetment mattresses, particularly Sylhet and the Chittagong area, as well as outside Bangladesh;
- current and reliable information on local rates and prices;

  charter rates for pontoons, mattress laying barges and associated craft.

The US dollar was adopted as the base currency for the cost estimates. During the period when the cost estimates were prepared, there were only small fluctuations in its exchange rate with other currencies.

-	Base date	:	July 1991
-	U.S.$ 1.00	:	36.00 Taka
		:	1.90 Dutch Florins

No allowances have been included in the estimates for import duties or VAT on imported materials or construction plant.

8.3 Estimating Methods and Information

8.3.1 Bank Protection Works

During the feasibility stage, several schemes were developed, each involving dredging, reclamation and slope protection for the arrangements of revetments, bunds and groynes required for the alternative solutions.

As part of the preferred scheme selection procedure, costs were compared at prime cost level, for which several composite rates were established. These composite rates were formed from planned methods of construction and known outputs drawn from previous experience of similar works or operations such as the Jamuna Bridge Project and the Feni River Closure Dam.

Rates for dredging were derived following a detailed study of the material to be dredged and the depths, pumping distances and volumes required. Outputs, relevant to the appropriate equipment selection and applied to current fuel and charter rates, were combined with mobilization and ancillary plant costs to form a scale of rates for use in the estimates.

Total volume for each of the options were checked against the programme to ensure that the required outputs reconciled with the capacity of the selected dredgers, without undue downtime.

Costs for the bank protection works include for reclamation of the dredged material, pumped and graded to specified lines, levels and densities within the Works.

For slope protection, the cost of rock mattresses was compared with that of concrete block mats. Quotations were obtained for the supply of rock from West Bengal, Malaysia and Indonesia as well as from the Chittagong Hill Tracts. In each case delivery was to be by barge. Use of the Chittagong rock would require further study to establish reserves and mobilisation periods.

To arrive at the total costs for the bank protection works, allowances were made for access dredging from the navigable river channel, for earthworks above river level, for access roads along the top of the protection works for inspection and maintenance purposes. In addition to these measured work items, allowances were made for temporary site facilities, supervision, and contractors' overheads and margins to bring the total to the levels anticipated for bids for these works as separate contract packages.

An appropriate part of the cost of establishment and running of the contractors' temporary site facility (proportional to the planned level of use) has been allocated to the bank protection works. No allowance has however been made in the estimate for the residual value of offices and staff accommodation in the contractors' temporary site facility since these have been assumed to revert to the BWDB for use in the monitoring and maintenance of the Works.

8.3.2 Operation and Maintenance

Schedules have been drawn up to identify the requirements for operation and maintenance and to enable them to be quantified and priced on the following assumptions:

- an organization will be established dedicated solely to the tasks of operation and maintenance of the bank protection works;
- items for maintenance include monitoring and preventative measures, periodic and predictable works;
- items not included are in respect of defects of construction materials or workmanship, and unpredictable damage, all of which are deemed to be the responsibility of others, or an insurable risk;
- items for operation include surveillance and organizational management.

Allowances for maintenance of the bank protection works include for a stockpile of repair material to be stored at a depot, for regular studies by consultants to forecast river movements, and sums for periodic contracts for remedial works.

8.4 Analysis and Results

8.4.1 Analysis

The estimating method employed was based on spreadsheets in which the required resources were allocated into the elements:

- local labour
- expatriate labour
- local materials
- imported materials
- plant and fuel

The sub-totals obtained in this way formed an essential cross-cast checking system and enabled a summary analysis to be abstracted as required for economic appraisal.

8.4.2 Cost Estimate Summaries

The estimated costs for the bank protection works at all seven priority sites are presented in Tables 8.1 to 8.9 including estimate for the emergency works at Chandpur Nutan Bazar.

8.4.3 Expenditure Programme

Major construction activities which are planned and priced on an operational basis with resource allocation form well defined packages which can be related to programmed periods. By spreading the expenditure based on anticipated resource usage and procurement considerations for each of these major activities and integrating them on the overall project programme, a reasonably accurate cash flow picture was obtained.

Since each of the activities have the main resources already allocated it was a relatively simple matter to produce these expenditure programmes in a resourced format. This has been done for expenditure incurred during both the construction and maintenance periods.

8.4.1 Anticipated Range of Cost

As is normal for Feasibility Study Estimates, an assessment has been made to quantify the likely range of contractors' bids due to possible changes in circumstances (excluding inflation) between the date of the estimate and the receipt of tenders. The results of this assessment have been used in the sensitivity analysis.

An objective review was made of each of the elements of the major activities identified in the estimating procedure including the following:

- design status;
- accuracy of quantities and information;
- confidence in methods and programme
- reliability of quoted rates and prices;
- competitive market factors;
- alternative designs.

Using these criteria with similar weightings for each of the contract packages and taking into account a possible local deterioration of the site (scour, bank slides), an average range from 7.3% to -[illegible] 4% was found for those sites for which detailed designs were the basis for the cost estimate: Bhairab Bazar, Munshiganj, Chandpur.

Obviously, the average range of costs will be much larger (say -15 to +15%) for cost estimates based on feasibility level designs (Eklashpur, Haimchar) or pre-feasibility level designs (Maniknagar, Meghna R&H Bridge).

Table 8.1 COST ESTIMATE ADVANCED PROTECTION [illegible] BAZAR
(Prices in US$ at mid-1991 level)

	Item	Cost in *1,000 US$
1	Dredging	5,824
2	Working area/materials	0,138
3	Earthworks above SLW	0,331
4	Clear site and reinstate	0,023
5	Open stone asphalt	0,820
6	Fascine Matress	1,747
7	Boulders in falling apron	1,412
8	Grouting of boulders	0,106
9	Contractors cost and supervision	0,641
10	MOB and DEMOB	0,060
		=======
		11,103
11	Physical contingencies (10%)	1,110
12	Contractors margins and fees (20%)	2,221
13	Engineering and supervision (7.5%)	0,833
		=====
TOTAL		15,267

Table 8.2 COST ESTIMATES FOR PROTECTION WORKS MUNSHIGANJ
(Prices in US$ at mid-1991 level)

Item		Cost in *1,000 US$
1	Dredging	1,780
2	Working area/materials	0,148
3	Temporary acces diversions and culverts	0,124
4	Earthworks	0,509
5	Open stone asphalt	0,708
6	Fascine Matress	1,320
7	Boulders in falling apron	0,198
8	Grouting of boulders	0,117
9	Clear site and reinstate	0,046
10	Contractors cost and supervision	0,608
11	MOB and DEMOB	0,080
		=======
		5,322
12	Physical contingencies (10%)	564
13	Contractors margins and fees (20%)	1,128
14	Engineering and supervision (7.5%)	0,423
		======
TOTAL		7,753

Table 8.3 PRELIMINARY COST ESTIMATES FOR ALTERNATIVE PROTECTION WORKS AT MANIKNAGAR

Item	Alternative	Cost in US$
i	Overall protection	12,964,717
ii	Series of groynes (earth filling)	11,838,105
iii	Series of sand sausages	20,551,285
iv	Deviation of flow with groyne	9,142,974

Table 8.4 PRELIMINARY COST ESTIMATES FOR ALTERNATIVE PROTECTION WORKS AT R&H BRIDGE

Item	Alternative	Phase	Construction in year	Cost in US$	Total cost in US$
i	protection of ferry ghat and vortex area	no phasing	1992	5,207,667	5,207,667
ii	Protection of ferry ghat and vortex area and groyne of 200m upstream of bridge	protection of ferry ghat and vortex area	1992	5,207,667	16,014,553
		groyne of 200 m	2003	10,806,886	
iii	Spurdike which guides flow lines (toplayer of CC-blocks)	no phasing	1992	5,570,846	5,570,846
iv	Spurdike which guides flow lines (toplayer of sand cement stone blocks)	no phasing	1992	5,155,115	5,155,115

Table 8.5 COST ESTIMATES PROTECTION WORKS EKLASHPUR

Item	Alternative	Phase	Construction in year	Cost in US$	Total cost in US$
i	Protection of existing embankment	Phase 1 (protection and extension of BWDB design)	1993	10,078,510	26,502,036
		Phase 2 (protection adjacent upstream part)	1998	8,211,763	
		Phase 3 (protection adjacent upstream part)	2005	8,211,763	
ii	Retired embankment (guide bund)	No phased investment	2003	42,154,950	42,154,950
iii	Groyne upstream of Eklashpur	No phased investment	2003	40,185,745	40,185,745

Table 8.6 COST ESTIMATE PROTECTION WORKS CHANDPUR, NUTAN BAZAR
(Prices in US$ at mid-1991 level)

Item		Cost in *1,000 US$
1	Dredging	14,626
2	Working area/materials	0,215
3	Earthworks above SLW	0,413
4	Clear site and reinstate	0,083
5	Open stone asphalt	0,688
6	Fascine Matress	7,370
7	Rock in falling apron	6,810
8	Grouting of rock	0,096
9	Containment bunds	9,684
10	Contractors cost and supervision	1,356
11	MOB and DEMOB	0,088
		=======
		41,433
12	Physical contingencies (15%)	6,215
13	Contractors margins and fees (22%)	9,115
14	Engineering and supervision (7.5%)	3,107
		======
TOTAL		59,870

Table 8.7 COST ESTIMATE PROTECTION WORKS CHANDPUR, NUTAN BAZAR AND PURAN BAZAR

Item	Cost in US$
1 Dredging	12,142,106
2 Working area/materials	337,216
3 Earthworks above SLW	473,040
4 Clear site and reinstate	236,520
5 Open stone asphalt	1,292,797
6 Fascine mattress rock	7,905,255
7 Fascine mattress boulders	403,530
8 Falling apron	6,861,106
9 Grouting of rock and boulders	116,716
10 Containment bunds	13,187,577
11 Contractors cost and supervision	1,647,200
12 MOB and DEMOB (excl.dredging equipment)	88,000
13 MOB and DEMOB dredging equipment	4,563,157
	======
	49,284,220
14 Physical contingencies	7,392,633
15 Contractors margins and fees	10,834,528
16 Engineering and supervision	3,696,317
	======
TOTAL	71,215,698

Table 8.8 COST ESTIMATE EMERGENCY PROTECTION WORKS

Item	Quantity	Unit	Unit Cost (US$)	Cost in US$
1 Dredging	2,381.963	m3	3.03	7,228,948
2 Working area/materials	1	-	173,956	173,956
3 Earthworks above SLW	1	-	177,390	177,390
4 Clear site and reinstate	1		130,086	130,086
5 Open stone asphalt	12,000	m2	35.12	421,497
6 Fascine Mattress	102,000	m2	48.03	4,898,761
7 Rock in falling apron	37,000	m3	69.73	2,579,887
8 Grouting of rock	821 -	m	62.58	51,380
9 Containment bunds	210.000	m3	35.45	7,444,600
10 Contractors cost and supervision	1	-	752,000	752,000
11 MOB and DEMOB excl.dredging equipm.	1	-	88,000	88,000
12 MOB and DEMOB dredging equipment	1	-	2,281,578	2,281,578
				=======
				26,228,084
12 Physical contingencies	15	%		3,934,213
13 Contractors margins and fees	22	%		5,770,178
14 Engineering and supervision	7.5	%		1,967,106
				=======
TOTAL				37,885,581

Table 8.9 COST ESTIMATE PROTECTION WORKS HAIMCHAR

Item	Alternative	Phase	Construction in year	Cost in US$	Total cost in US$
i	guiding protection	protection (length=3,800)	1993	18,371,682	18,371,682
		replace embankment (length=6,500m)	2008		
ii	guiding *) protection	protection (length=2,800m)	1993	12,990,712	23,210,329
		protection (length=1,000m)	2008	10,219,617	
		replace embankment (length=6,500m)	2008		
iii	guiding *) protection	protection (length=1,800m)	1993	10,923,482	29,320,365
		protection (length=1,000m)	1998	8,012,504	
		protection (length=1,000m) replace embankment (length=6,500m)	2008 2008	10,384,379	
iv	protection of existing embankment **)	protection (length=2,800m) protection (length=2,800m)	1993 2008	12,990,712 12,990,712	25,981,424

*) guiding protection = the short protection shaped like a guide bund protecting partly the existing embankment and replacement of embankment;

**) protection of the existing embankment = as indicated by definition without replacement of embankment.

9. MONITORING AND MAINTENANCE

It is a known fact in Bangladesh that maintenance of hydraulic engineering structures (like for instance slope protection works) in most cases either is not carried out at all or, if done, is carried out in a haphazard way on an ad-hoc basis.

Many reasons can be given for this situation: lack of inspection, lack of interest from the side of the owner, lack of funds, bureaucratic procedures, etc.

Now it must be emphasized first of all that such a situation is not only found in Bangladesh. All over the world infrastructure whether it concerns earthworks or structures is in many cases not maintained as it should be. Exceptions are for instance roads (where a lack of maintenance is immediately felt and seen by owners and users) and bridges (where easy jobs like periodic painting can be done on a routine basis).

However, hydraulic engineering works like embankments, revetments, regulators are situated for the greater part under water (where the damage occurs) and maintenance as a periodically returning event (like painting) is not required.

Moreover, inspection is difficult, i.e. requires for instance soundings or the assistance of divers, damage is in the early stages not visible and, last but not least, repair works are costly.

This all implies that a great effort has to be made by the local governmental organization which is responsible to have maintenance carried out before it is too late. The (invisible) damage has to be measured first by third parties (which may involve costs), it has to be reported and cost of repairs estimated, it then has to go through all the bureaucratic procedures before a budget is approved. Subsequently, the maintenance will be tendered, a contractor appointed and finally the repair work is carried out.

The time lapse between the inspection of the damage and start of repair works may well result in failure of the structure before these repair works start.

As already said this situation is not only found in Bangladesh. In the past this phenomenon was a reason for designers to design and construct hydraulic engineering works such that practically no maintenance was required during the design life and that only after occurrence of a design flood or a design wave pattern a thorough inspection was carried out.[1]

This "redundancy" of a structure, as it is generally called, was however not only due to conservative design principles but also to lack of insight in the possibility of failure and the actual 'state of the art' at that time (no good design formulas) which resulted in (too) high safety factors.

In modern design the designer tries to design a structure having a minimum capitalized cost. This may well lead to less investment and more maintenance.

Now the problem is that an owner through prequalification of contractors, quality assurance, quality control during construction and site supervision in principle can assure that he obtains a good product. The quality and timing of monitoring and maintenance, however, required during the life time of the project is not so easily guaranteed.

---

1 This statement is for instance valid for a breakwater in front of a harbour: At Rotterdam Harbour in the 100 years of its existence the break waters in the North Sea at the entrance of the New Waterway only once required major significant when a ship during a storm was pushed through it.

In Annex G, Section 1.7.2 and Appendix G/3 the monitoring and maintenance aspects and related repair work are described in detail. Moreover, the tender documents for protection works at Bhairab Bazar/Munshiganj and Chandpur stipulate the possibility to retain certain special contractors equipment for maintenance purposes while also at each site a stockpile of materials for maintenance will be made available at the end of the construction period.

However, all these proposals and recommendations may not automatically lead to maintenance carried out timely and to the required level of quality.

A solution which then comes to mind is to initially invest more and to depend less on monitoring and maintenance. This however is not a feasible solution: the knowledge of, for instance, the behaviour of a falling apron or of the river morphology (i.e. scour) is still too limited to arrive at a design which requires no maintenance whatsoever. Also, if such a structure would be technically feasible then it would not be economically attractive. In other words there would be no project.

If therefore follows from the above that the institutional side of maintenance (apart from the technical and financial aspects dealt with Annex G) is the key to a successful and long life of the river bank protection works.

A similar situation will exist at the Jamuna Bridge after its completion. Also here high investments will have been made in, amongst others, river training works. The nature of these works is the same as of those designed for the seven priority sites along the Meghna River.

In the Jamuna Phase II Feasibility Report (Annex L) proposals are given for "additional powers and responsibilities to operate and maintain the Bridge ....." It is recommended that JMBA shall have power to, inter alia, cover the following functions:

- the operation and maintenance of the bridge;

- the power to enter into contracts.

Apart from a legal setting such power will require a certain organization and staffing. Recommendations given in this respect focus on:

(a) power for the highest JMBA official on the bridge site (the Bridge Director) to be absolute in cases of emergency,

(b) a small capable staff at site,

(c) efficiency and team spirit,

(d) maintenance by contractors,

(e) presence of staff 24 hours a day, 365 days a year.

Now, obviously, a multipurpose bridge in operation cannot be compared in all its characteristics with "sleeping" river bank protection works, but a number of aspects are the same.

It therefore is suggested to consider the possibility of for instance a locally based (i.e. in Chandpur or Bhairab Bazar) Meghna River authority which is responsible for, inter alia, maintenance of all river bank protection works:

Such a river authority would be founded by GOB through an ordinance and it could for instance be based on the following:

- power to enter into contracts;
- maintenance only by experienced contractors, possibly using the authority's special equipment;
- regular monitoring especially of underwater works according to a fool proof method;
- maintenance fund to be created by receiving annual contributions from GOB which can be deposited in a bank and be used as required;
- small efficient staff which dares to take decisions and which is technically capable to make these;
- periodic assistance by expatriate consultants for carrying out inspections, to specify repairs required and to inspect repair work done.

Obviously, these ideas need further elaboration and discussion with GOB and IDA.

Preferably the set-up and functioning of a special monitoring and maintenance organization should be part of the loan agreement for the construction of the bank protection works described in this Report.

Finally, it is noted that under FPCO a FAP-component, FAP-13, exists which is called "O and M Study". It would appear that such a study should also make recommendations on the future maintenance of projects following from FPCO sponsored studies like the Meghna Short Term Study (FAP-9B).

The same applies to FAP-26 "called Institutional Development Programme" which aims at:

> "a programme to establish institutional requirements of the Action Plan, assess existing concerned institutions and recommend appropriate arrangements for planning, implementing and managing the Action Plan projects. To undertake special institutional development activities to implement the recommendations".

10. ECONOMIC EVALUATION

10.1 Introduction

The economic evaluation analysis presented in this annex is executed within the framework of the Meghna River Bank Protection Short Term Study. At the request of the Bangladesh Water Development Board, a team of experts has investigated the technical and economic feasibility of river bank protection works at specific sites along the Meghna River.

This chapter describes the economic analysis of the proposed river bank protection works at the selected project sites. After this introductory section a general description is given on the evaluation method applied in Section 10.2. Specific issues related to individual sites are discussed in the respective sections assigned to the economic feasibility analysis of these sites. Sections 10.3 to 10.9 deal with the economic evaluation of the bank protection works in Bhairab Bazar, Munshiganj, Chandpur, Eklashpur, Haimchar, Road and Highway Bridge and Maniknagar respectively. Section 10.10 discusses the preliminary economic evaluation of a long-term bank protection scheme for the whole Lower Meghna.

For detail information on data used and the analysis carried out reference is made to Annex F and Appendix F/1 to this Annex.

10.2 Evaluation Method

In order to streamline techniques, bring consistency into the appraisals and facilitate comparison of potential investment opportunities, the Flood Plan Coordination Organization (FPCO) of the Ministry of Irrigation, Water Development and Flood Control has prepared standard procedures.

The standard procedures have been laid down in Guidelines for Project Assessment. These guidelines draw attention to special issues which experience indicate are of importance in Bangladesh. Their aim is to provide a sound base for decision-makers in choosing between alternative water resource strategies and investment opportunities.

The present study follows these guidelines closely. However, these procedures are focusing on flood control projects. Hence, they cannot be applied to erosion control projects without careful consideration and modification.

On the one hand, special attention must be given to information available and collected: (i) data on relevant aspects of river bank protection works are not accurate and consistent, (ii) benefits are difficult to quantify.

On the other hand, the mechanism of river bank erosion requires a deviation from the guidelines regarding the assessment of the damage probability function. Being an erosion protection, rather than a flood protection project, implies that erosion probability, unlike the flood probability, is not directly associated with high water levels in the Lower Meghna. Many other factors, e.g. geo-technical conditions, waves, sudden fall and rises of the water levels, play a decisive role in erosion of the river banks. Hence, extreme value probabilities have been determined by directly applying the extreme value theory on recorded and estimated damage rather than on weak regressions between such damages and the probability of physical phenomena such as high water levels which only partly explain the occurrence of damages.

10.2.1 Scenarios to be evaluated

In agreement with the FPCO-guidelines for project assessment, in the present economic feasibility analysis of the short term bank protection works a comparison is made between two future scenarios, (i) the scenario with permanent river bank protection works (with-scenario) and (ii) the scenario without such protection works (without-scenario).

In the without-scenario situation the present day practice regarding river bank repair and maintenance activities is continued. However, it must be noted that the without-scenario is not equal to the present situation, but represents an extension of the present situation into the future.

The most likely future situation without the project is surely not the situation in which all interests along the river bank (urban area, irrigation districts, etc.) will be completely abandoned. If such would be the case the whole economic added value of e.g. the Bhairab Bazar Bridge, Meghna-Dhonagoda and Chandpur Irrigation Projects could be taken into account as benefits to the bank protection projects. Experience from the past, however, indicate that the most probable future scenario without the bank protection projects considered in this study is described by continuous efforts of the authorities to protect the interests along the river banks in a non-sustainable way by either bank protection works, haphazardly designed and carried out, or by regular withdrawing of embankments.

This has, in general, the following consequences:

(i) Experience from Chandpur Town protection measures in the past decades, where expenses for repair and maintenance showed an average growth rate of [illegible] over the last 10 years, and the repair measures in Bhairab Bazar, where the annual growth rate for these expenses was over 25% in the past five years, show that expenses needed to repair and maintain the present river bank protection at isolated locations along the water front in the non-sustainable present practice are likely to increase dramatically in the future. Based on that experience it has been estimated that such expenses in the without-scenario will increase by an annual ten percent.

(ii) Experience from Chandpur Irrigation Project shows that the embankments will be retired to the extent bank erosion cannot be stopped by non-sustainable bank protection works, carried out in an ad-hoc way. For the Meghna-Dhonagoda and the Chandpur Irrigation Districts (Eklashpur and Haimchar), the without-scenario is therefore characterized by the extrapolation of this present day practice.

10.2.2 Period of analysis

The guidelines for project assessment indicate that for FAP project planning a discounting period of 30 years from the start of project construction must be used. No reason has been identified to change this period for the economic feasibility analysis of river bank protection.

10.2.3 Financial and economic analysis

The analysis of river bank protection is basically an economic analysis. Consequently, prices used to calculate benefits and cost are economic prices, reflecting the opportunity cost of goods and services to the economy. However, financial prices form the base for the economic prices used in the economic feasibility calculations.

10.2.4 Unit prices and rates

10.2.4.1 Price level

All prices and cost are expressed in mid-1991 prices in Taka. This conforms to the FPCO-guidelines for project assessment.

10.2.4.2 **Financial and economic costs**

As it was stated before the economic analysis is based on the financial analysis in which the financial cost and benefits are transferred into economic inputs and outputs by discriminating between traded goods, non-traded goods and by applying the corresponding conversion factors to the different economic resources.

(i) Traded goods

Traded goods refer to all commodities that are traded on the international markets. Traded goods are valued on the basis of their international border prices, with adjustment for quality, transport cost, handling charges and marketing margins. All estimates for international prices are derived from the World Bank's Commodity Price forecasts and converted to mid-1991 constant economic prices. Hence, all internationally traded goods are expressed in Taka-values applying the official mid-1991 exchange rate.

(ii) Non-traded goods

The term non-traded goods refers to all items which cannot be valued on the basis of international border prices: e.g. local non-exported products, animals, local building materials, labour. Their economic price is derived from the mid-1991 market price by applying a conversion factor in order to eliminate the divergence between border prices and domestic prices.

(iii) Conversion factors

The Planning Commission recommends a standard conversion factor for Bangladesh. This factor is 0.82 for non-traded goods, exclusive unskilled labour. The shadow wage rate for unskilled labour is obtained by using a conversion factor of 0.71, reflecting unemployment and under-employment in the rural economy. No reasons have been identified to deviate from the conversion factors recommended by the Planning Commission and the FPCO.

10.2.4.3 **Value of property**

In the economic appraisal of projects much attention is given to the economic value of structures. This aspect becomes important in the appraisal of river bank protection in Bhairab Bazar, Munshiganj and Chandpur, where houses, commercial enterprises and industries are at peril.

Through the socio-economic surveys reliable information was obtained on the value of houses and enterprises. The survey value represents the cost of materials used, without labour for construction. For the financial calculation of the cost of destroyed and damaged structures this surveyed value serve for estimating the cost of destructed and damaged structures. However, the imputed figure does not represent the construction or replacement value of structures as labour and some other cost factors are not covered.

A consistent financial appraisal requires that these costs are included in the value of the structures. The labour and non-covered components were estimated at 45% of material cost of structures. Hence, the financial cost of construction could be estimated more accurately.

In the economic appraisal of river bank protection works the economic opportunity cost of structures must be used, which may be lower than the economic replacement value. The opportunity cost of destroyed and damaged houses or commercial and industrial enterprises is the net value of production and services foregone when structures are destroyed or damaged. The following sections highlight the methods used in the economic analysis.

(i) Destruction of habitations

When property has been washed away persons cannot return to their homes and consequently economic resettlement cost must be used. However, it is unlikely that all inhabitants will be in the position to rebuilt a house somewhere else; 25% is estimated to remain homeless. Moreover, the alternative house is less expensive than the one destroyed. Hence, it seems appropriate to impute for the economic cost of destroyed habitations a percentage of construction cost after correction for the foreign exchange premium. Details on this assumption are presented in the appendix.
In section F/1.5.1 of the appendix it is explained that 6[illegible]% of the economic construction value is an appropriate value for shadow pricing the cost of destroyed houses.

(ii) Destruction of commercial and industrial enterprises

When commercial and industrial enterprises are destroyed by floods it is very likely that traders and industrialist will engage again in their traditional occupation in one way or another. They may possess enough savings to start trading again. Or else they could obtain a loan from a supplier, which enables them to start again.

The replacement value of the destroyed building is less appropriate as for calculation of the economic cost. One may expect that in Bangladesh considerations of investment security and prestige may have pushed land and building prices well above their economic value. Hence, their market prices is not a realistic economic estimator either. Many times the alternative will be to take the rental value: a renter is not likely to pay a premium for prestige or investment security and thus will not pay a rent higher than the contribution the land or building can make to the economic activity he proposes to undertake. Hence, the rental value is more appropriate than the market price or replacement value.

The economic rental value is a good indicator for the annual costing purposes. However, the rent is not only used for a single year, but applies for the full period of the study. Hence, this rental value should be discounted over a range of years at an interest rate which reflects the opportunity cost of capital. The net present value thus derived can be imputed in the economic appraisal of investments.
The socio-economic surveys give indications on the rental value of commercial and industrial buildings. Details are provided in the appendix. Although, attractiveness of location, floor-space, land value may have influence on the rental value, it appears from the survey results that rents are consistent. For commercial and industrial enterprises an average rent of Tk. 57,000 per years is found. This value applies for each of the sites where town protection is evaluated. For more rural areas a lower value is used. The rental value is discounted over a period of 30 years at an interest rate which reflects the opportunity cost of capital. In Bangladesh the assumed opportunity cost of capital is 12%. For more details reference is made to the appendix, section F/1.5.2.

(iii) Damage to houses

Houses near the river bank could be damaged by the erosion force of the river. This does not mean directly that these houses are destroyed, but merely that part of the walls are damaged or that some of the foundation works are washed away. In almost all cases it means that the owner will vacate the house and tear it down, thus saving building materials. With this materials a new home will be built elsewhere or the owner may sell materials and find other means of accommodation.
For those buildings which are torn down and rebuilt this means in economic terms that the following cost are involved:

- labour for tearing down the old building;
- transport cost for bringing materials to a new building site;
- labour cost for rebuilding the home; and
- additional material cost to replace what was lost.

Attention must be paid to the fact that a proportion of damaged houses are not rebuilt, simply because the owners do not possess the financial means to do so. This percentage is estimated at 25% (for more details reference is made to the Appendix F/1, Section F/1.5.3). Based on this and the breakdown of house construction cost and what is needed to rebuild a house, it is estimated that the economic value lost as a result of house damage is 50% of the construction price. Details are provided in the appendix.

(iv) Damage to commercial and industrial enterprises

Commercial and industrial enterprises damaged by erosion are likely to be left and the owners will start operation elsewhere. In this respect damage cost are the same as cost of destruction, although with this difference that hardly any land is lost. Hence, the economic cost of damage to structures is similar to these cost when buildings are destructed; this means that the rental value is used as an indicator for the economic cost. For details reference is made to section F/1.5.2 of the appendix.
Table 10.2.1 indicates which cos[illegible]ents have been used for pricing the value of assets. More details are explained in Annex [illegible] (section F/1.5 of the Appendix F/1).

TABLE 10.2.1 ELEMENTS FOR CALCULATION OF THE VALUE OF PROPERTY

Element	Financial appraisal (Market price)	Economic appraisal (Shadow price)
Cost of damage to habitations	50% of replacement value, excl. land value	50% of replacement value, excl. land value(after correction for foreign exchange premium)
Cost of damage to buildings of commercial and industrial enterprises	Discounted annual rent (12% and 30 years): Tk. 516,145	Discounted annual rent (12% and 30 years), after correction for foreign exchange premium: Tk. 423,239
Cost of destructed habitations	65% of replacement value c building, incl. land value	65% of replacement value, incl. land (after correction for foreign exchange premium)
Cost of destructed buildings of commercial and industrial enterprises	Discounted annual rent (12% and 30 years): Tk. 516,145	Discounted annual rent (12% and 30 years), after correction for foreign exchange premium: Tk. 423,239

10.2.4.4 Agricultural base rates

For the calculation of economic values of land lost due to erosion of the river banks, it has been considered appropriate to use agricultural base rates. The base rate is a combination of the following factors:

(i) Crop economics

In the agricultural areas prone to erosion the loss of irrigated crops can be averted by protection works. This aspect becomes important for protection works in Chandpur, Eklashpur, Haimchar and Maniknagar. Hence, the economic appraisal of agriculture must give attention to the crop economics.
After reviewing cropping patterns in the selected project sites it was decided to consider only a limited

number of crops. The overall importance in the cropping pattern of rice varieties (and wheat makes the analysis of other crops needless.

Because the feasibility analysis stretches over a period of 30 years it is necessary to adjust prices of inputs and commodities. In calculating the economic returns of crops mid-1991 economic prices for the year 2005 were used. The World Bank's Commodity Prices forecast served as basis for price calculation. Table 10.2.2 provides a summary of economic returns per crop.

TABLE 10.2.2 SUMMARY OF NET ECONOMIC RETURNS PER CROP

AREA: 1 ha
PRICES: mid-1991 constant economic prices
VALUES: Tk.

Crop	Type	Econ. return
HYV Boro	irr.	9 522
L Boro	non-irr.	9 824
B Aus	non-irr.	316
LT Aman	non-irr.	6 594
Wheat	non-irr.	6 755

(ii) Land use and cropping pattern

The calculation of the lost economic returns are based on actual land use and cropping patterns. For lands outside embankments which border the river rice is the sole crop considered. With respect to Eklashpur and land upstream from Chandpur the land use and cropping pattern in the Meghna-Dhonagoda project was used. Land use and cropping pattern of the Chandpur Irrigation project apply for areas downstream of Chandpur and in Haimchar. The Gumti project land use and cropping pattern has been applied in Maniknagar.

(iii) Agricultural infra-structure

Loss of agricultural land in the three irrigation projects mentioned above would lead to the loss of irrigation infra-structure. Based on information concerning irrigation projects on the Meghna's left bank an estimated was made of replacement cost of irrigation infra-structure. The overall value on a per ha base is calculated at Tk. 1,677, based on the following assumptions (see section F/1.6 of the appendix):

- each low lift pump serves an area of 16 ha;
- economic replacement cost of that part of the irrigation structures that cannot be removed (e.g. canals, concrete structures) is evaluated at Tk. 26,835 at mid-1991 prices.

(iv) Value of land

Although it may be argued that for every hectare of arable land lost due to river bank erosion, somewhere else in the delta area a hectare of new land may become available on a char, the economic benefits of this new land has been neglected in the evaluation since it normally takes a long time before such land will give a substantial agricultural produce and the new land is even after that period not equally productive because of the absence of any irrigation infrastructure. Hence, the economic evaluation includes the value of agricultural land that is lost as a result of erosion.

One may expect that in Bangladesh considerations of investment security and prestige may have pushed land prices well above their economic value. Hence, the market price is not a realistic economic estimator. 'In these instances, we will not want to accept the market purchase price as a good estimate of the economic opportunity cost and must search for an alternative. Many times that alternative will be to take the rental value of the land', according to Price Gittinger (World Bank, 1982), when discussing the economic value of agricultural land.

The economic rental value is a good indicator for shadow pricing purposes. The annual rent as a value-indicator, however, applies to a specific single year. Hence, the annual rental value has been discounted over the 30-year study period at an interest rate of 12%, generally been taken as the economic opportunity cost of capital. The present value (PV) thus derived reflects the economic value of land lost and can be imputed in the economic appraisal of investments. Details are provided in the Annex F, Appendix, section F/1.6.2.

The economic value of cropped land is based on share cropping arrangements in the area. For each individual crop the rent has been calculated as the money value of production quota provided by the share cropper to the landowner. Based on the prevailing cropping pattern in the Meghna-Dhonagoda, Chandpur and Gumti irrigation projects the average economic rental value is calculated.

For the economic analysis the avoidable losses in (i) production and (ii) land eroded are compared in the with and without project situation. Using the arrangements for share cropping, which are, like the production value, linked to the production only, as an indicator for the value of the land does not imply any double counting.

10.2.4.5 Base rates for river works

The cost of the river bank protection works relate to construction and engineering cost. As a result of the complexity of the river conditions (high water depths and strong current) and the high level of skill needed for river bank protection works to be carried out under such conditions, it is envisaged that qualified contractors with the required construction capacity and equipment are not available in Bangladesh and that (i) international competitive bidding by pre-qualified contractors and (ii) supervision by a qualified engineer with experience in this type of work are conditions for their proper implementation. The costing of the works has been based on this assumption.

In addition to the construction cost more cost components have to be considered in the economic analysis, notably monitoring and maintenance cost. Monitoring cost have been based on survey cost experienced during the execution of this short term river bank study; an acceptable estimate for survey cost and other monitoring expenses is Tk. 2.0 million (mid-1991 economic prices) per site. Annual maintenance expenses of protection works have been estimated at 4% of the cost of surface protection; e.g. open stone asphalt, fascine mattress, boulders in falling apron and grouting of boulders.

Initially the unit prices and base rates for infra-structural works and river training works were based on the BWDB's Standard Schedule of Rates. The schedule of rates of river training works for the Jamuna Bridge also served as a guide. These unit rates refer to mid-1990 prices. They have been inflated by the general price index of 10% in order to adjust prices to mid-1991.

At the later stage, **a contractor's approach** was applied to determine the definitive cost estimate of the works designed. All cost items have been subdivided into local and foreign components.

10.2.5 Benefits from River Bank Protection Works

When comparing the with- and without-project case, the benefits from the river bank protection project are related to (i) savings and reduction of costs associated with the present day practice of protecting the interests along the river bank and (ii) damage occurring due to the erosion of the river banks.

Theoretically the best way to identify such damages would be to assess a wide range of different scenarios of damage due to the erosion of the river banks (failure of a bank, failure of infrastructure such as bridges to the complete inundation of irrigation districts), to identify the probability of occurrence and to calculate in agreement with the FPCO-guidelines the mathematical expectation of the damages. This methodology has been followed where applicable.

286

In relation to possible damage to irrigation districts, however, this method could not be applied, since failure probabilities and the extent of the damage of future likely events could not be easily assessed. For irrigation districts, therefore a more deterministic approach has been applied: (i) definition of a deterministic future bank protection strategy as discussed in F.2.2 in combination with an expected erosion rate derived from the geo-morphological study (Annex B).

Some of the benefits are associated with population growth or economic growth rate. They will, therefore, increase annually. The FPCO-guidelines give a 3%- to 4% growth rate. For the feasibility studies a growth rate of 3% has been used, as it reflects the economic growth for Bangladesh over the period 1985 to 1990. However, no information is available for economic growth for each of the project sites individually.

The benefits thus identified are related to the following aspects:

(i) Cutbacks in maintenance and repair cost

The present and future annual expenses for repair and maintenance to the eroding river banks in the situation without appropriate bank protection works will be avoided by the well designed and constructed protection works.

(ii) Reduction of loss and damage in town areas affected by erosion

The estimated present and future annual economic loss and damage due to the bank erosion in the situation without appropriate bank protection works will also be avoided by the well designed short term bank protection works. The loss and damage of private and public property have therefore been evaluated and an estimate of the future annual loss and damage has been made. The estimate has been based on the value of the identified assets in the area prone to erosion and the assumption that the average value of such assets is homogenously distributed over the urban area.
Referring to specific sites, specific infra-structural facilities which are likely to be affected in the situation without the permanent bank protection works, deserve special attention: the railway and IWTA terminal complexes in Chandpur, the railway bridge and oil terminal in Bhairab Bazar, etc.

(iii) Disruption of economic activities

The estimated present and future net revenues of economic activities in the commercial and industrial areas lost due to the river bank erosion in the situation without appropriate bank protection works will be avoided in the project situation with well design bank protection works. Due to the fact that commercial and industrial enterprises in the project area in the situation with appropriate bank protection works will no longer be subject to damage, economic activity will be likely to increase.

(iv) Reduced damage to the agricultural sector

Proper bank protection works will stop the annual erosion and damage to the agricultural sector and its irrigation infrastructure in the areas along the eroding river banks. The economic value of the increased production and the avoided losses to the irrigation infrastructure are benefits of the protection works.

(v) Social benefits

Employment is the major social benefit. Within the protected area either agricultural or commercial and industrial activities employ a substantial number of persons. It is obvious that permanent erosion protection works may reduce employment. Another impact of the works could be temporary increase of employment opportunities during construction. Although, these employment as such is not elaborated for the individual sites, their economic effects are already incorporated in any disruption of economic activities.

(v) Environmental benefits

In general, river bank protection works will have positive and negative environmental impacts and no cost are attached to mitigative measures for environmental protection. Where environmental monitoring may be needed, costs are included in overall monitoring.

(vi) Secondary benefits

Secondary benefits refer to land reclamation in the process of constructing river bank protection. The economic value of reclaimed land and the employment generated are, however, considered secondary benefits. Secondary benefits are not identified for the individual protection sites.

10.2.6 **Evaluation Crit... Feasibility Study**

The economic feasibility of the river bank protection works is first evaluated by comparing the discounted values of benefits against cost. The economic internal rate of return (EIRR) is the discounting percentage at which the benefits balance cost over the 30-year evaluation period.

A common indicator for the profitability of projects is the net present value (NPV). The economic net present value for the short term bank protection works has been calculated for a discounting rate of 12%, which is generally assumed to be the opportunity cost of capital.

In addition, the FPCO-guidelines for project assessment require the two net present value ratios (NPVR). The first one (NPVR(1))is the ratio between the net present value and the present value of public capital and operation and maintenance cost at financial prices.

The second one (NPVR(2)) is similar, but takes also private capital into consideration in the denominator. The river bank protection works are likely to be financed by a loan or grant from a development bank. This means that only public capital will be involved and no private capital will be used to finance the bank protection works. The two NPVR's therefore will be the same, above.

10.2.7 Data sources

For the collection of up-to-date information on the socio-economic interests of the areas prone to river bank erosion, a sampl... survey was executed for all sites during the months of April and May 1991.

Statistics on a variety of items, e.g. population, national income, were taken from the Bangladesh Statistical Yearbook 1991.

Data on actual expenditures for maintenance and repair of river bank protection works during the past years, were obtained from the BWDB. The information collected gives details on procurement and placing of boulders, fabrication and dumping of blocks and various other components. Information on the cost of works executed by the BWDB on behalf of the Power Development Board for protection of transmission towers in Bhairab Bazar was also collected.

From Bangladesh Railway data were received on the cost of maintaining and repairing protection works for the railway bridge. Furthermore, the railway authority provided valuable information on passenger and cargo flows crossing the bridge . In particular, the information booklets of Bangladesh Railways are worth mentioning (B.R. Information books from 1987 to 1990).

The IWTA provided information on the value of their terminal in Chandpur, while Jamuna Oil Company provided the cost of relocation of the oil terminals in Bhairab Bazar.

Two very useful reports on agriculture in the Chandpur irrigation project and the Meghna-Dhonagoda project provided the base for estimation of cropping patterns. The first concerns Paul M. Thompson: "The impact of flood control on agriculture and rural development in Bangladesh (1990). Secondly, Hunting Technical Services Ltd: "Rapid rural appraisal of Meghna-Dhonagoda irrigation project (1991)" provided useful data.

Information on crop economics were kindly provided by the South East Region Water Resources Development Program (FAP 5).

Reports on earlier feasibility studies and other projects executed in Bangladesh were consulted (e.g. Gumti phase II). They form the secondary data sources used for this study. Especially, the economic study of the Jamuna Bridge project has been consulted.

Report of the Task Forces on Bangladesh Development Strategies for the 1990's
University Press Limited, Dhaka, Bangladesh, 1991. This report was only available at the very last moment.

Finally, Lyn Squire and Herman G. van der Tak: "Economic analysis of projects (1975)" and J. Price Gittinger: "Economic analysis of agricultural projects (1982)" ... consulted.

10.3 Bhairab Bazar

10.3.1 Present Situation and Previous Studies

Bhairab Bazar, a major inland port in Bangladesh, is located upstream of the confluence of Meghna River and the old Brahmaputra River. The historical township is a centre of commercial and industrial activity due to its strategic location at the hub of vital rail, road and water routes.

The present and future position of the township is constantly threatened by the eroding force of the Upper Meghna River. The river not only threatens commercial and industrial buildings along its waterfront, but also the railway bridge located north of the town. This bridge is vital in the network of Bangladesh Railway as it is the only means of crossing the Meghna in the railway network, linking Chittagong to the eastern part of the country.

The dramatic events in 1988, when not only part of the Railway property was lost, but also severe damage was caused to the river's right bank at the township, has given new momentum to the search for sustainable solutions to protect Bhairab Bazar Town and its railway bridge. In the years after the 1988 flood the river bank was damaged again despite the bank protection works carried out.

Already in October 1988, almost two month before the dramatic events that reached the national headlines, a report was presented addressing the protection of Bhairab Bazar Town. Following the loss of a considerable portion of Railway property in 1988, various specialists presented reports. In December 1990, DDC submitted a report for the protection of Meghna Railway Bridge.

These reports and studies focus mainly on technical aspects of protection works and the costs involved. The economic feasibility of the proposed works is more difficult to assess. The DDC report for instance covers only the cost of works and makes a comparison between blocks and stone revetment.

The present study falls within the scope of the Flood Action Plan. Solutions presented must not only be technically sound, but equally financially, economically and environmentally sound.

The situation in Bhairab Bazar is particular as this location covers two of the eight sites under consideration, notably the township and the railway bridge. Both are combined in one single economic feasibility study as the envisaged protection works encompasses the township as well as the railway bridge. This point of view has been supported by the ADB in a meeting with the Consultants to discuss possible ideas of Bangladesh Railways to protect only the right abutment of the bridge in the coming low water season.

10.3.2 Area Affected

The area covered by the study reaches from the ferry ghat just North of the railway bridge to the confluence of the old Brahmaputra River, some three kilometres to the South. Bank protection works have been designed for the right bank of the Meghna to protect:

- the Town (commercial and industrial buildings),
- the right abutment and first pillar of the railway bridge;
- the Jamuna oil terminal,
- the two PDB transmission towers.

10.3.3 Alternative River Bank Protection

Construction of durable protection works on the existing bank of the Meghna would involve the clearing of a stretch of land along the river bank, where houses and commercial enterprises are located now. Although this may prove to be an adequat and financially attractive solution for the protection of the town area and the bridge, it is likely to face strong resistance from the local authorities and population. Consequently, another protection concept has been studied as well, whereby a new, advanced, bankline is created away from the existing one.

This latter advanced[1] protection concept involves the construction of a complete new bank line, some twenty metres from the old bank line. This option has been selected for practical reasons. With this option there is no need to remove all buildings and structures over a 20 m wide strip along the water front and the alignment can be much smoother. Moreover, a proper slope can be achieved by the application of hydraulic fill.

For design purposes the accepted failure probability of the protection works has been evaluated. Under the assumption that maintenance works are realized for 80%, the accepted failure probability for the protection works designed becomes five times in one thousand years (5.0 E-03).

10.3.4 Benefits of Bhairab Bazar bank protection

10.3.4.1 Reduction of repair and maintenance

From information collected on cost of maintenance and repair of erosion damage, the amounts spent in the past by the BWDB, Bangladesh Railway and the PDB were calculated. The information collected referred to accounted amounts for the financial years 1985/86 to 1990/91.

The analysis of the avoidable repair and maintenance costs as benefits from the bank protection works designed is based on the assumption that such repair and maintenance costs due to river bank erosion can be evaluated by applying the probabilistic extreme value theory to the recorded and estimated historic records.

---

1 'Advanced' refers in principle to the position only and not necessarily to advanced techniques.

10.3.4.2 Loss and damage to properties

Past erosion damage was estimated from records on destruction and damage to property, which were supplied by the upazila and municipality. The average value of property could be calculated from the socio-economic survey results. However, the survey outcome only gives financial construction cost, which must be converted to economic values. These values for destroyed houses and commercial buildings have been calculated as follows:

- the value of houses is estimated at 65% of its economic construction value in order to take account of the lower quality of replacement homes after destruction;

- the economic value of destroyed commercial and industrial buildings is estimated as the rental value, thus taking into account that construction cost are not a reliable indicator for shadow pricing.

As far as property is concerned, which was damaged but not destroyed, the imputed average value used is a percentage of the total value. For houses and homesteads this percentage is estimated at 15%, while for commercial and industrial properties it is evaluated at 25%. For details on these estimates reference is made to Appendix F/1.

Since the data only concern loss and damage of private property a surcharge is taken into account to reflect the loss and damage of the public infrastructure of the town. Taking into account the average occupation of public and private infrastructure the total loss and damage to public infra-structure has been evaluated at 25% of the loss and damage of private property. The final result is presented in Table F.3.3. More details are provided in the appendix, section F/1.3.

10.3.4.3 Disruption of economic activities

The destruction of commercial and industrial properties leads to a loss in net profits (after payment of taxes) and employment. The first is considered in the financial and economic evaluation, while the latter is a social aspect of river bank erosion damage. The computation of losses in profitability assumes that losses as a result of destruction or damage of property are the equivalent of 12 months net economic returns (profits). Details are provided in the appendix F/1.

10.3.4.4 Computation of avoidable repair, maintenance, loss, damage and lost profits

In Table 10.3.1 a summary is presented of the cost of repair and maintenance, losses and damage and lost net economic return for the years 1985 to 1990. River bank protection would result in a substantial decrease in losses and consequently the total amount represents avoidable losses. Hence, the benefits of erosion control works are defined as a saving in future maintenance and repair cost, loss of and damage to property and profit losses for a scenario where no protection is undertaken. A computation of these savings over the evaluation period gives the benefit flow.

The annual figures are ranked in size and a frequency is assigned in agreement with their ranking. Subsequently, the cost are correlated with their frequency by fitting the Gumbel extreme value probability function. Based on this function and the procedures outlined by the FPCO-guidelines for project assessment, the expected annual economic cost due to erosion are evaluated.

TABLE 10.3.1 REPAIR AND MAINTENANCE COSTS, LOSS, DAMAGE AND LOST PROFITS DUE TO BANK EROSION IN BHAIRAB BAZAR

PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million

Year	REPAIR/MAINT.COST:			DAMAGE/LOSS PRIV/PUB.INFRA			LOST	GRAND
	BWDB	Bgd.Rail	TOTAL	Loss	Damage	TOTAL	PROFITS	TOTAL
1985	5.916	0.787	6.703	12.038	7.443	19.481	0.379	26.563
1986	5.378	0.716	6.094	14.640	9.902	24.542	0.635	31.271
1987	8.658	26.074	34.732	19.995	12.482	32.477	1.459	68.669
1988	15.051	29.205	44.256	28.071	17.540	45.611	2.503	92.370
1989	10.318	8.995	19.313	16.540	9.614	26.155	1.441	46.909
1990	6.264	7.036	13.300	7.741	4.659	12.400	0.721	26.420

Sources: S[illegible], BWDB, Bangladesh Railway, Power Development Board
Notes:
1) Cost repair and maintenance BWDB includes amount paid by Power Development Board and the protection expenses of Jamuna Oil Company
2) Deflator of 10% is used to adjust expenses for repair and maintenance (value of deflacor is according to Planning Commisison)

Table 10.3.2 presents the mathematical expectation of annual avoidable costs due to repair, maintenance, loss, damage and lost profits, evaluated at Tk. 50 million economically. Figure 10.3.1 gives the damage-frequency curve for Bhairab Bazar.

For reasons indicated in Section 10.2.2 a 10% annual growth factor has been applied to the annual expected value of repair and maintenance (Tk 19 million) when extrapolating the present day practice. Concerning loss and damage to private and public infra-structure and loss of profit (Tk 31 million), the annual increase is 3% reflecting the growth and increase of economic activity in the affected area.

10.3.4.5 Disruption of rail transport

Damage to the railway bridge will cause a disruption of rail traffic from and to Dhaka; passengers and cargo will either divert to other routes and modes or will have to disembark at Bhairab Bazar or Ashuganj, then cross the river by ferry and embark a train to proceed to their destination. This involves in general additional [illegible] the economy, such as (a) economic value of lost time, (b) extra transport cost for passengers and cargo and/or extra cargo handling cost, (c) repair cost of the bridge and (d) other cost referring in particular to the expenses needed for upgrading the ferry ghat.

In this study the analysis is based on a review of the passenger and cargo flows presently using the bridge and their likely alternative route. The additional financial costs are estimated from financial transport, cargo handling and ferry costs for with and without protection scenarios. By using the economic conversion factors, the financial costs have been converted in economic prices.

The incremental failure probability of various degrees of damage to the bridge has been assessed, together with the costs and time required for the repairs. See Appendix G/5 to Annex G.
The total additional transport costs and the costs for repairs can then be evaluated as a (Gumbel extreme value) function of the failure probability.

On the basis of this damage probability function the expected annual costs have been evaluated at Tk. 17.2 million in financial term. This corresponds to Tk. 14.1 million in economic terms. The following sections provide details on the calculation of this value.

A detailed description of the methodology is presented in Annex F, Section F.3.5. A summary of the results is given in Table 10.3.2. This table provides details on the mathematical expectation calculated. Figure 10.3.1 gives the damage-frequency curve.

TABLE 10.3.2 MATHEMATICAL EXPECTATION ANNUAL DAMAGE TO DISRUPTION OF RAIL TRANSPORT

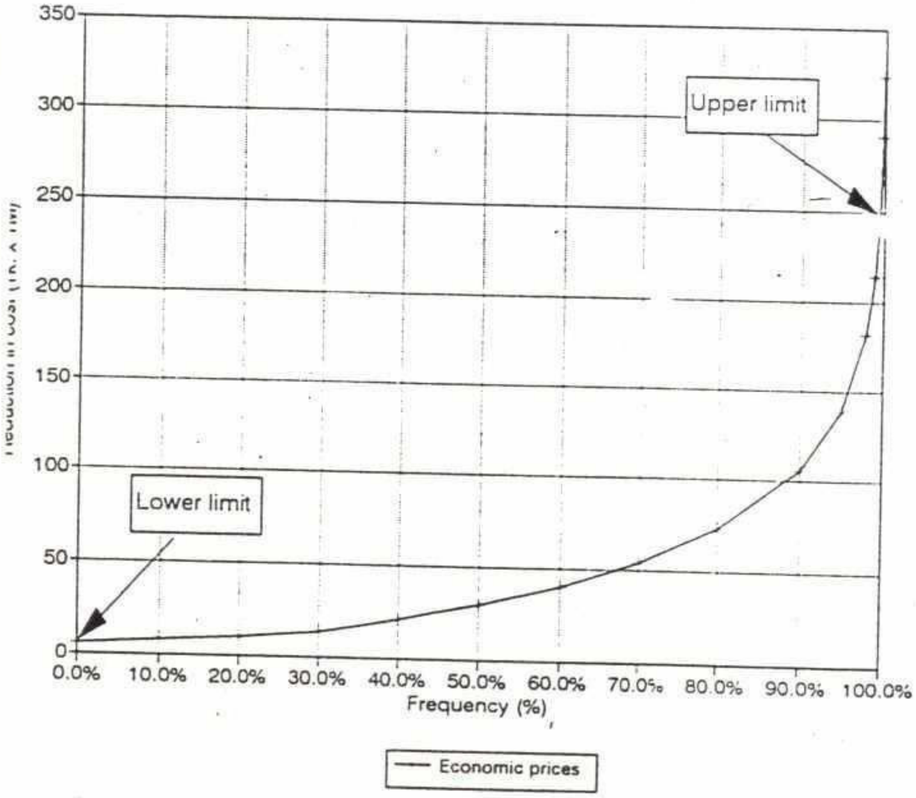
PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million

Freq. (non-exc)	Return period (yrs)	Total damage	C&F differ.	Cum. C&F diff.	Convers. to USS x 1M
0.00%		0.000	0.000	0.000	0.000
10.00%		8.588	0.429	0.429	0.012
20.00%		18.188	1.339	1.768	0.049
30.00%		29.072	2.363	4.131	0.115
40.00%		41.637	3.535	7.667	0.213
50.00%	2	56.498	4.907	12.573	0.349
60.00%		74.686	6.559	19.133	0.531
70.00%		98.135	8.641	27.774	0.771
80.00%	5	131.184	11.466	39.240	1.090
90.00%	10	187.682	15.943	55.183	1.533
95.00%	20	244.180	10.797	65.979	1.833
97.50%		300.677	6.811	72.790	2.022
99.50%	200	431.861	7.325	80.116	2.[illegible]
99.75%	400	488.359	1.150	81.266	2.257
99.80%		506.548	0.249	81.515	2.264
99.83%		519.435	0.150	72.940	2.026
99.90%	1000	563.045	10.365	83.155	2.310
99.95%		619.543	0.296	83.450	2.318
100.00%		864.583	0.353	83.803	2.328
100.00%		1210.051	0.025	83.828	2.329

Notes:
1) Conversion to USS 1 = Tk. 36
2) Annual benefits at economic prices: Tk. 14.136 million

According to what has been explained in Section 10.2 and in line with the FPCO-guidelines, the expected annual cost avoided through protection works grow annually with a rate of 3%.

FIGURE 10.3.1 DAMAGE-FREQUENCY CURVE FOR BHAIRAB BAZAR TOWN PROTECTION



10.3.4.6 Disruption of power supp y

Destruction or heavy damage t- '' - power towers will cause disruption of power supply to a number of industrial enterprises. No details are obtained on the end-users of electricity passing the Meghna at Bhairab Bazar. It can, however, be assumed that almost all electricity going through the power lines is used by industries. PDB is in the capacity to supply power from other sources or through alternative routes at additional cost. The additional cost refer to (a) supply of electricity forgone during the period the transmission towers are out of order and (b) replacement cost of transmission towers and lines. A detailed description of the analysis is provided in Section F.3.4.6 of Annex F. Table 10.3.6 presents the basic data and the result of the analysis. The mathematical expectation of the avoidable economic costs are evaluated at Tk 1.3 million.

10.3.4.7 Oil terminal

In Bhairab Bazar there are two oil terminals near the waterfront south of the railway bridge. Without adequate protection works one terminal will be engulfed within 5 years and the second within 10 years. According to engineers from Jamuna Oil Company, which were contacted on this subject, it would cost Tk. 20 million to relocate each terminal. No break-down of these cost could be provided by the oil companies. Hence, protection benefits are the avoidable cost of relocation of these terminals.
In the economic feasibility analysis an amount of Tk. 16.2 million (the economic equivalent of the financial Tk. 20 million) is imputed in 1998 and 2003 to reflect the avoidable costs as a benefit to the bank protection works.

10.3.5 Costs of the River Bank Protection Works

The economic costs of the advanced protection concept are evaluated at Tk. 463.6 million or US$ 12.9 million. A breakdown of the economic costs is given in Table 10.3.3. An estimated 53% of the total investment cost are local currency expenditures, while the foreign component amounts to 47%.

Table 10.3.3 ECONOMIC INVESTMENT COSTS FOR THE BHAIRAB BAZAR BANK PROTECTION WORKS

PRICES: mid-1991 economic prices
UNIT: US $ x 1,000

No	Summary	TOTAL	LOCAL LABOUR	EXPAT. LABOUR	IMPORTED MATERIALS	LOCAL MATERIAL	PLANT & FUEL
1	Dredging	5 088.3				3 381.3	1 707.0
2	Working/material area	102.2	24.7			35.9	41.7
3	Earthworks above SLW	258.1	86.5				171.6
4	Clear site and reinstate	17.7	6.2				11.5
5	Open stone asphalt	664.4	50.3		122.7	332.9	158.5
6	Fascine matress	1 425.5	42.2		438.2	613.8	331.4
7	Boulders in falling apron	1 148.2	53.2			684.2	410.9
8	Grounting of boulders	86.7	3.6			78.9	4.2
9	Containment bunds	0.0					
10	Construction cost and supervision	525.6		378.0	127.9	19.7	
11	Mobilization/demobilization	49.2			49.2		
	COST OF MATERIALS AND WORKS	9 366.0	266.6	378.0	738.0	5 146.5	2 836.9
	Physical contingencies (10%)	936.6					
	TOTAL COST OF MATERIALS AND WORK	10 302.6					
	Contractors margins and fe- --	1 873.2					
	TOTAL CONSTRUCTION COST	12 175.8					
	Engineering and supervision (7.5%)	702.4					
	TOTAL INVESTMENT COST	12 878.2					
	Total (Tk x 1M)	463.6					

Notes:
1) Overall lokal cost component is 53.5%
Overall foreign cost component is 46.5%
2) Annual maintenance is estimated as %-age of surface protection: open stone asphalt, fascine matress, boulders in falling apron and grounting of boulders. Percentage: 4%
So, annual maintenance cost are estimated at T 4.8 million
3) Conversion: 1 US$ = Tk 36

Annual monitoring and maintenance costs of the bank protection designed have been evaluated in agreement with the assumptions presented in Section 10.2 at Tk 4.8 million in economic terms. At this stage it can be assumed that costs for environmental monitoring will be low and can be covered from the normal monitoring budget.

Budgetary estimates are based on the annual monitoring and maintenance co... and are elaborated in financial terms taking into account a 10% inflation rate. The foll... budgets will be required: Tk 8.2 million in 1993, gradually increasing to Tk 13 million in 1998 and Tk 35 million in 2008.

10.3.6 Economic feasibility analysis

In Table 10.3.4 the economic cash flow is given.

The economic net present value for the short term bank protection works in Bhairab Bazar, evaluated at a discount rate of 12%. is equal to Tk. 446 million. The NPVR. being the ratio between the net present value and the present value of public capital and operation and maintenance cost at financial prices is evaluated at 0.75.

A sensitivity analysis was carried out to investigate to what extent the EIRR depends on changes in investment cost, monitoring and maintenance expenditure and estimated value of benefits. Results are summarized in Table 10.3.5

The conclusions drawn from this chapter comprise the following:

(a) The bank protection works show an EIRR of about 21% and are fully justified in economic terms.

(b) The rate realized is well above the interest rate normally required by (international) development banks. In this respect, interest obligations and repayment c... ...ly be guaranteed.

(c) The NPV at 12% is positive, which indicates that the ... te of return is above this discount rate. In view of a scarcity of development resources, this project may very well obtain the priority of the Government.

10.3.7 Delays in construction

An increase of the construction period envisaged means that the estimated benefits come into effect on a later date. This leads, in general, to a lower economic internal rate of return. With respect to the standard and improved protection concepts the estimated construction period is one year. Doubling of the construction period leads to a negligible reduction in the economic internal rate of return of the project. No arguments can be found to increase the construction period even more. Within one year and at most two years the work can be carried out.

TABLE 10.3.4 ECONOMIC CASH FLOW FOR THE BHAIRAB BAZAR BANK PROTECTION

PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million
STARTI 1993
CONST 1 years

EIRR:	20.62%	NPV:	446.4	NPVR1:	0.75

	WITH-PROJECT SITUATION COST:				PROJECT BENEFITS:					CASH	Cash F.
Year	Invest.	M&M	Other	Total	T.prot	Prot.Rb.	Pw.Sup	Oil term.	Total	FLOW	(US$x1M)
1993	463.6	6.8	2.3	472.7						-472.7	-13.1
1994	0.0	6.6	2.3	9.1	59.7	15.4	1.4		76.5	67.4	1.9
1995		6.8	2.3	9.1	63.2	15.9	1.4		80.6	71.5	2.0
1996		6.8	2.3	9.1	67.1	16.4	1.5		84.9	75.8	2.1
1997		[illegible]	2.3	9.1	71.2	16.9	1.5		89.6	80.5	2.2
1998		6.8	2.3	9.1	75.7	17.4	1.6	16.4	111.1	102.0	2.8
1999		6.8	2.3	9.1	80.6	17.9	1.6		100.1	91.0	2.5
2000		6.8	2.3	9.1	85.9	18.4	1.7		105.9	96.8	2.7
2001		6.8	2.3	9.1	91.6	19.0	1.7		112.3	103.2	2.9
2002		6.8	2.3	9.1	97.6	19.6	1.8		119.1	110.0	3.1
2003		6.8	2.3	9.1	104.5	20.2	1.8		126.4	117.3	3.3
2004		6.8	2.3	9.1	111.8	20.8	1.9		134.4	125.3	3.5
2005		6.8	2.3	9.1	119.7	21.4	1.9		143.0	133.9	3.7
2006		6.8	2.3	9.1	128.4	22.0	2.0		152.4	143.3	4.0
2007		6.6	2.3	9.1	137.8	22.7	2.0		162.5	153.4	4.3
2008		6.8	2.3	9.1	148.0	23.4	2.1	16.4	189.9	180.8	5.0
2009		6.8	2.3	9.1	159.2	24.1	2.2		185.4	176.3	4.9
2010		6.8	2.3	9.1	171.4	24.8	2.2		198.4	189.3	5.3
2011		6.8	2.3	9.1	184.6	25.5	2.3		212.5	203.3	5.6
2012		6.8	2.3	9.1	199.1	26.3	2.4		227.8	218.7	6.1
2013		6.8	2.3	9.1	214.9	27.1	2.4		244.4	235.3	6.5
2014		6.8	2.3	9.1	232.2	27.9	2.5		262.6	253.5	7.0
2015		6.8	2.3	9.1	251.1	28.7	2.6		282.4	273.3	7.6
2016		6.8	2.3	9.1	271.7	29.6	2.7		304.0	294.9	8.2
2017		6.8	2.3	9.1	294.3	30.5	2.7		327.5	318.4	8.8
2018		6.8	2.3	9.1	318.9	31.4	2.8		353.2	344.0	9.6
2019		6.8	2.3	9.1	345.9	32.3	2.9		381.2	372.1	10.3
2020		6.8	2.3	9.1	375.5	33.3	3.0		411.8	402.7	11.2
2021		6.8	2.3	9.1	407.9	34.3	3.1		445.2	436.1	12.1
2022		[illegible]	2.3	9.1	443.3	35.3	3.2		481.8	472.7	13.1
SUM	463.6	203.6	69.5	736.8	5312.9	698.5	62.6	32.8	6106.8	5370.0	149.2

Notes:

1) INVESTMENT COST:
   Tk. x 1M — 463.6
2) O&M COST (Tk. x 1M):
   Maintenance — 4.8
   Survey cost — 2.0
3) OTHER COST:
   Tk. x 1M — 2.3
4) BENEFITS (Tk. x 1M):
   Savings damage/loss — 31.5
   Annual increase — 3%
   Savings repair/maint — 19.0
   Annual increase — 10%
   Damage railway bridge — 14.1
   Annual increase — 3%
   Damage power supply — 1.3
   Annual increase — 3%
   Re-loaction oil terminal — 16.4 (in 1998)

PV (12%) benefits:	
MTk.	933.7

TABLE 10.3.5 RESULTS OF THE SENSITIVITY ANALYSIS FOR BHAIRAB BAZAR

VALUE Economic Internal Rate of Return (EIRR)
UNIT: percent

Change investm.	CHANGE IN BENEFITS: -30%	-20%	-10%	0%	10%	20%	30%
-30%	20.08%	22.43%	24.75%	27.04%	29.33%	31.61%	33.89%
-20%	18.19%	20.30%	22.37%	24.41%	26.43%	28.44%	30.45%
-10%	16.67%	18.60%	20.48%	22.32%	24.14%	25.95%	27.75%
0%	15.41%	17.20%	18.93%	20.62%	22.29%	23.93%	25.56%
10%	14.34%	16.02%	17.63%	19.20%	20.74%	22.26%	23.76%
20%	13.42%	15.00%	16.52%	17.99%	19.43%	20.84%	22.23%
30%	12.61%	14.12%	15.55%	16.94%	18.29%	19.62%	20.92%

Change M&M	CHANGE IN BENEFITS: -30%	-20%	-10%	0%	10%	20%	30%
-30%	15.78%	17.57%	19.31%	21.01%	22.68%	24.34%	25.98%
-20%	15.66%	17.45%	19.18%	20.88%	22.55%	24.20%	25.84%
-10%	15.53%	17.32%	19.06%	20.75%	22.42%	24.07%	25.70%
0%	15.41%	17.20%	18.93%	20.62%	22.29%	23.93%	25.56%
10%	15.29%	17.08%	18.81%	20.49%	22.15%	23.80%	25.43%
20%	15.17%	16.96%	18.68%	20.37%	22.02%	23.66%	25.29%
30%	15.05%	16.84%	18.56%	20.24%	21.89%	23.53%	25.15%

10.4 Munshiganj

10.4.1 Introduction

Munshiganj, the centre of potato growing in Bangladesh is located on the Dhaleswari River. As a result of the importance of potato growing in the region, the town harbours a large number of cold storage units where the product is kept in store. In addition to this cold storage, industrial activity, comprising many twining and spinning plants, is important in Munshiganj.

The township is nevertheless constantly threatened by the eroding force of the Dhaleswari River. The river not only threatens the road along the river bank and the ferry ghat upstream but also commercial and industrial buildings along its waterfront. Until this moment only some efforts were made to protect the ferry ghat by the Roads and Highway Department, while the Municipality and private firms undertook some actions to protect the waterfront.

10.4.2 Area Affected

The area covered by the study reaches from the ferry ghat West of the town to the wharf some three kilometres to the East. Bank protection works have been designed along the right bank of the Dhaleswari River to protect:

- the road along the right bank,
- the Town (commercial, industrial buildings),
- habitations,
- the ferry ghat upstream.

10.4.3 Alternative River Bank Protection Works

The erosion along the perimeter of Munshiganj is not due to earth slides into deeply scoured river channels, but rather due to wave attack. At most locations there seems to be a foreland with a width of 25 to 50 or more meters. Construction of a durable protection works can be achieved by a revetment made on a re-constructed embankment. The embankment could be made of dry fill (sand). Once the new embankment has been made it can be covered with a revetment. There are suitable locations for stockpiles of sand outside the present embankment for which this alternative would not face resistance from the local authorities and population.

10.4.4 Benefits of Munshiganj bank protection

10.4.4.1 Reduction of repair and maintenance

The information collected referred to accounted amounts for the financial years 1985/86 to 1990/91. From information collected on cost of maintenance, damage and repair, the amounts spent in the past by the Road and Highway Department and the Municipality on these aspects were calculated.

The analysis of benefits that can be attributed to the permanent river bank protection works to be designed in this project is based on the general assumption that the repair and maintenance expenses are directly related to the bank erosion.

Future benefits of permanent bank protection works have been estimated as the avoidable annual costs of the non-permanent and non-sustainable bank protection works being carried out in the future in the without-scenario.

10.4.4.2 Loss and damage to properties

To assess the historic losses, damage and economic revenue lost due to bank erosion a socio-economic sample survey was carried out and data were collected from the upazila and municipality. Table 10.4.1 provides details on the destruction and damage of structures during the past years.

The average value of property was calculated from the socio-economic survey results. However, the survey outcome only give financial construction cost, which must be converted to economic prices. The economic value for destructed houses and commercial buildings has been calculated as follows:

- the value of houses is estimated at 65% of its economic construction value in order to take account of the lower quality of replacement homes after destruction;
- the economic value of destroyed commercial and industrial buildings is estimated as the rental value, thus taking into account that construction cost are not a reliable indicator for shadow pricing.

Average value of damaged property is the value of repairs as a percentage of the total construction value. For houses and homesteads this percentage is estimated at 15%, while for commercial and industrial properties it is evaluated at 25%. For details reference is made to the Appendix F/1.

Since the data only concern loss and damage of private property a surcharge is taken into account to reflect the loss and damage of public infra-structure of the town. Taking into account the average occupation of public and private infra-structure the total loss and damage to public infra-structure has been evaluated at 25% of the loss and damage of private property. The final result is presented in Table 10.4. Reference is made to Appendix F/1.

10.4.4.3 Disruption of economic activities

The destruction of commercial and industrial properties leads to a loss in net profits (after payment of taxes) and employment. The first must be accounted for in the economic evaluation, while the latter is a social aspect of flood damage. The computation of losses in profitability assumes that losses due to the destruction or damage to property are the equivalent to 1[illegible] net economic returns.

10.4.4.4 Computation of avoidable repair, maintenance, loss, damage and lost profits

In Table 10.4.1 a summary is presented of the cost of repair and maintenance, losses and damage and lost net economic return for the years 1985 to 1990. River bank protection would result in a substantial decrease in losses and consequently the total amount represents avoidable losses. Hence, the benefits of erosion control works are defined as a saving in future maintenance and repair cost, loss of and damage to property and profit losses for a scenario where no protection is undertaken. A computation of these savings over the evaluation period provides the cash flow of benefits.

TABLE 10.4.1 REPAIR AND MAINTENANCE COSTS, LOSS, DAMAGE AND LOST PROFITS DUE TO BANK EROSION IN MUNSHIGANJ

PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million

Year	REPAIR COST	DAMAGE/LOSS PRIV/PUB.INFR Loss	Damage	TOTAL	LOST PROFITS	GRAND TOTAL
1985	0.000	4.777	3.018	7.795	0.811	8.607
1986	0.000	7.960	6.870	14.830	1.055	15.885
1987	1.240	15.152	11.942	27[illegible]	1.868	30.202
1988	0.598	25.420	21.508	46.928	2.692	50.217
1989	0.000	30.097	26.599	56.696	2.293	58.989
1990	1.093	20.236	17.643	37.879	1.339	40.311

Sources: Field survey
Notes:
1) Deflator of 10% is used to adjust expenses for repair and maintenance (value of deflacor is according to Planning Commisison)

Table 10.4.2 presents the mathematical expectation of annual avoidable costs due to repair, maintenance, loss, damage and lost profits, evaluated at Tk. 30 million economically. Figure 10.4.1 gives the damage-frequency curve for Munshiganj.

As a result of an ongoing erosion over the years the expected value of the annual avoidable costs identified above are assumed to increase. With respect to damage, destruction and loss in profits, it is expected that the annual increase will be 3%. This reflects the expected economic growth for Bangladesh and is not related to changes in the prices of commodities. Concerning repair and maintenance expenses, the annual increase of these is evaluated at 10%, because in the present-day practice of the without-scenario repair and maintenance expenses are expected to increase in the future.

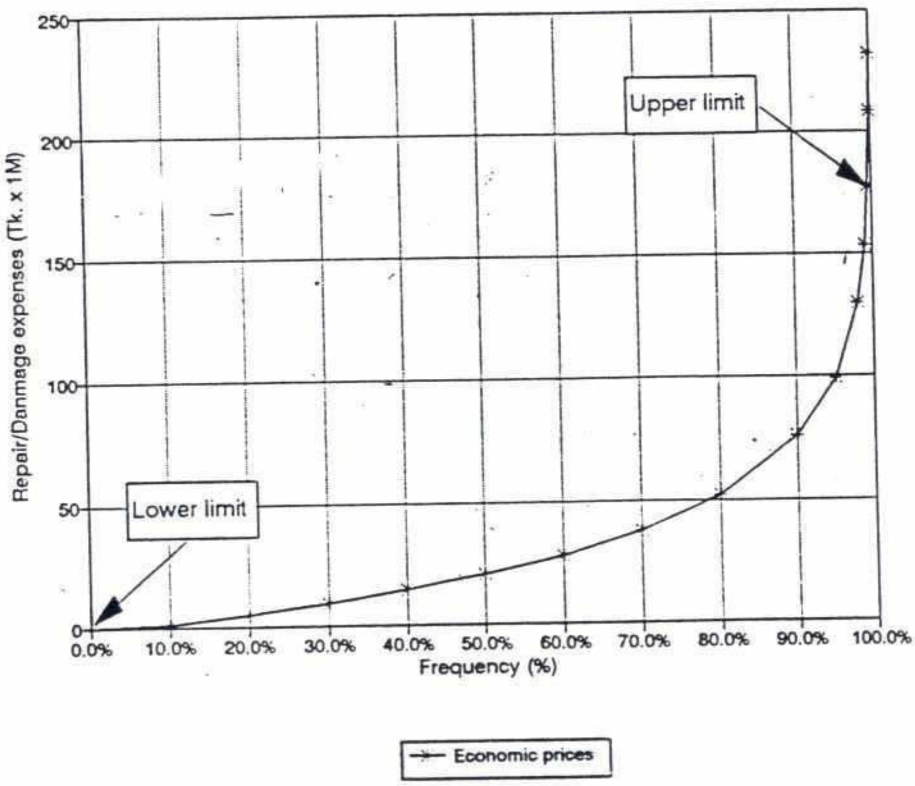
TABLE 10.4.2 MATHEMATICAL EXPECTATION OF ANNUAL AVOIDABLE COSTS IN MUNSHIGANJ

PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million

Freq. (non-exc)	Return period (yrs)	REAPAIR AND MAINTENACE: Total cost	C&F differ.	Cum C&F diff.	LOSSES AND DAMAGE: Total cost	C&F differ.	Cum C&F diff.	GRAND TOTAL	Covers. to US$ x 1M
0.00%		0.000		0.000	0.000		0.000	0.000	0.000
10.00%		0.000	0.000	0.000	0.851	0.043	0.043	0.043	0.001
20.00%		0.000	0.000	0.000	4.736	0.279	0.322	0.322	0.009
30.00%		0.000	0.000	0.000	9.141	0.694	1.016	1.016	0.028
40.00%		0.000	0.000	0.000	14.226	1.168	2.184	2.184	0.061
50.00%	2	[illegible]	0.003	0.003	20.240	1.723	3.907	3.911	0.109
60.00%		0.301	0.019	0.022	27.601	2.392	6.299	6.321	0.176
70.00%		0.600	0.045	0.067	37.091	3.235	9.534	9.601	0.267
80.00%	5	1.021	0.081	0.148	50.466	4.378	13.912	14.060	0.391
90.00%	10	1.741	0.138	0.286	73.331	6.190	20.102	20.388	0.566
95.00%	20	2.461	0.105	0.391	96.195	4.238	24.340	24.731	0.687
98.00%	50	3.413	0.088	0.479	126.421	3.339	27.679	28.159	0.782
99.00%	100	4.133	0.038	0.517	149.286	1.379	29.058	29.575	0.822
99.50%	200	4.853	0.022	0.540	172.151	0.804	29.861	30.401	0.844
99.80%	500	5.805	0.016	0.556	202.376	0.562	30.423	30.979	0.861
99.90%	1000	6.525	0.006	0.562	225.241	0.214	30.637	31.199	0.867

Notes:
1) Coversion to US$ 1 = Tk. 36

FIGURE 10.4.1 DAMAGE-FREQUENCY CURVE FOR MUNSHIGANJ TOWN PROTECTION



10.4.5 Costs of the river bank protection works

The economic costs of protection works are evaluated at Tk 215 million or US$ 6.0 million. A breakdown of the economic costs is given in Table 10.4.3. An estimated 31% of the total investment cost are local currency expenditures, while the foreign component amounts to 69%.

Monitoring and maintenance of protection structures is an important component, which affects directly the sustainability of protection works. Monitoring and maintenance are an integral part of river bank protection, the probability of failure of the structures may very well increase rapidly in the future if they are poor.

Monitoring activities comprise sounding of bed and bank level. They are estimated at Tk 2.0 million per annum in economic terms. After critical judgement of the protection works it is further assumed that annual maintenance of 4.0% of the investment costs of all revetment components is required. Consequently, annual maintenance for the protection works has been evaluated at Tk 2.8 million in economic terms. Budgetary estimates are based on the annual monitoring and maintenance costs and are elaborated in financial terms taking into account a 10% rate of inflation. The following budgets will be required in financial terms: Tk 9.4 million in 1998 and Tk 24 million in 2008.

TABLE 10.4.3 ECONOMIC INVESTMENT COSTS FOR THE MUNSHIGANJ BANK PROTECTION WORKS

PRICES: mid-1991 economic prices
UNIT: US $ x 1,000

No	Summary	TOTAL	LOCAL LABOUR	EXPAT. LABOUR	IMPORTE MATERIAL	LOCAL MATERIAL	PLANT & FUEL
1	Dredging	1 207.6			805.1		402.5
2	Working/material area	116.9	31.3			7.8	77.8
3	Temporary access, diversion and culverts	99.9	10.4		55.4	8.2	25.9
4	Earthworks	399.9	114.8				285.1
5	Open stone asphalt	575.4	43.4		106.0	287.5	138.5
6	Fascine matress	1 093.3	31.9		331.0	480.1	250.4
7	Boulders in falling apron	161.3	7.5			96.1	57.7
8	Grounting of boulders	95.6	4.0			87.0	4.6
9	Clear site and reinstate	36.4	10.4				25.9
10	Construction cost and supervision	491.7	42.6	399.9	32.8	16.4	
11	Mobilization/demobilization	65.6			65.6		
	COST OF MATERIALS AND WORKS	4 343.6	296.3	399.9	1 395.8	983.0	1 268.5
	Physical contingencies (10%)	434.4					
	TOTAL COST OF MATERIALS AND WORKS	4 778.0					
	Contractors margins and fees (20%)	868.7					
	TOTAL CONSTRUCTION COST	5 646.7					
	Engineering and supervision (7.5%)	325.8					
	TOTAL INVESTMENT COST	5 972.4					
	Total (Tk x 1M)	215.0					

Notes:

1) Overall lokal cost component is 30.8%
   Overall foreign cost component is 69.2%
2) Annual maintenance is estimated as %-age of surface protection: open stone asphalt, fascine matress, boulders in falling apron and grounting of boulders. Percenta 4%
   So, annual maintenance cost are estimated at Tk. 2.8 million
3) Conversion: 1 US$ = Tk. 36

10.4.6 Econ... feasibility analysis

In Table 10.4.4 the economic cash flow is given. The short-term bank protection works give an economic rate of return of 16.1% which above the assumed opportunity cost of capital for this type of projects as well as in Bangladesh (12%).

The economic net present value evaluated at a discount rate of 12%, is equal to Tk 76.1 million. The ratio between the net present value and the value of public capital and operation and maintenance costs at financial prices (NPVR) as required by the Guidelines for Project Assessment has been evaluated at 0.27.

A sensitivity analysis was carried out to take into account the uncertain future events and imperfect data. This implies an analysis of the economic internal rate of return as function of changes in investment cost, monitoring and maintenance expenditure and estimated value of benefits. The results are summarized in Table 10.4.5

From the economic evaluation, The following conclusions can be drawn:

(i) The bank protection works show an EIRR of 16% and are fully justified in economic terms.

(ii) The rate realized is well above the interest rate normally required by international development banks. In this respect, interest obligations and repayment can easily be guaranteed.

(iii) The NPV at 12% is positive, which indicates that the rate of return is higher. In view of a scarcity of development resources, this project may very well obtain the priority of the Government.

TABLE 10.4.4 ECONOMIC CASH FLOW FOR THE MUNSHIGANJ BANK PROTECTION

PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million
STARTING: 1993
CONSTR: 1 years

EIRR: 16.11% NPV: 76.1 NPVR1: 0.27

	WITH-PROJECT SITUATION COST:				BENEFITS			CASH	Cash F
Year	Invest.	M&M	Other	Total	Town pro.	Rep/main	Total	FLOW	(US$x1M)
1993	215.0	4.8	0.2	220.0				-220.0	-6.1
1994	0.0	4.8	0.2	5.0	32.6	0.7	33.3	28.4	0.8
1995	0.0	4.8	0.2	5.0	33.6	0.8	34.4	29.4	0.8
1996		4.8	0.2	5.0	34.6	0.9	35.5	30.5	0.8
1997		4.8	0.2	5.0	35.7	1.0	36.6	31.6	0.9
1998		4.8	0.2	5.0	36.7	1.1	37.8	32.8	0.9
1999		4.8	0.2	5.0	37.8	1.2	39.0	34.0	0.9
2000		4.8	0.2	5.0	39.0	1.3	40.2	35.2	1.0
2001		4.8	0.2	5.0	40.1	1.4	41.5	36.5	1.0
2002		4.8	0.2	5.0	41.3	1.5	42.9	37.9	1.1
2003		4.8	0.2	5.0	42.6	1.7	44.3	39.3	1.1
2004		4.8	0.2	5.0	43.9	1.9	45.7	40.7	1.1
2005		4.8	0.2	5.0	45.2	2.0	47.2	42.2	1.2
2006		4.8	0.2	5.0	46.5	2.3	48.8	43.8	1.2
2007		4.8	0.2	5.0	47.9	2.5	50.4	45.4	1.3
2008		4.8	0.2	5.0	49.4	2.7	52.1	47.1	1.3
2009		4.8	0.2	5.0	50.8	3.0	53.8	48.8	1.4
2010		4.8	0.2	5.0	52.4	3.3	55.7	50.7	1.4
2011		4.8	0.2	5.0	53.9	3.6	57.6	52.6	1.5
2012		4.8	0.2	5.0	55.6	4.0	59.5	54.6	1.5
2013		4.8	0.2	5.0	57.2	4.4	61.6	56.6	1.6
2014		4.8	0.2	5.0	58.9	4.8	63.8	58.8	1.6
2015		4.8	0.2	5.0	60.7	[illegible]	66.0	61.0	1.7
2016		4.8	0.2	5.0	[illegible]	5.8	68.4	63.4	[illegible]
2017		4.8	0.2	5.0	64.4	6.4	70.8	65.8	1.8
2018		4.8	0.2	5.0	66.3	7.1	73.4	68.4	1.9
2019		4.8	0.2	5.0	68.3	7.8	76.1	71.1	2.0
2020		4.8	0.2	5.0	70.4	8.6	78.9	73.9	2.1
2021		4.8	0.2	5.0	72.5	9.4	81.9	76.9	2.1
2022		4.8	0.2	5.0	74.7	10.4	85.0	80.0	2.2
SUM	215.0	143.2	6.5	364.6	1475.5	106.8	1582.2	1217.6	33.8

Notes:

1) INVESTMENT COST:
   Tk. x 1M 215.0
2) M&M COST (Tk. x 1M):
   Maintenance 2.8
   Survey cost 2.0
3) OTHER COST:
   Tk. x 1M 0.2
4) BENEFITS (Tk. x 1M):
   Town protection 29.9
   Annual increase 3%
   Reduction rep/main 0.5
   Annual increase 10%
5) Conversion US$ 1 = Tk. 36

PV (12%) benefits:
MTk. 345.2

TABLE 10.4.5 RESULTS OF THE SENSITIVITY ANALYSIS FOR MUNSHIGANJ

VALUES: Economic Internal Rate of Return (EIRR)

UNIT: percent

Change investm.	CHANGE IN BENEFITS: -30%	-20%	-10%	0%	10%	20%	30%
-30%	15.18%	17.43%	19.63%	21.81%	23.96%	26.10%	28.24%
-20%	13.53%	15.56%	17.54%	19.48%	21.40%	23.30%	25.18%
-10%	12.19%	14.06%	15.86%	17.63%	19.36%	21.07%	22.77%
0%	11.06%	12.81%	14.48%	16.11%	17.70%	19.26%	20.81%
10%	10.11%	11.75%	13.31%	14.83%	16.30%	17.75%	19.18%
20%	9.28%	10.83%	12.31%	13.73%	15.12%	16.47%	17.80%
30%	8.54%	10.03%	11.43%	12.78%	14.09%	15.36%	16.61%

Change M&M	CHANGE IN BENEFITS: -30%	-20%	-10%	0%	10%	20%	30%
-30%	11.72%	13.46%	15.14%	16.77%	18.36%	19.94%	21.50%
-20%	11.50%	13.24%	14.92%	16.54%	18.14%	19.71%	21.27%
-10%	11.28%	13.02%	14.70%	16.32%	17.92%	19.49%	21.04%
0%	11.06%	12.81%	14.48%	16.11%	17.70%	19.26%	20.81%
10%	10.85%	12.59%	14.26%	15.89%	17.48%	19.04%	20.59%
20%	10.63%	12.38%	14.05%	15.67%	17.26%	18.82%	20.36%
30%	10.41%	12.16%	13.84%	15.46%	17.04%	18.60%	20.14%

10.4.7 Displacement of population

From the socio-economic survey of Munshiganj follows that in the area prone to erosion live 4,260 persons. These persons would be displaced in the coming 30 years if no protection works are built. As no detailed geo-morphological information is available on bank-migration per five-year period, we assume that migration will be the same for each five-year period.

Based on the Statistical Yearbook of Bangladesh for 1991 (table 2.08, page 45), the annual population increase was 2.17% over the last 10 years. Using this factor for the coming 30 years would give total numbers for each five-year period, see table 10.4.6.

TABLE 10.4.6 DISPLACEMENT OF POPULATION IN MUNSHIGANJ

Period	Number of persons displaced
1993-1998	790
1998-2003	880
2003-2008	980
2008-2013	1,090
2013-2018	1,210
2018-2013	1,350
Total	6,300

Source: Socio-economic survey 1991

10.5 Chandpur Town (Nutan/Puran Bazar)

10.5.1 Present Situation and Previous Efforts for Protection

Chandpur is an important inland harbour on the Lower Meghna. Its location on one of the waterways leading to Dhaka and India has made Chandpur a centre of commercial and industrial activity. In the old days the town played an important role as the point where railway and river transport met. Although the importance of railway transport has declined, Chandpur is at present, and will remain so in the future, beyond any doubt an important trading and industrial centre in the national economy of Bangladesh.

The present and future position of the township is nevertheless constantly threatened by the eroding force of the Lower Meghna River. The river not only threatens public assets and private commercial and industrial buildings along its waterfront, but could make Chandpur into an isolated island, completely surrounded by the waters of the Meghna. The serious threat by the ever active and unpredictable river has been for years the focus of studies and research.

Events since 1988, when part of the township disappeared in the river, have given new momentum to the search for sustainable solutions to protect Chandpur. In the period after the 1988 cyclone the river caused almost every year damage to the old town, in spite of erosion control works carried out.

During the past seasons embankments downstream of Chandpur have been severely damaged, threatening the Chandpur Irrigation project. Upstream of the town the river banks are eroded causing the loss of irrigated agricultural lands in the Meghna-Dhonagoda Irrigation District. The migration of the river bank towards the east has progressed every year and for the foreseeable future erosion will continue.

Much efforts have been made to protect Chandpur against the waters of the Meghna. Before BWDB embarked on measures for protection of Chandpur town, Bangladesh Railway had already tried to protect the railway station at Nutan Bazar by dumping large quantities of boulders on the river bank. From the early seventies onwards protective works started under the umbrella of BWDB.

As a result of the protection works executed by the Bangladesh Railway and later by the BWDB, the rate of migration of the river bank has considerably been reduced, contributing also in the protection to the Meghna-Dhonagoda and Chandpur Irrigation Districts, north and south of the town. However, in spite of all the (temporary and emergency) bank protection works carried out so far, the left bank of the Meghna, both upstream and downstream of Chandpur town has shown considerable migration. Without proper action and permanent river bank protection works, this will eventually lead to the outflanking of the town.

In this light one may assume that sooner or later measures will be taken against such a drastic shift of the Lower Meghna. At whatever time such measures are taken, the nature of the guiding or harnessing works will probably not be very different. The only difference, overall, as to the timing of the regulation works will be the width strip of land and infra-structure that has been eroded by the river.

10.5.2 Area Affected

The river bank protection works aim at a sustainable protection of the area of the town and its associated benefits. As a result of the short-term works designed it is expected that bank erosion at Chandpur town will be stopped completely. Moreover, there will be mitigating effects of the bank erosion immediately upstream and downstream of the town, increasing the protection of parts of the Meghna-Dhonagoda and Chandpur Irrigation Districts.

The area covered by the feasibility analysis consists therefore of the town area and the area of influence upstream and downstream of the town. It can be divided in four parts, notably:

- town area of Chandpur (Nutan and Puran Bazar);
- river bank of the Lower Meghna upstream of the town;
- river bank downstream of Chandpur; and
- the left and right bank of the Dhakatia river including the BIWTA terminal.

10.5.3 <u>Alternative river bank protection works</u>

Construction of durable and sustainable protection works (bank revetment) on the existing bank of the Lower Meghna at Chandpur is not a feasible option. It would involve the destruction of houses to create a stable slope and a work space while the river bank line has become so erratic, that construction of an acceptable slope is difficult. Therefore, the option under review is based on an advanced protection concept which involves the construction of a complete new bank line, at some distance from the old bank line. A characteristic in this type of constructions are containment bunds with hydraulic fill behind, which facilitate construction of stable slope (see Annex C).

Should it not appear to be possible to "hang on" to Chandpur, which is in fact the only site along the Lower Meghna where major protection works have ever been made, then the question arises how far the Lower Meghna will continue to shift in easterly direction. In view of historical trends and in view of the fact that more easterly courses (from the confluence of Upper Meghna and Padma till the Bay of Bengal) do not appear to impose more hydraulic resistance on the river flow, there is no good reason to assume that such a further shift will be minor. A shift of, say, 50 km during the next couple of centuries would not be out of line with historical developments. In principle no nett erosion will result from such a shift, but the entire infrastructure in this strip km will be destroyed and will later have to be rebuilt on the future right bank of the Lower Meghna. Also the accumulated social consequences will, to say the least, be substantial, consequences **which go beyond** establishing the economic feasibility of the required short-term measures.

10.5.4 <u>Benefits of Chandpur town protection</u>

10.5.4.1 Reduction in maintenance and repair expenses

Expenditures on erosion protection works in Chandpur have been collected from BWDB for the period 1981-1990. The information collected refers to real financial expenditures which have been deflated by an annual 10% to reflect the mid-1991 price level.

The analysis of benefits is based on the general assumption that the repair and damage expenses are directly related to the bank erosion. However, expenditure in one year does not always relate to the very year that damage occurred; design, decision on allocation of funds form the major bottleneck for direct action after damage happens. The recorded and estimated expenses on repair and maintenance have therefore been incurred to the year the erosion damage occurred.

Future benefits of the permanent bank protection works can be estimated as the avoidable annual costs of the non-permanent and non-sustainable bank protection works being carried out in the future. The analysis has been based on the assumption that damage and repair expenses are a associated with a series of extreme conditions, referring not only to the recorded high water levels, but also regarding extreme geo-technical conditions, wave attack, etc. Therefore, the probabilistic extreme value theory is directly applied to the repair recorded and estimated in relation to bank erosion.

The amounts spent in the past twenty years on the protection of Chandpur show an annual growth rate of between 25 and 40%. The steadily growing investments required to maintain the present situation is in agreement with the technical concept that the eroding forces gradually become stronger and stronger because of the protection works carried out. It can be expected that without the construction of the permanent protection works the national and regional authorities will pursue the protection of the town with all possible means. Hence, it is very likely that the expenditures in the past are a poor reflection of what may happen in the future. When extrapolating the present practice, therefore, an annual growth rate of 10% is applied to the annual expectation value of the repair and maintenance costs during the 30 year evaluation period.

10.5.4.2 Loss and damage to properties

To be able to assess the historic losses, damage and economic revenu[illegible] due to bank erosion a socio-economic sample survey was carried out and data were collected from the upazila and municipality. Past erosion damage was estimated from records on destruction and damage to property, which were supplied by the upazila and municipality. In Annex F, Table F.5.1 presents an overview of destruction and damage to construction. Tables F.5.2 and F.5.3 summaries the economic value of houses, homesteads, commercial and industrial enterprises that were either destructed or damage during the period 1985 to 1990.

The average value of property could be calculated from the socio-economic survey results. However, the survey outcome only give financial construction cost, which must be converted to shadow prices. The economic value for destructed houses and economic buildings has been calculated as follows:

- the value of houses is estimated at 65% of its economic construction value in order to take account of the lower quality of replacement homes after destruction;
- the economic value of destroyed commercial and industrial buildings is estimated as the rental value, thus taking into account that construction cost are not a reliable indicator for shadow pricing.

As far as property is concerned which was damaged but not destroyed, the imputed average value used is a percentage of the total value. For houses and homesteads this percentage is estimated at 50%, while for commercial and industrial the rental value is used. Reference is made to Appendix F/1 for more details.

Since the data only concern loss and damage of private property a surcharge is taken into account to reflect the loss and damage of the public infrastructure of the town. In the analysis on loss and damage of the private and public infrastructure a number of public facilities have not yet been taken into account. These assets refer to the railway complex and the BIWTA terminals, the fish market, the Chandpur water works and treatment plants, schools, power lines, etc. The railway complex and IWTA terminal are discussed in detail later. Taking into account the average occupation of public and private infrastructure and the value thereof the total loss and damage to public and urban infra-structure has been evaluated at 25% of the loss and damage of private property. More details are provided in Annex F, Appendix F/1.

10.5.4.3 Disruption of economic activities

The destruction of commercial and industrial properties leads to a loss in net profits (after payment of taxes) and employment. The first is considered in the financial and economic evaluation, while the latter is a social aspect of river bank erosion damage. The computation of losses in profitability assumes that losses are the equivalent of 12 months net economic returns (profits). Results are summarized in Annex F, Table F.5.3.

10.5.4.4 Computation of avoidable repair, maintenance, loss, damage and lost profits

In Table 10.5.1 a summary is presented of the cost of repair and maintenance, losses and damage and lost net economic return for the years 1981 to 1990. The figures for loss and damage to property and lost profits have been interpolated to the years 1952, when there was no bank erosion. River bank protection would result in a substantial decrease in losses and consequently the total amount represents avoidable losses. Hence, the benefits of erosion control works are defined as a saving in future maintenance and repair cost, loss of and damage to property and profit losses for a scenario where no protection is undertaken. A computation of these savings over the evaluation period gives the cash flow of benefits.

TABLE 10.5.1 REPAIR AND MAINTENANCE COSTS, LOSS, DAMAGE AND LOST PROFITS DUE TO BANK EROSION IN CHANDPUR

PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million

Year	REPAIR/ MAIN.CST	DAMAGE/LOSS PRIV/PUB.INFRA: Loss	Damage	TOTAL	LOST PROFITS	GRAND TOTAL
1981	3.433			24.175	10.278	37.885
1982	4.144			24.930	10.632	39.705
1983	6.849			25.709	10.986	43.544
1984	3.782			26.512	11.341	41.635
1985	5.920	17.828	9.513	27.341	11.695	44.956
1986	11.134	29.685	16.530	46.214	19.473	76.822
1987	15.963	86.959	46.761	133.720	57.045	206.729
1988	65.640	133.360	71.435	204.795	87.484	357.918
1989	52.844	68.407	40.208	108.615	44.875	206.333
1990	[illegible]	85.927	67.257	153.184	56.368	213.078

Notes:
1) Total loss/damage to property and lost profits for the years 1981-1984 were estimated by dicreasing the 1985 damage lineair

The total economic repair expenses and cost of erosion damage for the recent past are computed. It is assumed that the totals have an extreme value distribution. The annual figures are subsequently ranked in size and a frequency is assigned in agreement with their ranking. The expenses are then correlated with their frequency by fitting the Gumbel extreme value probability function. This equation forms the basis for the calculation of the mathematical expectation values of loss and damage due to erosion.

Table 10.5.2 presents the mathematical expectation of annual avoidable costs due to repair, maintenance, loss, damage and lost profits, evaluated at Tk. 86 million economically. Figure 10.5.1 gives the damage-frequency curve for Chandpur.

As a result of an ongoing erosion over the years the expected value of the annual avoidable costs identified above are assumed to increase. In Annex F section F.5.4.1 the annual increase of 10% in the annual cost for repair and maintenance has already been discussed. Concerning, the loss and damage to private and public infra-structure and loss of profits (Tk 71 million) when extrapolating the present day practice, the annual increase is 3% per. This increase is not related to changes in the prices of commodities, but reflects merely aspects related to population growth and increase of economic activity in the affected area as was discussed in chapter 2.

TABLE 10.5.2 MATHEMATICAL EXPECTATION OF ANNUAL AVOIDABLE COSTS IN CHANDPUR

PRICES mid-1991 economic prices
UNIT Tk. x 1 million

Freq. (non-exc)	Return period (yrs)	REPAIR AND MAINTENACE Total cost	C&F differ	Cum C&F diff	LOSSES AND DAMAGE Total cost	C&F differ	Cum C&F diff	GRAND TOTAL	Covers to US$ x 1M
0.00%		0.000		0.000	0.000		0.000	0.000	0.000
10.00%		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20.00%		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30.00%		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40.00%		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50.00%	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
60.00%		0.000	0.000	0.000	7.941	0.397	0.397	0.397	0.011
70.00%		2.367	0.118	0.118	57.133	3.254	3.651	3.769	0.105
80.00%	5	22.155	1.226	1.344	125.465	9.180	12.831	14.175	0.394
90.00%	10	55.982	3.907	5.251	244.989	18.573	31.403	36.655	1.018
95.00%	20	89.810	3.645	8.896	363.513	15.213	46.616	55.512	1.542
98.00%	50	134.527	3.365	12.261	520.194	13.256	59.872	72.133	2.004
99.00%	100	168.354	1.514	13.776	635.718	5.795	65.666	79.442	2.207
99.50%	200	202.162	0.926	14.702	757.242	3.490	69.156	83.858	2.329
99.75%	400	236.009	0.548	15.250	875.766	2.041	71.197	86.447	2.401
99.80%	500	246.899	0.121	15.370	913.923	0.447	71.645	87.015	2.417
99.90%	1000	280.727	0.264	15.634	1032.447	0.973	72.618	88.252	2.451

Notes:
1) Coversion to US$ 1 = Tk. 36

10.5.4.5 Computation of Avoidable Losses to Railway Complex and BIWTA Terminal

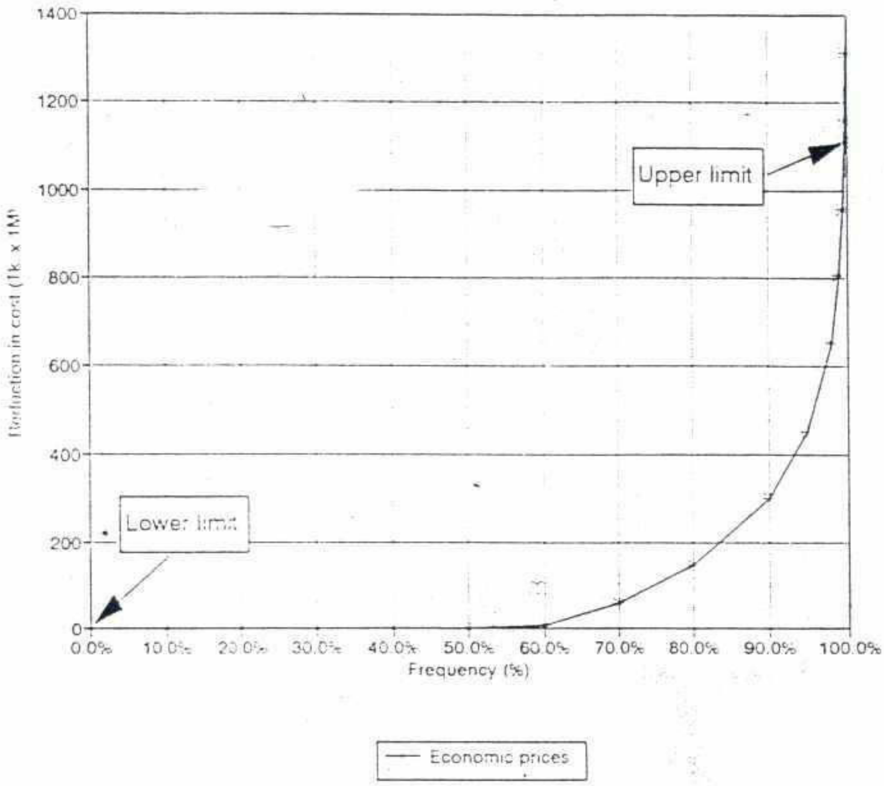
The railway complex in Chandpur is a very large compound with harbours schools, a hospital and mosque as well as accommodation for railway personnel. The total surface of the complex is 72 ha, according to information collected in Chandpur with BR and the Municipality. The total value is estimated at Tk. 500 million. This amount is in financial prices, which must be converted to economic prices with the help of the overall conversion factor of 0.82. Hence, the economic value of the complex is Tk. 410 million. For details reference is made to the appendix F/1, section F/1.9.

Within the stretch Station road and Dakatia River in Nutan Bazar, land the terminal of BIWTA is also located. Without any protection works year after year part of the complex and the terminal would be eroded. However, within 30 years not only the whole complex will vanish. Over the 30 year evaluation period a total of 120 thousand m^2 will be eroded according to the geo-morphological estimate of erosion rate.

Information of the BIWTA terminal has been collected with the association in Dhaka and in Chandpur. It has been possible to evaluate the value of the terminal in economic prices. The terminal and its buildings cover and area of 36 thousand m^2. Relocation of the terminal would cost Tk. 43 million, as has been calculated in the appendix F/1.

For an estimation of the avoidable losses to the railway complex and IWTA terminal use has been made of a deterministic approach. Based on the map of bank mi--ration of Chandpur waterfront, see figure F/1.1, the areas of the railway complex and the IWTA terminal that will erode in the coming 30 years are measured.

FIGURE 10.5.1 DAMAGE-FREQUENCY CURVE FOR CHANDPUR TOWN PROTECTION



10.5.4.6 **Agricultural benefits**

The agricultural benefits are associated with the protection of arable land of the Meghna-Dhonagoda and Chandpur Irrigation projects upstream and downstream of Chandpur due to the permanent bank protection works proposed in the project. In agreement with the FPCO-guidelines the benefits result from the reduction of net agricultural revenues lost and loss of irrigation infra-structure or land due to erosion. To evaluate this reduction the following steps have been taken:

(i) Based on the results of the geo-morphological survey for the area, the change of the river bank position can be forecast for scenarios with and without embankment protection.

(ii) Based on this forecast a prediction has been made, for the 30 year evaluation of the project, of the reduction of the area lost as a result of the project.

(iii) The annual net economic revenue of this reduction has been taken into account as a benefit of the permanent bank protection works undertaken at Chandpur. Crop budgets are presented in the appendix, section F/1.6.

(iv) Apart from the annual net revenue of the area otherwise lost, the annual value of Tk 1,677 per hectare associated with the irrigation infrastructure can also be considered as avoidable costs and, hence, as a benefit of the permanent bank protection works at Chandpur. It is based on analysis of data from the South-East Regional Water Resources Development Programme (FAP-5). The appendix F/1 provides details.

(v) Apart from the annual net revenue of the area otherwise lost, there is also the reduction in loss of land as a productive asset to be considered. Land has been valued at its rental value as has been argued in chapter 2. More in detail the rental value is discussed in the appendix F/1.

The net annual economic revenue of the Meghna-Dhonagoda and Chandpur Irrigation Districts have been evaluated at Tk 11,920 per ha and Tk 9,263 per ha, adapted from Thompson (1990). The rental value has been evaluated at Tk. 73,244 per ha per year for the Meghna-Dhonagoda Irrigation Project and at Tk. 49,896 per ha per year for the Chandpur Irrigation Project. Reference is made to the appendix for further explanation. In Annex F, Table F.5.9 and F.5.10 provides details of agricultural benefits over the 30-year period of the feasibility study for the zones of influence upstream and downstream of Chandpur.

10.5.5 Costs of the river bank protection works

Cost of the short-term sustainable protection works are evaluated at Tk. 2,076 million or US$ 58 million (mid-1991 economic prices). An estimated 33% of the total investment cost are local currency expenditures, while the foreign component amounts to 67%. Table 10.5.3 shows the economic investment cost for the protection works.

The above investment cost comprise works executed in 1993. However, for a sustainable protection of Chandpur, it is eminent that additional protection works have to be executed in the coming 10 - 15 years. The works envisaged prevent the short-term works from being outflanked and the additional investments required amount to Tk. 221 million in economic terms and should be incurred in the year 2003.

TABLE 10.5.3 ECONOMIC INVESTMENT COSTS FOR THE CHANDPUR SHORT PROTECTION WORKS

PRICES: mid-1991 economic prices
UNIT: US $ x 1,000

No	Summary	TOTAL	LOCAL LABOUR	EXPAT LABOUR	IMPORTED MATERIAL	LOCAL MATERIAL	PLANT & FUEL
1	Dredging	13 793.3	0.0		9 195.5		4 597.8
2	Working/material area	264.2	61.8			79.6	122.6
3	Earthworks above SLW	368.8	123.5				245.2
4	Clear site and reinstate	184.4	61.8				122.6
5	Open stone asphalt	1 044.9	91.4		142.3	519.2	291.9
6	Fascine matress	6 411.1	125.2		5 694.9	94.4	495.7
7	Rock in falling apron	5 562.5	143.9			4 306.1	1 112.5
8	Grounting of boulders	95.1	4.0			86.5	4.6
9	Containment bunds	10 423.9	2 511.2			5 012.4	2 900.3
10	Constractors cost and supervision	1 347.7		1 108.2	190.2	49.2	
11	Mobilization/demobilization	72.2			72.2		
12	Fascine matress boulders	329.3	5.7		293.9	3.3	26.4
	COST OF MATERIALS AND WORKS	39 897.2	3 129.5	1 108.2	15 589.0	10 151.0	9 919.5
	Physical contingencies (15%)	5 984.6					
	TOTAL COST OF MATERIALS AND WORKS	45 881.8					
	Contractors margins and fees (22%)	8 777.4					
	TOTAL CONSTRUCTION COST	54 659.2					
	Engineering and supervision (7.5%)	2 992.3					
	TOTAL INVESTMENT COST	57 651.4					
	Total (Tk x 1M)	2 075.5					

Notes:

1) Overall lokal cost component is 33.0%
   Overall foreign cost component is 67.0%

2) Annual maintenance is estimated as %-age of surface protection: open stone asphalt, fascine matress, boulders in falling apron and grounting of boulders. Pe 4%
   So, annual maintenance cost are estimated at Tk. 19.0 million

3) Conversion: 1 US$ = Tk. 36

Annual monitoring and maintenance costs of the bank protection works designed have been evaluated in agreement with Section 10.2 at Tk 25.6 million per annum in mid-1991 financial prices just after completion of the works. Assuming an annual inflation rate of 10%, it means the operation and maintenance cost become Tk 41.2 million after five years and Tk. 119 million after fifteen years.
Cost of required environmental monitoring are considered small. Annex I provides details on work to be carried out. It is expected that these cost are largely covered by the imputed amount in other costs.

10.5.6 Economic Evaluation

The cash flow computation for river bank protection for Chandpur makes a comparison of benefits and cost over the period of the study. In Table 10.5.4 the economic cash flow of river bank protection works at Chandpur town is given. The economic internal rate of return (EIRR), the discount rate at which the benefits balance cost over the period of the study, has been evaluated at 6.1% and depends very much on the estimate of the future annual repair and maintenance of the river bank in the situation without permanent bank protection works.

The economic net present value for the erosion control in Chandpur calculated for a discount rate of 12%, is evaluated at Tk. - 983 million, which means that the internal rate of return is below that discount rate. When considering infra-structural projects like bank protection, it is, however, doubtful whether a rate of 12% is the appropriate criterion for an investment decision.

TABLE 10.5.4 ECONOMIC CASH FLOW OF THE CHANDPUR BANK PROTECTION WORKS

PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million
STARTI 1993
CONST 1 years

EIRR:	6.07%	NPV:	-983	NPVR1:	-0.36

	WITH-PROJECT SITUATION COST:				PROJECT BENEFITS:				CASH	Cash F.
Year	Invest.	S&M	Other	Total	T.prot	BR/IWT	Agric.	Total	FLOW	(US$x1M)
1993	2075.5	21.0	2.1	2098.5				0.0	-2098.5	56.3
1994	0.0	21.0	2.1	23.1	98.1	3.8	-	[illegible]	79.1	2.2
1995	0.0	21.0	2.1	23.1	102.5	3.8	0.3	106.6	83.5	2.3
1996		21.0	2.1	23.1	107.1	3.8	0.4	111.3	86.2	2.5
1997		21.0	2.1	23.1	112.0	3.8	0.5	116.3	93.2	2.6
1998		21.0	2.1	23.1	117.3	4.7	0.5	122.5	99.4	2.8
1999		21.0	2.1	23.1	122.9	4.7	1.4	129.0	105.9	2.9
2000		21.0	2.1	23.1	128.9	4.7	1.6	135.1	112.0	3.1
2001		21.0	2.1	23.1	135.2	4.7	1.8	141.7	118.6	3.3
2002		21.0	2.1	23.1	142.1	4.7	2.0	148.7	125.6	3.5
2003	221.4	23.3	2.1	246.7	149.4	4.0	2.2	155.6	-91.2	-2.5
2004		23.3	2.1	25.3	157.2	4.0	3.6	164.9	139.5	3.9
2005		23.3	2.1	25.3	165.6	4.0	4.1	173.7	148.4	4.1
2006		23.3	2.1	25.3	174.6	4.0	4.6	183.2	157.9	4.4
2007		23.3	2.1	25.3	184.3	4.0	5.1	193.4	168.1	4.7
2008		23.3	2.1	25.3	194.8	1.5	5.6	201.9	176.5	4.9
2009		23.3	2.1	25.3	206.0	1.5	8.7	216.2	190.8	5.3
2010		23.3	2.1	25.3	218.1	1.5	9.7	229.3	204.0	5.7
2011		23.3	2.1	25.3	231.2	1.5	10.8	243.4	218.1	6.1
2012		23.3	2.1	25.3	245.3	1.5	11.9	258.7	233.3	6.5
2013		23.3	2.1	25.3	260.6	1.4	13.0	275.0	249.7	6.9
2014		23.3	2.1	25.3	277.1	1.4	15.4	293.9	268.6	7.5
2015		23.3	2.1	25.3	294.9	1.4	16.9	313.3	288.0	8.0
2016		23.3	2.1	25.3	314.3	1.4	18.5	334.2	308.9	8.6
2017		23.3	2.1	25.3	335.3	1.4	20.2	356.9	331.6	9.2
2018	0.0	23.3	2.1	25.3	358.1	2.1	21.9	[illegible]	356.7	9.9
2019		23.3	2.1	25.3	382.8	2.1		411.2	385.9	10.7
2020		23.3	2.1	25.3	409.7	2.1	28.6	440.4	415.1	11.5
2021		23.3	2.1	25.3	438.9	1	31.1	472.1	446.8	12.4
2022		23.3	2.1	25.3	470.7	2.1	33.7	506.5	481.2	13.4
SUM	2296.9	675.2	62.3	3034.3	6534.6	84.0	300.5	6919.3	3885.0	107.9

Notes:

1) INVESTMENT COST:
   - Tk. x 1M — 2075.5

PV (12%) benefits:	
MTk.	1 125

2) O&M COST (Tk. x 1M):
   - Maintenance — 19.0
   - Survey cost — 2.0
3) OTHER COST:
   - Tk. x 1M — 2.1
4) BENEFITS (Tk. x 1M):
   - Savings damage/loss — 71.2
   - Annual increase — 3%
   - Savings repair/maint. — 15.2
   - Annual increase — 10%
   - Annual increase savings agricultural loss — 3%
5) Conversion US$ 1 = Tk. — 36

The cropping pattern in the Meghna-Dhonagoda irrigation project and the net economic return of irrigated agriculture were adapted from Thompson (1990) and results of work done by FAP-5.

Apart from the annual net revenue of the area inside the embankment otherwise lost, a value of Tk. 1,677 per hectare associated with the irrigation infra-structure can also be considered as avoidable costs and, hence, as benefit of protection works in Eklashpur. The net annual economic revenues of the Meghna Dhonagoda irrigation project have been evaluated at Tk. 11,920 per ha. Details are reported in Table 10.6.1 and in the appendix F/1.

TABLE 10.6.1 ANNUAL NET REVENUES PER HECTARE IN THE MEGHNA-DHONAGODA IRRIGATION PROJECT

PRICES: constant mid-1991 economic prices
UNIT: Tk.

Item	Unit	Unit return	Fraction in area	Annual return
Cultivation:				
Rabi crops 1)	ha	6 755	82.3%	5 557
HYV Boro	ha	9 522	4.7%	447
B Aus	ha	316	81.3%	257
TL Aman	ha	6 594	85.5%	5 639
Sub-total	ha		90.3%	11 899
Fish-ponds 2)	yr	20 736	0.1%	21
Orchards 2)	yr	218	0.0%	0
Other areas			9.6%	
TOTAL				11 920
Rental value	yr			73 244

Notes:
1) Rabi crop considered is wheat
2) Adapted from Thompson (1990)
3) Rental value is adapted from crop budgets

10.6.2 Area Affected

The area of influence of the proposed works reaches from the point where the Padma and the Meghna join the Dhonagoda River and end some two kilometres south of it. The area protected covers lands outside the existing embankment bordering the river and parts of the Meghna-Dhonagoda irrigation project located inside the embankment.

Design of river training and bank protection works are undertaken by the Meghna River Bank Short Term Study, which envisages the protection of:

- the river bank and the embankment in Eklashpur,
- the existing embankment and the irrigation pump station;
- habitations and small commercial enterprises, along the shore of the Lower Meghna.

The progress of bank erosion in the without-scenario situation can be estimated from the results of the geo-morphological study (see Annex B). This progress is expected to be important in the coming 30 years; without any protection works large parts of the existing embankment and land of the MDIP will disappear.

10.6.3 **Alternative River Bank Protection Works**

Three types of short-term river bank protection works have been investigated, notably (a) a groyne just north of Eklashpur reaching out for some 600 m into the river, (b) protection of the existing bank and (c) guide protection along the existing embankment.

The first option, a groyne, is the most expensive, but it will lead to sedimentation and create additional land, though it may take many years before a substantial area will become available and productive. Moreover, high investment cost vis-a-vis benefits are affecting the rate of return. The second option, bank protection works, has an important economic advantage: investments are much lower and not concentrated at the start of the 30 year study period, but staggered. The third option consists of guide bunds at Eklashpur and at the confluence of the Meghna and Dhonagoda. Guide bunds are river training works and as such a good alternative for a groyne. However, they are far more expensive than bank protection works and slightly more expensive than the groyne alternative.

10.6.4 **Benefits of Eklashpur protection works**

10.6.4.1 **Reduction in repair and maintenance expenses**

Maintenance and repair of the embankments of the Meghna-Dhonagoda irrigation project is carried out each year by the BWDB. So far the amount allocated has been small. BWDB spends about Tk. 500 thousand per year. Expenditures required in the coming years, however, will increase rapidly; in 1990/91 a total of Tk. 104 million has been spent on CC blocks to repair embankments.

A retirement of the embankment is foreseen every five years from 1998 onwards. Because only small sections of the embankment are renewed, emergency protection cannot be neglected altogether. Based on the considerable amount spent in 1990/91, it has been assumed that annual maintenance required will initially be about 2% of the amount spent in 1990/1991. Together with the regular maintenance Tk. 2.6 million per year is assumed the present-day repair and maintenance budget. This amount is expected to increase rapidly by an estimated 10% per year and has to be considered as additional to the costs incurred for regular retirement of embankments.

These costs in repair and maintenance can be saved and can be considered as benefits from adequate sustainable river training works.

292

10.6.4.2 Relocation of irrigation pump station

The present pump station is located at a spot which could be eroded by the river in the year 1998, according to the results of the geo-morphological survey. A relocation of this pump station to a site more inland is needed. It is assumed that one relocation only will take place during the period of the study. Hence, the new location of the pump station must be somewhere near to the expected bank line in year 2020, which marks the end of the study period.

The cost of relocation of the pump stations are based on earlier cost estimates for construction of similar stations. These data have been inflated by the Planning Commission's inflator (10%) in order to give mid-1991 prices.

10.6.4.3 New retired embankments

As the river bank shifts towards the east, it will destroy the existing embankment. From the results of the geo-morphological study (see Annex B) it could be estimated how far the bank line will recede. The without-project scenario foresees that, every five years, a new stretch of embankment must be constructed in order to protect the Meghna-Dhonagoda Irrigation Project. In Annex F, Table F.6.1 gives details, which are based on expected progress of erosion. From data of earlier embankment constructions, the actual price for this type of works has been estimated. Per kilometre-length [illegible] ...ment construction cost is Tk. 7.83 million.

10.6.4.4 Destruction of buildings and urban infra-structure

River bank erosion will cause loss of buildings and damage to existing structures. Some inhabitants have already moved their homes more inland to protect them from the water of the Meghna. However, a considerable number of houses and commercial buildings in the area remain prone to erosion.

From the results of the geo-morphological study the progress of bank erosion could be estimated as well as how much land is likely to disappear. Based on the socio-economic surveys in Bhairab Bazar, Munshiganj and Chandpur an estimate could be made of the average price of houses and other buildings. The calculated average economic price per square meter land area is Tk. 1,065. In view of the type of structures observed in Eklashpur in comparison to those in the three sites surveyed, it has been assumed that structures in Eklashpur have a 25% lower value. Consequently, the economic price of structures is estimated at Tk. 799 per square meter land area.

No account was taken of losses in revenues of commercial enterprises. The nature of commerce in Eklashpur is such that one may expect that stocks and equipment are removed well before erosion will wash them away.

10.6.4.5 Agriculture

Agricultural benefits are associated with protection of arable land which would otherwise be lost as a result of bank migration. Behind the embankment one finds mainly irrigated lands, while outside the embankment non-irrigated cropping takes place.

In agreement with the FPCO-guidelines the agricultural benefits of river training and bank protection works result from reduction of net agricultural revenues lost due to erosion of arable land. Based on the results of the geo-morphological survey for the area, the change of the river bank position could be forecast for scenarios with and without investments. Hence, a prediction could be made of reduction in the area lost as a result of river training works, covering the evaluation period.

The cropping pattern in the Meghna-Dhonagoda irrigation project and the net economic return of irrigated agriculture were adapted from Thompson (1990) and results of work done by FAP-5.

Apart from the annual net revenue of the area inside the embankment otherwise lost, a value of Tk. 1,677 per hectare associated with the irrigation infra-structure can also be considered as avoidable costs and, hence, as benefit of protection works in Eklashpur. The net annual economic revenues of the Meghna Dhonagoda irrigation project have been evaluated at Tk. 11,920 per ha. Details are reported in Table 10.6.1 and in the appendix F/1.

TABLE 10.6.1 ANNUAL NET REVENUES PER HECTARE IN THE MEGHNA-DHONAGODA IRRIGATION PROJECT

PRICES: constant mid-1991 economic prices
UNIT: Tk.

Item	Unit	Unit return	Fraction in area	Annual return
Cultivation:				
Rabi crops 1)	ha	6 755	82.3%	5 557
HYV Boro	ha	9 522	4.7%	447
B Aus	ha	316	81.3%	257
TL Aman	ha	6 594	85.5%	5 639
Sub-total	ha		90.3%	11 899
Fish-ponds 2)	yr	20 736	0.1%	21
Orchards 2)	yr	218	0.0%	0
Other areas			9.6%	
TOTAL				11 920
Rental value	yr			73 244

Notes:
1) Rabi crop considered is wheat
2) Adapted from Thompson (1990)
3) Rental value is adapted from crop budgets

Apart from the loss of agricultural production as a result of bank erosion, there is also the reduction in loss of land as a productive asset to be considered. The economic value of cropped land is based on share cropping arrangement in the area. For irrigated land inside the embankment the rental value is Tk. 73,244 per ha. The rental value for non-irrigated land is calculated as Tk. 40,686 per ha. For more details reference can be made to the appendix F/1.

Table 10.6.2 provides details of total agricultural benefits over the 30-year period of the feasibility study. In the table with and without-project scenarios are compared. Benefits of river training works are given by the balance, which represents the reduction in losses to cropping.

TABLE 10.6.2 AGRICULTURAL BENEFITS

PRICES: constant mid-1991 economic prices
UNIT: Tk x 1000

Year	SITUATION (W): Areas lost (ha): in.emb.	out.emb.	Production loss(CUM)	Land + infra value	SITUATION (WO): Areas lost (ha): in.emb.	out.emb.	Production loss([illegible]	Land + infra value	Protection benefits (W)-(WO)
1993	0.0	21.6	192.6	886.1	0.0	21.6	192.6	886.1	0.0
1994	0.0	30.8	465.3	1 254.9	0.0	30.8	465.3	1 254.9	0.0
1995	0.0	30.8	738.0	1 254.9	0.0	[illegible]	738.0	1 254.9	0.0
1996	0.0	30.8	1 010.7	1 254.9	0.0	30.8	1 010.7	1 254.9	0.0
1997	0.0	30.8	1 283.4	1 254.9	0.0	30.8	1 283.4	1 254.9	0.0
1998	0.0	30.8	1 556.1	1 254.9	0.0	30.8	1 556.1	1 254.9	0.0
1999	0.0	28.8	1 810.4	1 169.9	0.0	34.0	1 856.7	1 382.9	259.3
2000	0.0	28.8	2 064.6	1 169.9	0.0	34.0	2 157.2	1 382.9	305.6
2001	0.0	28.8	2 318.8	1 169.9	0.0	34.0	2 457.7	1 382.9	351.9
2002	0.0	28.8	2 573.1	1 169.9	0.0	34.0	2 758.2	1 382.9	398.2
2003	0.0	28.8	2 827.3	1 169.9	0.0	34.0	3 058.8	1 382.9	444.5
2004	0.0	16.7	2 975.3	681.2	15.2	22.5	3 398.0	1 696.5	1 438.0
2005	0.0	16.7	3 123.3	681.2	15.2	22.5	3 737.2	1 696.5	1 629.2
2006	0.0	16.7	3 271.4	681.2	15.2	22.5	4 076.4	1 696.5	1 820.3
2007	0.0	16.7	3 419.4	681.2	15.2	22.5	4 415.6	1 696.5	2 011.5
2008	0.0	16.7	3 567.4	681.2	15.2	22.5	4 754.8	1 696.5	2 202.7
2009	0.0	11.0	3 664.5	446.7	11.0	18.7	5 021.6	1 327.0	2 237.6
2010	0.0	11.0	3 761.6	446.7	11.0	18.7	5 288.8	1 327.0	2 407.6
2011	0.0	11.0	3 858.6	446.7	11.0	18.7	5 555.8	1 327.0	2 577.5
2012	0.0	11.0	3 955.7	446.7	11.0	18.7	5 822.8	1 327.0	2 747.5
2013	0.0	11.0	4 052.7	446.7	11.0	18.7	6 089.9	1 327.0	2 917.5
2014	0.0	13.1	4 168.3	531.7	19.3	24.6	6 486.3	1 997.1	3 783.4
2015	0.0	13.1	4 283.8	531.7	19.3	24.6	6 882.7	1 997.1	4 064.3
2016	0.0	13.1	4 399.4	531.7	19.3	24.6	7 279.0	1 997.1	4 345.1
2017	0.0	13.1	4 514.9	531.7	19.3	24.6	7 675.4	1 997.1	4 626.0
2018	0.0	13.1	4 630.5	531.7	19.3	24.6	8 071.8	1 997.1	4 906.8
2019	0.0	17.8	4 787.6	723.2	23.0	36.1	8 604.0	2 654.7	5 747.9
2020	0.0	17.8	4 944.8	723.2	23.0	36.1	9 136.1	2 654.7	6 122.9
2021	0.0	17.8	5 102.0	723.2	23.0	36.1	[illegible]	[illegible]	6 497.9
2022	0.0	17.8	5 259.1	723.2	23.0	36.1	[illegible]	2 654.7	6 872.8
SUM	0.0	594.8	94 580.6	24 200.6	319.4	819.1	139 699.7	49 797.6	70 716.1

Notes:
1) Tk. 1 677 per ha is the value of irrigation infra-structure based on an analysis of data from SERWRDP (FAP5)
2) Inside the existing embankment land is irrigated, outside the embankment land is not irrigated
3) Tk. 9 263 is the economic unit value of land in the Chandpur irrigation project
Tk. 8 842 is the economic value of land outside embankments, assuming 90% use for cropping
4) Tk. 40 686 per ha is the rental value of land outside embankments

10.6.5 Cost of River Bank Protection Works

A design for protection works has been made, notably protection of the existing bank. This type of protection is less expensive at the beginning of the 30-year study period. However, in later years to guarantee the sustainability of the works, additional works must be carried out. Initial investment cost are evaluated at US$ 7.90 million or Tk 260.8 million, while in 1998 an additional Tk. 264.4 million must be invested. A final investment is needed in 2005, requiring also Tk. 264.4 million. Local currency expenditure is 45% and the foreign component totals 55%.

10.6.6 Economic Evaluation

The cash flow computation for river training works at Eklashpur compares benefits and cost over the 30-year evaluation period. The investment costs have been discussed in detail in the previous section. Table 10.6.3 provides the cash flow calculation for protection of the existing bank, the option which economically is most attractive.

TABLE 10.6.3 ECONOMIC CASH FLOW EKLASHPUR PROTECTION OF THE EXISTING BANK

PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million
START: 1993
CONSTR: 1 years

EIRR 2.83% NPV: -293.0 NPVR1: -0.45

	WITH-PROJECT SITUATION COST:				BENEFITS:					CASH	Cash F.
Year	Invest.	M&M	Other	Total	Repair c.	Nw.emb.	Urban pr.	Agric.	Total	FLOW	(US$x1M)
1993	284.5	8.9	0.3	293.7	0.0	0.0	0.0	0.0	0.0	-293.7	-8.16
1994	0.0	8.9	0.3	9.2	3.4		2.1	0.1	5.7	-3.5	-0.10
1995	0.0	8.9	0.3	9.2	3.8		2.1	0.2	6.0	-3.1	-0.09
1996		8.9	0.3	9.2	4.2		2.[illegible]	0.2	6.4	-2.7	-0.08
1997		8.9	0.3	9.2	4.6		2.1	0.2	6.9	-2.3	-0.06
1998	246.4	13.3	0.3	260.0	5.0	52.0	2.1	0.2	59.3	-200.7	-5.57
1999		13.3	0.3	13.6	5.5		23.4	2.0	30.9	17.3	0.43
2000		13.3	0.3	13.6	6.1		23.4	2.2	31.7	18.2	0.50
2001		13.3	0.3	13.6	6.7		23.4	2.5	32.6	19.1	0.53
2002		13.3	0.[illegible]	13.6	7.4		23.4	2.8	33.6	20.0	0.56
2003		[illegible]	0.3	13.6	8.1	31.3	23.4	3.1	65.9	52.4	1.45
2004		13.3	0.3	13.6	8.9		35.9	4.2	49.1	35.5	0.99
2005	246.4	17.7	0.3	264.4	9.8		35.9	4.6	50.4	-214.0	-5.95
2006		17.7	0.3	18.0	10.8		35.9	5.0	51.8	33.8	0.94
2007		17.7	0.3	18.0	11.9		35.9	5.[illegible]	53.3	35.3	0.98
2008		17.7	0.3	18.0	13.1	35.2	35.9	5.	90.1	72.1	2.00
2009		17.7	0.3	18.0	14.4		18.8	5.0	38.2	20.2	0.56
2010		17.7	0.3	18.0	15.8		18.8	5.2	39.8	21.9	0.61
2011		17.7	0.3	18.0	17.4		18.8	5.5	41.6	23.7	0.66
2012		17.7	0.3	18.0	19.1		18.8	5.7	43.6	25.6	0.71
2013		17.7	0.3	18.0	21.0	43.1	18.8	5.9	88.8	70.8	1.97
2014		17.7	0.3	18.0	23.1		30.1	7.1	60.3	42.3	1.18
2015		17.7	0.3	18.0	25.4		30.1	7.4	63.0	45.0	1.25
2016		17.7	0.3	18.0	28.0		30.1	7.8	65.9	47.9	1.33
2017		17.7	0.3	18.0	30.8		30.1	8.2	69.1	51.1	1.42
2018		17.7	0.3	18.0	33.9	61.1	30.1	8.5	133.6	115.6	3.21
2019		17.7	0.3	18.0	37.3		48.9	10.2	96.3	78.3	2.18
2020		17.7	0.3	18.0	41.0		48.9	10.7	100.6	82.6	2.30
2021		17.7	0.3	18.0	45.1		48.9	11.3	105.3	87.3	2.43
2022		17.7	0.3	18.0	49.6		48.9	11.9	110.4	92.4	2.57
SUM	777.3	456.2	8.5	1242.0	511.1	222.7	747.4	149.1	1630.3	388.3	10.79

Notes:

1) INVESTMENT COST (Tk. x 1M):

Year	1993	284.5
	1998	246.4
	2005	246.4

2) M&M COST (Tk. x 1M):

Maintenance:	1993	6.9
	1998	4.4
	2005	4.4
Monitoring		2.0

3) OTHER COST:

Tk. x 1M 0.3

4) BENEFITS (Tk. x 1M):

Savings repair	2.1
Annual mainten.	0.5
Annual increase	10%

5) Conversion US$ 1 = Tk. 36

PV(12%) of benefits:	
Tk. x 1M	244.1
US$ x 1M	6.8

The mere protection of the existing bank requires less investment at the start of the 30-year period, although later on additional investment are needed. From Table 6.8 it can be concluded that the EIRR for this option is about 3%. The benefits just offset the costs needed for protection.

The economic NPV for the bank protection works at Eklashpur, at a discount rate of 12%, has been evaluated at Tk. -293 million. The NPVR ratio as required by the FPCO-guidelines yields -0.45.

The economic analysis of bank protection is based on uncertain future events and imperfect data. Because of this, it is important that sensitivity analyses be undertaken. This implies an analysis of the economic internal rate of return as function of changes in investment cost, monitoring and maintenance expenditure and estimated value of benefits. The results of the sensitivity analysis are presented in Table 10.6.5. When assuming that construction costs will not increase when the implementation of the works is postponed, it can be concluded from the cashflow that deferring construction until 1998 is beneficial, since hardly any benefits are generated till this year. The EIRR will increase to about 4%.

The conclusions from this chapter comprise:

(i) Bank protection at Eklashpur to protect the existing interests has a low economic rate of return when compared to the present-day practice of gradually shifting the embankment to the extent erosion progresses.

(ii) In spite of the low return, it may be worthwile to consider such bank protection schemes in a long-term strategic planning for the Lower Meghna

TABLE 10.6.5 RESULTS OF THE SENSITIVITY ANALYSIS FOR EKLASHPUR

VALUES: Economic Internal Rate of Return (EIRR)
UNIT: percent

Change in investm.	CHANGE IN BENEFITS: -30%	-20%	-10%	0%	10%	20%	30%
-30%	3.86%	4.44%	5.00%	5.54%	6.05%	6.56%	7.04%
-20%	2.89%	3.45%	3.98%	4.50%	4.99%	5.47%	5.93%
-10%	2.05%	2.60%	3.11%	3.61%	4.08%	4.54%	4.99%
0%	1.32%	1.85%	2.35%	2.83%	3.29%	3.73%	4.16%
10%	0.67%	1.18%	1.67%	2.14%	2.59%	3.02%	3.44%
20%	0.08%	0.58%	1.06%	1.52%	1.96%	2.38%	2.78%
30%	0.00%	0.04%	0.51%	0.96%	1.39%	1.80%	2.20%

Change in Mon&Mai	CHANGE IN BENEFITS: -30%	-20%	-10%	0%	10%	20%	30%
-30%	2.35%	2.85%	3.32%	3.78%	4.22%	4.65%	5.06%
-20%	2.01%	2.52%	3.00%	3.47%	3.91%	4.34%	4.76%
-10%	1.67%	2.18%	2.68%	3.15%	3.60%	4.04%	4.46%
0%	1.32%	1.85%	2.35%	2.83%	3.29%	3.73%	4.16%
10%	0.97%	1.51%	2.02%	2.51%	2.98%	3.43%	3.86%
20%	0.61%	1.16%	1.68%	2.18%	2.66%	3.12%	3.56%
30%	0.25%	0.81%	1.35%	1.86%	2.34%	2.81%	3.26%

10.6.7 Displacement of population

For the rural areas along the Lower Meghna no surveys were executed. Hence, there are no data for the number of persons displaced as a result of likely bank migration. Moreover, the 1991 Statistical Yearbook for Bangladesh is inconclusive with respect to population densities in the aforementioned rural areas. The overall population density for the country is about 750 persons per km² in 1991 (Statistical Yearbook 1991). Present day rural population counts for about 70% and is expected to reduce to about 50% over the project period ('Developing the Infrastructure. Volume Three of the Report of the Task Forces on Bangladesh Development Strategies for the 1990's' 1991). The averaged rural population density is therefore estimated at 400 people per square kilometer. Since the total rural area likely to be lost to erosion in the coming 30 years without the erosion protection works being carried out is estimated at some 1000 ha, about 4.000 persons will be affected.

10.7 Haimchar (CIP)

10.7.1 Present Situation and Previous Efforts for Protection

Haimchar is situated on the left bank of the Lower Meghna River, about 20 km south of the town of Chandpur. Erosion has attacked the river bank for more than a decade and is the result of both current and wave action. In 1989 the village was retired more inland after the floods. Agriculture is the main economic activity in the area.

has been

Rehabilitation of the Chandpur irrigation project ~~is being~~ studied ~~at present~~ by the FAP-5. The FAP project is mainly concerned with agricultural production, irrigation and drainage. Hence the scope is not on protection works to avert erosion of the existing embankment. Data on economic indicators for this project can also be found in Thompson's study on the impact of flood control on agriculture (1990) and missing information was kindly provided by FAP-5.

If the embankment of the Chandpur project is breached, the whole benefit of flood control for the area would be lost. Without any river training works or any other form of protection, the embankment is likely to be engulfed and irrigation infra-structure will be destroyed.

10.7.2 Area [illegible]

Embankments at Haimchar protect the Chandpur irrigation project. Flood protection commenced in 1976/77, while the project started effective irrigation in 1978/79. Drainage is a major problem in the project, while flooding from the waters of the Meghna has sofar only been a minor obstacle to production.

The area of influence of the proposed works reaches from a point some 3 km north of Haimchar and goes as far as 7 km south of the village. The area to be protected covers land outside the existing embankment bordering the river as well as parts of the Chandpur irrigation project located inside the embankment.

It is more than likely, that the river bank will continue being eroded considerably in the coming 30 years. Hence, the embankment will have to be retired time and again.

Without any protection works large parts of the existing embankment and land of the irrigation project will disappear. Hence, it is more than likely that retired embankments will be constructed at regular intervals. Such as is the case in Eklashpur, it is emphasized that the complete loss of the Chandpur Irrigation Project has not been taken as the without-scenario, since that is not likely to occur. As a result of the sustainable short-term bank protection works executed, less agricultural land will disappear, fewer structures lost and agricultural produce hig .er.

299

10.7.3 Alternatives for protection

Three types of river bank protection have been investigated. notably (a) a groyne just north of Haimchar reaching out for some 500 m into the river, (b) protection of the existing bank and (c) guide bund protection along the existing embankment.

The second option consists of protection of the existing river bank at Haimchar. However, this option does not aim at training the river; it simply provides protection. Initial costs are lower than those of a groyne, but additional costs have to be incurred in 2008.

10.7.4 Benefits of Haimchar bank protection works

10.7.4.1 Reduction in repair and maintenance expenses

Maintenance and repair of the embankments of the Chandpur irrigation project is carried out each year by the BWDB. In the past the allocated amount has been very small, with the exception of years when major works were carried out. In 1989/90 a total of Tk. 10 million has been spent on retirement of embankments and in 1973/77 Tk. 14.3 million were spent on new embankments. Expressed in mid-1991 prices these investments correspond to an average Tk. 5 million per year. Moreover, BWDB spends annually Tk. 300 thousand on maintenance of the embankments.

From the experience at Chandpur, a rapid increase of such repair and maintenance expenditures may be expected if Haimchar will continue to be protected by the non-sustainable present-day approach. These expenses are therefore expected to increase annually by 10%. This amount is additional to the costs incurred for the regular retirement of embankments.
These annual costs of repair and maintenance can be saved if adequate sustainable bank protection works are carried out and, hence, can be considered as benefits originating from such works.

10.7.4.2 New retired embankments

From the results of the geo-morphological study it could be estimated how far the bank line will progress. The without-project scenario foresees that every five years a new stretch of embankment must be constructed in order to protect the Chandpur irrigation project.
The actual price for this type of works has been estimated in Tk 7.8 million per kilometre-length embankment construction cost. Because, no new retired embankment construction is required if the proposed river training or protection works are implemented, the cost figures from the table are savings due to the project. Hence, they represent expected benefits.

10.7.4.3 Destruction of buildings and urban infra-structure

River bank erosion has caused loss of buildings and damage to existing structures in the recent past. Some inhabitants have already moved their homes more inland to protect them from the water of the Meghna. However, a considerable number of houses and commercial buildings in the area are still prone to erosion.

It is estimated from field observations that about 10% of the area of influence is used for non-agricultural purposes, being either commercial enterprises or homes. This percentage also includes social and town infra-structure.

From Annex B it could be estimated how far the bank line will progress and how much land surface is likely to disappear. Based on the socio-economic surveys in Bhairab Bazar, Munshiganj and Chandpur an estimate could be made of the average price of houses and other buildings. In the three towns surveyed, we have estimated that social and town infra-structure covers 25% of the built-on area. The average economic price calculated per square meter land area is Tk. 1,065.

Apart from the infra-structural losses as a result of bank erosion, also loss of land is to be considered. The fact that it washes away and is lost means that it must be considered in the economic evaluation. However, all land was accounted for in the analysis of agricultural production, assuming that agriculture is the nearest-best economic activity. Moreover, double-counting has thus been avoided. Such as explined for Eklashpur, no account was taken of losses in revenues of commercial enterprises.

10.7.4.4 Agriculture

Agricultural benefits are associated with protection of arable land which would otherwise be lost as a result of bank migration. Behind the embankment one finds mainly irrigated lands, while outside the embankment non-irrigated cropping takes place.
In agreement with the FPCO-guidelines the agricultural benefits of river training and bank protection works result from reduction of net agricultural revenues lost due to erosion of arable land. Based on the results of the geo-morphological survey for the area, the change of the river bank position could be forecast for scenarios with and without investments. Table 10.7.1 presents the estimated economic value of destruction of buildings and urban infra-structure.

TABLE 10.7.1 VALUE OF DESTRUCTION OF BUILDINGS AND URBAN INFRA-STRUCTURE

PRICES: constant mid-199[illegible] economic prices
UNIT: Tk [illegible]

Year	SITUATION [W]: Area lost (ha)	Urban assets	SITUATION [WO]: Area lost (ha)	Urban assets	Protection benefits [W]-[WO]
1993	21.6	17.411	21.6	17.411	0.000
1994	30.8	24.657	30.8	24.657	0.000
1995	30.8	24.657	30.8	24.657	0.000
1996	30.8	24.657	30.8	24.657	0.000
1997	30.8	24.657	30.8	24.657	0.000
1998	30.8	24.657	30.8	24.657	0.000
1999	28.8	22.985	34.0	27.172	4.186
2000	28.8	22.985	34.0	27.172	4.186
2001	28.8	22.985	34.0	27.172	4.186
2002	28.8	22.985	34.0	27.172	4.186
2003	28.8	22.985	34.0	27.172	4.186
2004	16.7	13.384	37.6	30.092	16.708
2005	16.7	13.384	37.6	30.092	16.708
2006	16.7	13.384	37.6	30.092	16.708
2007	16.7	13.384	37.6	30.092	16.708
2008	16.7	13.384	37.6	30.092	16.708
2009	11.0	8.776	29.7	23.725	14.949
2010	11.0	8.776	29.7	23.725	14.949
2011	11.0	8.776	29.7	23.725	14.949
2012	11.0	[illegible]	29.7	23.725	14.949
2013	[illegible]	8.776	29.7	23.725	14.949
2014	13.1	10.447	43.9	35.104	24.657
2015	13.1	10.447	43.9	35.104	24.657
2016	13.1	10.447	43.9	35.104	24.657
2017	13.1	10.447	43.9	35.104	24.657
2018	13.1	10.447	43.9	35.104	24.657
2019	17.8	14.210	59.1	47.239	33.029
2020	17.8	14.210	59.1	47.239	33.029
2021	17.8	14.210	59.1	47.239	33.029
2022	17.8	14.210	59.1	47.239	33.029
SUM	594.8	475.502	1138.5	910.114	434.612

Notes:
1) Tk. 0.799 x 1000 per sq.m is the estimated average value of urban infra-structure and buildings
2) At 10% is estimated the urbanised area

The cropping pattern in the Chandpur irrigation project and the net economic return of irrigated agriculture were adapted from Thompson (1990) and results of work done by FAP5. An assumption was made for the cropping pattern of lands outside the irrigation scheme: only one crop per year is cultivated, notably L.Boro. The annual net economic revenues of reduced losses in agricultural area are taken into account as benefit of works undertaken at Haimchar.

Apart from the annual net revenue of the area inside the embankment otherwise lost, a value of Tk. 1,677 per hectare associated with the irrigation infra-structure can also be considered as avoidable costs and, hence, as benefit of protection works in Haimchar. This figure was derived from data supplied by FAP5.

The net annual economic revenues of the Chandpur irrigation project have been evaluated at Tk. 9,263 per ha. Details are reported in Table 10.7.2. For cropping outside the embankment net annual economic revenues are estimated at Tk. 8,842 per ha, assuming that 90% of the land is cropped once per year.

TABLE 10.7.2 ANNUAL NET REVENUES PER HECTARE CHANDPUR IRRIGATION PROJECT

PRICES: constant mid-1991 economic prices
UNIT: Tk./ha

Item	Unit	Unit return	Fraction in area	Annual return
Cultivation:				
Rabi crops 1)	ha	6 755	10.4%	706
HYV Boro	ha	9 522	43.2%	4 116
B Aus	ha	316	8.5%	27
TL Aman	ha	6 594	57.7%	3 806
Sub-total	ha		62.2%	8 655
Fish-ponds 2)	yr	5 660	5.4%	306
Orchards 2)	yr	2 206	13.7%	302
Other areas			18.7%	
TOTAL				9 263
Rental value	yr			49 896

Notes:
1) Rabi crop considered is wheat
2) Adapted from Thompson (1990)
3) Rental value is adapted from crop budgets

Apart from the loss of agricultural production as a result of bank erosion, there is also the reduction in loss of land as a productive asset to be considered. The fact that land washes away and is directly lost for cropping means that it must be considered in the economic evaluation. Hence, the value of this asset must be estimated, while avoiding loss of agricultural land is considered as a benefit of river training or bank protection works.
As already indicated for Eklashpur, the present value of the economic annual rental value has been taken into account in the economic assessment of the short-term bank protection works.

The economic value of cropped land is based on share cropping arrangement in the area. For each individual crop the rent has been calculated as the money value of production quota provided by the share cropper to the landowner. Based on the prevailing cropping pattern in the Chandpur irrigation project and lands outside the embankment, the average economic rental value is calculated. For irrigated land inside the embankment the rental value is Tk. 49,896 per ha. The rental value for non-irrigated land is calculated as Tk. 40,686 per ha. For details reference is made to the appendix.

Table F.7.5 in Annex F, provides details of total agricultural benefits on lands prone to erosion covering the 30-year period of the feasibility study. In the table with and without-project scenarios are compared. Benefits of river training works are given by the balance, which represents the reduction in losses to cropping.

10.7.5 Cost of alternative protection options

Table 10.7.3 provides a summary of investment cost for all three options. The third option comprises guide bunds. Although this alternative may be more expensive than the previous options, investment scenarios have been evaluated whereby costs are staggered over more years. For the scenario where construction is broken up in three parts, initial economic investment cost are estimated at US$ 4.5 million or Tk. 163.7 million. In later years additional investments of Tk 199.5 million and Tk. 264.1 million are needed. An estimat[illegible] total investment cost are local currency expenditure and the foreign component is 63%.

TABLE 10.7.3 SUMMARY OF ECONOMIC INVESTMENT COST FOR WORKS AT HAIMCHAR

Type	Investment cost and year	Local/foreign currency
Large groyne	1993: MTk. 667.9	Local: 36% Foreign: 64%
Protection of existing bank	1993: MTk. 381.7 1998: MTk.1381.7	Local: 31% Foreign: 69%
Guide bunds: - Scenario 1	1993: MTk. 632.7	Local: 40% Foreign: 60%
Guide bunds: - Scenario 2	1993: MTk. 381.7 2008: MTk. 264.1	Local: 39% Foreign: 61%
Guide bunds: - Scenario 3	1993: M[illegible]k. 163.7 1998: MTk. 199.5 [illegible]08: Mtk. 264.1	Local: 37% Foreign: 63%

10.7.6 Economic Evaluation

The cash flow computation for river training works at Haimchar makes a comparison of benefits and cost over the 30-year evaluation period. The investment costs have been discussed in detail in the previous section. Table 10.7.4 provides the cash flow calculation of the guide bund protection scenario 3 option. The economic net present value for the guide bund bank protection at Haimchar has been evaluated at Tk. -216 million for a discount rate of 12%. The NPVR ratio required by the FPCO-guidelines can be calculated at -0.50.

The third protection option, which provides protection through guide bunds, yields an economic internal rate of return just below 2%. The other options show even a slightly negative internal rate of return. It means that bank protection works via guide bunds is, from the economic point of view, marginally better than the extrapolated present-day practice of non-sustainable repair and maintenance together with retirement of embankments to the extent bank erosion progresses.

TABLE 10.7.4 ECONOMIC CASH FLOW HAIMCHAR GUIDE PROTECTION SCENARIO-3

PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million
START: 1993
CONSTR: 1 years

EIRR: 1.65% NPV: -215.9 NPVR1: -0.50

	WITH-PROJECT SITUATION COST:				BENEFITS					CASH	Cash F.
Year	Invest	M&M	Other	Total	Repair c.	Nw.emp.	Urban pr	Agric.	Total	FLOW	(USSx1M)
1993	163.7	5.0	0.2	168.8	0.0	9.4	0.0	0.0	9.4	-159.4	-4.43
1994	0.0	5.0	0.2	5.1	2.8		0.0	0.0	2.8	-2.3	-0.06
1995	0.0	5.0	0.2	5.1	3.1		0.0	0.0	3.1	-2.0	-0.06
1996		5.0	0.2	5.1	3.4		0.0	0.0	3.4	-1.7	-0.05
1997		5.0	0.2	5.1	3.7		0.0	0.0	3.7	-1.4	-0.04
1998	199.5	8.6	0.2	208.3	4.1	14.1	0.0	0.0	18.2	-190.0	-5.28
1999		8.6	0.2	8.8	4.5		4.2	0.3	9.0	0.2	0.01
2000		8.6	0.2	8.8	5.0		4.2	0.3	9.5	0.7	0.02
2001		8.6	0.2	8.8	5.5		4.2	0.4	10.0	1.3	0.03
2002		8.6	0.2	8.8	6.0		4.2	0.4	10.6	1.9	0.05
2003		8.6	0.2	8.8	6.6	18.0	4.2	0.4	29.3	20.5	0.57
2004		8.6	0.2	8.8	7.3		16.7	1.5	25.5	16.7	0.47
2005		8.6	0.2	8.8	8.0		16.7	1.7	26.4	17.7	0.49
2006		8.6	0.2	8.8	8.8		16.7	1.9	27.4	18.7	0.52
2007		8.6	0.2	8.8	9.7		16.7	2.1	28.5	19.7	0.55
2008	264.1	12.3	0.2	276.6	10.7	24.3	16.7	2.3	53.9	-222.7	-6.19
2009		12.3	0.2	12.5	11.8		14.9	2.3	29.0	16.5	0.46
2010		12.3	0.2	12.5	12.9		14.9	2.5	30.3	17.8	0.50
2011		12.3	0.2	12.5	14.2		14.9	[illegible]	31.8	[illegible]	0.54
2012		12.3	0.2	12.5	15.6		[illegible]	[illegible]	33.4	20.9	0.58
2013		12.3	0.2	12.5	17.2	43.8	14.9	3.0	79.0	66.5	1.85
2014		12.3	0.2	12.5	18.9		24.7	3.9	47.5	35.0	0.97
2015		12.3	0.2	12.5	20.8		24.7	4.1	49.6	37.1	1.03
2016		12.3	0.2	12.5	22.9		24.7	4.4	52.0	39.5	1.10
2017		12.3	0.2	12.5	25.2		24.7	4.7	54.6	42.1	1.17
2018		12.3	0.2	12.5	27.7	56.4	24.7	5.0	113.7	101.2	2.81
2019		12.3	0.2	12.5	30.5		33.0	5.8	69.4	56.9	1.58
2020		12.3	0.2	12.5	33.5		33.0	6.2	72.8	60.3	1.67
2021		12.3	0.2	12.5	36.9		33.0	6.6	76.5	64.0	1.78
2022		12.3	0.2	12.5	40.6		33.0	7.0	80.6	68.1	1.89
SUM	627.2	295.9	4.9	928.0	418.2	166.0	434.6	72.1	1090.9	162.9	4.52

Notes:

				SC1	SC2	SC3
1) INVESTMENT COST (Tk. x 1M):						
Year	1993	163.7		532.7	381.7	163.7
	1998	199.5		0.0	0.0	199.5
	2008	264.1		0.0	264.1	264.1
2) O&M COST (Tk. x 1M):						
Maintenance:	1993	3.0		7.2	5.4	3.0
	1998	3.6		0.0	0.0	3.6
	2008	3.7		0.0	3.7	3.7
Monitoring		2.0		2.0	2.0	2.0
3) OTHER COST:						
Tk. x 1M		0.2	EIRR:	1.82%	1.35%	1.65%
4) BENEFITS (Tk. x 1M):			NPV:	-417.4	-314.6	-215.9
Savings repair cost		2.1	NPVR1:	-0.62	-0.57	-0.50
Annual mainten.		0.03				
Annual increase		10%				
5) Conversion US$ 1 = Tk.		36				

PV(12%) of benefits:	
Tk. x 1M	136.6
US$ x 1M	3.8

The economic analysis of bank erosion protection is based on uncertain future events and imperfect data. Because of this, it is important that sensitivity analyses be undertaken. This implies an analysis of the economic internal rate of return as function of changes in investment cost, monitoring and maintenance expenditure and estimated value of benefits. The results are presented in Table 10.7.5. When assuming that construction costs will not increase if the implementation of the works is postponed, it can be concluded from the cashflow that deferring the construction until 1998 is beneficial, since hardly any benefits are generated till this year. The EIRR will increase to about 3%.
The following conclusions can be drawn:

(i) Guide bund bank protection works at Haimchar to protect the existing interests along the river bank show a low economic internal rate of return, when compared to the present-day practice of gradually shifting the embankments to the extent bank erosion progresses.

(ii) In spite of the low return on investments, it may be worthwile to consider such bank protection schemes in a long term strategic planning for the Lower Meghna.

TABLE 10.7.5 RESULTS SENSITIVITY ANALYSIS HAIMCHAR

VALUES: Economic Internal Rate of Return (EIRR)
UNIT: percent

Change in investm.	CHANGE IN BENEFITS: -30%	-20%	-10%	0%	10%	20%	30%
-30%	0.35%	1.81%	3.10%	4.24%	5.29%	6.25%	7.16%
-20%	-0.54%	0.90%	2.15%	3.27%	4.28%	5.22%	6.08%
-10%	-1.32%	0.09%	1.32%	2.41%	3.40%	4.31%	5.16%
0%	-2.03%	-0.63%	0.58%	1.65%	2.63%	3.52%	4.34%
10%	-2.67%	-1.29%	-0.09%	0.97%	1.93%	2.80%	3.61%
20%	-3.26%	-1.89%	-0.70%	0.35%	1.29%	2.15%	2.95%
30%	-3.80%	-2.44%	-1.26%	-0.22%	0.71%	1.56%	2.34%

Change in Mon&Mai	CHANGE IN BENEFITS: -30%	-20%	-10%	0%	10%	20%	30%
-30%	-0.91%	0.38%	1.51%	2.53%	3.46%	4.31%	5.11%
-20%	-1.28%	0.04%	1.20%	2.24%	3.18%	4.05%	4.85%
-10%	-1.65%	[illegible]	0.89%	1.95%	2.90%	3.78%	4.60%
0%	-2.03%	-0.63%	0.58%	1.65%	2.63%	3.52%	4.34%
10%	[illegible]	-0.98%	0.26%	1.36%	2.35%	3.25%	4.08%
20%	-2.80%	-1.33%	-0.06%	1.06%	2.07%	2.98%	3.83%
30%	-3.20%	-1.68%	-0.38%	0.76%	1.78%	2.71%	3.57%

10.7.7 Displacement of population

For the rural areas along the Lower Meghna no surveys were executed. Hence, there are no data for the number of persons displaced as a result of likely bank migration. Moreover, the 1991 Statistical Yearbook for Bangladesh is inconclusive with respect to population densities in the aforementioned rural areas. The overall population density for the country was 750 persons per km^2 in 1991 (Statistical Yearbook 1991). Present day rural population counts for about 70% and is expected to reduce to about 50% over the project period ('Developing the Infrastructure, Volume Three of the Report of the Task Forces on Bangladesh Development Strategies for the 1990's' 1991). The averaged rural population density is therefore estimated at 400 people per square kilometer.
The total rural area likely to be washed away by erosion during the 30-year project evaluation period is estimated at 315 ha. Hence an estimated 1,260 persons would be affected during the same period.

10.8 Meghna Roads and Highways Bridge

10.8.1 Present situation

Crossing the Meghna by bridge has only been possible by rail for a long time. The railway bridge in Bhairab Bazar exists already 50 years, but all other traffic used to cross the river by ferry. In 1990 the Meghna R&H Bridge was opened and it forms the first chain of bridges in the road network linking Dhaka and Chittagong.

Construction of the bridge was finished in 1990. Local protection works (mainly gabions) to safeguard the engulfment of abutments and the approach roads were included in the construction of the bridge. However, at this date large parts of these protections for the left abutment are damaged.

10.8.2 Area Affected

Protection works considered by the Meghna River Bank Protection Short-Term Study concentrate on structures to train the river at a point some 2 kilometre upstream of the bridge and/or protecting the old ferry ghat and the vortex area downstream this point. Five alternatives have been studied (pre-feasibility level) for the protection of the bridge, of which four include protection of the ferry ghat and vortex area.

10.8.3 Alternatives for river bank protection

Protection of the R&H Bridge can be undertaken in different ways. Based on the results of the geo-morphological study (Annex B) five scenarios have been developed for protection works. These scenarios can be grouped in three types of protection works:

(a) repair of the existing bank protection together with protection of the ferry ghat and the vortex area,

(b) a combination of the works undertaken under (a) and a groyne of 200 m upstream of the bridge, and

(c) construction of a spur dike (groyne) guiding the flow on the left bank near the ferry ghat.

10.8.4 Benefits of protection works

10.8.4.1 Disruption of road transport

Based on the results of the site investigation and the geo-morphological study of the upper Meghna, it is expected that the R&H Bridge, in the coming 30 years, may be damaged to such an extent that traffic is disrupted over a considerable period of time required for repairs. Consequently, a detailed study is needed to evaluate the impact of such a disruption to the national economy. In view of the data available only a limited analysis at pre-feasibility level has been carried out.

Damage to the bridge will cause a disruption of road traffic from and to Dhaka; passengers and cargo will either divert to other routes and modes or will have to cross the river by ferry to proceed to their destination. This involves the following:

- loss in time;
- extra cargo handling cost;
- extra transport cost for passengers and cargo.

For an economic evaluation of road traffic disruption the following cost components must be evaluated:

(a) Economic value of lost time
Depending on the length of the disruption, the total number of lost man-days can be calculated and appreciated in economic terms.

(b) Increased handling and transport cost
Increased transport and handling cost are evaluated over the length of the disruption period. One may expect that cargo transport will in general use the ferries, although it is also foreseen that a small portion of cargo will divert to the rail transport mode.

(c) Repair cost
The cost for repair of damage to the bridge is evaluated and comprises a benefit to the project.

(d) Other cost
This refers in particular to the expenses needed for upgrading the ferry ghat and assuring that enough ferries are available.

In this study the analysis is based on a review of traffic flows over the bridge during a 12 months period. The incremental failure probability of various degrees of damage to the bridge has been assessed, together with the costs and time required for repairs. On the basis of a damage probability function the expected annual costs have been evaluated at Tk 207 million in economic mid-1991 terms.

(ii) Flows over bridge

From statistics provided by the R&H department the total flow over the bridge could be estimated. However, no long time series could be provided as the bridge only was only opened in 1990. Hence, only 1990/91 records are available. Per 12 months 11 million persons cross the bridge and 3 million ton of cargo passes.

(iii) Passenger's crossing

Failure of the bridge will result in a disruption of passenger traffic over the bridge. The most likely alternative for crossing by bus or car would be to cross the river by ferry or boat. This increases the trip by 4 to 5 hours. Hence, the total hours lost as result of bridge failure are estimated at 44.9 million hours per year.

Half of this time is considered an economic loss to the country, which is evaluated at Tk. 7.5 per hour (market prices), in agreement with the wage for unskilled labour. The SWR conversion factor is 0.71. Hence, this represents an economic loss to the country of Tk. 119.5 million on an annual basis (mid-1991 economic prices).

Ferry crossing has been evaluated from estimations made for the Jamuna Bridge study. Based on this study the estimated additional ferry cost are considered to be Tk. 2 per person (financial prices) or Tk. 1.6 per person (economic prices). Hence, the additional economic ferry cost per year are Tk. 18.4 million. Table 10.8.2 in Annex F gives details.

(iv) Cargo transport

Alternatives for cargo transport in case of bridge failure are difficult to predict because no detailed information could be provided on destinations and flows. Hence, likely cargo flows are estimated on the basis of prevailing flow patterns:

- Originating from Chittagong with destination Dhaka: 65% of volume;
- Originating from Dhaka with destination Chittagong: 25% of volume;
- Short distance transport over the bridge: 10% of volume.

Alternatives for transport between Chittagong and Dhaka vice versa are ferry crossing, railway and river transport. Few details are known on the likely reaction of transporters as to the choice of alternative transport modes. It is, however, very unlikely that any cargo will be diverted to Bangladesh Rail services. Water transport is more likely as an alternative, but this mode of transport can be neglected as it is more suitable for bulk products and special items, rather than for general cargo. Hence, it is assumed that all (long haul) cargo will use ferry services when the bridge will fail.
Short distance transport will also cross the river by ferry. Any possible additional cargo handling charges have been excluded, because additional cargo handling is not [illegible]d variations of cargo handling costs for different modes of transport are marginal.
Ferry costs are based on prevailing ferry costs in Bhairab Bazar and Daudkandi. Based on the assumption that all cargo is transported by five tons carriers and that crossing the river by ferry will take an additional four hours, the additional cost for ferry crossing has been estimated at Tk. 45 per ton in financial and Tk. 34 per tonne in economic prices.

Conclusively, it follows that the total additional transport cost in case of failure of the bridge amounts to Tk. 105 million per annum. Details are given in Table 10.8.1

TABLE 10.8.1 ADDITIONAL ANNUAL COST CARGO TRANSPORT

Prices: mid-1991 economic prices
Unit: Tk.

Item	unit	value	total (x1000)
Fractions:			
Chittagong-Dhaka	ton	65%	2 034
Dhaka-Chittagong	ton	25%	782
Short distance transport	ton	10%	313
Total	ton		[illegible]
Additional annual transport costs:			
Ferry crossings	Tk.	33.6	105 134

(v) Other cost

Since over a year the operation of ferries has ceased at the location of the bridge. During that period the ferry ghat have been damaged by the river and to start operation again would involve additional cost. Reparation of the existing ferry ghats is expected to cost Tk. 20 million (Tk. 200 lakh).

10.8.4.2 Avoidable repair costs

Three situations with a different degree of damage to the bridge have been investigated. For these situations the incremental failure probability has been assessed, the repair costs have been estimated and the period of disruption of transport indicated.
Since no detailed cost information was obtained related to the construction of the bridge, the preliminary cost estimates have been based on adjusted figures from the Jamuna Bridge. The situations considered are characterized by:

(a) Failure of abutment

- Incremental probability estimated at 4.0 E-01
- Repair costs estimated at Tk. 8.9 million
- Disruption of traffic for a period of one year

(b) Failure of abutment and two spans

- Incremental probability estimated at 1.0 E-01
- Repair costs estimated at Tk. 177.1 million
- Disruption of traffic for a period of one and a half year

(c) Failure of embankment approach road

- Incremental probability estimated at 5.0 E-02
- Repair costs estimated at Tk. 295.2 million
- Disruption of traffic for a period of two years

10.8.4.3 Total avoidable transport and repair costs

Total costs for each of the failure scenarios have been summarized in Table 10.8.2.

TABLE 10.8.2 ADDITIONAL COSTS DUE TO DISRUPTION TRANSPORT OVER R&H BRIDGE

Prices: mid-1991 economic prices
Unit: Tk. x 1M

Item	Freq. (failure)	Dur.fail. (yrs)	Repair cost	Repair ferry gh.	Ec.cost pers.	Ec.cost cargo	Total cost
No failure	1.0E+00	0	0.0	0.0	0.0	0.0	0.0
Abutment failure	4.0E-01	1	8.9	20.0	137.9	105.1	271.9
Failure 2 spans	1.0E-01	1.5	177.1	20.0	206.9	157.7	561.7
Failure approach embankment	5.0E-02	2	295.2	20.0	275.9	210.3	801.3

Notes:
1) Tk. 36 is conversion rate for 1 US$

For each of the three situations the total costs of repair and additional transport and cargo handling have been estimated and these values have been correlated with the incremental failure probability of the bridge by fitting the Gumbel extreme value probability function. Based on this function and following the procedures outlined in the FPCO-guidelines for project assessment, the expected annual financial costs due to disruption of road traffic over the bridge has been evaluated at Tk. 223 million. Table 10.8.3 gives the mathematical expectation of annual avoided cost. Figure F.8.1 in Annex F, presents the frequency-damage relationship for the R&H Bridge.

TABLE 10.8.3 MATHEMATICAL EXPECTATION ANNUAL DAMAGE

PRICES: mid-1991 economic prices
UNIT: Tk x 1 million

	Return	SAVINGS REPAIR/ADD.COST:		
Freq. (non-exc)	period (yrs)	Total cost	C&F differ.	Cum C&F diff.
0.00%		0.0		0.0
10.00%		203.8	10.2	10.2
20.00%		252.0	22.8	33.0
30.00%		291.1	27.2	60.1
40.00%		327.8	30.9	91.1
50.00%	2	365.4	34.7	125.7
60.00%		406.4	38.6	164.3
70.00%		454.7	43.1	207.4
80.00%	5	517.8	48.6	256.0
90.00%	10	618.8	56.8	312.9
95.00%	20	715.6	33.4	346.2
95.90%	24	743.0	6.6	352.8
97.50%	40	810.6	12.4	365.2
98.00%	50	841.0	4.1	[illegible]
99.00%	100	934.9	8.9	378.2
99.40%	167	1,003.9	3.9	382.1
99.50%	200	1,028.5	1.0	383.1
99.86%	709	1,199.1	4.0	387.1
99.90%	1000	1,245.3	0.5	387.6
99.97%	3546	1,415.7	1.0	388.6
99.99%	16129	1,619.5	0.3	388.9

10.8.5 Costs of the river bank protection

Five alternatives for protection have been considered. Four scenarios for protecting the bridge include repairing the existing bank protection and protection of the ferry ghat and vortex area. In two scenarios protection works are combined with a groyne of 200 metre, which is constructed in the river some 2 kilometres upstream.
A fifth scenario comprises a groyne stretching out from the ferry ghat downstream.
Table 10.8.4 gives a summary of investment cost.

Monitoring and maintenance of protection structures is an important component, which affects directly the long term effectiveness of protection works. Monitoring and maintenance are an integral part of river bank protection, the probability of failure of the structures may very well increase rapidly in the future if they are poor.

Monitoring activities comprise sounding of bed and bank level. They are estimated at Tk 2.0 million per annum in economic terms. After critical judgement of protection work items it is assumed that annual maintenance is 4.0% of the investment costs of all revetment components. Table F.8.7 provides details on annual monitoring and maintenance.

TABLE 10.8.4 SUMMARY OF INVESTMENT COST

Type	Investment cost and year	Local/foreign currency
Repair existing protection, ferry ghat and vortex	1993: MTk. 184.0	Local: 55% Foreign: 45%
Repair existing protection, ferry ghat and vortex plus groyne of 200m	1993: MTk. 184.0 2003: MTk. 312.2	Local: 43% Foreign: 57%
Repair existing protection, ferry ghat and vortex plus groyne of 200m	1993: MTk. 237.9	Local: 43% Foreign: 57%
Repair existing protection, ferry ghat and vortex	1993: MTk. 151.8	Local: 51% Foreign: 49%
Guiding spurdik[illegible] groyne	1993: MTk. 126.8	Local: 66% Foreign: 34%

Budgetary implications of the bank protection works relate in general to recurrent cost, which must be met by the national budget. The following cost are considered to be covered by this budget:
In Annex F, Table F.8.8 an overview of current expenditure for monitoring and maintenance operations at the start of the project, after five years and in the year 2008.

10.8.6 Economic Evaluation

In Table 10.8.5 the economic cash flow is given for the groyne protection. The cash flow table requires no further discussion.

The rate achieved for all of the protection scenarios is very high above one hundred percent. Investment cost are fully repaid within the period of one year after completion. Hence, all protection scenarios are fully justified in economic terms.

The economic net present value for the five protection scenarios has been calculated for a discounting rate of 12% and amounts to over Tk 2000 million for the groyne alternative solution. The NPVR ratio as required by the FPCO-guidelines reaches 12.8.

The conclusion drawn from this preliminary analysis is obviously that the additional bank protection works to guarantee the stability of the bridge show a very high EIRR and are fully justified in economic terms. A sensitivity or multicriteria analysis is, at this preliminary stage, therefore not considered required.

TABLE 10.8.5 ECONOMIC CASH FLOW FOR PROTECTION OF THE MEGHNA R&H BRIDGE BY A GUIDING SPURDIKE OR GROYNE

PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million
START: 1993
CONSTR. 1 years

EIRR: 189.88% NPV: 2074.1 NPVR1: 12.78

Year	WITH-PROJECT SITUATION COST Invest.	M&M	Other	Total	BENEFITS Bridge	CASH FLOW	Cash F (USSx1M)
1993	126.8	2.3	0.1	129.3	0.0	-129.3	-3.59
1994	0.0	2.3	0.1	2.5	244.0	241.5	6.71
1995	0.0	2.3	0.1	2.5	251.3	248.8	[illegible]
1996		2.3	0.1	2.5	258.8		7.12
1997		2.3	0.1	2.5	266.6	264.1	7.34
1998	0.0	2.3	0.1	2.5	[illegible]	272.1	7.56
1999		2.3	0.1	2.5	[illegible]	280.4	7.79
2000		2.3	0.1	2.5	291.3	288.9	8.02
2001		2.3	0.1	2.5	300.1	297.6	8.27
2002		2.3	0.1	2.5	309.1	306.6	8.52
2003		2.3	0.1	2.5	318.3	315.9	8.77
2004		2.3	0.1	2.5	327.9	325.4	9.04
2005	0.0	2.3	0.1	2.5	337.7	335.3	9.31
2006		2.3	0.1	2.5	347.9	345.4	9.59
2007		2.3	0.1	2.5	358.3	355.8	9.88
2008		2.3	0.1	2.5	369.0	366.6	10.18
2009		2.3	0.1	2.5	380.1	377.6	10.49
2010		2.3	0.1	2.5	391.5	389.0	10.81
2011		2.3	0.1	2.5	403.3	400.8	11.13
2012		2.3	0.1	2.5	415.4	412.9	11.47
2013		2.3	0.1	2.5	427.8	425.4	11.82
2014		2.3	0.1	2.5	440.7	438.2	12.17
2015		2.3	0.1	2.5	453.9	451.4	12.54
2016		2.3	0.1	2.5	467.5	465.0	12.92
2017		2.3	0.1	2.5	481.5	479.0	13.31
2018		2.3	0.1	2.5	496.0	493.5	13.71
2019		2.3	0.1	2.5	510.8	508.4	14.12
2020		2.3	0.1	2.5	526.2	523.7	14.55
2021		2.3	0.1	2.5	541.9	539.5	14.99
2022		2.3	0.1	2.5	558.2	555.7	[illegible]
SUM	126.8	70.3	3.8	200.9	11032.5	[illegible]	[illegible]

Notes:

1) INVESTMENT COST (Tk. x 1M):

Year	1993	126.8
	1998	0.0
	2005	0.0

2) O&M COST (Tk. x 1M):

Maintenance:	1993	0.3
	1998	0.0
	2005	0.0
Monitoring		2.0

3) OTHER COST:

Tk. x 1M 0.1

4) BENEFITS (Tk. x 1M):

Savings repair cost 223.3
Annual increase 3%

5) Conversion USS 1 = Tk. 36

10.9 Maniknagar

10.9.1 Present Situation

Maniknagar is situated on the left bank of the Meghna, south of Bhairab Bazar. Erosion has attacked the river bank for more than a decade and is the result of both current and wave action. Agriculture is the main economic activity in the area. The area is the location for the future Gumti phase II project and erosion could very well threaten this irrigation project in the future.

The feasibility of the Gumti II project was studied in 1990 by a consortium of Bureau of Consulting Engineering Ltd. of Bangladesh and Sir William Halcrow and Partners Ltd. of the United Kingdom. The aim of the project is to increase agricultural production. For protection against floods a new embankment at some distance of the river was planned. However, the scope was not on river training works to avert erosion of the proposed embankment.

Without adequate protection the outer bend of the Meghna could migrate some 700 m inland in the coming 30 years and destroy the bazar. A substantial area of agricultural land would be engulfed as well. Hence, benefits of river training and bank protection works relate to a reduction of agriculture and urban losses.

10.9.2 Area affected

Along the shore of the Meghna there are a number of habitations and small commercial enterprises, which would be protected.
The area of influence of the proposed river training and protection works reaches from the point where the Meghna splits in two arms just south of Bhairab Bazar to where both arms confluence again. The area protected covers lands bordering the river which will be parts of the future Gumti phase II irrigation project.

The economic pre-feasibility analysis covers four alternatives, notably (a) protection through groynes, (b) overall bank protection works over a length of 5,000 m, (c) a series of sand-sausages and (d) closure of the river arm at the bifurcation upstream of Maniknagar. A comparison is made between a future scenario with river training or protection works (with-scenario) and without any works being implemented (without-scenario).

10.9.3 Alternative bank protection works

Four types of river bank protection have been investigated, notably (a) one large groyne or a series of groynes, (b) revetment of the existing bank, (c) sand-sausages in the river to train the flow and (d) closure of the river arm.

10.9.4 Benefits of Maniknagar of protection works

10.9.4.1 Reduction in repair and maintenance xpenses

Maintenance and repair expenses for damage caused by the Meghna have been negligible in the past. There is every reason to believe that this will remain so in the future without-scenario situation. Hence, there are no savings in maintenance and repair expenses which can be attributed to protection works.

10.9.4.2 Destruction of buildings and urban infra-structure

River bank erosion will cause loss of buildings and damage to existing structures. Some inhabitants move their homes every now and then more inland to protect them from the water of the Meghna during

২৭২

the flood season. However, other houses and commercial buildings in the area are still prone to erosion. Many houses are simple one-storey kutcha structures which have a marginal value and can be moved at low cost, mainly labour.

From the results of the geo-morphological study (see Annex B) it could be estimated how far the bank line will recede and how much land is likely to disappear. To estim... ...age value of public and private property per square meter for Maniknagar, the same assumptions have been made as for Eklashpur and Haimchar, yielding an value of Tk 799. See Chapters 6 and 7 of this Annex.

Apart from the infra-structural losses as a result of bank erosion, there is also loss of land to be considered. The fact that it washes away and is lost means that it must be considered in the economic evaluation. However, all land was accounted for in the analysis of agricultural production, assuming that agriculture is the nearest-best economic activity. Moreover, double-counting has thus been avoided.

10.9.4.3 Agriculture

The actual cropping pattern in the area was derived from the feasibility study of the Gumti phase II project. Net economic return of irrigated agriculture were adapted from Thompson (1990) and from results of work done by FAP 5. The annual net economic revenues of agricultural area lost due to erosion are taken into account as benefit of works undertaken at Maniknagar.

Apart from the annual net revenue of the area inside the embankment otherwise lost, a value of Tk. 1,677 per hectare associated with the irrigation infra-structure can also be considered as avoidable costs and, hence, as benefit of protection works in Maniknagar. This figure was derived from data supplied by FAP 5.
The net annual economic revenues of actual cropping in the Gumti irrigation project have been evaluated at Tk. 10.593 per ha. Details are reported in Table 10.9.1.

TABLE 10.9.1 ANNUAL NET REVENUES PER HECTARE GUMTI PHASE II

PRICES: constant mid-1991 economic prices
UNIT: Tk.

Item	Unit	Unit return	Fraction in area	Annual return
Culivation:				
Rabi crops 1)	ha	6 755	37.8%	2 553
HYV Boro	ha	9 522	17.3%	1 647
B Aus	ha	316	15.1%	48
TL Aman	ha	6 594	74.8%	4 932
Sub-total	ha		82.1%	9 180
Fish-ponds 2)	yr	20 736	6.8%	1 410
Orchards 2)	yr	218	1.1%	2
Other areas			10.0%	
TOTAL				10 593
Rental value				51 681

Notes:
1) Rabi crop considered is wheat
2) Returns are adapted from Thompson (1990)
3) Rental value is adapted from crop budgets

Apart from the loss of agricultural production as a result of bank erosion, there is also the reduction in loss of land as a productive asset to be considered.

The capitalized economic rental value of land has been considered in the economic evaluation. This value has been estimated at Tk. 51.681 per ha.

Table 10.9.2 provides details of total agricultural benefits over the 30-year period of the feasibility study. In the table with and without-project scenarios are compared. Benefits of river training works are given by the balance, which represents the reduction in losses to cropping.

10.9.5 Cost of alternative protection options

10.9.5.1 Investment cost

Estimated cost for river training works are based on the preliminary design. Economic investment cost for a large groyne at Maniknagar is estimated at US$ 7.38 million, which equals to Tk. 265.6 million. An estimated 43% of investment cost are local currency expenditure and the foreign component amounts to 57%. Also evaluated is the construction of a series of groynes, costing US$ 9.55 million or Tk. 343.7 million. No details are provided on construction of a closure dam because this solution may face strong resistance from river transporters and fisherman.

An second design for protection has been made, notably a continuous revetment of the existing bank. This type of protection is costing US$ 12.97 million or Tk 466.7 million. Local currency expenditure is 50% and foreign component totals 50%.

The third option comprises of sand-sausages to train the river. For this type of investment economic investment cost are estimated at US$ 15.4 million or Tk. 554.9 million. An estimated 40% of investment cost are local currency expenditure and the foreign component is 60%. Table 10.9.3 provides a summary of investment cost for all three options.

Monitoring comprises regular inspection of structures as well as topographic and bathymetrical measurements. Annual maintenance is estimated at 4% of surface components, e.g. open stone asphalt, fascine mattress, boulders in falling apron and grouting of boulders.

Sand-sausages requires very few maintenance, although they have to be monitored more frequently to deter any damage.

Monitoring and maintenance expenditure for river training works must normally be met by the national budget. Assuming a general level of price increase of 10% per annum, means that the cost met by the budget increase substantially over the years. Moreover, expenses for environmental monitoring and, if such is necessary, mitigative measure must equally be met by the national budget.

In Annex F, Table F.9.6 a summary is presented of current expenditure for monitoring and maintenance operations at the start of the project, after five years and in the year 2008.

10.9.6 Economic evaluation

The computation of the cash flow has been limited to the most profitable alternative. Table 10.9.4 provides the cash flow for river training by a large groyne.

The construction of a groyne just gives a positive EIRR. This means that the economic value of the interests to be protected are just offset by the costs of the protective measures. All other protection options show a negative EIRR. Hence, none is acceptable on economic grounds.

The economic NPV has been calculated for a discount rate of 12% and found to be negative for all options considered. The NPVR ration as required by the FPCO-guidelines has been evaluated at -0.53.

A sensitivity analysis, nor a multicriteria analysis, will give any added value to the conclusions drawn from this preliminary analysis and have not been presented in this report.

TABLE 10.9.2 AGRICULTURAL BENEFITS

PRICES: constant mid-1991 economic prices
UNIT: Tk x 1000

Year	SITUATION [WO]: Area lost(ha)	Product. loss(CUM)	Land+Infr value	Total
1993	16.3	166.8	871.6	1 038.4
1994	11.4	283.3	609.2	892.6
1995	11.4	399.9	609.2	1 009.1
1996	11.4	516.4	609.2	1 125.7
1997	.4	633.0	609.2	1 242.2
1998	11.4	749.6	609.2	1 358.8
1999	13.6	888.3	725.5	1 613.8
2000	13.6	1 027.1	725.5	1 752.6
2001	13.6	1 165.9	725.5	1 891.4
2002	13.6	1 304.7	725.5	[illegible]
2003	13.6	1 443.5	725.5	2 169.0
2004	14.1	1 587.0	750.1	2 337.1
2005	14.1	1 730.5	750.1	2 480.7
2006	14.1	1 874.1	750.1	2 624.2
2007	14.1	2 017.6	750.1	2 767.7
2008	14.1	2 161.1	750.1	2 911.2
2009	15.5	2 319.6	828.8	3 148.4
2010	15.5	2 478.2	828.8	3 307.0
2011	15.5	2 636.7	828.8	3 465.5
2012	15.5	2 795.3	828.8	3 624.1
2013	15.5	2 953.9	828.8	3 782.6
2014	16.6	3 123.4	886.3	4 009.7
2015	16.6	3 293.0	886.3	4 179.3
2016	16.6	3 462.6	886.3	4 348.8
2017	16.6	3 632.1	886.3	4 518.4
2018	16.6	3 801.7	886.3	4 688.0
2019	18.2	3 987.9	973.1	4 961.0
2020	18.2	4 174.0	973.1	5 147.2
2021	18.2	4 360.2	973.1	5 333.4
2022	18.2	4 546.4	973.1	5 519.6
SUM	445.4	65 513.9	23 763.5	89 277.4

Notes:.
1) Tk. 1 677 per ha is the value of irrigation i :ra-structure based on an analysis of data from SERWRDP (FAP5)
2) At 50% is estimated the level of irrigation in the Maniknagar region
3) Tk. 10 593 is the economic unit value of land in the Maniknar - region
Tk. 9 824 is the economic value of non-irrigated land

TABLE 10.9.3 SUMMARY OF ECONOMIC INVESTMENT COST FOR WORKS AT MANIKNAGAR

Type	Investment cost and year	Local/foreign currency
Large groyne	1993: MTk. 265.6	Local: 43% / Foreign: 57%
Series of groynes	1993: MTk. 343.7	Local: 45% / Foreign: 55%
Overall bank protection (5,000 m)	1993: MTk. 466.7 (1)	Local: 50% / Foreign: 50%
Sand-sausages	1993: MTk. 554.9	Local: 40% / Foreign: 60%

TABLE 10.9.4 ECONOMIC CASH FLOW MANIKNAGAR RIVER TRAINING WORKS (LARGE GROYNE)

PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million
START: 1993
CONSTR: 1 years

EIRR: 0.17% NPV: -190.6 NPVR1: -0.56

	WITH-P[illegible]ATION COST:				BENEFITS:				CASH	Cash F.
Year	Invest.	M&M	Other	Total	Repair c.	Urban pr.	Agric.	Total	FLOW	(US$x1M)
1993	265.6	5.0	0.3	270.9	0.0	0.0	0.0	0.0	-270.9	-7.5
1994	0.0	5.0	0.3	5.2	0.0	9.1	0.9	10.0	4.8	0.1
1995	0.0	5.0	0.3	5.2	0.0	9.1	1.0	10.1	4.9	0.1
1996		5.0	0.3	5.2	0.0	9.1	1.1	10.3	5.0	0.1
1997		5.0	0.3	5.2	0.0	9.1	1.2	10.4	5.1	0.1
1998		5.0	0.3	5.2	0.0	9.1	1.4	10.5	5.2	0.1
1999		5.0	0.3	5.2	0.0	10.9	1.6	12.5	7.2	0.2
2000		5.0	0.3	5.2	0.0	10.9	1.8	12.6	7.4	0.2
2001		5.0	0.3	5.2	0.0	10.9	1.9	12.8	7.5	0.2
2002		5.0	0.3	5.2	0.0	10.9	2.0	12.9	7.7	0.2
2003		5.0	0.3	5.2	0.0	10.9	2.2	13.0	7.8	0.2
2004		5.0	0.3	5.2	0.0	11.2	2.3	13.6	8.3	0.2
2005		5.0	0.3	5.2	0.0	11.2	2.5	13.7	8.5	0.2
2006		5.0	0.3	5.2	0.0	11.2	2.6	13.9	8.6	0.2
2007		5.0	0.3	5.2	0.0	11.2	2.8	14.0	8.8	0.2
2008		5.0	0.3	5.2	0.0	11.2	2.9	14.1	8.9	0.2
2009		5.0	0.3	5.2	0.0	12.4	3.1	15.6	10.3	0.3
2010		5.0	0.3	5.2	0.0	12.4	3.3	15.7	10.5	0.3
2011		5.0	0.3	5.2	0.0	12.4	3.5	15.9	10.6	0.3
2012		5.0	0.3	5.2	0.0	12.4	3.6	16.0	10.8	0.3
2013		5.0	0.3	5.2	0.0	12.4	3.8	16.2	11.0	0.3
2014		5.0	0.3	5.2	0.0	13.3	4.0	17.3	12.0	0.3
2015		5.0	0.3	5.2	0.0	13.3	4.2	17.5	12.2	0.3
2016		5.0	0.3	5.2	0.0	13.3	4.3	17.6	12.4	0.3
2017		5.0	0.3	5.2	0.0	13.3	4.5	17.8	12.6	0.3
2018		5.0	0.3	5.2	0.0	13.3	4.7	18.0	12.7	0.4
2019		[illegible]	0.3	5.2	0.0	14.6	5.0	19.5	14.3	0.4
2020		5.0	0.3	5.2	0.0	14.6	5.1	19.7	14.5	0.4
2021		5.0	0.3	5.2	0.0	14.6	5.3	19.9	14.7	0.4
2022		5.0	0.3	5.2	0.0	14.6	5.5	20.1	14.9	0.4
SUM	265.6	149.3	8.0	422.9	0.0	343.0	88.2	431.2	8.3	0.2

Notes:

			Large groyne	Serie of groynes
1) INVESTMENT COST:				
Tk. x 1M	265.6		265.6	343.7
2) M&M COST (Tk. x 1M):				
Maintenance	3.0		3.0	6.2
Survey cost	2.0		2.0	2.0
3) OTHER COST:				
Tk. x 1M	0.3	EIRR:	0.17%	0.00%
4) BENEFITS (Tk. x 1M):		NPV:	-190.6	-287.2
Savings repair	0.0	NPVR:	-0.56	-0.63
Annual mainten.	0.0			
Annual increase	10%			
5) Conversion US$ 1 = Tk.	36			

PV(12%) benefits	
Tk. x 1M	88.8
US$ x 1M	2.5

The conclusions drawn from this preliminary assessment are summarized below:

(i) Bank protection works to protect the present-day infrastructural and economic interests along the river bank are only marginally cover the associated costs. They are therefore not attractive from the economic point of view.

(ii) Within the framework of the Gumti II Project the benefits of bank protection works have to be compared with the option to witndraw the originally planned embankment alignment over about 700 m.

10.10 Left Bank of the Lower Meghna River

10.10.1 Introduction

The Lower Meghna is the largest river of the region, discharging the flows from the Ganges, Jamuna and Meghna into the Bengal Gulf. Year after year the course of the Lower Meghna has shifted towards the east despite all efforts made by the authorities. Although, much attention has been paid in the past to protect the town of Chandpur and irrigation projects upstream and downstream of the town, no comprehensive concept has been proposed yet for long term protection.

Within the terms of reference of the Meghna River Bank Protection Short Term Study an assessment of an overall protection of the Lower Meghna was not included, although the short term measures to be proposed must be sustainable by themselves and must also allow being included in a long term strategic development plan of the Lower Meghna. Therefore, a preliminary assessment has been made of a possible river training scheme aiming at a complete regulation of the Lower Meghna incorporating the short term measures designed for Eklashpur, Chandpur and Haimchar.

In addition to the short term bank protection works elaborated for Eklashpur, Chandpur and Haimchar, preliminary designs have been prepared for structures in the intermediate zone, covering the area between Eklashpur and Chandpur and the area from Chandpur to Haimchar, aiming at fixing the left bank of the Lower Meghna in its present position.

At this stage of the study, only a preliminary economic assessment of of the long term protection scheme for the left bank of the Lower Meghna could be prepared. The basis of the assessment is provided by the sustained protection works for Chandpur town in combination with the short term protection works at Eklashpur and Haimchar and completed by protection works in the intermediate zone.

The methodology followed for the economic assessment of the long term bank protection scheme is largely based on data [illegible] the calculation of economics of protecting Chandpur, Eklashpur and Haimchar. Hence, reference is made to chapters 10.2, 10.5, 10.6 and 10.7 of this Annex.

10.10.1.2 Area covered

The feasibility assessment covers the left bank of the Lower Meghna where river bank protection and river training works are envisaged which are aimed at keeping the river within it present bed. The area covered ranges from the confluence of the Meghna and Padma just north of Eklashpur to Haimchar some 10 km south of Chandpur. Figure 10.10.1 provides an overview of the area involved.

10.10.2 Alternatives for protection

The construction of long term protection works for the left bank of the Lower Meghna comprise a series of bank protection and river training structures. As a result of the preliminary nature of the analysis only one alternative was investigated which consists of the following works:

(a) Protection of the existing bank at Eklashpur to be executed in 1993, 1998 and 2005.

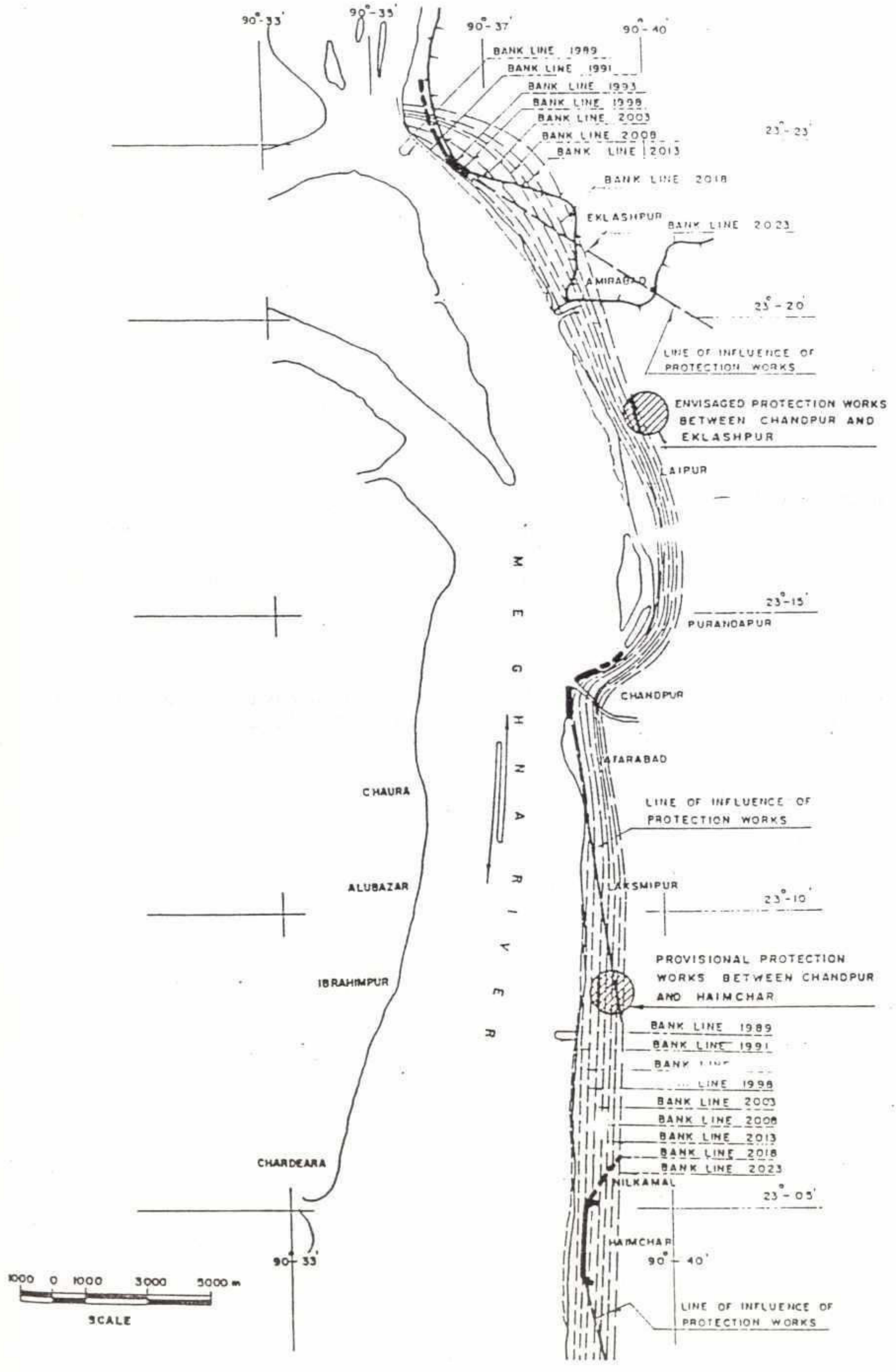
(b) Protection works between Eklashpur and Chandpur, envisaged for the year 2002.

(c) Sustainable town protection at Chandpur, first phase in 1993 and additional works to be executed in and 2002 [illegible]

(d) Protection between Chandpur and Haimchar, planned for the year 2002.

(e) Guide bund protection works at Haimchar to be executed in 1993, 1998 and 2008.

FIGURE 10.10.1 AREA COVERED BY THE LOWER MEGHNA ECONOMIC ASSESSMENT



10.10.3 Benefits of protection

10.10.3.1 Protection of Chandpur

Reference is made to section 10.5.4 of annex F. The following paragraph summarizes the results of the calculation of benefits for protection of Chandpur town.

(i) Savings on repair and maintenance, damage and loss

Based on total economic repair and maintenance expenses and cost of erosion damage for the recent past expected savings as a result of protection works are calculated. It is assumed that the annually recorded and estimated economic repair and maintenance expenses and cost of erosion damage have an extreme value distribution. The annual figures are ranked in size and a frequency is assigned in agreement with their ranking. The expenses are then correlated with their respective frequency by fitting the Gumbel extreme value probability functic In agreement with the FPCO-guidelines the mathematical expectation of avoidable cost can be calculated.

The matl.ematical expu...ion of annual avoidable costs due to repair, maintenance, loss, damage and lost profits, is evaluated at Tk. 85 million economically. Of this Tk. 15 million refer to repair and maintenance expenses, while Tk. 71 million are the result of avoidable losses and damage to structures and economic activities. Details are presented in Annex F, Section 10.5.4.4.
As a result of ongoing erosion over the years the expected value of the annual avoidable costs identified above are assumed to increase. Savings in repair and maintenance expenses are likely to increase by a 10% per annum, while avoidable losses and damage to structures and net economic returns increase by 3% per annum. This increase is not related to changes in the prices of commodities, but reflects merely aspects related to ever increasing cost to protect Chandpur, as well as population growth and increase of economic activity.

(ii) Railway complex and IWTA terminal

Protection of the town of Chandpur would avoid the engulfment of the railway complex and the IWTA terminal. Details of the cost avoided are presented in Annex F, Section 10.5.4.5. Benefits range between Tk. 1.4 million per year and Tk. 4.7 million per year depending on the stage of erosion.

(iii) Agricultural benefits

The agricultural benefits as a result of protection works at Chandpur are associated with the protection of arable land of the Meghna-Dhonagoda and Chandpur Irrigation projects upstream and downstream of Chandpur due to the permanent bank protection works proposed in the project. In agreement with the FPCO-guidelines th... result from a reduction of net agricultural revenues lost and loss of irrigation infra-structure or land due to erosion. Details are presented in section 10.5.4.5 of this annex and are summarized in Tables 10.5.9 and 10.5.10.

10.10.3.2 Protection Eklashpur

A detailed discussion of benefits related to protection works in Eklashpur is provided in section 10.6.4. This section summarizes the results.

(i) Savings on repair and maintenance

Without any protection works a retirement of the embankment is foreseen every five years from 1998 onwards. Because only small sections of the embankment are renewed, emergency protection cannot be neglected altogether. Based on the considerable amount spent by the BWDB in 1990/91, we expect that annual amounts for repair and maintenance will rapidly increase. For the 1991 situation an anual repair and maintenance budget of Tk. 2.6 million has been estimated. This value is expected to increase annually by about 10%.

(ii) Relocation of pump station

One pump station of the Meghna-Dhonagoda irrigation project is located at a spot which could be eroded by the river in the year 1998, according to the results of the geo-morphological study. A relocation of this pump station to a site more inland is needed. The estimated economic cost for relocation of the pump station are Tk. 32.4 million.

(iii) Retirement of embankments

As the river bank shifts towards the east, it will destroy the existing embankment. From the results of the geo-morphological study (see Annex B) it could be estimated how far the bank line will recede. The without-project scenario foresees that every five years a new stretch of embankment must be constructed in order to protect the Meghna-Dhonagoda irrigation project. Because, no new retired embankment construction is required if the proposed protection works are implemented, the cost figures from the table are savings. Hence, they represent expected benefits. A summary is given in Table 10.6.2.

(iv) Damage and loss to public and private property

River bank erosion will cause loss of buildings and damage to existing structures. Already inhabitants have moved their homes more inland to protect them from the water of the Meghna. However, there remain a considerable number of houses and commercial buildings in the area prone to erosion. for details on the avoidable damage and destruction to urban structure reference is made to section 10.6.4.4. In Table 10.6.3 the balance of damage to and destruction of urban assets ara presented for the with- and without scenarios.

(v) Agricultural benefits

Agricultural benefits are associated with protection of arable land which would otherwise be lost as a result of bank migration. Behind the embankment one finds mainly irrigated lands, while outside the embankment non-irrigated cropping takes place. Hence, for economic feasibility analysis it has been assumed that irrigated agriculture takes place inside the embankment and non-irrigated agriculture outside it. Details on the agricultural benefits are presented in section 10.6.4.5 and reference is made to Table 10.6.5.

10.10.3.3 **Protection of Haimchar**

A detailed discussion of benefits related to protection works in Eklashpur is provided in section 10.7.4. This section summarizes the outcome.

(i) Savings on repair and maintenance

Maintenance and repair of the embankments of the Chandpur irrigation project is carried out each year by the BWDB. In the past the allocated amount has been very small. However, a retirement of the embankment is foreseen every five years from 1993 onwards. Because only small sections of the embankment are renewed, emergency protection and repair cannot be neglected altogether. Similar estimates as made for Eklashpur were made for the annual amount to be spend on repair and maintenance of the non-sustainable bank protection works on Haimchar in the without-scenario. An annual expenditure of Tk. 2.4 million has been estimated. This amount is expected to increase by an annual 10%.

(ii) Retirement of embankments

As the river bank shifts towards the east, it will destroy the existing embankment. From the geo-morphological survey results it could be estimated how far the bank line will progress. The without-project scenario foresees that every five years a new stretch of embankment must be constructed in order to protect the Chandpur irrigation project. Reference is made to Table 10.7.2 for details on the cost of the retired embankments envisaged. Because, no new retired embankment construction is required if the proposed river training or protection works are implemented, the cost figures from the table are savings. Details are presented in section 10.7.4.2 of this annex.

(iii) Dam... and loss of public and private infrastructure

River bank erosion has caused loss of buildings and damage to existing structures in the recent past. Already inhabitants have moved their homes more inland to protect them from the water of the Meghna. However, a considerable number of houses and commercial buildings in the area is still prone to erosion. In section 10.7.4.3 and Table 10.7.3 the balance of damage to and destruction of houses and commercial buildings has been presented for the with- and without-scenarios.

(iv) Agricultural benefits

Agricultural benefits are associated with protection of arable land which would otherwise be lost as a result of bank migration. In agreement with the FPCO-guidelines the agricultural benefits of river training and bank protection works result from reduction of net agricultural revenues lost due to erosion of arable land. Based on the results of the geo-morphological survey for the area, the change of the river bank position could be forecast for scenarios with and without investments.

Table 10.7.5 provides details of total agricultural benefits on lands prone to erosion covering the 30-year period of the feasibility study. In the table with and without-project scenarios are compared. Benefits of river training works are given by the balance, which represents the reduction in losses to cropping. More details can be found in section 10.7.4.4.

10.10.3.4 Protection of the intermediate zone

The calculation of benefits in the intermediate zone comprises reduced losses to urban infra-structure and agriculture. Based on the results of the geo-morphological study it has been estimated that without protection 1,200 ha would be lost from the year 2002 until 2022. The annual losses are estimated as the average yearly erosion between 2002 and 2022, which is 57 ha per year. It is assumed that there is no need for retirement of the embankments of the Meghna-Dhonagoda and Chandpur Irrigation Projects.

(i) Damage to and loss of urban infra-structure

As everywhere in Bangladesh the population lives along the river banks, where at regular intervals one finds clusters of houses. Often such clusters form a village with a small market. Although many houses will be moved when the waters of the Meghna rise, damage to and loss of structures are still to be expected every year. Protection against bank erosion will prevent the loss of houses and market infra-structure. The benefits as a result of avoidable losses in urban infra-structure are calculated in the same manner as for Eklashpur or Haimchar. Table 10.10.1 provides a summary of these losses for the whole of the Lower Meghna.

(ii) Agricultural benefits

Agricultural benefits are associated with protection of arable land which would otherwise be lost as a result of bank migration. In agreement with the FPCO-guidelines the agricultural benefits of river training and bank protection works result from reduction of net agricultural revenues lost due to erosion of arable land. Most of the lands prone to erosion form part of the Meghna-Dhonagoda and Chandpur Irrigation projects.

The production value and rental value of land lost as a result of erosion is based on the assumption that the average of those values for Eklashpur and Haimchar give a good estimate of the values for the intermediate zone. Based on the annual loss of 57 ha per year between 2002 and 2022, the avoidable agricultural losses are calculated. Table 10.10.2 summarizes the total losses to the agriculture for the Lower Meghna.

TABLE 10.10.1 VALUE OF DESTRUCTED BUILDINGS AND URBAN INFRA-STRUCTURE FOR THE LOWER MEGHNA

PRICES: constant mid-1991 economic prices
UNIT: Tk x 1M

	EKLASH.	HAIM.	INTERMEDIATE ZON		TOTAL
Year	Total	Total	Area(ha)	U.assets	
1993	1.4	0.0	0.0		1.4
1994	2.1	0.0	0.0	0.0	2.1
1995	2.1	0.0	0.0	0.0	2.1
1996	2.1	0.0	0.0	0.0	2.1
1997	2.1	0.0	0.0	0.0	2.1
1998	2.1	0.0	0.0	0.0	2.1
1999	23.4	4.2	0.0	0.0	27.6
2000	23.4	4.2	0.0	0.0	27.6
2001	23.4	4.2	0.0	0.0	27.6
2002	23.4	4.2	57.1	4.6	89.3
2003	23.4	4.2	57.1	4.6	89.3
2004	35.9	16.7	57.1	4.6	114.4
2005	35.9	16.7	57.1	4.6	114.4
2006	35.9	16.7	57.1	4.6	114.4
2007	35.9	16.7	57.1	4.6	114.4
2008	35.9	16.7	57.1	4.6	114.4
2009	18.8	14.9	57.1	4.6	95.5
2010	18.8	14.9	57.1	4.6	95.5
2011	18.8	14.9	57.1	4.6	95.5
2012	18.8	14.9	57.1	4.6	95.5
2013	18.8	14.9	57.1	4.6	95.5
2014	30.1	24.7	57.1	[illegible]	116.5
2015	30.1	24.7	57.1	4.6	116.5
2016	30.1	24.7	57.1	4.6	116.5
2017	30.1	24.7	57.1	4.6	116.5
2018	30.1	24.7	57.1	4.6	116.5
2019	48.9	33.0	57.1	4.6	143.6
2020	48.9	33.0	57.1	4.6	143.6
2021	48.9	33.0	57.1	4.6	143.6
2022	48.9	33.0	57.1	4.6	143.6
SUM	748.8	434.6	1 200.0	95.9	2 479.3

Notes:
1) Table does not cover Chandpur town protection
2) Tk. 0.799 x 1000 per sq.m is the estimated average value of urban infra-structure and buildings
3) At 10% is estimated the urbanised area

10.10.4 Cost of protection works

10.10.4.1 Investment cost

Total investment cost for the Lower Meghna are high, although not all investments are made in the same year; implementation is staggered. The first part of protection w[illegible] constructed as short term protection in 1993. In later years more works are carried out in order to guarantee a long term sustainable bank protection of the Lower Meghnad. Table 10.10.3 provides details on the investment cost and the year construction would take place. It is noted that an additional investment of Tk. 270 million might be required between Eklashpur and Chandpur in the year 2002. This will reduce the EIRR by about 1%.

TABLE 10.10.2 AGRICULTURAL BENEFITS FOR THE LOWER MEGHNA

PRICES: constant mid-1991 economic prices
UNIT: Tk x 1M

Year	CHANDPUR		EKLASH	HAIM	INTERMEDATE ZONE:			TOTAL
	Upstr.	Downstr	Total	Total	Area(ha)	Prod(CUM	Infra/land	
1993	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
1994	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.4
1995	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.5
1996	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.5
1997	0.0	0.4	0.2	0.0	0.0	0.0	0.0	0.6
1998	0.0		0.2	0.0	0.0	0.0	0.0	0.7
1999	0.0	0.8	2.0	0.3	0.0	0.0	0.0	3.1
2000	0.3	0.9	2.2	0.3	0.0	0.0	0.0	3.7
2001	0.3	1.0	2.5	0.4	0.0	0.0	0.0	4.2
2002	0.4	1.1	2.8	0.4	57.1	0.6	3.9	66.2
2003	0.4	1.1	3.1	0.4	57.1	1.2	3.9	67.3
2004	0.5	1.8	4.2	1.5	57.1	1.8	3.9	70.8
2005	0.7	2.0	4.6	1.7	57.1	2.4	3.9	72.4
2006	0.8	2.1	5.0	1.9	57.1	3.0	3.9	73.9
2007	0.9	2.3	5.5	2.1	57.1	3.6	3.9	75.3
2008	0.9	2.5	5.9	2.3	57.1	4.2	3.9	76.8
2009	1.1	3.1	5.0	2.3	57.1	4.8	3.9	77.4
2010	2.2	3.3	5.2	2.5	57.1	5.4	3.9	79.7
2011	2.4	3.6	5.5	2.6	57.1	6.1	3.9	81.1
2012	2.6	3.8	5.7	2.8	57.1	6.7	3.9	82.5
2013	2.8	4.0	5.9	3.0	57.1	7.3	3.9	83.9
2014	3.0	4.5	7.1	3.9	57.1	7.9	3.9	87.4
2015	3.5	4.8	7.4	4.1	57.1	8.5	3.9	89.4
2016	3.8	5.1	7.8	4.4	57.1	9.1	3.9	91.1
2017	4.0	5.3	8.2	4.7	57.1	9.7	3.9	92.9
2018	4.2	5.6	8.5	5.0	57.1	10.3	3.9	94.7
2019	4.6	6.3	10.2	5.8	57.1	10.9	3.9	98.8
2020	5.5		10.7	6.2	57.1	11.5	3.9	101.6
2021	5.8	7.0	11.3	6.6	57.1	12.1	3.9	103.8
2022	6.2	7.3	11.9	7.0	57.1	12.7	3.9	106.1
SUM	56.9	87.7	149.2	72.1	1 200.0	139.8	81.1	1 786.8

Notes:

1) Total 1 200 ha land is saved as result of river training between Eklashpur and Chandpur-upstream and between Chandpur-downstream and Haimchar (intermediate zone)

2) Tk. 6 031 per ha is the value of irrigation infra-structure based on an analysis of data from SERWRDP (FAP5)

3) Tk 10 591 per ha is the economic production value of lands in the intermediate zone

4) Tk. 61 570 per ha is the average rental value of lands in the in the intermediate zone

10.10.4.2 Monitoring and maintenance cost

Monitoring and maintenance of river training works is an important component, which affects directly the long term effectiveness of protection against bank erosion. They form an integral part of protection works and the rate of failure of structures may increase rapidly in the future if maintenance works are carried out poorly.

TABLE 10.10.3 SUMMARY OF INVESTMENT COST FOR THE LOWER MEGHNA

PRICES: mid-1991 economic prices
UNIT: Tk. x 1M

Protection	Year investm.	Total cost	Annual maint.	Annual monitor.	Total
Chandpur town	1993	2 075.5	19.0	2.0	21.0
Haimchar (1st part)	1993	314.6	3.8	2.0	5.8
Eklashpur (1st part)	1993	290.3	3.5	2.0	5.5
Eklashpur (2nd part)	1998	236.5	2.8	2.0	4.8
Haimchar (2nd part)	1998	236.5	2.8	2.0	4.8
Chandpur (length 400m)	2003	216.0	2.6	2.0	4.6
Eklashpur (3rd part)	2005	236.5	2.8	2.0	4.8
Haimchar (3rd part)	2008	299.1	3.6	2.0	5.6
Total		3 904.9	40.9	16.0	56.9

Notes:
1) Maintenance % based on average of detailed designs:
average for LME investmen 1.20%
2) Compounded conversion factor for changing financial prices into economic prices is 0.8

Monitoring comprises regular inspection of structures as well as topographic and bathymetrical measurements. The annual cost of monitoring is estimated at Tk. 2.0 million per year (mid-1991 economic prices) per site. With protection works for which a detailed design and costing was prepared, annual maintenance is estimated at 4% of surface components, e.g. open stone asphalt, fascine mattress, boulders in falling apron and grouting of boulders. Annual maintenance for all other protection works was estimated from total investments by using the fraction of respective maintenance in total cost of works with a detailed design and costing. Details of monitoring and maintenance expenditure are provided in Table 10.10.3.

10.10.4.3 Budgetary implications

Monitoring and maintenance expenditure for river training works must normally be met by the national budget. Assuming a general level of price increase of 10% per annum, means that the cost met by the budget increase substantially over the years. As a result of staggered investments in protection works for the Lower Meghna, these cost increase dramatically. Annual monitoring and maintenance cost in current prices are calculated as follows:

- 1993: Tk. 39.3 million
- 1998: Tk. 82.3 million
- 2008: Tk. 289 million

10.10.5 Economic feasibility assessment

10.10.5.1 Cash flow

The cash flow computation makes a comparison between benefits and cost of river training works for the Lower Meghna, covering the 30-year evaluation period. The benefit and cost have been discussed in detail in the previous sections. For reasons already explained in e.g. Chapter 10.2, it has been assumed that the avoidable maintenance and repair expenses increase annually by 10%. This increase is justified by the ever increasing cost of protecting land against the water of the Meghna in the present situation without sustainable river bank protection. Other benefits associated with population growth and increasing economic activities have been assumed to increase by 3% per year. This reflects the economic growth of Bangladesh, which was between 3 and 4% over the last planning period.

Table 10.10.4 provides the outcome of the cash flow calculation. The figures in rows for town protection benefits and avoidable repair and maintenance expenses are higher than the mid-1991 economic values; they have been increased with the annual growth percentage for the respective years of the cash flow. Moreover, the method of calculation and the table require no further explanation.

TABLE 10.10.4 ECONOMIC CASH FLOW FOR LOWER MEGHNA RIVER BANK PROTECTION

PRICES: mid-1991 economic prices
UNIT: Tk. x 1 million
STARTING 1993
CONSTR: 1 years

EIRR: 6.69% NPV: -1313.5 NPVR1: -0.34

	WITH-PROJECT SITUATION COST:				PROJECT BENEFITS:						CASH	Cash F.
Year	Invest.	S&M	Other	Total	T.prot.	BR/IWTA	Rep/maint.	Nw.emb.	Rural	Total	FLOW	(USSx1M)
1993	2680.3	32.3	2.7	2715.2				9.4		9.4	-2705.8	-75.2
1994		32.3	2.7	34.9	77.8	3.8	26.5		2.5	110.6	75.7	2.1
1995		32.3	2.7	34.9	80.1	3.8	29.2		2.6	115.7	80.8	2.2
1996		32.3	2.7	[illegible]	82.5	3.8	32.1		2.6	121.1	86.2	2.4
1997		[illegible]	[illegible]	34.9	85.0	3.8	35.3		2.7	126.9	91.9	2.6
1998	473.0	41.9	3.2	518.1	87.6	4.7	38.9	66.1	2.8	200.0	-318.1	-8.8
1999		41.9	3.2	45.1	90.2	4.7	42.8		30.7	168.3	123.3	3.4
2000		41.9	3.2	45.1	92.9	4.7	47.0		31.3	176.0	130.9	3.6
2001		41.9	3.2	45.1	95.7	4.7	51.7		31.8	183.9	138.8	3.9
2002	0.0	41.9	3.2	45.1	98.6	4.7	56.9		155.5	315.7	270.6	7.5
2003	216.0	46.5	3.4	265.9	101.5	4.0	62.6	49.3	156.6	374.0	108.2	3.0
2004		46.5	3.4	49.9	104.6	4.0	68.9		185.1	362.6	312.7	8.7
2005	236.5	51.8	3.6	291.9	107.7	4.0	75.7		186.8	374.3	82.3	2.3
2006		51.8	3.6	55.4	110.9	4.0	83.3		188.3	386.5	331.1	9.2
2007		51.8	3.6	55.4	114.3	4.0	91.7		189.7	399.6	344.2	9.6
2008	299.1	58.0	3.9	360.9	117.7	1.5	100.8	59.5	191.2	470.7	109.7	3.0
2009		58.0	3.9	61.9	121.2	1.5	110.9		172.8	406.4	344.6	9.6
2010		58.0	3.9	61.9	124.8	1.5	122.0		175.1	423.5	361.6	10.0
2011		58.0	3.9	61.9	128.6	1.5	134.2		176.5	440.8	378.9	10.5
2012		58.0	3.9	61.9	132.4	1.5	147.6		178.0	459.5	397.6	11.0
2013		58.0	3.9	61.9	136.4	1.4	162.4	86.9	179.4	566.5	504.7	14.0
2014		58.0	3.9	61.9	140.5	1.4	178.6		203.9	524.4	462.5	12.8
2015		58.0	3.9	61.9	144.7	1.4	196.5		205.9	548.5	486.6	13.5
2016		58.0	3.9	61.9	149.1	1.4	216.1		207.6	574.3	512.4	14.2
2017		58.0	3.9	61.9	153.5	1.4	237.7		209.4	602.1	540.2	15.0
2018		58.0	3.9	61.9	158.1	2.1	261.5	117.5	211.1	750.3	688.5	19.1
2019		58.0	3.9	61.9	162.9	2.1	287.7		242.4	695.1	633.2	17.6
2020		58.0	3.9	61.9	167.8	2.1	316.4		245.3	731.6	669.7	18.6
2021		58.0	3.9	61.9	172.8	2.1	348.1		247.5	770.5	708.6	19.7
2022		58.0	3.9	61.9	178.0	2.1	382.9		249.7	812.7	750.8	20.9
SUM	3904.9	1488.9	105.3	5499.1	[illegible]18.0	84.0	3946.1	388.7	4264.7	12201.5	6702.4	186.2

Notes:

		1998	2002	2003	2005	2008
1) INVESTMENT COST: Tk. x 1M	2 680.3	473.0	0.0	216.0	236.5	299.1
2) S&M COST (Tk. x 1M):	32.3	9.7	0.0	4.6	4.8	5.6

3) OTHER COST:
As % investments 0.1%

4) BENEFITS (Tk. x 1M):
Protection Chandpur town 71.2
Annual increase 3%
Savings repair/maintenance:
Chandpur 15.2
Eklashpur 2.6
Haimchar 2.1
Annual increase repair/maintenance 10%

5) Conversion US$ 1 = Tk. 36

10.10.5.2 Economic Internal Rate of Return

The Economic Internal rate of Return (EIRR) is evaluated by comparing the discounted value of benefit and cost. The EIRR is the interest rate at which the discounted values of benefits and costs over the 30-year evaluation period are in balance.
The bank protection scheme for the whole Lower Meghna give an EIRR of about 7%%. This means that the benefits are sufficient to offset the cost. As has already been mentioned in section 10.10.4.1 the EIRR will reduce to about 6% when an additional investment of Tk. 270 million will be required in the year 2002 to provide an additional hard point between Eklashpur and Haimchar.

10.10.5.3 Net Present Value

The economic net present value of the bank protection scheme for the Lower Meghna, evaluated at a discout rate of 12%, is negative (Tk. -658 million). The NPVR [illegible] required by the FPCO-guidelines can be calculated at -0.17.

10.10.6 <u>Sensitivity analysis</u>

The preliminary assessment of the bank protection scheme is based on uncertain future events and imperfect data. Therefore, a sensitivity analysis is presented. This implies an analysis of the economic internal rate of return as function of changes in investment cost, monitoring and maintenance expenditure and estimated value of benefits. Details are provided in Table 10.10.5 and Figures 10.10.2 to 10.10.4.

TABLE 10.10.5 SENSITIVITY ANALYSIS LOWER MEGHNA

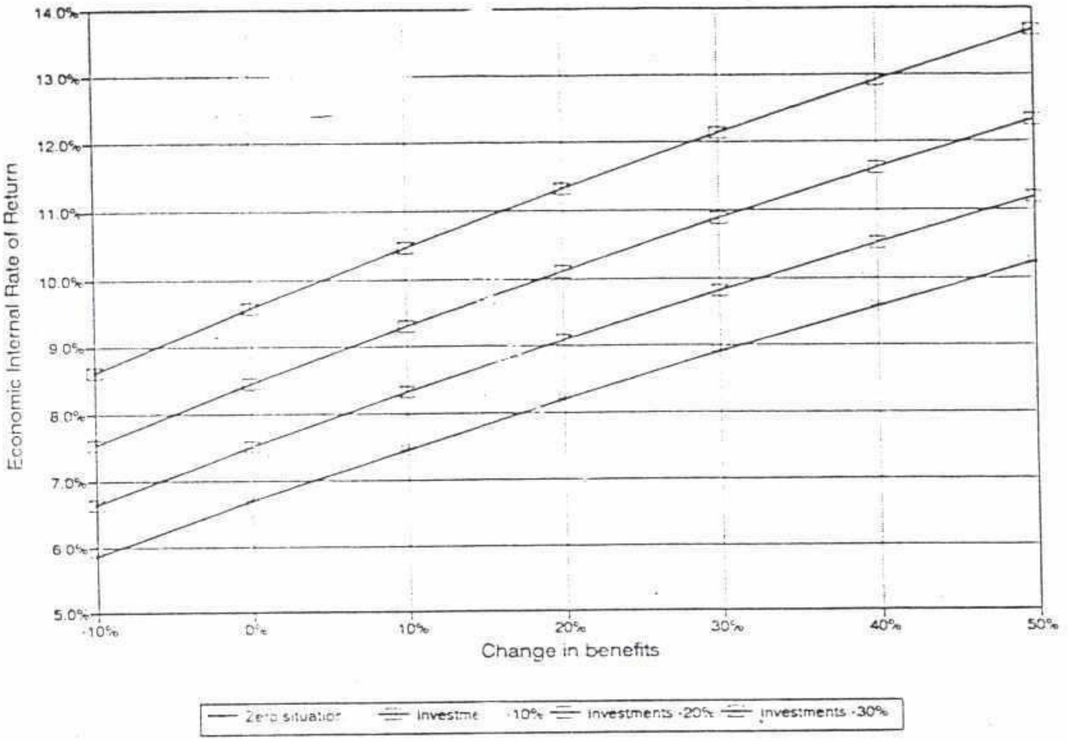
VALUES: Economic Internal Rate of Return (EIRR)
UNIT: percent

Change	CHANGE IN BENEFITS:						
investm.	-10%	0%	10%	20%	30%	40%	50%
-30%	8.62%	9.57%	10.47%	11.32%	12.13%	12.92%	13.67%
-20%	7.55%	8.46%	9.30%	10.11%	10.87%	11.61%	12.32%
-10%	6.65%	7.51%	8.32%	9.09%	[illegible]	10.52%	11.19%
0%	5.86%	6.69%	7.47%	8.21%	8.91%	9.58%	10.22%
10%	5.17%	5.97%	6.73%	7.44%	8.12%	8.76%	9.38%
20%	4.55%	5.33%	6.07%	6.76%	7.42%	8.04%	8.64%
30%	3.99%	4.76%	5.48%	6.15%	6.79%	7.40%	7.98%

Change	CHANGE IN BENEFITS:						
M&M	-10%	0%	10%	20%	30%	40%	50%
-30%	6.16%	6.99%	7.76%	8.50%	9.19%	9.86%	10.50%
-20%	6.06%	6.89%	7.67%	8.40%	9.10%	9.76%	10.40%
-10%	5.96%	6.79%	7.57%	8.31%	9.00%	9.67%	10.31%
0%	5.86%	6.69%	7.47%	8.21%	8.91%	9.58%	10.22%
10%	5.76%	6.59%	7.38%	8.12%	8.82%	9.49%	10.13%
20%	5.66%	6.49%	7.28%	8.02%	8.72%	9.40%	10.04%
30%	5.55%	6.40%	7.18%	7.93%	8.63%	9.30%	9.95%

202

FIGURES 10.10.2 AND 10.10.3 RESULTS OF SENSITIVITY ANALYSIS FOR THE LOWER MEGHNA



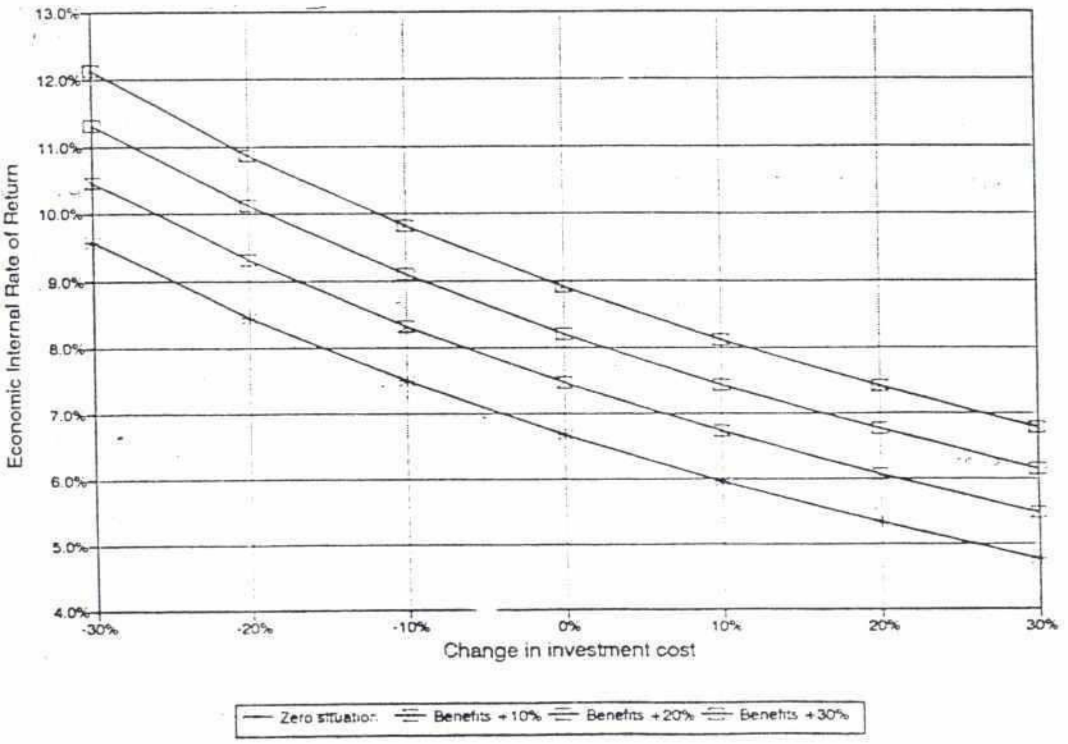
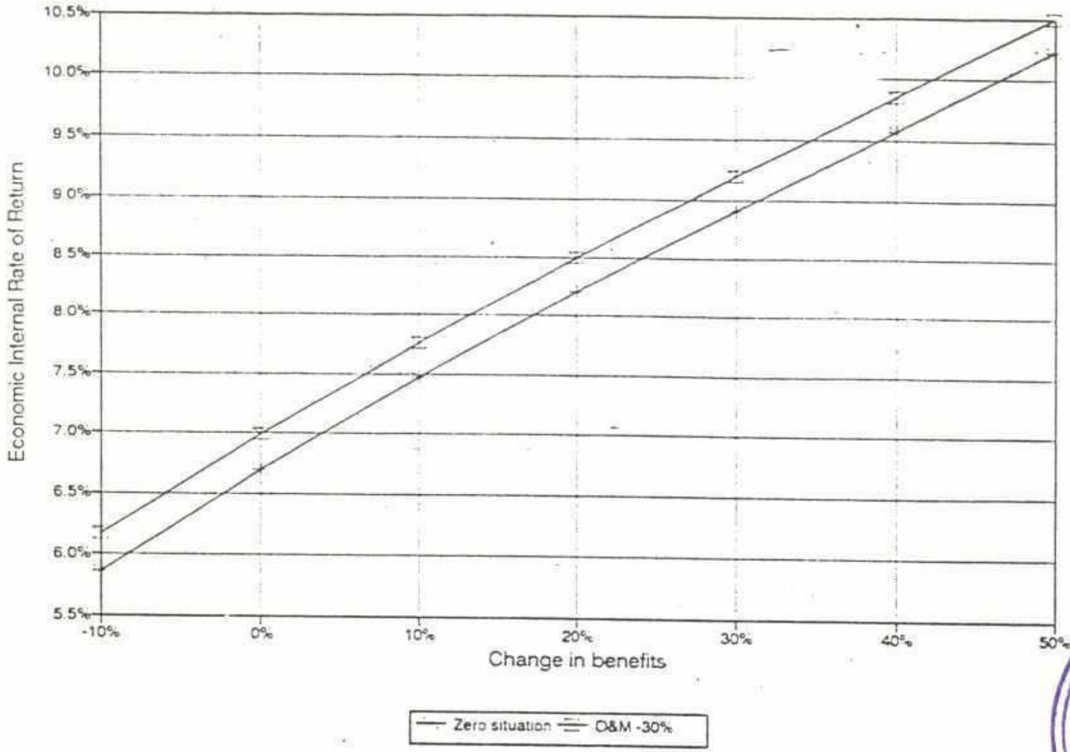


FIGURE 10.10.4 RESULTS OF SENSITIVITY ANALYSIS FOR THE LOWER MEGHNA



10.10.7 Displacement of population

Based on the result of the socio-economic survey and th migration of the bankline in the town area of Chandpur, it has been possible to estimate the number of persons affected by erosion. The area covered by the survey was estimated from the street map as 293,000 m^2 and 2,620 residents in this area were identified. Hence, the population density is 8,940 persons per km^2.

Based on the Statistical Yearbook of Bangladesh for 1991 (table 2.08, page 45), the annual population increase was 2.17% over the last 10 years. Using this factor and the area lost shows that about 17,000 people in Chandpur Town will be affected by erosion in the coming 30 years.

For the rural areas along the Lower Meghna no surveys were executed. Hence, there are no data for the number of persons displaced as a result of likely bank migration. Moreover, the 1991 Statistical Yearbook for Bangladesh is inconclusive with respect to population densities in the aforementioned rural areas. The overall population density for the country was 750 persons per km^2 in 1991 (Statistical Yearbook 1991). Present day rural population counts for about 70% and is expected to reduce to about 50% over the project period ('Developing the Infrastructure, Volume Three of the Report of the Task Forces on Bangladesh Development Strategies for the 1990's' 1991). The averaged rural population density is therefore estimated at 400 people per square kilometer. The total rural area likely to be lost along the Lower Meghna in the coming 30 years is estimated at 3,570 ha. It is therefore estimated that about 14,000 people will be affected in the rural areas outside Chandpur Town.

10.10.8 Conclusions

The conclusions from this preliminary economic assessment read:

(i) Although protection of the whole Lower Meghna gives an EIRR below the opportunity cost of capital, the assessed rate might be considered as acceptable for this type of infrastructural works.

(ii) A more detailed study is justified and required to provide more substantiated conclusions.

ABBREVIATIONS AND GLOSSARY OF TERMS

ADB	Asian Development Bank
BCSIR	Bangladesh Council for Scientific and Industrial Research
BBS	Bangladesh Bureau of Statistics
B/C	benefit cost ratio
BCL	Bangladesh Consultants Limited
BETS	Bangladesh Engineering and Technological Services Ltd
BH	Bore hole
BIWTA	Bangladesh Inland Water Transport Authority
BIWTC	Bangladesh Inland Water Transport Corporation
BOD	Biological Oxygen Demand
BR	Bangladesh Railway
BS	British Standards
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
^{o}C	degree Celsius
CC blocks	concrete blocks
CIF	Cost, insurance and freight
CPT	Cone Penetration Test
Crore	10,000,000
DH	Delft Hydraulics (Netherlands)
Dollar (US)	taken at an exchange rate of Tk.36 for the Study
EIA	environmental impact assessment
EIRR	economic internal rater of return
FAO	Food and Agricultural Organization (United Nations)
FAP	Flood Action Plan
F/C	foreign currency
Fig(s)	figures(s)
FML	fortnightly mean water level
FPCO	Flood Plan Coordination Organization
g	acceleration due to gravity
GL	ground level
ha	hectare(s)
hr	hour(s)
IBRD	International Bank for Reconstruction and Development
ICB	international competitive bidding
IDA	International Development Association
IRR	internal rate of return
IWTA	Inland Water Transport
JICA	Japan International Cooperation Agency

kg	kilogramme(s)
km	kilometre(s)
Km^2	square kilometre(s)
km/h	kilometre per hour
Kn	kilonewton
Lakh	100,000
L/C	local currency
LCB	local competitive bidding
LWL	Low water level
m	metre(s)
MAT	Manual and automatic tidal gauge
MCA	multi-criteria analysis
m/s	metre(s) per second
m^2	square metre(s)
m^3	cubic metre(s)
m^3/s	cubic metre(s) per second (cumecs)
MG	Metre Gauge
mm	millimetre(s)
MMSS	Mica schist silty sand
MN	meganewton
MPO	Master Plan Organization
MSL	mean sea level
N	Newton
NEDECO	Netherlands Engineering Consultants
NMC	natural moisture content
N-value	standard penetration test value
ODA	Overseas Development Agency
OECF	Overseas Economic Cooperation Fund
OMC	optimum moisture content
p.a	per annum
PDB	Power Development Board
PDF	Probability density function
PWD	Public Works Department (datum)
RC	reinforced concrete
RHD	Roads and Highways Department
RPT	Rendel, Palmer & Tritton Limited
RRI	River Research Institute
RTW	river training works
s,sec	second
SHW(L)	standard high water (level
SLW(L)	standard low water (level)
SOB	Survey of Bangladesh
SPT	standard penetration test
SWMC	Surface Water Modelling Centre
sq.km	square kilometre(s)

t(tons)	metric tons
Tk	taka
TOR	Terms of Reference
US$(or$)	US dollar(s)
USCS	Unified soil classification system
WB	World Bank

Geotechnical Investigations

N. Broug	Geotechnical Expert
M.A Mullah	Soil Mechanics Engineer
S.M. Muhibullah	Soil Mechanics Engineer

Surveys

Ali Ahmed	Surveyor

APPENDIX 1 CLIENT AND CONSULTANT STAFF

Names of:

(A) Client Staff
(B) Consultants' Staff and Experts

A. BANGLADESH WATER DEVELOPMENT BOARD

- Management

M. A Razzaque	Member Planning
Liaquat Hossain	Chief Engineer, Planning
S.A.M Rafiquzzaman	Director Planning, (General)
Md Lutfur Rhaman	Superintending Engineer Monitoring-I

B. CONSULTANTS HASKONING/Delft Hydraulics/BETS LTD

- Management

H.J. Opdam	Project Director
F. Carvajal M.	Team Leader
S.M.H [illegible]	Deputy Team Leader

- River Engineering

G. te. Slaa	River bank protection Expert
F. Carvajal M.	Design Engineer
J.H. Laboyrie	River Engineer
M. Ahmed	Design Engineer
A.H.S Alam	Design Engineer
H.J.M. Ogink	Hydrologist
M. van der Wal	Hydraulic Lab Expert
J.H.J. Wijbenga	Math Modelling Expert
G.J. Klaassen	Geomorphologist
Q. Saifuddin	Hydrologist/Morphologist

- Contract documentation and evaluation

R. Kuijpers	Contract Specialist
M. Loqman	Contract Specialist

Economics

H.J. Raad	Agro/Socio-economist
A. Haque	Economist

Environmental Impact Assessment

M. Dijkstra	Environmental Expert
M.Q. Mirza	Environmental Expert