Environmental Assessment/Analysis Reports

Bangladesh - River Bank Protection Project
EA Category B

River Training Studies of the Brahmaputra River
July 1992

This report has been prepared by the Borrower or its Consultant
Government of the People's Republic of Bangladesh
Bangladesh Water Development Board

River Training Studies of the Brahmaputra River

River Bank Protection Project
Brahmaputra Right Bank Priority Works

Environmental Impact Assessment

July 1992

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Sir William Halcrow & Partners Ltd.
in association with

Danish Hydraulic Institute
Engineering & Planning Consultants Ltd.
Government of the People's Republic of Bangladesh
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Sir William Halcrow & Partners Ltd.
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Danish Hydraulic Institute
Engineering & Planning Consultants Ltd.
Design Innovations Group
Dear Mr Hossain,

River Bank Protection Project
Brahmaputra Right Bank Priority Works
Environmental Impact Assessment

Further to paragraph 15 of the IDA Appraisal Mission's draft Aide-Memoire, I am pleased to enclose three copies of the Environmental Impact Assessment for the Priority Works. As noted in Section 1.4.1, the EIA adheres as closely as possible to the concepts of the FAP Guidelines.

The EIA contains an Executive Summary which includes an Action Plan for monitoring and mitigating impacts.

I trust that the EIA will meet with your approval.

Yours sincerely,

M R West
Team Leader

cc Mr S A M Rafiquzzaman, Director Planning (General), BWDB, Dhaka
Mr S A Rana, Water Resource Adviser, World Bank, Dhaka (2 copies)
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# GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
# BANGLADESH WATER DEVELOPMENT BOARD
# RIVER TRAINING STUDIES OF THE BRAHMAPURA RIVER
# RIVER BANK PROTECTION PROJECT
# BRAHMAPUTRA RIGHT BANK PRIORITY WORKS
# ENVIRONMENTAL IMPACT ASSESSMENT

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BRAHMAPUTRA RIVER TRAINING STUDY
PRIORITY WORKS FOR IMPLEMENTATION UNDER
RIVER BANK PROTECTION PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

EXECUTIVE SUMMARY

Introduction

The Brahmaputra is one of the largest braided rivers in the world. Its multiple channels are
forever shifting and while some of its the mid-river islands chars have a certain permanency,
others are formed and destroyed over a matter of a few years; the smaller sandbars, some
3 km long, can migrate downriver at more than 30 m/day, changing shape as they go.

Cyclical bank erosion and accretion is a feature of any braided river but in the case of the
Brahmaputra there is strong evidence that the right bank has been experiencing a
substantial net erosion over the past 30 years, which appears to be associated with a
tendency for the river to increase its overall width (although probably not its main channel
width), through a process of island growth. Morphological evidence shows that the right
bank of the river is, as a whole, currently further west than it has previously been in recent
geological times. The indications are that this westward trend of the right bank is continuing,
although there is insufficient data to allow this to be quantified at present.

Following the favourable outcome of studies carried out in the 1950’s, a flood embankment
was constructed parallel to the right bank during the late 1960’s and early 1970’s stretching
from the Teesta down to the Hurasagar confluence. This Brahmaputra Right Embankment
(BRE) was set back between 1.6 and 2.4 km from the river bank at the time.

Problem Identification

By the first years of the 1980’s bank erosion was already threatening certain sections of the
BRE and portions had to be reconstructed further back from the river bank. Erosion
continues and currently more than 15 km of the BRE is within 300 m of the river bank and
nearly 70 km is within 500 m and thus vulnerable to breaching as a result of the rapid bank
retreat (often more than 600 m/y) that is associated with the more aggressive bends.

In addition to this destruction of good agricultural land, which reappears as much poorer
sandy soiled and unstable chartland, towns and villages are destroyed and many thousands
are made homeless and destitute. Two particular problems stand out from this as being
of immediate concern: the town of Sirajganj, population greater than 100,000, is being
directly threatened by the river and there is serious concern about the consequences of a
breakthrough of the Brahmaputra into the Bangali river: at present the two rivers are only
1,000 m apart at two locations and with bank erosion proceeding at around 300 m/y in this
vicinity, a breakthrough appears imminent.

\[\text{\textsuperscript{1} measured from December 1990 aerial photography}\]

ES.1
Although the priority works are small when seen in the context of the river as a whole, they will play an important part in the longer term goal of full stabilisation of the bankline. It happens that both locations are closely associated with strategic "nodal" points of the river platform and it is expected that bank protection carried out in these reaches will also make a contribution to river bank stabilisation at the larger scale.

The Environmental Assessment

This report follows as far as possible the FPCO guidelines for EIA that were drawn up for the Regional Studies and are therefore not in some respects directly applicable to this form of study. Where it has been necessary to diverge in a matter of detail, every effort has been made to comply with the spirit of the guidelines.

The finding of this report is that there will be no significant sustained negative environmental impact expressed in physical, ecological, human or economic terms. Potential longer term impacts, such as the excessive use of timber for brick-making, can be addressed by ensuring strict compliance with the conditions specifically written into the ICB contract for this purpose. Temporary impacts during construction have been clearly identified and quantified and provision made for appropriate measures to minimise these short-term and reversible adverse effects. The importance of continuous monitoring before, during and post-construction has been highlighted and specific recommendations have been made in this respect.

The positive impacts will be far-reaching and benefit a far larger group than those directly benefitting from the local bank stabilisation. In the Sariakandi area, the prevention of the breaching of the BRE and the serious likelihood of a breakthrough into the Bangali river will be to the advantage of farmers on both banks of the Bangali-Ichamati river system as far south as Siraigani. Reduction in the rate of bank erosion alone will, over a period of 10 years, prevent further loss of land and livelihood for some 50,000 people in the rural areas and the displacement of the majority of the population of Siraigani.

The principle features of the Environmental Monitoring and Action Plan are as follows:
ACTION PLAN FOR MONITORING AND MITIGATING IMPACTS

1. Land Acquisition for Permanent Works

(a) Bank Protection
   - Consultation with affected persons and thana chairmen at least one year prior to commencement of construction (BWDB/DC)
   - Fixing of cross-bar alignments to minimise fragmentation of holdings, and avoid interference with homesteads etc (BWDB/BRTS/RBPP)
   - Timely completion of land acquisition procedures (BWDB)
   - Establish formal liaison and regular meetings between thana chairmen, BWDB Executive Engineer and Contractor, chaired by the Resident Engineer (RBPP)
   - Construction Programme to be sensitive to cropping programme.

(b) BRE Realignment
   - Consultation with affected persons and thana chairmen at least one year prior to commencement of construction (BWDB/DC/RBPP)
   - Fixing of alignments to minimise fragmentation of holdings, and avoid interference with homesteads etc (BWDB/RBPP)
   - Timely completion of land acquisition procedures (BWDB)
   - Establish formal liaison and regular meetings between thana chairmen, RBPP BRE Planning Unit and local contractors, chaired by Executive Engineer (BWDB/RBPP)
   - Construction Programme to be sensitive to cropping programme.
   - Occupation of refuge berm on landward side of BRE to be restricted to those displaced by bank erosion (BWDB/DC).
   - One-off compensation to be paid to tenants and landowners on river-side of new BRE (WB/BWDB/DC).

2. Temporary Resettlement of Squatters (Sirajganj)

   - Preliminary identification of persons affected (BRTS/RBPP)
   - Make provision in civil works contract BOQ and Specification for temporary resettlement (BRTS/BWDB)
   - Consultation with affected persons and town authorities at least one year prior to commencement of construction (BWDB/DC/RBPP)
   - Establish detailed procedures in accordance with World Bank Directive on Involuntary Resettlement (WB/RBPP)
   - Final identification of persons affected prior to Award of civil works contract (BWDB/DC)
   - Establish formal liaison and regular meetings between town authorities, squatters' representative, BWDB Executive Engineer and Contractor, chaired by the Resident Engineer (RBPP)
   - Maintain formal liaison with the DC (RBPP)
5. Dredging and Hydraulic Fill

- Confirmation that river bed and bank material contains no significant amount of toxic materials (BRTS).
- Provisions written into the ICB Contract Conditions and Specification (see list of clauses) making the Contractor responsible for ensuring that his activities do not unreasonably interfere with navigation and fisheries (BRTS/BWDB).
- Locations of all sources of dredged material either shown on Drawings or subject to approval of the Engineer (BRTS/RBPP-RE).
- Establish formal liaison and regular meetings between BWTA/BR/DOF and representatives of country boat operators and fishermen, BWDB. Executive Engineer and Contractor, chaired by the Resident Engineer (RBPP).
- Contractor to furnish detailed method statement for approval of the Engineer prior to commencement of any work (RBPP-RE).
- Compliance with provisions and method statement to be monitored and enforced by the Resident Engineer (RBPP-RE).
- Samples to be taken during hydraulic fill operations and analysed for toxic content (RBPP-RE).
- Sediment concentrations to be monitored downstream of dredging operations (Contractor/RBPP-RE).
- Procedure to be established for recording and evaluating complaints and feedback to the Resident Engineer (BWDB).
- Contractor required to take all practicable measures to minimise turbidity arising from dredging (see list of Clauses) (BRTS/BWDB).
- Contractor required to observe:
  - Environmental Pollution Act
  - Marine Pollution Ordinance
  - Inland Shipping Ordinance

and, when enacted, the Inland Waterways III project requirement for river bed sample testing prior to dredging (see list of Clauses) (BRTS/BWDB).

7. Utilisation of Borrow Pits

- Provisions written into the ICB Contract Conditions and Specification (see list of clauses) making the Contractor responsible for ensuring that borrow pits do not constitute a health hazard during the construction period and are left on completion in a suitable condition for subsequent use by farmers (BRTS/BWDB).
- Design of works to include suitable vegetation to be planted to stabilise the borrow pits (BRTS/BWDB).
- Consultation with landowners and tenants concerning the location of borrow areas (BWDB/RBPP).
- Contractor to furnish detailed method statement for approval of the Engineer prior to commencement of any work (RBPP-RE).
- Compliance with provisions and method statement to be monitored and enforced by the Resident Engineer (RBPP-RE).
**LIST OF ABBREVIATIONS USED IN ACTION PLAN**

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<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>BIWTA</td>
<td>Bangladesh Inland Water Transport Authority</td>
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<td>BOQ</td>
<td>Bill of Quantities</td>
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<td>BR</td>
<td>Bangladesh Railway</td>
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<td>BRE</td>
<td>Brahmaputra Right Embankment</td>
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<td>BRTS</td>
<td>Brahmaputra River Training Studies (FAP-1)</td>
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<td>BWDB</td>
<td>Bangladesh Water Development Board</td>
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<tr>
<td>CCT</td>
<td>Computer Compatible Tapes</td>
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<td>DC</td>
<td>Deputy Commissioner</td>
</tr>
<tr>
<td>DOF</td>
<td>Department of Fisheries</td>
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<td>FAP</td>
<td>Flood Action Plan</td>
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<td>FPCO</td>
<td>Flood Plan Co-ordination Organisation</td>
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<tr>
<td>ICB</td>
<td>International Competitive Bidding</td>
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<tr>
<td>MMU</td>
<td>Monitoring and Maintenance Unit</td>
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<tr>
<td>RBPP</td>
<td>River Bank Protection Project</td>
</tr>
<tr>
<td>RE</td>
<td>Resident Engineer</td>
</tr>
<tr>
<td>TA</td>
<td>Technical Assistance</td>
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<td>WB</td>
<td>World Bank</td>
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**LIST OF CLAUSES PERTAINING TO MITIGATION OF IMPACTS**

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<td>Site Operations and Methods of Construction</td>
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<td>13.1</td>
<td>Work to be in Accordance with Contract</td>
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<tr>
<td>19.1</td>
<td>Safety, Security and Protection of the Environment</td>
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<td>26.1</td>
<td>Compliance with Statutes, Regulations</td>
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<td>29.1</td>
<td>Interference with Traffic and Adjoining Properties</td>
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<td>30.1</td>
<td>Avoidance of Damage to Roads</td>
</tr>
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<td>30.2</td>
<td>Transport of Contractor's Equipment or Temporary Works</td>
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<td>Transport of Materials or Plant</td>
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<td>32.1</td>
<td>Contractor to Keep Site Clear</td>
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<td>33.1</td>
<td>Clearance of Site on Completion</td>
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<td>45.1</td>
<td>Restriction on Working Hours</td>
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2. **Conditions of Particular Application**

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<td>Clause No.</td>
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<td><strong>Part 1</strong></td>
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<td>Working Areas (Contractor responsible for temporary acquisition of additional land)</td>
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<td><strong>Preliminary and General</strong></td>
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<td>Drains, Streams, Watercourses, etc.</td>
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<td>Access (restriction on construction traffic, etc)</td>
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409 Dredging Method Statement

412 Compliance with Regulations

417 Filling in Reclamation Area (including submission of method statement)

Part 5 Concrete

504 Aggregates - General

504(5) - source to be approved by the Engineer

505 Coarse Aggregate

505(5) - requirement to use only coal-fired kilns for bricks

Part 6 Revetment Works

617 Rock Armour (alternative armouring to c.c. blocks)

617(2)&(5) - quarry rock to be supplied only from sources approved by the Engineer

617(8) - Contractor to submit proposals for rock handling and stockpiling

618 Brick Filter Layer (bricks to conform to Sub-Clause 505(5)).

619 Revetment Construction Method Statement

Part 7 Roads (Contract No. 2 only)

703 Aggregate Sources for Bitumen Macadam (subject to the Engineer’s approval)

Part 8 Piling (Contract no. 2 only)

801 Piling Plant and Methods

801 (1) - Contractor to submit details for the Engineer’s approval

806 Disturbance and Noise
INTRODUCTION

1.1 Introduction

This report presents the Environmental Impact Assessment (EIA) of the works arising from the River Training Studies of the Brahmaputra River (BRTS), part of the Flood Action Plan (FAP), in respect of the immediate concerns of ensuring the security of certain parts of the Brahmaputra River Embankment (BRE) and major concentrations of infrastructural investment along the right bank of the river. The structural works associated with the first phase of this programme of bank stabilisation are known as the Priority Works. The EIA has been undertaken to ascertain what are the likely, significant environmental changes as a result of the implementation of the Priority Works and, if these changes are negative, what mitigating measures should be taken to lessen their impact both during construction and thereafter. These package of measures is sometimes referred to as an Environmental Management Plan (EMP).

There is ample and readily visible evidence that during the 25 years of its existence the BRE has provided effective relief from the uncontrolled and sustained inundation originating from the high flood flows in the Brahmaputra River and that this has assisted in the very substantial increase in agricultural production and general development in the protected areas.

This level of security against damaging floods is now under threat from the continuing erosion of the right bank of the river (see Table 1.1), which is increasingly causing breaches of the BRE. In addition to this problem there is the more direct hardship that arises from the massive erosion of fertile farmland along the bankline and the displacement of the farmers, who are forced to take refuge on the remaining flood embankment as the only safe haven available. Contrary to the belief held by some, there is no discernible link between the construction of the BRE flood embankment and this rapid bank erosion, which has been a feature of the river since its avulsion some 200 years ago.

These breaches and the ensuing sudden floods have become more frequent over recent years as progressively greater lengths of the BRE become within range of the more aggressive river bends. The consequent displacement of families from their homes and land has added to the already daunting problems of homelessness, resettlement and unemployment. As an example of the order of magnitude of the problems, the potential damage in the short term is given in Table 1.2, for six locations along the BRE that have been experiencing severe bank erosion during the past four or five years. Because of the cyclical nature of erosion, as the threat to these sites reduces so attack will intensify at others, resulting in similar levels of damage.
section that occur as the highly mobile smaller chars (islands) migrate down the river. The development of these bends is therefore very hard to predict and the current state of knowledge permits only approximate forecasts of the location and severity of erosion.

The flows in the river during the dry season range from 3,500 m$^3$/s to 6,500 m$^3$/s. In April the melting snows in the Himalayas and Tibetan plateau cause the flow to increase rapidly and this is then reinforced by the monsoon rainfall falling in Assam, resulting in peak flows that may exceed 100,000 m$^3$/s (100 year return period) in July.

The sediment transport capacity of the river is high, the majority of it occurring during the period while the river remains within its banks. The annual sediment discharge of the river is of the order of 500 million cubic metres, some 90 percent of which is in the form of washload or suspended sand. At high discharges the flow is very turbulent, causing massive "boils" to appear on the surface. The mean depth of flow during the wet season is only around 7 m but concentrations of flow, particularly where two channels merge downstream of a char, can result in scour depths of more than 30 m. These scour holes can develop very rapidly and may then travel downstream as the river planform alters.

There is strong circumstantial evidence that the river is moving westwards as a whole, but insufficient data to quantify this trend beyond saying that it may be of the order of 40 to 50 m/year over a timescale of centuries. Definite evidence that in the last 30 years the mean rate of right bank retreat has been as high as 100 m/year; and that the river is generally getting wider. The rate of widening may be expected to slow down over the next 20 to 30 years but could then be replaced by increased bodily drift. The macro-geotechnical processes that have resulted in the river moving to its present course remain active, and further significant planform movement must be seen as probable rather than possible unless there is some form of intervention.

The only place on the right bank that net accretion has occurred during the last 30 years is south of Sirajganj although that reach has seen erosion on both banks in recent years. It is possible that the notable relative stability of the river planform south of Sirajganj since the early 1960's could be linked to the sustained efforts that have been made to harden the bank in the vicinity of the town during this period. If this incipient hard point were to fail the there could be very rapid and large scale adjustment of the planform between Sirajganj and Belkuchi.

Following the favourable outcome of a feasibility study, the 220 km long earth embankment, known as the Brahmaputra Right Embankment (BRE), was constructed in the late 1960s - early 1970's on the western bank of the Jamuna River to protect the flood plain lands against the sustained deep flooding caused by the passage of the annual flood wave down the Brahmaputra river. The BRE performed very satisfactorily during the first 15 years or so, and the parts that remain intact are generally in fair to good condition. However river erosion is increasingly causing serious problems.

The major cause of failure of the BRE is undercutting due to rapid bank erosion or, less frequently, direct erosion by high flow velocities as the main river channel coming within a few tens of metres of the embankment. Every year the BRE has to be retired landward in order to maintain its continuity. A total length of about 140 km
substantially inferior and will have no protection from inundation, and consequently its productivity will be much lower. The newly emerged land is in any case not available for use by those who have been displaced since it is legally the property of whoever held title to that area before the river earlier occupied it. In practice the situation is less well defined with the larger landowners wielding much influence.

Breaching of the BRE will also continue to occur even if the nominal "five year set back" rule is correctly applied and planned retirement of the embankment is implemented. It would be socially unacceptable, an economically unjustifiable, to set the embankment far enough back to reduce to a minimal value the risk of the occasional very aggressive bend, that can erode the bank at more than 800 m per year, from causing a breach.

Analysis of significantly scouring bends which have occurred over the last 20 years suggests that on average six right bank concave significant bends can be expected to be discernible each year of which about half will be in their active period. In the absence of an effective system for identifying potentially aggressive bends and instituting pre-emptive retirement of the embankment, an average of one or two breaches a year would thus not be exceptional.

The damage resulting from a breach of the BRE will vary with location and the water levels in the Brahmaputra at the time. Estimates for immediate agricultural damage from a single breach range from about Tk 10 million in the vicinity of the breach, though the average is nearer Tk 30 - 60 million over the affected area. In addition the direct damage to roads and other infrastructure and the interruption to land communication is substantial.

1.3.2 Breakthrough to the Bangali River

The Bangali river is now within the range of one of the more aggressive bends on the Brahmaputra river that have occurred during the past 15 years. If no preventative action is taken it would appear highly probable that the Brahmaputra river will break through into the Bangali river within a matter of a few years, with the added risk that in the medium to longer term the Brahmaputra might favour this channel and eventually occupy it as a major anabranch.

Once the breakthrough had occurred it would be necessary to realign the Bangali channel itself westwards in order to maintain the continuity of the BRE while ensuring that drainage of the area to the north was not severely impeded. It has been estimated that such a realignment could cost of the order of Tk 2,000 million in construction costs alone, and require the acquisition of 850 ha of prime agricultural land, together with the displacement of a large number of farming households. During the construction period the BRE would be substantially ineffective over this reach and downstream areas would suffer accordingly. The negative social and consequential economic impacts of such a breakthrough would be massive.

1.3.3 Security of Sirajganj and Fulcharighat

The important district centre of Sirajganj with its population of about 125,000 is under constant threat of erosion from the river. It is the only significant river port on the Brahmaputra and it is the railhead for the southern ferry crossing. During the past four years the erosive attack has switched from a deep embayment north of the
satisfactorily high level of security to those on the landward side of the embankment than currently enjoyed. Simply, more people and land benefit for more of the time.

This form of strategic retirement of the BRE could be seen as a pragmatic compromise measure for much of its length but it does not address the problems of:

- the potential breakthrough into the Bangali River,
- the security of Sirajganj and the Fulchari railway ferry terminal.
- The future security of the Jamuna Bridge.

Selective and carefully planned bank stabilisation (Option c) is the only solution that will satisfy all the objectives. The concept of bank stabilisation is not new or untried. Sirajganj is an example of the largely successful application of the principle over a period of at least 20 years, although the method may be seen in retrospect to be have less than cost-effective.

The distinction needs to be made between intervention aimed at confining the river to one or more defined channels and hardening the bank in order to prevent the river from continuing to widen and occupy more land. Whereas the former is a very active form of intervention, in which the river is constrained to follow a path dictated by man, and one that could result in unforeseen consequences, the latter is more passive in principle and may be seen as artificially providing more resistant banks, as could occur in nature as the migrating river came into contact with more resistant formations (for example the Barind Tract).

The principal practical limitation is the availability of finance and the decision to allocate resources to this objective.

1.4 Assessment methodology

1.4.1 FAP Environmental Guidelines

In the course of this project, FAP-16 has produced Environmental Guidelines and an EIA Manual to be followed by the FAP regional studies. These guidelines are designed for schemes involving active intervention measures aimed at flood control and drainage, such as the construction of new flood embankments and polders, and as such are not directly applicable to the Brahmaputra situation. Nevertheless, the latest issues of the Guidelines and Manual have been used as the formwork for preparing this report; the concepts behind these documents have been adhered to as closely as possible.

1.4.2 Data collection and analysis

The project area for the Master Plan covers the right bank of the Bramhaputra (Jamuna) River from its confluence with the Teesta River to the Hurasagar confluence.

Extensive field work has been undertaken by the BRTS team over a period of two years and sophisticated numerical modelling techniques have been used in support
Within these components, and from the data obtained by the surveys and field visits, together from consultations with the interested authorities in Bangladesh, and the donor agencies, it was possible to identify important issues that could be examined in detail against activities in the project cycle. The separation of the important/less important issues was done by an system of assessment/evaluation, which allowed qualitative assessments be recorded and evaluated with greater objectivity and reproducibility than simple subjective judgments of the consultant team. This assessment and evaluation system is discussed in Section 6.

1.5 Format of the report

The EIA has followed, within the project constraints, the form of assessment developed for the Flood Action Plan, and contained in the Guidelines for EIA approved by the Flood Plan Coordinating Organization (FPCO). The report is laid out in a sequential form: discussing the project and the existing environmental situation, considering the possible impacts and their consequences, evaluating any alternative strategies for project execution (if relevant); identifying possible mitigating measures; providing a qualitative cost/benefit analysis of the options; and providing notes on other matters pertinent to the environmental aspects of the project and the post-project situation. In Chapter 5 the Environmental Monitoring and Action Plan, sometimes referred to as an environmental management plan, is set out.

All data is not yet available to provide a complete environmental assessment covering the full scope of the master plan, and so the report has been divided into two parts:

"Part 1 : The Priority Works"

containing chapters dealing with the project and the present environmental situation of the project as a whole, as well as the impact assessment and conclusions for the Priority Works (to allow the EIA to become part of the immediate process for funding and execution of these works).

"Part 2 : The Master Plan"

covering the additional impact assessments relating to the Master Plan and which will form part of the BRTS Final Report.
2 PROJECT DESCRIPTION

2.1 Project location and scale

2.1.1 Project Area and Scope

The recurrent breaching of the Brahmaputra Right Embankment (BRE) as a direct consequence of progressive erosion of the right bank of the river and the government's desire to urgently address this serious problem was the principle reason for the formulation of the project. It is for this reason that the scope of the BRTS is confined to the right bank of the Brahmaputra River lying between the Teesta and Hurasagar confluences (see Figure 2.1). This rather narrow focus is unsatisfactory when analysing the river's behaviour and in practice for much of the study work it has been necessary to consider the river as a whole. Any specific intervention measures on the left bank or relating directly to the stabilisation of the numerous chars are however outside the scope of this study.

The westward limit of the study is strictly the present alignment of the BRE but for quantifying the benefits due to the flood embankment and evaluating any negative impacts it has been necessary to extend certain aspects of the study to cover parts of the right bank flood plain. In general however, the identification and quantification of problems to the west of the BRE and the preparation of means of addressing these problems, falls within the scope of the North-West Regional Study (FAP-2), with which close liaison has been maintained throughout.

The river is usually known as the Jamuna over most of this length and this name will be used when describing the project area and scheme preparation.

The study has two distinct components. The master plan, described in the following Section, will set out a strategy whose long term objective is the stabilising the full length of the right bank of the river within the study limits. The timescale for such a massive undertaking is measured in decades if not centuries. The second component is the preparation of a scheme for implementation, consisting of bank stabilisation works at priority locations where the consequences of bank erosion are particularly severe and early action is called for in advance of completion of the master plan. It is intended that the timescale for the implementation of these priority works should be less than five years from identification.

In accordance with the study TOR, six priority locations were selected using a ranking system designed for this purpose. From this short-list of six, three sites stood out clearly from the others in terms of both economic and sociological considerations and it is these three, two of which are closely related, that have been identified by the IDA (World Bank) as being suitable subjects for financing under the River Bank Protection Project. This report covers all six priority sites but the greater emphasis is on the three that are scheduled for treatment in the near future: Sirajganj, Mathurapara and Sariakandi. The other three locations being Fulcharighat, Kazipur and Betil.

The town of Sirajganj is situated 70 km upstream of the Ganges confluence and 7 km upstream of the site for the proposed Jamuna Multipurpose Bridge (JMB). The scope of the structural measures are shown in Figure 2.5, from which it can
incorporated in the study recommendations are implemented, analysis of this data in conjunction with direct field measurements will be continuously carried out to provide a progressively better understanding of the relationship between intervention and the morphological and ecological consequences.

The short-term bank stabilisation works, that is the Priority Works, are the main focus of this report since it is intended that these be implemented as early as organisational constraints permit.

These short-term works are large in human terms but when placed within the perspective of the Jamuna River they can be seen to be relatively minor. The length of hardened bank will be some 3 km out of a total of 220 km in the study area alone. The affected length may amount to about 17 km or less than 8 percent.

Similarly although the quantities of dredging and reclamation may at 2 to 3 Mcm appear large when taken out of context, they represent only a small fraction of the quantity of similar material eroded from the right bank and transported by the river every year (around 150 Mcm) or the total sediment transported by the river annually (around 500 Mcm).

2.2 Project Preparation

2.2.1 Background

The first systematic morphological study of the Jamuna River was undertaken by J M Coleman between June 1967 and March 1968 culminating in his paper "Brahmaputra River: Channel Processes and Sedimentation" published in 1969. He was the first to identify, from interpretation of aerial photography, that the course of the river had progressively moved westward during the Recent geological period until the major avulsion that took place around the end of the 19th century. He tentatively concluded that westward migration was continuing. In addition to this important piece of deductive work he observed and documented many of the sediment transport processes that are distinctive features of the river's braided form. Although Coleman's interpretation of his observations provides much valuable material on the behaviour of the river, he was not concerned with structural intervention in any form and therefore did not focus on many those aspects that are of primary relevance when considering bank stabilisation.

The next set of studies were related to the feasibility of constructing a bridge across the Jamuna. The first field work consisted of a programme of sub-soil investigations and soil testing completed by Soltech, with financing from JICA, in 1975. These were followed by further studies carried out during the period 1986 to 1989 by Rendell Palmer Tritton (RPT) in association with NEDECO and Bangladesh Consultants Ltd. and included a substantial morphological study based on the analysis of river surveys data, the interpretation of maps and satellite imagery, and physical and mathematical modelling. The studies added considerably to the information available on the behaviour of the river but naturally focussed on the particular issues that were relevant to the construction of a bridge at the preferred site 7 km south of Sirajganj.

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1 Sedimentary Geology, Vol 3, August 1969: Elsevier
- location, length, frequency of breaches;
- causes of breaches
- relationship, if any, between original embankment geometry, soils, construction techniques, vegetative cover, use, maintenance regime, and the probability/frequency of failure.

(c) To provide the basis for drawing up guidelines for construction of embankments that will have the desired life. In particular to identify possible measures and their technical feasibility, for improved performance of the BRE in terms of flood protection, including the practicability of retirement of the embankment in different reaches.

(d) To obtain opinions from the communities living on the BRE as to the efficacy and value of the BRE and the causes of failures.

It has proved difficult to build up a reliable history of breaches. Most people's recollection becomes hazy prior to the 1988 breaches and official records other than the bankline sketch maps maintained by the BWDB since about 1980, are not readily available.

From the latter it is possible to estimate that the first retirements took place, possibly in the vicinity of Kazipur, around 1975, only a little over 10 years after the original construction but that the problem started to become significant in the early 1980's. It is clear however that the problem has been becoming more serious over the past 5 years as progressively more of the BRE becomes within range of aggressive bend erosion. The number of times that different lengths of the BRE have been reconstructed is illustrated in Figure 2.7.

The survey showed that the embankment was generally in fair to good condition except for short stretches that had been constructed to a low standard as emergency measures to repair a breach. Direct undermining as a consequence of bank erosion was reported as by far the major cause of breaches and only one substantiated case of piping failure was recorded (it was caused by rat holes and is attributable to insufficient maintenance). Public cuts occur from time to time but are confined to the most northern reach, upstream of Fulcharighat, and are associated with breaches in the Teesta section of the BRE causing flood water to build up on the landward side of the Jamuna section of the BRE. With this exception, the general perception of the farmers receiving the protection of the BRE was found to be positive and favourable. This is consistent with the common experience that public pressure is always for reconstructing a breached section of the BRE as close to the river as feasible, so that the largest number of people benefit. Unfortunately this pressure results in a higher risk of future breaches occurring.

The only options open to reduce the frequency of breaching are therefore either to construct the embankment sufficiently far back from the river, which leaves a large number of farmers unprotected, or to stabilise the bankline.

**Towns and Ferryghats**

Erosion of the river bank poses not only a threat to the integrity of the BRE but also results in the destruction of property and infrastructure and the disruption of
principle, which is being followed for the Priority Works, is a relatively mild form of intervention in morphological terms and is unlikely to result in any significant adverse consequences. The next and far more actively interventionist step of stabilising the planforms of the anabranches themselves is considerably more ambitious and calls for a higher order of understanding of the river processes than is available today if it is to be successful and sustainable.

2.2.3 Problem quantification

The BRTS Programme

The first 18 months of the three year programme was occupied largely with the identification of the problems followed by the execution of an extensive programme of river surveys and other primary data collection and analysis. Physical models were constructed at the RRI facilities at Faridpur and 1-D and 2-D mathematical models were set up and calibrated using the data that had been collected for this purpose. Old maps were obtained and compared with more recent maps and satellite imagery in order to elicit as much information as possible about the morphological dynamics of the river, such as bank erosion rates and the life cycle of anabranch bends. During the subsequent 6 months various analytical techniques were coordinated in order to quantify the magnitude of the problems and to assess alternative options for their amelioration.

Simultaneously the data necessary for the design of structural measures for bank stabilisation were being collected and criteria were drawn up and material specifications prepared.

The following sections outline the scope of these varied activities.

River surveys

A very extensive programme of river and topographical surveys were carried out, mainly directly by BRTS team members. This was the first time that river survey work had been carried out on the Jamuna River during the monsoon period and a series of logistical and technical problems had to be solved. The outcome was a comprehensive set of data covering two consecutive monsoon and dry seasons. The scope of the surveys is indicated in Table 2.1

The data collected, covering bathymetry, directional velocity measurements and sediment concentrations and gradings, was used for the setting up and calibration of both physical and mathematical models and, after analysis, provided the basis for determining design criteria for the Priority Works.

Geotechnical Investigations

Data from previous investigations for the Jamuna Bridge were collated and some further analysis carried out to supplement the information presented in the JMB feasibility report. Based on this, a limited programme of site investigations was drawn up by the BRTS and carried out by the BWDB Groundwater Circle. This achieved the objective, which was to confirm that the bank material was broadly homogeneous, in terms of relevant properties, over the whole study reach.
2-D morphological modelling (which includes 2-D hydrodynamic modelling), to gain insight into and to quantify the morphological processes that are associated with scour development and bank erosion and to investigate the viability of alternative means of influencing channel development.

1-D sediment transport modelling, as a part of the assessment of the magnitude of long term channel geometry changes that are associated with the alternative levels of river containment.

The mathematical modelling studies are now substantially complete and the results have been used in developing the designs for the Priority Works.

**Geomorphological analysis**

The objectives of the geomorphological studies are firstly to learn as much as possible about the morphological characteristics of the river from its historic behavioural patterns and then to extrapolate this understanding to provide a basis for predicting future behaviour.

Sources of information that have been used for this study are:

(a) old maps dating back to 1820 which provide a broad qualitative picture of the changes in the macro planform of the river;

(b) more recent maps from 1914 onwards which can be used to quantify bankline movements and island development on a coarse time scale;

(c) satellite imagery since 1973 which when rectified and digitised provides an accurate basis for the quantification of planform changes at a timescale of between 1 and 5 years;

(d) analysis of historic river cross-section surveyed annually since 1967, which when digitised provides information on channel geometry characteristics and trends; data quality however limit the value of these results.

(e) systematic field observations of river bank form and material characteristics.

(f) a large number of bathymetric surveys carried out by the BRITS and by IWTA.

The most reliable information that has been obtained from this multi-faceted study concerns the average bank erosion rates, braid width variation and maximum channel depths since 1967. Less reliable but nonetheless valuable has been the data derived from analysis of bend histories.

**Morphological Prediction**

Work is still on progress on the analysis of morphological data with the objective of deriving relationships and quantifying trends that can be used as the means of
bank of the river. It has been shown that the high cost of bank stabilisation can be justified, in conventional economic terms, in certain situations where the consequences of inaction will be particularly pronounced. These locations are tortuously located at morphologically important sections of the river and it is anticipated that stabilisation of the bankline in these vicinities will represent an important contribution to stabilisation of the river at the regional scale.

At the local level however, the proposed priority stabilisation works will have only a limited zone of influence and outside this the pattern of cyclical bank erosion will continue unchanged until such time as further investment funds become available for an extension of the bank stabilisation measures. Although the stabilisation of much of the river bank is therefore not financially feasible in the short term, there is a need to reduce the frequency of breaches in the BRE that are a direct consequence of the bank erosion. It is being proposed that this is addressed through a combined programme aimed at both the social and engineering issues involved with the objective of establishing a programme of strategic embankment retirement that is both socially acceptably and economically optimal. The success of such an approach hinges on a much improved level of consultation and the derivation of procedures that will reduce the level of uncertainty involved in determining the correct set-back distance for the embankment.

2.26

Selected Priority Works

Design Concept

The Priority Works that have the highest ranking for early implementation are those aimed at the stabilisation of the bankline in the immediate vicinity of Sirajganj and along the 15 km reach centred on Sariakandi where there is a high probability of an early breakthrough of the Brahmaputra into the Bangali River. These two situations are distinct in character and consequently involve different conceptual approaches to the design of bank protection measures.

Sirajganj

At Sirajganj the erosion of the bankline since the 1950's has resulted in parts of the old established town now fronting directly onto the river bank. In other areas urban and peri-urban development has expanded up to the river bank. The existing bank protection works, consisting of concrete block armouring but without an effective underlying filter layer, extends over a length of about 1.5 km and when this was threatened with outflanking in the 1980's, the Ranigram Groyne was constructed to the north of the town. The groyne has a sand core with concrete block armour but again no filter layer and an inadequate toe apron (falling apron). The total length provided with direct protection by these existing works is some 2.2 km.

It is very apparent from the 1992 bankline planform that this stabilised length of bankline forms a modest protrusion into the river. For reasons that are not clear, this is also the point on the river where the braiding intensity reduces markedly and linked to this is the fact that the main river channel tends to be more pronounced and somewhat less shifting than further upstream. In recent years the effect has been further enhanced by the gradual decline of the main left bank anabranch which has resulted in a larger proportion of the river flow passing down the right bank anabranch passing Sirajganj.
In this case the primary objective is distinctly different to that at Siraganj; although the associated protection of the small town of Sariakandi has certain similarities.

Over the past 30 years the right bank of the Jamuna (Brahmaputra) has shifted westwards by a net amount in the order of 3 km over a considerable length and there is now only a thin sliver of land separating it from the Bangali River; in places this strip is less than 1 km wide. This erosion is continuing and during the last monsoon season the bankline retreated a further 300 m on average over a length of several kilometres, further reducing the separation. Since aggressive bends can result in annual rates of bank erosion in the range 500 to 1000 m, and occasionally more, it is reasonable to anticipate an imminent breakthrough, although it is not possible to predict the particular year in which it will occur.

The meandering pattern of the Bangali means that the width of the separating band of land varies and therefore the most vulnerable stretches, in terms of the least amount of erosion required for a breakthrough, can be simply identified. However the pattern of the Jamuna bank erosion is of a complex stochastic nature and it is not necessarily most likely that the breakthrough will first occur at the narrowest point. The least width of separation at present is in fact to the north of Sariakandi on a stretch of the Jamuna river that has been relatively quiescent for a number of years and which at present shows no signs of becoming active again. Although by the nature of the river, this situation could change rapidly.

The objective in this case is therefore to stabilise the bankline in the most cost-effective way that will minimise the risk of a breakthrough occurring. In order to achieve this it is necessary to look at the reach as a whole and not to be unduly influenced by the variation in the width of the separating strip or the pattern of erosion that happens to be taking place in any one year. At the same time the presence of significant townships such as Sariakandi cannot be ignored.

The fundamental assumption that has been made, based on the interpretation of planform dynamics, is that it is unlikely that severe erosion will occur simultaneously to the north and south of Sariakandi and that although the focus may switch, this will take place over several years so that an appropriate timely response can be initiated.

The objective of the priority works is therefore narrowed to the stabilisation of the reach south of Sariakandi and the protection of the township itself.

The second important assumption is that the depth of embayments that will form between hardened lengths of the river bank will not exceed the most severe depth of penetration observed in the case of very aggressive bends. This assumption is also consistent with the conclusion reached by the JMB detailed design studies which was based on both morphological interpretation and physical modelling.

What remains largely a matter of conjecture is the worst re-entrant configuration that can occur immediately upstream of a hard-point. It is this form of erosion that can potentially result in outflanking and effective failure of the hardpoint. The most conservative approach would be to follow the methodology commonly employed in India for the determination of the length of guide bunds for barrages. The application of such a procedure in this case would however result in excessively long hard-points that would be out of proportion to the benefits involved.
protected slope must not be subject to slumping or other forms of deformation
under conditions having a comparable likelihood of occurrence (it is impracticable
and uneconomic to design for stability under the most extreme conditions).

The main elements of the revetment design are therefore:

- a slope that is designed to be stable under normal combined
earthquake loading and drawdown conditions;

- a geotextile fabric that is designed to permit drainage of the
underlying soil while preventing migration of soil particles under
differential pressures induced by wave action and soil-water flow;

- an armour layer designed to hold the geotextile firmly in position and
therefore capable of resisting the forces induced by high velocity flow
and wave action;

**Armour Layer Materials**

The armour layer can be composed of any material that will perform the function
described above; the main consideration being the submerged weight of the
elements. The choice at this time and in this situation lies between precast
concrete blocks using either crushed stone or brick aggregate, quarried rock and
boulders.

Boulders and concrete blocks have the advantage of a high local content, in terms
of both materials and manpower. Quarried rock has some structural and durability
advantages over concrete blocks but is not available in the country and must be
imported.

Boulders were eliminated from the selection in this case, because of the limited
availability of material of the required size, leaving the choice between the other
three forms. Other than the durability consideration, the engineering properties
are similar, and the main factors affecting a decision are: use of local labour and
resources, environmental impact, availability and cost. These last two are subject
to external influences that remain largely unpredictable and so some, subject to
adequate environmental safeguards, it is appropriate to leave the option open at
this stage and to allow the Contractor some flexibility in the matter.

**Implementation**

The construction of bank protection works on this scale and in a river of this size
call for resources and implementation experience that is not available within
Bangladesh at present. Moreover, the controls required both to minimise adverse
environmental impact and to ensure that the works are built in accordance with the
specification can only be achieved through the medium of ICBC civil works contracts
with supervision by an independent Engineer of suitable stature and experience.

**Post Construction**

The civil works have been designed to be robust and under normal conditions they
should require relatively little maintenance. However it is essential that when
situations arise that call for some remedial or supplementary works then the
3 DESCRIPTION OF THE ENVIRONMENT

3.1 Introduction

This chapter describes the present environment of the project area and the main components that would be affected by environment change brought about by project works.

There is a need to stress the confined boundaries of the project area, which have been set by historical events, as well as the scope of the project works. The master plan studies, although focused on the right bank have also by their nature to consider the entire river, and the environmental consequences that would flow from any training strategy. The immediate concern of the project is however the stabilisation of specific sections of the entire bankline where erosion is causing severe problems and the development of strategies for the improved performance of the existing BRE.

Detailed assessment of the floodplain of both left and right banks are being undertaken by other FAP studies, and the assessment of alternative strategies by the BRTS is closely interrelated with these companion studies.

In respect of the Priority Works, the impacts will be defined by the nature and locality of these works: their scale, and the environs/sectors affected by specific project proposals. The environment under consideration will be that of the right bank in the works' localities, as well as the sectors/environs that may be affected.

In all cases of works it is essential that the effect of scale be seen in its proper perspective. The Brahmaputra is a major river, whose anabranches are large enough to be considered as individual, large rivers. The initial works are likely to have an impact only in a relatively small area but in the long-term, the cumulative effect of these and similar future works will be to provide a far greater degree of security from river movement and erosion than is enjoyed by the occupants of the right bank at present.

3.2 The physical environment

The gross project area consists of the Brahmaputra-Jamuna river system, from the Brahmaputra/Teesta confluence to the Brahmaputra/Hurasagar confluence and, on the right bank, the 220 km long BRE earth embankment and, as a consequence, the lands protected by the BRE (Figure 2.1).

The region as a whole slopes from the north towards the south-east, with an altitude range of 90 m to less than 10 m above sea level. There is considerable physical diversity and micro-relief which has a major impact on agriculture and the incidence of flooding. The basic morphological division is between the geology of the flood plains and the old Himalayan Piedmont Plain. The Teesta flood plain dominates the northern part of the area, whilst the southern portion of the Brahmaputra-Jamuna valley is developed from the flood plain of this river and the Karatoya-Bangali flood plain (Figure 3.1).

The soils can be divided into Floodplain and Terrace soils, which are described as follows (Bogra, Gaibandha and Sirajganj are used as reference districts):
Slopes in the Barind Tract, which has non-alluvial soils, are generally steeper and flooding is much less widespread than in most parts of the alluvial zone. Rainfall varies substantially, being highest in the north-east (eg: Rangpur) and lowest in the south-west (eg: Raishai). The range of rainfall is shown in Tables 3.1 & 3.2 [with Bogra representing the central point of the area].

The landscape is agricultural, dominated by rice. This extensive monoculture is broken up in places where other crops provide a local dominance. Around Shariakandi large quantities of pepper (Capsicum frutescens) are grown, and moving northward small plantations of banana (Musa sapientum) are found. However, even where other crops are grown extensively, rice fields are still the dominant feature of the landscape. The landscape is flat and featureless, broken only by clusters of rural villages. The villages are dominated by copses of trees (mainly mango (Mangifera indica) and jack-fruit (Artocarpus heterophyllus)) and bamboo stands. These copses are the village forests of the area, and represent an important timber resource for the local community.

In the area of the Barind Tract there are extensive brickfields that take advantage of the large clay deposits. The major conurbations are at Betil, Shazapur and Belkuchi in the south, Sirajganj on the Brahmaputra river, Bogra on the western edge of the flood plain, and Gaibandha towards the north.

3.3 The Brahmaputra river

3.3.1 Brief history of the river

The first reliable information on the planform of the river is probably the map published by Rennell in 1765, showing a braided river hugging the Meghalaya hills and then taking a south-easterly alignment to follow the eastern edge of the Madhupur Forest tract, which is a slightly elevated area of more resistant Pliocene deposits. Somewhere in the vicinity of Mymensingh the river changed to a much more meandering pattern of low sinuosity.

The Brahmaputra had previously followed courses further to the north-east and had trended south-west to its 1765 course. Given this trend and its contact with the harder Madhupur material, the river was clearly poised for a major channel shift, or avulsion.

The factors initiating the shift, or the precise timescale, may never be fully known and are probably of only secondary importance in view of the long term trend. Unless the tectonic pattern changes substantially it would seem unlikely that the river would be inclined to return to its old course in the foreseeable future.

The map published by Wilcox in 1830 is considered to provide a reliable picture of the planform of the river a few years after it had effectively completed its avulsion. The river south of the avulsion point has an almost pure meandering single thread planform, whereas further north the braid pattern remains strongly pronounced. The underlying straight alignment, corresponding not only to the shortest course but also perhaps linked to the alignment of the local drainage pattern, is also noteworthy in terms of the river's macro-planform evolution.

By 1914 the major meander loops had broken down through a process of multiple chute channel development to create a largely braided appearance, but with a
work following an further assessment to resolve datum errors that appear to be present in data sets for certain years).

The sediment that is produced through the process of bank erosion is treated by the river in one of three ways:

(a) transported out to the Bay of Bengal;
(b) carried some distance before being deposited in a mobile bed form;
(c) transported some distance before being deposited as long-term storage in an upper level meta-stable char.

If the river is in dynamic equilibrium as suggested by the specific gauge analysis and the interpretation of the long section data, then it would be expected that the bed and suspended sand load entering at the head of the river reach should be equal to that leaving at the bottom of the reach, when measured over a reasonable period of time.

A pilot exercise was carried out using data from the 1986 and 1987 maps contained in the JMBA Report for the reach between sections J-1-1-7 and J-5-6 (a distance of 76 km) and the measurements of sediment load at Bahadurabad made during the interval (BRTS Second Interim Report : Annex 4).

These preliminary results would indicate that bank erosion in the study reach may add of the order of 15 to 30 percent to the wash load coming in from upstream, depending on the assumptions made in the analysis, but that the sand fraction is probably in balance with as much material being deposited in the form of char building/bank accretion as is yielded from bank erosion.

The inference is that a large proportion of bank silt yield follows is transported directly to the Bay of Bengal but the sand yield follows relatively short travel distances from bank source to either the mobile bed forms or the meta-stable chars.

These preliminary results are based on only part of the river over one year and must therefore be interpreted with extreme caution they demonstrate the potential value of this form of calculation. Recognition of the intimate link between bank erosion and char growth, and of the pivotal role of the sand size traction in both processes have important implications for predicting the river's response to bank stabilization and river training.

3.3.3 Chars

Perhaps the most prominent features of a braided river are the braid bars (chars) which are responsible for the river's characteristic multi-channel cross-section, very high width/depth ratio, braided planform and shifting nature.

A visual examination was made of the water surface elevation corresponding to dominant discharge in relation to char top elevations at all river cross-sections surveyed in 1988/89. Water surface elevations were taken from a preliminary run of the BRTS version of the Mike 11 1-D General Model, for a flow of 38,000 m$^3$/s. The results are shown in Figure 3.3.
located about 2 km inland from the alignment of the original embankment, which was built at a distance of 1.6 - 2.4 km from the 1968 river bankline.

In 1977, a BWDB feasibility study on rehabilitation and drainage of the BRE reported that up to 18 percent of the gross project area of about 600,000 acres (243,000 ha) was effectively protected by the BRE. The affected area varied between 20,000 acres (8,100 ha) in normal dry years to 100,000 acres (40,500 ha) in wet years.

Public cuts in the embankments are made from time to time: either where people living on the river side of an embankment seek to relieve high flood levels threatening their homesteads or land (by releasing water into adjoining protected land) or where run-off from heavy rainfall accumulates on the inside of an embankment and submerges farmers' crops (demanding immediate action). These cuts are normally confined to the reach north of the Manas Regulator where the natural land drainage is towards the Brahmaputra River.

In the years following the construction of the BRE, additional measures have been taken at various points, in attempt to maintain the security of the flood defence. These measures have included:

- cross-bars and groynes, with the aim of creating zones of low velocity flow immediately adjacent to the bank.
- bank revetment, with the aim of hardening the bank sufficiently so that it could withstand the near bank velocities.

A considerable amount of investment has been made in bank stabilisation measures over the past 20 years but the only example of relative success is the Siraiganj town protection, consisting primarily of multiple layers of randomly dumped concrete cubes. The protection of Shariakandi by means of the Kalitola groyne may be considered a partial success in that the erosion was controlled for long enough to see the main point of attack move further downstream. The survival of Kalitola is probably attributable to the fact that the most severe conditions did not develop at this location before the eroding bend died naturally due to a transfer of anabranch flow. If conditions such as experienced at Fulcharighat or Kazipur had developed it is unlikely that the groyne would have survived.

3.4.2 Priority locations

Priority locations for treatment have been identified, primarily based on the degree of economic losses/damage and social dislocation, arising from active bank erosion with, in almost all cases, an imminent risk of a breach in the BRE or where a breach has already occurred. However, the nature and rate of bank erosion, together with the amount of capital investment required at the different locations were also important considerations.

In addition, there is a very real concern that the Brahmaputra may break through to the Bangali River (if bank protection works are not implemented at Shariakandi/Deluabari and Mathurapara), which would result in a large proportion of the BRE project area being affected by prolonged inundation. The subsequent restoration of the continuity of the BRE without interruption of local drainage would

3.7
Sarakandi isolated on an island, and subjected to both active erosion and severe
flooding from both the Brahmaputra and the captured Bangali channel.
Furthermore, the significant increase in flows down the Bangali would inundate a
large proportion of the BRE protected area.

(d) Betil

Betil consists of two large villages/markets and an important weaving centre.
There is a high population density (1,800 per sq.km) for a rural area, with an
estimated 10,000 people under threat.

No measures have been taken to mitigate bank erosion. Although active erosion
appears to have subsided in 1991, there is still a very high probability that the BRE
will be breach in the very near future (at present the BRE is only 150 meters from
the river bank). Flooding from a breach in the BRE will severely disrupt this
weaving centre at substantial cost to the local inhabitants.

(e) Kazipur

In recent years there has been very active erosion which has resulted in almost
the entire loss of the old Kazipur town and Upazila headquarters. The Upazila HQ
have now been moved to a new site. The displaced population are mainly living
on the BRE. Population in the new market area (including BRE) and Upazila HQ
is estimated to be in the order of 8,500. Active erosion now appears to migrated
about 1 km downstream, but a large health complex and a number of semi-pucca
buildings remain under immediate threat.

Since the mid 1980s, the area has suffered from frequent breaches of the BRE.
These breaches have resulted in severe crop damage, as well as social and
economic dislocation. Retired embankments have also been recurrently built (with
associated land acquisitions problems), but have subsequently been breached.
The severely affected agricultural area has been subjected to a deposition of river
sand, which is clearly seen on the satellite imagery and aerial photography.

A new retired embankment has been constructed, which is currently intact.
(located approximately 0.5 km from the river bank).

(f) Mathurapara

This has been an area of very active bank erosion in recent years, which has
resulted in the relocation of Mathurapara market and a number of villages. The
BRE has also been frequently breached and during the 1991 monsoon season a
direct channel connection with the Bangali River was created by the flood flows.
That same year there was a very high rate of erosion (about 300 metres over a
length of 2 km) and very considerable displacement of people. The new
Mathurapara market (population of around 3,000) is now under immediate threat
of erosion, as it is now located on the present bank line. The new market has
already suffered from flooding from the breach which has destroyed or damaged
a number of pucca and semi-pucca buildings and severely disrupted the
population. Almost all the population are now living in Katcha houses or tin sheds
and many are displaced from recent river erosion.
sections. The persons interviewed were mainly those living along the embankment crest, and most would fall into the category of landless squatters who had migrated to the BRE for safety.

The responses were consolidated for each section and provide some insight into the opinion of this group of people. Not only was the positive/negative response to the BRE sought, but also any comment on its possible improvement. Only at three sections was there a general consensus that the BRE was not desirable. These sections were centred around Mathurapara/Chandanbaiwa and the BRE is under active erosion and multiple breaching has recently occurred.

The other sections provided views that the BRE was "good thing/doing its job/reliable". Some 80 percent of the people offered advice on improvements of the BRE covering aspects including: increase in height, better compaction, local retirement, width improvements, maintenance and overall improved construction standards.

Specific consultation visits were made in the course of the study (July 1991) to important districts along the BRE. In these visits the views of the local authorities, influential persons and villagers were determined through open discussion. These views were not confined to the BRE, but to the quality of life that existed within the protected areas, and the consequences experienced as a result of breaches in some areas.

The main issues raised in these visits are summarised below:

Kazipur

At the time of the visit the town was suffering from severe river bank erosion. Also visited were some chars, most of which were about to be inundated; with the people living there looking for shelters for themselves and livestock. Discussions were held with the local union Parishad chairman, teachers, farmers, shopkeeper and other local people.

The general opinion was that the BRE retirements do not last long (according to their observations) due to weak construction: and that the embankments should be raised so that flood water could not flow over during high flood period (although there is no evidence of failures due to overtopping).

Though fish production declined, crop production increased by almost double due to flood protection, which allowed production of three crops in a year. The embankments serve as a temporary shelter for flood affected people, besides providing a good road communication system in the rural areas when most of the land remains under water.

Though fish capture would have been higher had there been no flood protection devices, the people acknowledged that flood protection brought immense benefits to them. Prior to the 1964 embankment, huge damage in all sectors used to occur; the embankment of 1964 (and retirement of 1984) were certainly perceived to be of much benefit to them.

Their desire was for a fairly stable flood protection structure which would last for a considerable period (say about 15 - 20 years). Frequent breaches, especially at
retirement side and also in the char areas which are not flooded. Frequent shifting of Fulchari railway terminal due to erosion was causing dislocation of railway communications between the eastern and western part of the country.

Crops could not be raised effectively when flood water recedes, and the number of flood affected people is increasing every year. They considered that immediate flood protection as at Sirajganj (by building hard point or groyne) was necessary. The public also reported losses of lives due to water borne diseases when flood water recedes. Sanitation is poor, and drinking water is abstracted from a shallow aquifer about 12-15 m. This water is suspected to be contaminated with pathogenic bacteria due seepage of polluted surface water.

While these reports contain a certain degree of hyperbole, that is a common feature of such open consultation meetings, and some clear inconsistencies with established facts, the general picture that emerges is that at all levels in the rural society the BRE is perceived by the large majority as providing clear net benefits to the community as a whole. The desire is that ways be found to improve the performance of the BRE so that confidence in its function may be enhanced. This improved performance is commonly linked in peoples' minds with stabilisation of the river bank and the consequential reduction in loss of arable land and homesteads. There is however generally very little comprehension of the magnitude of the task and the scale of the costs involved.

### 3.6 Agriculture

#### 3.6.1 The rice crops

Rice in the region generally falls into three categories: local varieties, local improved varieties (pajam), and high-yielding varieties (HYV). The first crop is planted between mid-February and early September and is transplanted Boro rice. The spring rice, Aus, is usually broadcast (B Aus) in March/April, though occasionally is transplanted (T Aus). The summer crop is Aman rice. Fixed height Aman (local and HYV) is transplanted in July/August (T Aman). Floating Aman can be broadcast (alone or mixed with Aus) in March/April; or transplanted (after Boro) in June. Floating Aman is capable of growing to survive flood waters.

#### 3.6.2 Effect of breaches in BRE on rice crop

The direct consequences of flooding due to a breach of the BRE is the loss of at least one crop. Much depends on the severity of the breach, the duration of flood and the height of inundation. Crops are particularly vulnerable to flood damage at the time shown in Table 3.3. The cumulative effect of an open breach is most damaging, as it is very difficult to successfully cultivate a monsoon crop in subsequent years when the area is exposed to high velocity flood water and deep inundation.

Locally, heavy deposition of sand occurs at the time of the breach which initially renders the land unsuitable for crop production in the following Rabi season. In subsequent years farmers attempt to grow boro rice or other Rabi crops but productivity is low. Increasingly, these areas are being planted with sugar cane, which can withstand high levels of inundation, but with lower yields.
This is said to have led to a deterioration in livestock health and productivity, as well as a marked decline in livestock numbers; particularly cattle which are reported to have decreased by 25 percent to 40 percent over the past ten years in certain parts of the BRE protected areas. Coupled with the increase in cropping intensity, this decline has created a noticeable shortage of draft power, especially for small and marginal farmers.

The North-West Regional Study (FAP-2) indicated that draft animals are reducing both in numbers and strength; and that increased fodder production could only take place at the expense of human food production, thus making the availability of good quality cattle feed unlikely.

No accurate statistics are available on livestock losses. Discussion with farmers during the field surveys, reveal that significant livestock losses were experienced in the areas severely affected by a breach in the BRE. However, flooding from a breach in the BRE is not likely to make a significant contribution to livestock feed resources, and so will have neither a negative nor positive impact on future livestock populations and productivity. With regard to the impact on future livestock development within the BRE protected area, it has been assumed that breaches in the BRE would not have a significant overall effect.

3.7 Fisheries

The capture fisheries in the Brahmaputra river appear to have suffered seriously over the past decade. Reported annual fish catches since 1983 have dropped by over 50 percent in practically all stations (Figure 3.4). The data for Bogra and Tangail districts, both on the left bank, show very similar declines, and the fishery can be considered to be operating at barely subsistence level at present.

Capture fisheries has been identified as one of the sectors worse affected by flood control projects. The main negative effects of FCD/FCDI schemes on fish production can be summarised as follows:

- Construction of flood control embankments reduces the area of perennial beels and floodplain available for fish nursery and feeding grounds, thereby reducing the overall fish production potential.

- Construction of regulators and cross dams prevents migration of fish to and from breeding grounds, resulting in reduced stock of migratory species (principally higher value carp).

- Increased use of chemical fertilizers and pesticides, associated with the adoption of HYV leads to the pollution of natural water bodies and to higher fish mortality rates.

- The reduced areas of open water within flood protected area has severely restricted subsistence fishing, with detrimental consequences on the income and nutrition of the poorest section of the community.

- Reduced fish stocks and lower catch rates have endangered the livelihood of fishermen, many of whom have been forced to migrate from the protected areas in search of alternative employment.

3.15
The present situation with regard to the river fishery in general is one of a declining sector, with reliance on artisanal fisheries, and a reducing fish-spawn catch.

3.8 Water resources

Much of the water supply in the areas protected by the BRE are from groundwater sources, both from shallow aquifers and deep tube wells (DTW). However most rural families still use surface waters for bathing and washing, and even for drinking water in many cases. The relatively poor sanitation facilities (pit latrines), and cases of open defecation and animal faeces, can cause contamination of the shallow aquifer and surface waters as floods recede.

For communities along the bank of the Brahmaputra river, the river provides bathing and washing areas. In many of the villages, and along the BRE where squatter communities have developed, both local authorities and agencies such as UNICEF have provide village hand pumps for supply.

Most of the area of the Brahmaputra floodplain, and the northern area of the Teesta floodplain, appear to receive adequate recharge under present conditions. There is some concern about aquifer recharge in the southern areas of the region, especially in a belt north of the Ganges (Figure 3.6).

There is little data on the effect of pollution on water quality. Table 3.5 gives data for Sirajganj collected during the study. This indicates a generally acceptable quality for river water, although there are indications of increased iron concentrations in some samples. The need for continuous water quality data is highlighted by the results of this 'spot' analysis. The later set of samples (Table 3.6) do not exhibit these higher iron concentrations.
4  ENVIRONMENTAL IMPACT ASSESSMENT: PRIORITY WORKS

4.1  INTRODUCTION

4.1.1  Scale of works

In considering the possible environmental impacts of the project, it is important to remain aware of the scale of the works in relation to the natural processes that are occurring due to bank erosion by the Brahmaputra river, and breaching of the BRE. This has been described in Chapters 1 and 2 of this report.

The present, natural condition along the right bank of the river is that of extensive erosion (Table 1.1), and in order to maintain flood protection the BRE has had to be progressively retired.

The proposed urgent bank stabilisation works are relatively small, both in area and in their effect when set against the present river regime.

The Priority Works are however only a first stage in a longer term and continuous process of strategically improving bank stabilisation and, as a consequence, the standard of flood protection. In this context this EIA on the Priority Works will form a basis for future environmental assessments made on progressive stages of right bank stabilisation.

4.1.2  Evaluation of Impacts

The FPCO draft Guidelines for EIA have been followed in the assessment of environmental impacts. In order to provide a reproducible and objective assessment and evaluation, a system of impact scoring has been developed in this project, and translated to the evaluation scale recommended in the FPCO draft Guidelines.

The methodology used is discussed in Chapter 6. The important environmental components: physical/chemical, ecological, sociological/cultural and economic have been assessed against the actions/sectors detailed under three project phases: pre-construction, construction and post-construction.

Matrices have been produced summarising these assessments. Table 6.1 summarises the assessments on a without/with project basis, Table 6.2 shows the evaluated changes brought about by the project, and Table 6.3 summarises the possible means by which mitigation measures can be employed to reduce the negative impacts identified.

4.2  IMPACT ASSESSMENT: COMMON ISSUES

There are some issues common to all the Priority Works, and these are discussed here (though shown in the impact matrices against the appropriate project phase).
The project has a minimum requirement of bricks for the proposed revetment works. The options open for the main revetment armour layer involve the use of either brick or crushed stone aggregates for the manufacture of cement concrete (c.c.) blocks or the importation of quarry rock. Because of the large quantities of materials involved and the unpredictability of logistical constraints on the supply of the materials, it is considered prudent to plan for the possible use of all three options. The final choice, which may include a combination of the options, will be taken near the time of construction. Table 4.3 gives the estimate for materials.

The minimum project requirement would be of the order of 17.5 million (equivalent to the annual output from 13 double-burner brick works). If bricks were used as the only source for aggregate the requirement of over 150 million bricks would be equivalent to the annual output from 117 double-burner brick works. The project would demand a minimum of an extra fuel use equivalent to 4,000 tonnes of coal or almost 10,000 tonnes of timber, increasing (with the use of brick aggregate) to 35,000 tonnes of coal or almost 87,000 tonnes of timber.

Within the project area the timber would normally come from the village forests (the copses of fruit, shade trees and bamboo planted around the villages). There is concern lest the recent trend in the use of bamboo roots to fire the kilns may, in the longer term, reduce the stock of bamboo, which is the main housing material for katcha homes (more than 90 percent of rural housing).

Whilst this increase in brick production locally would certainly provide a positive benefit, in the form of increased local labour and services during the life of the project, the continuing use of timber for brick works in the area must lead to considerable concern over the further impact of timber resources that the project would impose on the present apparently un-controlled situation.

If the contractor chooses to use larger brick works outside the local area, there will be an increase in the impact of vehicles and boats in the transport of materials to the project site, a reducing of local employment benefit as well as in project related impacts and land degradation.

Mitigation

A minimum number of bricks are required for the project and the full impact of production cannot be offset by mitigation. There will be a degree of land degradation, and localised increase in dust/soot levels during the project/production period. The use of fuel cannot be avoided, but a contractual imposition can be placed on the civil works Contractor whereby he is obliged to obtain bricks only from specifically approved coal-only fired kilns. This has to be enforced through independent, regular monitoring of the designated brick works by the Engineer.

The question of the larger scale use of bricks as aggregate for the main armouring for the bank protection works is more difficult. The brickfields will bring considerable local employment for the production period, which must be seen as positive benefit, and the use of stone could add 30 - 40 percent to the cost of materials.

There are in this case two possible ways by which this problem can be reduced:
It may also be necessary for the contractor to undertake some channel development, particularly in the Shanakandi/Mathurapara area, if he intends to use motor vessels to bring in materials, as there is no suitable landing for such boats at present.

There is likely to be no disruption to the use of country boats during the construction period. Indeed, given the nature of the site at Shanakandi/Mathurapara, it is likely that there will be an increase of country boat use as a result of the project, which will provide a positive benefit to a significant proportion of the local river communities.

**Mitigation**

The impacts on navigation are thus likely to be small, and experienced only under dry season conditions and for short periods during the construction phase. There will be no long term adverse impact.

Conditions have been written into the ICB Contract Specification to ensure that all impacts on navigation are minimised. Sources of material of hydraulic fill will be sited on the western side of the main river channel to obviate interference to navigation from the floating pipelines.

Sedimentation of the main shipping channels is therefore unlikely to be a problem if the works are executed to the normal standards associated with International Competitive Bidding (ICB) and properly supervised by the Engineer.

Providing motor vessel berths at Shanakandi/Mathurapara may also disturb sediments, but these are more likely to temporarily impact on local artisanal fisheries than on any other river traffic. The conditions relating to ICB standards and supervision also would apply in this instance.

The railway and pontoon berths are designed to be simply and quickly relocated in response to the naturally rapidly changing channel conditions. Both BR and BIWTA have considerable experience in this and undertake such action on a routine basis. Provided that good liaison is maintained between the Contractor, through the Engineer, and the BIWTA, BR, any temporary impacts arising from the construction works can be kept to a minimal level. As a further safeguard, provision is being made in the civil works contract for the Contractor to carry out remedial dredging should the need arise.

**4.2.3 Dredging and Hydraulic Fill**

**Background**

There are requirements for both dredging and hydraulic fill operations to be carried out at both sites of the Priority Works. The concerns about these operations are their possible impacts on navigation and fisheries, particularly in the dry season, as during the monsoon such operations are reduced, and the natural sediment transport and flows in the Brahmaputra river are considerably increased.

Dredging operations will in general be localised, either for contractor's access, or for construction of the underwater portion of the revetments. At Shanakandi/Mathurapara there will be a small excess of dredged material that will
However this disruption is only temporary and can be partially mitigated by
designing the work programme to move from north to south, thus allowing
completed areas in the north to be used for fishing as the works move southward
with the river flow.

There should be little disruption to the fish-spawn fishery, since dredging works by
their nature will cease with the onset of the monsoon (between May-June). Where
local fishermen identify suitable fish-spawn catch areas (which may vary from year
to year), care should be taken to avoid construction activity in these areas for the
short catching season, and to carry out necessary dredging from areas
downstream wherever possible. The main areas of concern for this fishery may be
in the Sariiganj area (though this is reported to be a collection centre rather than
a fishery). Suitable provisions are incorporated in the civil works contract.

In all cases close liaison with the local fishermen, and the Department of Fisheries
(particularly the local district office in Sariiganj) will considerably reduce impacts.

4.2.4 Water, sanitation and public health

The Priority Works will not, in any foreseeable manner, alter the present situation
with regard to water supply or sanitation to the main dwellings in the project areas.
There will be a need to consider some new provision for these services in the case
of the relocation of squatter families in Sariiganj, but for the rest of the project sites
the works proposed should not interfere with existing services.

The Contractors facilities at the sites will create a large temporary concentration
of people for whom adequate facilities must be provided.

Public health is generally a matter of hygiene and disease transmission, mainly by
water or vectors. The Priority Works will temporarily extend water bodies during
the construction phase, and for this reason the Engineer has the power to ensure
adequate spraying or drainage to reduce the vector problem.

In this regard three main provisions are incorporated in the Specification and
Conditions for the civil works contract. The Contractor will be responsible for:

(a) provision of adequate drainage of inundation water in the area
enclosed by the extension of the Sariiganj embankment, particularly
in any areas for temporary re-location of squatter families. Such
drainage will also ensure that sanitation wastes are not brought up
through flooding, and so reduce the risk of water borne infection in
this area.

(b) spraying of the borrow pits created during the hard point/cross bar
construction (particularly where these are near to temporary work
camps, housing). At the end of the project these borrow pits are
expected to be used for crop/fish production.

(c) provision and maintenance of satisfactory water supply and sanitation
facilities for the Contractor's workforce and the Engineer's personnel.

(d) making good any damage caused to existing facilities during the
construction of the works or any associated activities.

4.7
The acquisition of the land will follow the established procedures for land acquisition, and compensation will allow the land owner to re-establish himself within the area.

**Contractor's land acquisition**

This component of the project will cause a temporary loss of agricultural land, mainly in the area south of the Ranigram groyne. This may result in some loss of employment as well as production, for the period of the project.

In mitigation there is likely to be greater opportunities for employment during the project life, and the land owner will be compensated for loss of production by the rents due on the land acquired.

The Contractor will be bound by the conditions of the ICB contract under the supervision by the Engineer. All land used for temporary works will be returned to their original state prior to the departure of the Contractor from the site.

**Hydraulic fill of town/groyne area**

The ecological impacts of this activity relate mainly to the impact on fisheries and possible interference with navigation. Section 4.2.2 has dealt with the navigation issues and Chapter 4.2.3 with the type and spread of sediments, their possible impacts and the mitigation measures available.

There may be some loss of production in the fill area during the life of the project, but this will have been compensated for during land acquisition. The short-term loss of income will be offset by project-generated employment, and the greater land area and security from flooding provided by the project in the long-term.

**Manufacture of bricks**

The impacts and mitigation on this aspect of the works has been covered in Section 4.2.1.

**Collection and stockpiling of materials**

No significant environmental impacts are envisaged for this activity.

There will be positive, though temporary, impacts from this component relating to the increase in project-generated employment on the contractor's site; and indirectly from the income obtained by local services to the contractor's workforce.

**Transport of materials/block making**

This activity could lead to considerable increase in traffic congestion on the main access road to Sirajganj. It is proposed that the contractor's essential vehicle traffic be confined to the north road of the town (to avoid the town centre) and use the crest of the embankment as a supply route for the works.

The obligations imposed on the Contractor through the Specification will provide him with a strong incentive to minimise the use of road transport in favour of water and rail transport, thereby mitigating the road traffic nuisance. An increase in water
4.4.2 Construction phase

Construction of upstream termination new revetment

Overall this phase will change the existing shoreline between the groyne and the town, providing a reveted embankment. Flooding of the present char land behind the embankment will be prevented. Any sediments dispersed during this activity are not expected to affect local fishing, which generally occurs further up- and down-stream, outside the effect of the plume.

There will be some temporary interference with the casual beaching and repair of country boats in this bay area during construction but this facility has only been available for two or three years since natural accretion developed in the area and does not constitute a long standing tradition. The potential for these activities to the north of Ranigram Groyne will not be affected.

Provision has been made in the design of the revetment for ghats (steps) suitable for the mooring of country boats and for access to the water for bathing. It would also be possible to construct ramps for vehicle access to ferries in this section.

As noted earlier, the form of the contract is designed to encourage the Contractor to make as much use as possible of water transport and it is envisaged that he will make use of this section for his own wharfage facilities during construction. The Contractor's essential land-based heavy transport will be limited to the peripheral roads and he will be responsible for the upkeep of such roads insofar as wear and tear by his vehicles is concerned.

There will be positive, though temporary, impacts from this component relating to the increase in project-generated employment on the contractor's site; and indirectly from the income obtained by local services to the contractor's work force.

Hydraulic fill of new section

The possible impacts and mitigation of this activity have been considered in Section 4.2.3. On completion of the fill the area will provide valuable additional flood free land for high value agricultural and urban development.

Upgrading of existing town revetments

There is a possibility of increased sediment concentrations in the river resulting in some temporary shoaling in the vicinity of the BIWTA vehicle ferry ghat during construction of the most downstream portion of the revetment but the railway ferry ghat is sufficiently downstream as to be out of range of any significant effect. The situation will be regularly monitored by the Contractor, under the supervision of the Engineer, and provision has been made in the civil works contract for the Contractor to undertake or arrange for remedial dredging to be undertaken should the necessity arise.

Access by vessels to the most downstream 300 m of the existing revetment and for perhaps another 200 m downstream of this, both of which are currently used by cargo boats for off-loading, will not be possible during the few weeks in which construction is taking place over this short section. Given adequate liaison with BIWTA and the shipowners this is not considered to present a serious problem.
placing of sand-filled geotextile bags, concrete blocks or rock from pontoons. This activity is not likely to cause any significant disturbance of any form and should be less than in terms of quantity than is carried out at present.

**Town area**

The construction phase will have brought a degree of temporary prosperity to certain sections of the town, which may disappear at the end of the works.

In the long-term, however, the town will have been left with a considerable number of positive advantages not available at present. The security of housing within the town area will have been ensured. New land will have been created benefitting from full flood protection. A new river-front road and better landings for all river craft will have been provided.

These advantages will become part of the future for the Sirajganj, and the pourashava should take account of these future long-term benefits in planning how Sirajganj can continue to maximise the benefits obtained from the project.

**Agriculture**

In local terms agricultural around Sirajganj town will benefit from greater security from flood and erosion by the Bramhaputra river, as well as the increase in land suitable for high value cropping created behind the new length of revetment.

**Fisheries**

It is unlikely that in the long-term there will be any positive or negative change in the river fisheries as a result of the works. The fisheries are already considerably depleted, and after completion of the works no long-term impacts are apparent. The expansion of the fish market in Sirajganj is a possibility, but this will largely depend on the natural recovery of the river fishery, rather than on the improvements in landing provided by the project.

**Water, sanitation and public health**

It is unlikely that in the long-term there will be any positive or negative change in these components as a result of the works.

**Wildlife**

This component has been discussed in Section 4.2.5. No significant change attributable to the project is anticipated.

4.5 ENVIRONMENTAL IMPACTS : SARIAKANDI/MATHURAPARA BANK PROTECTION WORKS

4.5.1 Pre-construction phase

Land acquisition for the civil works

The main impact of this aspect will be in the loss of a relatively small amount of
Transport of materials and concrete block making

The only direct access to the project area is by road or boat, and transport of materials to the three principle construction locations will require careful planning. All-weather road access is available by public road to Sariakandi but this in its present condition would not be suitable for the regular mass haulage of material, particularly as it would involve movement through the congested centre of Bogra town. The present ferry crossing of the Bangali river is also unsuitable for the regular transport of heavy goods vehicles.

There is no existing road to either the Mathurapara or the Sariakandi hardpoint sites. A country road in poor condition approaches the area from Chandanbaisa to the south but stops short. Use of the BRE has been specifically denied to the Contractor; it is not designed for this purpose and much of its length is occupied by squatters.

The options open to the Contractor are to temporarily acquire land for the construction of temporary haul roads, which could be brick surfaced to facilitate reinstatement, and to make maximum possible use of waterborne transport. A combination of these two methods will probably be necessary because of the uncertainty regarding the location of navigable channels at the time of construction.

It is recognised that access during construction will be a major concern for the Contractor and that this could potentially result in significant temporary impacts in the various areas of the project. The civil works contract Specification contains controls specifically designed to address these potentialities and the standard Conditions of Contract provide the Engineer with the power to monitor and enforce the Contractor's compliance with these provisions. An important contractual obligation in this respect is that the Contractor must submit a detailed Method Statement covering all aspects of his temporary and permanent works for the prior approval of the Engineer. He will not be permitted to commence any work until receiving this approval.

These obligations on the Contractor will encourage him to maximise the use of waterborne transport and it is accepted that this will have both cost and physical implications regarding the maintenance of navigable channels.

The making of concrete blocks will involve the crushing of either stone or bricks for coarse aggregate and this will result in some dust and noise nuisance but with reasonable precautions, including appropriate siting of the work areas, these can be maintained at an acceptable level. This situation is temporary, during the block production period, and seasonal in that conditions will be worst in the dry season.

There is little in the way of mitigation for these localised impacts, other than to ensure that the contractor executes these works in a manner sensitive to the local environment. Conditions to this effect are incorporated in the civil works contract and will be monitored and supervised by the Engineer.

There will be positive, though temporary, impacts from this component relating to the increase in project-generated employment on the contractor's site; and indirectly from the income obtained by local services to the contractor's work force.
**Construction of Hard Points**

The two hardpoints will consist largely of stabilisation of the existing bankline over a total length of about 1,000 m by the placing of armour material on a geotextile filter and will therefore involve minimal permanent land acquisition. Temporary acquisition will be required for the terminations, where the revetment is wrapped back in to the bank, but on completion of the works these areas will be reinstated and returned to their owners for normal use.

The siting of the hardpoints is determined by large scale morphological considerations and the final positioning can only be determined close to the time of construction when the current pattern of erosion and channel migration is known. Since much of this area has already been devastated by breach flows there is little in the way of homesteads in the proximity of the bankline at present and it is unlikely that the construction of the hardpoints will require the resettlement of any families.

The form of construction will follow the normal pattern of dredging to form the underwater profile for the placement of the launching apron followed by the placing of a geotextile filter and finally the dumping of the armour material. Some dredged material may be used as hydraulic but it is anticipated that there will be some excess which will be disposed of close to the existing bankline at a location to be approved by the Engineer that does not significantly interfere with any local navigation or fishing interests.

There is however not expected to be any other significant direct impact on navigation or fishing during the construction of these works, which as noted earlier, are relatively remote from population concentrations. The plume of more turbid water resulting from dredging activities will be confined to a strip of less than 500 m width and extending for no more than 1,000 m downstream of the works, which is a small area in relation to the width of the river at this point.

Provision has been made in the design of the revetment for ghats (steps) suitable for the mooring of country boats and for access to the water for bathing in situations where there are concentrations of homesteads requiring such access.

As noted earlier, the form of the contract is designed to encourage the Contractor to make as much use as possible of water transport and it is envisaged that he may construct temporary wharfage facilities close to one or both of these sites for this purpose, with temporary road links to his casting and stockpiling yards. The normal contractual conditions will apply and no significant additional impact is expected to arise from these temporary activities that require specific mitigation measures.

There will be positive, though temporary, impacts from this component relating to the increase in project-generated employment on the contractor's site: and indirectly from the income obtained by local services to the contractor's work force.

**Construction of Cross-Bars**

The cross-bars will consist of low earthfill embankments linking the hardpoints to the main BRE embankment. They will be provided with protection against erosion.
Provision is made in the civil works contract for the Contractor to provide on-the-job training in operation and maintenance activities to selected BWDB staff who will form a specialised O&M Unit established for this specific purpose, with offices and support facilities located in Sirajganj.

The scope of the maintenance works and the responsibilities of the O&M Unit have been described in Section 4.4.3. These routine activities will be largely carried out using waterborne transport and are not likely to cause any significant disturbance of any form.

From time to time it may be necessary to undertake extensions to the revetment work or to strengthen the launching apron in areas of severe attack and this could cause some temporary increase in suspended sediment concentrations. The scale of such works will be an order of magnitude less than the original construction and the impact will be commensurately less. If the system of local liaison set up during the project can continue, the effects of these impacts will be considerably reduced.

Town areas

The construction phase will have brought a degree of temporary prosperity to certain sections of the towns and larger villages in the area, which may disappear at the end of the works. The improvement in secure housing for displaced persons along the cross bars, the improved stabilisation of the river, and the security of flooding, will be positive benefits to the towns both directly and as a result of the growth in rural prosperity.

Agriculture

In the long-term, the possibility of a breakthrough of the Brahmaputra into the Bangali will have been greatly reduced, and the reliability of the BRE will be substantially enhanced. This will result not only in the virtual elimination of flood damage due to breach flows in this vicinity but also to a considerably improved sense of confidence extending over a very much larger area, which in turn will lead to more investment in agricultural development, increased agricultural productivity and a general raising of the standard of living in this wider area.

Fisheries

It is unlikely that in the long-term there will be any positive or negative change in the river fisheries as a result of the works. The fisheries are already considerably depleted, and after completion of the works no long-term impacts are apparent. The artisanal fishermen may gain some indirect benefit from any improvement in access to markets that the project may leave behind.

Water, sanitation and public health

It is unlikely that in the long-term there will be any positive or negative change in these components as a result of the works.

Wildlife

This component has been discussed in Section 4.2.5.
ENVIRONMENTAL MONITORING & ACTION PLAN

5.1 Introduction

It is important that the construction of the Priority Works not only proceed in an environmentally and socially sensitive manner, but also that the benefits of the works are maximised while any negative impacts are minimised. This requires a number of continuous actions that should begin in the pre-construction phase, and be maintained well after completion of the project.

Institutional responsibilities may change as the project proceeds, particularly in relation to decision making, although the fundamental data collection and analysis tasks remain the same. It is important, therefore, to provide a simple, yet effective, system of monitoring which can be readily transferred between agencies when the situation demands.

This approach demands, at the earliest moment, an effective, open and harmonious systems of liaison between a number of different bodies, and groups. Without this effective inter-action the benefits of the project become neutralised by ignorance or indifference, and a negative perception of the gains made by the investment can develop in the public mind.

Such a programme must operate within the legal, cultural and institutional frameworks that exist in Bangladesh. Given the urgency placed on the Priority Works, in respect of the natural negative consequences if they are not executed, it is not appropriate that the environmental monitoring/action plan be based on the existing situation. The plan has to be flexible and capable of initiating and executing changes by local institutions and groups, if necessary, in the future.

5.2 Liaison

For the full project benefits to be realized, a system of liaison between institutions and groups should be set up and maintained. Such liaison will allow all interested parties to become aware of the progress of the project; allow project decisions to respond to local interests and concerns as they may occur; provide greater public confidence in the purpose of the project; and ensure the efficient and economic execution of the works.

The BWDB will bear the responsibility for developing the system of liaison in conjunction with the Deputy Commissioners and local authorities, particularly within the localities of the project sites. The Engineer will have an important part to play in this aspect, and the actual functioning of the system will reflect his judgments on frequency, type and inputs into the liaison process.

Liaison will be required between local administration, other public institutions and utilities, and local public interest groups; all of which will require different degrees of inter-action with the project.

At the national level the FPCO and BWDB will continue to maintain an on-going exchange of information with the national bodies regulating sectors affected by the project, together with the donor agencies and international agencies.
There are a number of actions that can be taken in this consultation process, and the use of any, or any combination, will depend on the situation at any period in time.

Direct consultation with affected individuals, households and land owners are needed when land acquisition or displacement activities are planned. This consultation should include group and public meetings, as well as consultations with affected individuals. It is important to include in the consultation process all persons that might be affected in the localities, not merely the persons whose land or homes are to be acquired.

As a part of the consultation process, surveys of interest groups should be undertaken, particularly when a project activity has indicated a possible impact (positive or negative). These may be household or sector groups. To provide data for future decision making, follow-up surveys of these same groups should be undertaken to determine public opinion on the success of the operation.

In particular relation to the project sites, the impact of project phases on artisanal fishermen in both Sirajganj and Sariakandi/Mathurapara should be undertaken.

5.5 Monitoring

It has been shown that the project will not significantly impact on natural resources or sensitive ecological zones, but may provide local changes that need to be taken account of in river and floodplain management programmes, which fall within the remit of other projects under the Flood Action Plan (FAP).

There are no authorities that, at present, have the institutional capabilities or resources, at a local level, to monitor environmental change, or adequately provide a record of environmental and social change at this time. Accordingly a method must be found whereby some records can be presented at regular intervals to allow for independent scrutiny and evaluation of any on-going negative impacts.

It is proposed that the BWDB take on the responsibility for assessing these impacts during the course of the project for reporting on these aspects of the work. After completion of the project the BWDB may continue the process of monitoring or may mutually agree to pass this task over to a national or local body which may, by then, be able to take on this role.

Following completion of the works responsibility for monitoring will be vested in the specialist BWDB O&M Unit that it has been proposed will be established during the construction phase. The personnel for this Unit will have been provided with training by the Contractor and others. Until the formation of this Unit, the BWDB Executive Engineer for each area should be given the responsibility of ensuring the recording of the observed social and environmental changes, and reporting at six-monthly intervals (November and May) on these changes. In this regard the information supplied by the system of liaison that would set up in the local communities will be very important.

Specifically the record should contain monthly observations on the following:

(a) any squatter or other persons moved from the area to allow works to proceed. This information should record number of families affected;
consultation and feedback into the design procedure. At Sankandi/Mathurapara alignments will be set, as far as possible, to avoid dwellings and major human disruption.

Contractor's land acquisition and site development

World Bank approved ICB contract procedures will be followed to ensure minimal disruption and nuisance in contractor's site development, including a requirement for adequate consultation on site selection.

Collection and stockpiling of materials

The controls applying to the manufacture of bricks (see Section 4.2.1) will be strictly enforced. The main civil works contractor will be required to ensure adequate safety and security measures, and to minimise nuisance under the terms of the ICB contract.

Transport of materials

The Contractor will be responsible under the terms of his contract for ensuring that his use of road and water transport causes the minimum degree of congestion and nuisance and that all necessary action is taken to ensure that the interests of other users are adequately protected. In addition, prior consultation with the local authorities and with residents and businesses along alternative routes will be undertaken to facilitate this process. The importance attached to the Contractor's compliance with the contract conditions should be stressed at the Pre-Bid Conference, held during the tender period, that all tenderers will be obliged to attend.

Precasting of Cement Concrete Blocks

The conditions and specification forming part of the ICB contract will be enforced through the powers vested in the Engineer to ensure that this activity is undertaken in a safe manner, and that all nuisance and pollution is kept to a minimum.

Movement and re-settlement of families

Full consultation with the local authorities, the affected communities, and families will be undertaken. NGO's will be invited to participate in this process and to assist in reducing the impact of resettlement. The Contractor will be required to provide suitable temporary land, install or arrange the necessary water and sanitation services for the settlement site, and assist both with the transfer of the housing to the temporary area and its return and erection to the original location on completion of the works.

Dredging and hydraulic fill works

The conditions and specification forming part of the ICB contract will be enforced through the powers vested in the Engineer to ensure that this activity is undertaken in a safe manner and such that the interference with fisheries and navigation is kept to a minimum. Close liaison will be maintained with the BIWTA and the MOF so that the timing and scope of operations may as far as practicable be arranged to minimise impact, given due consideration to the strict limitations set
6 ASSESSMENT AND EVALUATION METHODOLOGY

6.1 Introduction

The assessment of the impacts of the project has relied on the results of the river morphology studies, the engineering design and strategy studies, and the BRE Inventory for primary data. Much of the environmental and social data has been obtained from secondary sources, mainly from other FAP programmes. Field visits have been made on a number of occasions at various times in the project, to obtain views of local individuals and organisations, as well as to confirm impressions by direct observation and inspection in the field.

The environmental assessment has identified the important environment factors within the project area and, with respect to these, assessed the impacts of project activities on a without and with project basis. For each of these components a score was determined, which provided a measure of the benefit/dis-benefit of the activity on the component.

To ensure that the evaluation complied with the FPCO multi-criteria analysis scale of ± 3, a conversion was derived by which the project assessment score could be confidently translated to the ± 3 scale. These values were recorded in an impact matrix (Table 6.1).

The change in impact from a without-project to a with-project situation has been quantified in each case, and the changes recorded in a second matrix (Table 6.2). A third matrix summarizes the negative impacts and the possible mitigation measures that could be employed in each case (Table 6.3). These three matrices thus provide a sequential summary of the environmental conditions, impacts (positive/negative) and possible mitigation for negative situations under the with-project conditions.

6.2 Discussion: project impact assessment

In conducting any impact assessment where reliance has to be placed on incomplete secondary data, and where no possibility exists for independent confirmation, or for primary data collection, assessment will tend to be subjective. This subjectivity can provide a competent analysis of the probable changes and effects, but suffers in that it is neither reproducible or transparent.

Where qualitative evaluation of impacts has to be made, it is important that these evaluations should conform to a defined system of analysis. EIA/EE evaluations need to be re-assessed with the passage of time, and the data contained therein should be open to scrutiny and revision as new data becomes available.

Wholly subjective and descriptive systems are not capable of such revision, dependent as they are on the expertise and experience of the original assessors and on the quality of the descriptive record left behind.

To provide some degree of transparency and objectivity in the qualitative assessment and evaluation of the impacts on this project, a system of scoring has been designed, to allow subjective judgments to be quantitatively recorded. This
6.3.2 Scales

The scale of ES scores will vary with the number of Group (A) and (B) criteria applied and also if the scales for each criteria vary. The advantages of using different criteria scales are that the sensitivity can be varied for each criterion, and that weighting can be applied directly in the assessment process. As the criteria and the scales are defined, this process is wholly transparent. The system also allows a "what if..." condition to be applied by varying the weighting given, particularly with respect to value criteria (Group (B)).

Benefit and dis-benefit can be obtained by using scales that pass from negative to positive values through zero. Zero thus becomes the 'no-change' or 'no-importance' value. The use of zero in this way in group (a) criteria, allows a single criteria to isolate conditions which show no change or are unimportant to the analysis.

Zero is a value to be avoided in the Group (B) criteria. If all Group (B) criteria score zero, the final result of the ES score will also be zero. This condition may occur even where the Group (A) criteria show that the condition of importance and should be recognised. To avoid this, scales for Group (B) criteria should use (1) as the 'no-change/no-importance' score.

6.3.3 Criteria used

The criteria used in this assessment comprise two under Group (A) and three under Group (B):

GROUP (A)

IMPORTANCE OF CONDITION (A1)

A measure of the importance of the condition, and is assessed against the spatial boundaries it will affect. The scales are defined:

- 4 = important to national/international interests
- 3 = important to regional/national interests
- 2 = important to areas immediately outside the local condition
- 1 = important only to the local condition
- 0 = no importance

MAGNITUDE OF CHANGE/EFFECT (A2)

Magnitude is defined as a measure of the scale of benefit/dis-benefit of an impact or a condition:

- +3 = major positive benefit
- +2 = significant improvement in status quo
- +1 = improvement in status quo
- 0 = no change/status quo
- -3 = negative change to status quo
- -2 = significant negative dis-benefit or change
- -3 = major dis-benefit or change
of no importance or represents the status quo, or a no change situation.

A condition that is outside local boundaries in importance \((A2=2)\) and shows significant change \((A2=2)\) is considered to be the point when a band separation should occur. The value condition should be one of a temporary, reversible, non-cumulative \((bT=6)\), the condition has a score \(ES=24\), and this score is taken as the lower limit of the second \((\pm/2)\) band.

The distinction between the second/third bands can be set by a regional/national condition \((A1=3)\) that undergoes a major change \((A2=3)\), of a temporary, reversible, non-cumulative nature \((bT=6)\). The conditions scores \(ES=54\), and this score becomes the lower limit of band \(\pm/3\).

The ranges and their FAP bands can be summarized:

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<th>FAP guideline value</th>
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</thead>
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<tr>
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<td>+3</td>
</tr>
<tr>
<td>+24 to +53</td>
<td>+2</td>
</tr>
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<td>+1 to +23</td>
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<td>0</td>
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<tr>
<td>-1 to -23</td>
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</tr>
<tr>
<td>-24 to -53</td>
<td>-2</td>
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<tr>
<td>-54 to -108</td>
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</tbody>
</table>

### 6.4 Environmental components

To use the evaluation system described, a matrix was produced for each project site, setting out all project activities, and possible sectors of impact, against four environmental components (each having a without/with project column). The four components used have been defined in Section 1.4.3.
INFORMATION SOURCES

The main information sources came from a large number of published reports, survey work undertaken during the project, discussions with local people and with specialists in related FAP projects, as well as other experts. The following are the main reports and organizations/individuals who have provide data to the project.

7.1 References

AHMED, M.,
"Bangladesh agriculture - Towards self-sufficiency"
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GARGAS, E & CHOWDHURY, M.Y.,

HALCROW, SIR WILLIAM & PARTNERS

HALCROW, SIR WILLIAM & PARTNERS

HALCROW, SIR WILLIAM & PARTNERS
SPACE RESEARCH & REMOTE SENSING ORGANIZATION (SPARRSO)

SPACE RESEARCH & REMOTE SENSING ORGANIZATION (SPARRSO)

SPACE RESEARCH & REMOTE SENSING ORGANIZATION (SPARRSO)

Organisations & Individuals

Bangladesh Water Development Board
Bangladesh Inland Water Transport Authority
Bangladesh Standards & Testing Institute, Dhaka
Dept. of the Environment, Ministry of Environment & Forestry
Dept. of Fisheries, Ministry of Fisheries & Livestock
Dept. of Forestry, Ministry of Environment & Forestry
Depts. of Chemistry & Soil Science, Univ. of Dhaka
Flood Action Plan Project Specialists
Local government officials, professionals and townspeople in:
  Kazipur
  Betil
  Sariakandi
  Fulchariaghat
  Sirajganj
  Mathurapara

7.3
Table 1.1  Overall Erosion Rates for the Period 1951-89

Right Bank

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<th>Reaches</th>
<th>Distances (km)</th>
<th>Year</th>
<th>Annual Mean Erosion Rate (m/y)</th>
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Left Bank

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<td>Total Economic Value ('000 Tk.)</td>
<td>Number of People Displaced by Bank Erosion</td>
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<td>Quantity</td>
<td>Unit</td>
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<tr>
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<td>Level Traverses For Topographic Surveys</td>
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<td>Plane Table Surveys</td>
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<td>Dune Tracking</td>
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TABLE 3.1

Annual rainfall at selected stations of Bangladesh (mm)

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<td>1530</td>
<td>1756</td>
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<td>2185</td>
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<td>Dinapur</td>
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<td>1197</td>
<td>1934</td>
<td>2068</td>
<td>2094</td>
<td>1983</td>
<td>2225</td>
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<td>1276</td>
<td>1456</td>
<td>2252</td>
<td>1282</td>
<td>1635</td>
<td>1545</td>
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<td>1576</td>
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<td>3523</td>
<td>2872</td>
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<td>3242</td>
<td>2497</td>
<td>1878</td>
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<td>-</td>
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<td>1874</td>
<td>1927</td>
<td>1981</td>
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Source: Bangladesh Meteorological Department
TABLE 3.2

Monthly Rainfall in mm during '989

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<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
<th>Total Rainfall</th>
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<tr>
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<td>00</td>
<td>15</td>
<td>02</td>
<td>04</td>
<td>462</td>
<td>229</td>
<td>605</td>
<td>102</td>
<td>282</td>
<td>25</td>
<td>00</td>
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<tr>
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<td>07</td>
<td>15</td>
<td>02</td>
<td>00</td>
<td>335</td>
<td>219</td>
<td>719</td>
<td>110</td>
<td>414</td>
<td>48</td>
<td>04</td>
<td>02</td>
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<tr>
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<td>08</td>
<td>05</td>
<td>02</td>
<td>224</td>
<td>190</td>
<td>350</td>
<td>117</td>
<td>332</td>
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### TABLE 3.5

RESULTS OF DIFFERENT PARAMETERS OF 6 WATER SAMPLES

(Result has been expressed in PPM except pH & EC - Value)

<table>
<thead>
<tr>
<th>Lab Sl No</th>
<th>Station/ Hole No</th>
<th>Location (U. Z. &amp; Dist)</th>
<th>Sample Collection Dept</th>
<th>Date of Collection</th>
<th>pH</th>
<th>EC Value μmhos/cm</th>
<th>Free CO₂</th>
<th>CO₂</th>
<th>HCO₃⁻</th>
<th>SO₄</th>
<th>Cl⁻</th>
<th>Ca⁴⁺</th>
<th>Na⁺</th>
<th>Total Hardness as CaCO₃</th>
<th>Fe</th>
<th>TDS</th>
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<td>1</td>
<td>SQ/1</td>
<td>BTU/1</td>
<td>Bell High School</td>
<td>13.3.91</td>
<td>7.81</td>
<td>445</td>
<td>4.99</td>
<td>NT</td>
<td>233.63</td>
<td>8.33</td>
<td>27.33</td>
<td>30.00</td>
<td>15.56</td>
<td>143.19</td>
<td>3.1</td>
<td>238</td>
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<tr>
<td>2</td>
<td>KPI/1</td>
<td>BTU/1</td>
<td>Bell High School</td>
<td>22.3.91</td>
<td>7.88</td>
<td>624</td>
<td>28.26</td>
<td>*</td>
<td>564.66</td>
<td>12.25</td>
<td>175.93</td>
<td>61.00</td>
<td>34.80</td>
<td>295.61</td>
<td>378</td>
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<tr>
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<td>KPI/1</td>
<td>BTU/1</td>
<td>Bell High School</td>
<td>28.3.91</td>
<td>7.83</td>
<td>203</td>
<td>11.28</td>
<td>*</td>
<td>122.00</td>
<td>38.75</td>
<td>16.89</td>
<td>23.60</td>
<td>5.40</td>
<td>81.15</td>
<td>33</td>
<td>152</td>
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<tr>
<td>4</td>
<td>KPI/1</td>
<td>BTU/1</td>
<td>Bell High School</td>
<td>4.4.91</td>
<td>7.48</td>
<td>475</td>
<td>14.98</td>
<td>*</td>
<td>192.78</td>
<td>12.25</td>
<td>46.11</td>
<td>42.60</td>
<td>12.60</td>
<td>158.25</td>
<td>0.24</td>
<td>370</td>
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<tr>
<td>5</td>
<td>KPI/1</td>
<td>BTU/1</td>
<td>Bell High School</td>
<td>23.4.91</td>
<td>7.20</td>
<td>292</td>
<td>13.40</td>
<td>*</td>
<td>199.10</td>
<td>7.35</td>
<td>26.33</td>
<td>27.60</td>
<td>20.88</td>
<td>154.39</td>
<td>0.54</td>
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<tr>
<td>6</td>
<td>FC/1</td>
<td>BTU/1</td>
<td>Bell High School</td>
<td>29.4.91</td>
<td>7.30</td>
<td>414</td>
<td>14.62</td>
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<td>242.65</td>
<td>4.90</td>
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**NOTE:**
1. **N T** = Not traceable
2. The test results for pH, EC-Value & TDS of sample bearing hole No. SQ/1 have already been sent vide this office Memo No W-18/91/RRR/Soil/93 dated 6.4.91 (Report No. CHEM 3/91), but for information which again shown in this Table along with other parameters.
3. Fe test of the sample BTU/1 could not done as acidified sample was not supplied.
**Table 3.6**

Results of different parameters of 5 river water samples taken south of Sirajganj on 24 April 1992

Testing by RRI, Faridpur

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Bottle No</th>
<th>Carbonate</th>
<th>Bi-Carbonate</th>
<th>Sulphate</th>
<th>Chloride</th>
<th>Total Hardness</th>
<th>Calcium</th>
<th>Magnesium</th>
<th>Iron</th>
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<tr>
<td>1</td>
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<td>N.T</td>
<td>18.69</td>
<td>9.80</td>
<td>13.91</td>
<td>72.19</td>
<td>21.00</td>
<td>4.80</td>
<td>0.40</td>
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<tr>
<td>2</td>
<td>B2 BRTS</td>
<td>N.T</td>
<td>17.30</td>
<td>9.82</td>
<td>15.90</td>
<td>69.78</td>
<td>23.00</td>
<td>3.00</td>
<td>0.28</td>
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<tr>
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<td>C3 BRTS</td>
<td>N.T</td>
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<td>7.35</td>
<td>21.17</td>
<td>64.81</td>
<td>22.00</td>
<td>2.40</td>
<td>0.32</td>
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<tr>
<td>4</td>
<td>D4 BRTS</td>
<td>N.T</td>
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<td>19.18</td>
<td>89.64</td>
<td>27.00</td>
<td>5.40</td>
<td>0.36</td>
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<tr>
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<td>N.T</td>
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*Note: N.T = Not traceable.*
### Table 4.1: Major Materials Resources Requirements (Indicative only)

#### Priority Works

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<th>Mathurapara</th>
<th>Sirajganj</th>
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<tr>
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<td>tonne</td>
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<td>15,508</td>
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<td>92,263</td>
<td>110,379</td>
<td>298,763</td>
</tr>
<tr>
<td>Bamboo</td>
<td>lin.m</td>
<td>132,059</td>
<td>63,751</td>
<td>422,034</td>
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<tr>
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<td>tonne</td>
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<td>tonne</td>
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<td>12,889</td>
<td>57,593</td>
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<td>Bricks : fuel required (coal)</td>
<td>tonne</td>
<td>6,550</td>
<td>5,201</td>
<td>23,240</td>
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<td>6,375</td>
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<td><strong>AGGREGATE BLOCKS</strong></td>
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<td>Cement</td>
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<td>lin.m</td>
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<td>63,751</td>
<td>422,034</td>
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<tr>
<td>Bricks</td>
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<td>11,635,929</td>
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<td>6,633</td>
</tr>
<tr>
<td>Bricks : fuel required (coal)</td>
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<td>452</td>
<td>2,676</td>
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<td>110,379</td>
<td>298,763</td>
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<td>lin.m</td>
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<td>63,751</td>
<td>422,034</td>
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<tr>
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<td>no.</td>
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<td>1,965,165</td>
<td>11,635,929</td>
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<tr>
<td>Bricks : fuel required (wood)</td>
<td>tonne</td>
<td>2,179</td>
<td>1,120</td>
<td>6,633</td>
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<tr>
<td>Bricks : fuel required (coal)</td>
<td>tonne</td>
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<td>452</td>
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Table 6.1: Evaluation of Environmental Changes

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<td>Without project</td>
<td>With project</td>
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<td>0</td>
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<tr>
<td>Contractor's land acquisition</td>
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<td>0</td>
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<tr>
<td>Transport of materials &amp; block-making on site</td>
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<tr>
<td>Completion of town revetments</td>
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<td>ECOLOGICAL</td>
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Table 6.2: Matrix of Environmental Change  
(Changes between Without/With Project)

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<td>Fisheries (local)</td>
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<td>+ (P)</td>
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Notes:

(T) = Temporary change  
(P) = Permanent change  
+ = positive change  
- = negative change
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Notes:

(T) = Temporary change
(P) = Permanent change
+ = positive change
- = negative change
Table 6.3: Matrix of Mitigations Measures  
(Negative Changes between Without/With Project)

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Notes:
- (TP) = Temporary condition during project life
- (NM) = No mitigation
- (ICB) = Mitigation required as ICB contract conditions enforced by international supervision
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**Notes:**

(NM) = no mitigation

(ICB) = mitigation required as ICB contract conditions enforced by international supervision
Future Works at Fulchari

Figure: 2.2
Priority and Future Works at Sariakandi and Mathurapara

Figure: 2.4
Priority and Future Works at Sirajganj

Figure: 2.5
Figure 2.6

Future Works at Betil
Teesta, Jamuna and Karatoya - Bangali Flood Plains

Figure: 3.1
Typical River Cross-section showing Upper and Lower Char top Levels

Figure 3.3
Annual Fish Catches in the Jamuna 1983 to 1989

- **Jamuna River**
- **Bogra District**
- **Tongail District**

**Years:** 83/84, 84/85, 85/86, 86/87, 87/88, 88/89

**Metric Tones x 1000:**
- 8000
- 7122
- 6244
- 5367
- 4489
- 3611
- 2733
- 1856
- 978
- 100
Fish Spawn Catches, Jamuna Right Bank, 1986 to 1989

FISH-SPAWN CATCHES (RIGHT BANK)

PERCENT TO TOTAL RIGHT BANK CATCH


Locations: Sirajganj, Fulchari, Kazipur, Serikandi
AREAS AFFECTED BY LOWERING OF SEASONAL WATER TABLE BELOW 7.75m (SUCTION LIMIT) TO CURRENT DEVELOPMENT

Source: UNICEF 1987. Scale 1:1250000

Areas Affected by Lowering of Seasonal Water Table

Figure 3.6
**Silt Plume Estimate**

**ASSUMPTIONS:**
Discharge: Continuous single point discharge, rate 60 m$^3$/hour (44.2 kg/s at density 2.65 t/m$^3$).
Flow velocity: 1 m/s across the entire section.

**Channel cross-section:**
Rectangular, Width 2000 m, Depth 8 m.
Settling velocity: 0.025 m/s (Fine sand, d$_{50}$ = 0.18 mm).

**Source:** DANISH HYDRAULIC INSTITUTE MARCH 1992

**Figure:** 4.1