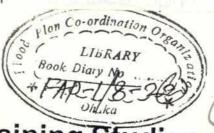
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River Training Studies of The Brahmaputra River

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River Training Studies of The Brahmaputra River

Inception Report May 1990

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Sir William Halcrow & Partners Ltd. in association with

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Engineering & Planning Consultants Ltd.
Design Innovations Group

River Training Studies of the Brahmaputra River

Sir William Halcrow & Partners Ltd

in association with

Danish Hydraulic Institute Engineering and Planning Consultants Ltd. Design Innovations Group

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3rd June 1990

Our ref

HBD/BRT/314

Your ref

Dear Mr. Razzaque,

RIVER TRAINING STUDIES OF THE BRAHMAPUTRA RIVER (BRTS) INCEPTION REPORT

I have pleasure in submitting 30 copies of our Inception Report as required by Clause 28(a) of the Terms of Reference.

We have undertaken a review of the work programme and staff schedule in accordance with the additional instructions received from the BWDB.

The Inception Report has taken into account the role of the BRTS within the Flood Action Plan as well as a prospective Brahmaputra Left Embankment. The Report includes our recommendations for a revised work programme, staff schedule and logistical support arising from this, which we are submitting to you for your consideration.

There is a need for an early approval of our revised programme and inputs so that the BRTS remains on programme.

I wish to acknowledge the invaluable assistance given by the ${\tt BWDB}$ during the Inception Report.

Assuring you our best services.

Yours sincerely,

Dr. Eng. E.M. Lates

Team Leader

cc: J. Ahmed, Project Director, Halcrow
P. Mortensen, Resident Manager, DHI
Zeaul Huq, Managing Director, EPC
Faisal Mahboob, Managing Director, DIG
Prof. M.K. Alam, Team Leader, BUET Advisory Group

RIVER TRAINING STUDIES OF THE BRAHMAPUTRA RIVER

INCEPTION REPORT

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SUMMARY

The Bangladesh Water Development Board (BWDB) appointed Sir William Halcrow and Partners Ltd. (Halcrow) in association with Danish Hydraulic Institute (DHI), Engineering and Planning Consultants Ltd. (EPC) and Design Innovations Group (DIG) to undertake the River Training Studies of the Brahmaputra River (BRTS). A BUET advisory team will form part of the Consultant's team. Consultancy staff inputs commenced on 1st March 1990. This Inception Report has been prepared at the end of the three-month inception period.

The primary objective of the project is to prepare a Master Plan for the long-term protection of the Brahmaputra Right Embankment (BRE). Continuing bank erosion is threatening the security of the BRE and has resulted in a level of damage which is regarded to be unacceptably high.

In addition the design of short-term measures at critical sections along the right bank for immediate implementation have been included in the BRTS programme.

The original Terms of Reference were prepared prior to the formulation of the Flood Action Plan (FAP). Following inclusion of the BRTS with the FAP, the BWDB instructed the Consultants to review and update their work plan and staff schedule to co-ordinate the project with the FAP and maintain consistency with the overall concepts of the FAP.

The inception phase activities have focussed on gaining an appreciation of the existing situation, reviewing data and past studies and reviewing the method of approach and work programme. During the course of this review, BWDB, FPCO, RRI, BUET and other concerned organizations were consulted.

The method of approach proposed for the BRTS centres on an interrelated set of specialist studies and physical and mathematical modelling analyses to provide an understanding of the river channel processes and flood plain characteristics. This will then be used in the formulation of a Master Plan and in the engineering design of river training and embankment protection works.

The studies to be carried out under the BRTS can be broadly classified as follows:

- River studies including hydrological, geomorphological, geotechnical and environmental studies
- Mathematical model studies
- Physical model studies
- Agro-socio-economic studies
- Engineering studies.

The studies will be supported by a data collection and river survey programme which will provide data for the development and calibration of the mathematical and physical models, as well as for the geomorphological, geotechnical and agro-socio-economic studies.

The BRTS work programme takes into account the need to undertake the designs of short-term measures along the BRE as soon as possible. Since the designs for these works will precede the detailed master plan analyses, they will not be able to draw on all the results of the specialist studies, and mathematical models. However, there is scope in the physical modelling programme to allow for models to be set up for the design of these works.

The Master Plan is envisaged as an overall plan for river training along the BRE, which, when fully implemented, will protect the BRE from erosion.

Phased implementation of the Master Plan is envisaged. During the course of its implementation, changes to the river may occur due to natural or man-made causes. A flexible approach to the design and selection of works to be included within each successive implementation phase will therefore need to be retained, within the context of the overall aim of the plan. This will permit full integration of the Master Plan with the Flood Action Plan.

The co-ordination and integration with related components of the FAP, are considered to be key activities in the overall BRTS strategy. Two FAP components (North West Regional Study and the North Central Regional Study) and seven supporting activities will directly or indirectly influence the Master Plan study.

The confinement of the Brahmaputra River by means of the BRE and a continuous flood embankment along its left bank (BLE) will affect the river flood levels and its morphology. This interaction between works on the right and left banks should be taken into account in formulating the Master Plan. The BRTS programme has been enlarged in scope to include specific aspects of the BLE studies such as mathematical model studies and an inventory and erosion survey along the left bank. The need for additional geomorphological and geotechnical inputs specific to the left bank will be identified in the First Interim Report.

The Master Plan is therefore envisaged to include:

- (a) An overall strategic plan identifying appropriate measures for embankment refurbishment, river training, and bank protection works along the right bank of the river while taking into account proposals for flood alleviation on the left bank
- (b) Inclusion in the BRTS of specific aspects of the planning studies for the BLE
- (c) Recommended implementation phases in response to priority needs and reflecting available resources

- (d) Detailed design of the initial phase of works for immediate implementation along the right bank
- (e) Recommendations on proposed solutions for particular problem areas such as ferry terminals, and an appraisal of river training works designed outside the framework of BRTS
- (f) Recommendations for establishing a monitoring programme as part of the master plan implementation procedure to evaluate the effectiveness of river training works that have been constructed and feed this information back into the design of works for subsequent phases
- (g) Recommendations for the establishment of the physical and engineering infrastructure required for the implementation of the works described in (c) above.

The work programme and staffing schedule have been revised following a wider appreciation of the project gained during the inception phase. It reflects the inclusion of specific aspects of the BLE in the scope of work for the BRTS, and takes account of the inclusion of the BRTS in the FAP.

The primary project objectives, as defined in the original Terms of Reference, together with the additional instructions received from BWDB, were taken full account of in the review. The effect of the delayed start to the project has also been evaluated, particularly with respect to the river survey programme and the design of short-term measures.

As a result of this review, changes are recommended to the programme, staff inputs and logistical requirements. The main changes recommended are outlined below:

- (a) An enhanced programme for geomorphological and geotechnical data collection and studies
- (b) Revisions to the data collection and river survey programme to take account of the delayed start to the project. For this reason, the design of the short-term measures cannot be completed before Month 18
- (c) The large sectoral and sectional physical models should be excluded from the physical modelling programme, and additional local and partial models should take their place
- (d) The BRTS programme allows for participation in the BLE planning studies
- (e) Maintenance of close co-ordination and integration of the BRTS with related FAP studies
- (f) An increase in expatriate and local staff inputs to cover additional works for the BLE and integration with the FAP

(g) Additional logistical requirements for the data collection and river survey programme.

The principal change to the staffing concerns the role of Team Leader which would best be taken on by the expatriate Design Engineer rather than be carried out by the Physical Modelling Specialist (who will have to spend significant periods outside Dhaka at RRI, Faridpur). The conceptualisation and design of the Master Plan relies on the coordination and synthesis of the multidisciplinary studies to be carried out under the BRTS. Furthermore, the inclusion of BLE studies and integration of the BRTS with the FAP requires continuous coordination and more extensive project management than envisaged in the original Terms of Reference.

It is anticipated that the BRTS can be completed in the 3-year period as given in the original Terms of Reference. Since the related FAP studies have yet to commence, it is recommended that the First Interim Report (March 1991) should include a co-ordination programme and a review of the co-ordination strategy. This recognises the need to maintain a flexibility of approach to the planning and execution of the study up to, and beyond the First Interim Report Stage.

INTRODUCTION

1.1 Background

The security of the Brahmaputra Right Embankment (BRE) and consequently the area protected by the BRE has been seriously threatened by continued bank erosion. Since the economic and social consequences of the present approach in dealing with the problem may not be acceptable in the long-term, the Government of Bangladesh (GOB) has commissioned the River Training Studies of the Brahmaputra River (BRTS) to seek a long-term strategy for the protection of the BRE. The project, funded under the IDA sponsored Bangladesh Second Small Scale Flood Control, Drainage and Irrigation Project (Credit No. 1870 BD), will be executed by the Bangladesh Water Development Board (BWDB).

In 1987 and 1988 Bangladesh experienced two of the most severe floods on record in which several thousand people lost their lives, many thousands more became homeless and there was significant damage to agriculture, infrastructure and the national economy. These floods created a national and international awareness which led to the drawing up by the Government of Bangladesh of a National Flood Protection Programme.

In November 1989, a five year Flood Action Plan (FAP), coordinated by the World Bank was agreed with the Government of Bangladesh. The FAP is connected with an initial phase of studies directed towards the development of a comprehensive system of long term flood control and drainage works. Priority has been given to the alleviation of flooding from major rivers, of which the Brahmaputra is a significant source. The BRTS therefore, forms component No 1 of a total of 26 components comprising the FAP during the plan-period 1990-1995.

BWDB appointed Sir William Halcrow and Partners Ltd. (Halcrow) in association with Danish Hydraulic Institute (DHI), Engineering and Planning Consultants Ltd. (EPC) and Design Innovations Group (DIG) to undertake this three-year study.

An advisory group comprising leading academics from the Bangladesh University of Engineering and Technology (BUET) will work with the Consultants' Team. The River Research Institute (RRI) have been nominated to carry out the important range of physical modelling studies required by the BRTS.

A Letter of Intent was issued by the BWDB on 24th January 1990 to commence the project. The contract for consultancy services was signed between BWDB and Halcrow on 12th March 1990. The Consultant commenced the project on 6th February 1990 by making arrangements to mobilize staff and establish an office and support facilities. Staff inputs commenced on 1st March 1990.

The Consultant has been instructed to review and revise their original work programme in order to integrate it within FAP. Since a number of major components of the FAP have an influence on the Brahmaputra River, it is necessary that the Brahmaputra River Training Study should be coordinated with these components.

Discussions with the BWDB and the Flood Plan Co-ordinating Office (FPCO) have confirmed that the programme for the BRTS needs to be increased to achieve the necessary interface and interaction with the FAP.

As required by the Terms of Reference (TOR), this Inception Report has been prepared three months after the commencement of Consultants' staff inputs. It describes the inception phase activities and gives a detailed description of the revised work programme and method of approach for the project.

1.2 The Project

The Brahmaputra-Jamuna river system (Figure 1.1) is one of the largest in the world, and is also the largest and most important river system in Bangladesh, accounting for more than 50% of the total inflow into Bangladesh from all cross border rivers.

The Brahmaputra rises in the Tibet region of China between the Kailas Range to the north and the Ladakh Range to the south, which is the northern range of the Himalayas. It enters Bangladesh about 75km north of Bahadurabad and is joined by the Teesta River at Chilmari. The river takes on the name Jamuna at Bahadurabad and, after cutting across the middle of Bangladesh for about 220km, is met on its right bank by the Ganges at Goalanda. It then turns southeast and is called the Padma for 100km until it meets the Meghna River from the north. The Meghna estuary meets the open sea of the Bay of Bengal about 160km to the south of the Meghna-Padma confluence.

The Brahmaputra moved to its present course (Figure 1.2) about 200 years ago. It is a braided river without fixed banks and with frequently shifting channels. Short-term channel migration can be quite drastic with annual rates of movement as high as 800m. The bank erosion process is a complex mechanism and is influenced by a number of factors. In Bangladesh the total river width varies between 4km and 15km. The river cross-section has a highly irregular bed elevation and the main channel may be up to 40m deep.

A 240km long earth embankment, known as the Brahmaputra Right Embankment (BRE), has been constructed on the western bank of the Jamuna River to protect the lands against the ravages of yearly flood. However, every year this embankment has to be retired landward at several places due to bank erosion; a total length of about 100km of retired embankment has been constructed over the past 20 years. The damage from erosion to agriculture, infrastructure, buildings and houses, together with the cost of repairs and construction of retired embankment, are regarded to be unacceptably high. Furthermore, failure of the embankment during a flood could have severe effects in terms of threat to human life and damage to agriculture and infrastructure.

River erosion is also causing serious problems at the specific locations such as ferry crossings, where the terminal stations (ghats) have to be shifted as a result of eroding river banks.

According to the original TOR, the primary objective of the BRTS will be to formulate recommendations for the permanent protection of the BRE and, hence, improve its performance as a flood protection embankment. The project activities will, therefore, need to be focussed on two planning horizons:

- Short-term measures for immediate protection of critical sections of the BRE as a consequence of the threat posed by bank erosion
- A master plan for river training works which will recommend a strategy for the long-term protection of the BRE.

The revised scope of works for the project following its inclusion in the FAP will require coordination with other FAP studies including, principally:

- (a) The consequence of drainage and flood control in the North-West Region on the BRE
- (b) The consequences of drainage and flood control in the North-Central Region on the Brahmaputra River
- (c) The proposed Brahmaputra Left Embankment (BLE).

The project has also to include a programme of activities linking to other relevant components of the FAP. These are described in Section 10.

1.3 Report Objectives

This Inception Report outlines the programme of activities for the project. The report's objectives may be summarised under the following items:

- (a) Review of data and past studies
- (b) Providing an appreciation of the existing situation of the Brahmaputra River and the BRE
- (c) Method of approach for the project activities including:
 - morphological, hydrological and geotechnical studies
 - mathematical modelling studies
 - physical modelling studies
 - agro-socio-economic studies
 - engineering studies and designs
- (d) Description of the data collection and river survey requirements and detailed work programme
- (e) Proposals to coordinate the BRTS with other relevant components of the FAP
- (f) Describing a revised work programme and staff schedule including necessary links to the FAP.

The review and revision of the work programme has required careful consideration, since it will result in a fundamental change to the overall strategy of the project. Clearly the multi-disciplinary aspect of the project, following its inclusion in the FAP, now requires a greater emphasis than was envisaged in the original. Also, the enhanced scope of work will require a revised staff programme including additional inputs.

1.4 Inception Phase

The three month inception phase has been mainly concerned with the following activities:

- Mobilisation
- Reconnaissance field visits
- Review of available data and past studies
- Arrangements for data collection and river surveys
- Meetings with BWDB and other concerned organisations
- Preparation of the Inception Report, including a revised work programme drawn up in conjunction and consultation with relevant groups including RRI and BUET.

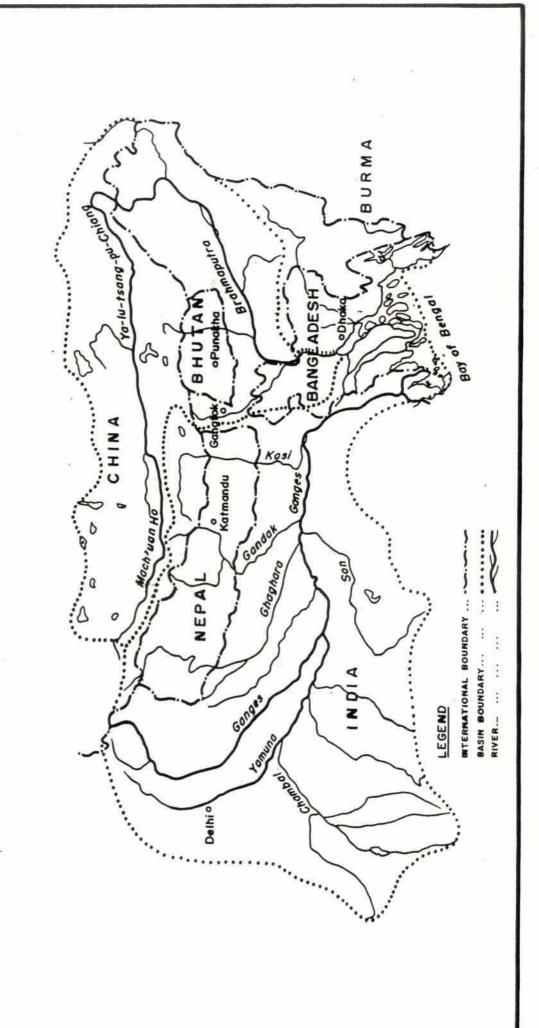
A resumé of these activities have been given in each of the Consultants' Monthly Reports.

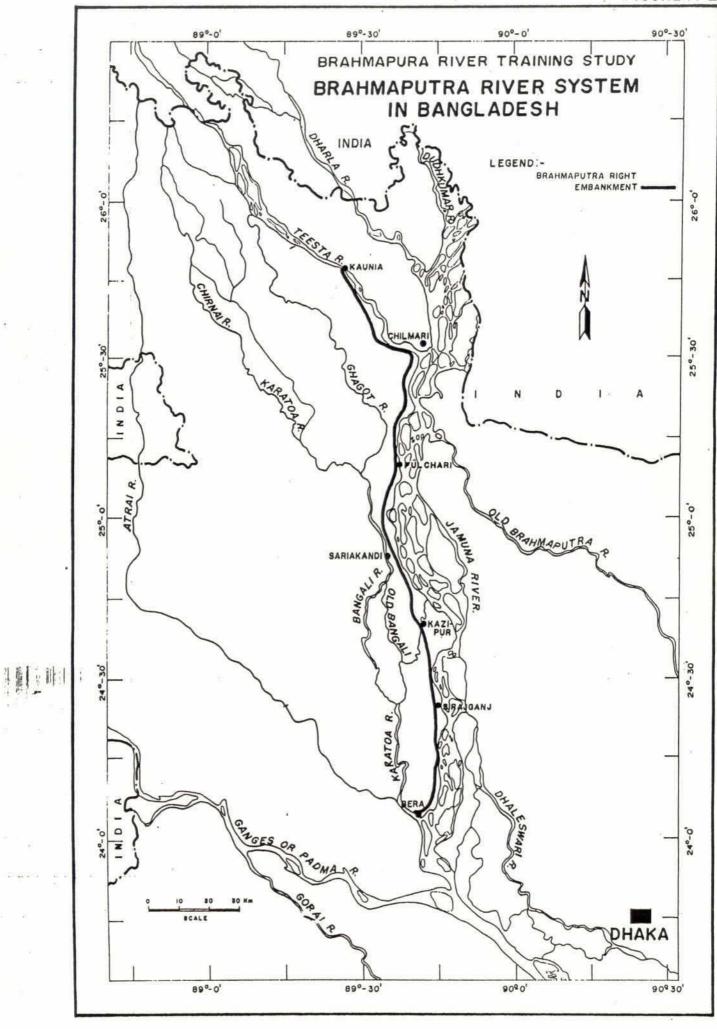
The mobilisation of the Consultants' Team and support facilities progressed satisfactorily during the Inception Phase in spite of the delayed start to the project. A total of 9 expatriate and 8 local key personnel provided inputs during this period, along with the BUET technical advisory group.

A summary of staff mobilised and inputs provided are given in Appendix A. The Appendix also includes a schedule of organisations consulted during the inception period.



BRAHMAPUTRA RIVER TRAINING STUDY
GANGES - BRAHMAPUTRA BASINS





Book Diary No

TERMS OF REFERENCE

2.1 Scope of Work According to the Original TOR

The scope of work in the original Terms of Reference is tailored to satisfy the primary project objective of formulating recommendations for the permanent protection of the BRE. The project studies are expected to provide:

- Technically and economically feasible proposals for the improved performance of the BRE
- River training schemes required for the permanent protection of the BRE, including consideration of the operation and maintenance aspects associated with them
- An implementation schedule for the proposed BRE protection schemes. This schedule is to be flexible and allow for the phased implementation of the works.

These activities will give rise to a master plan for river training works for the long-term protection of the BRE. The Master Plan for training works will be a recommended strategy for the containment of the Brahmaputra River from Chilmari to its confluence with the Hurasagar River. This plan will include recommendations for the type and layout of river training works required to be implemented according to a phased programme to provide permanent protection for the BRE.

In addition, short-term measures will also be designed in response to the need for immediate protection of critical sections of the BRE as a consequence of the threat posed by river bank erosion. These short-term measures for immediate implementation will where possible, be consistent with the Master Plan.

The scope of works can be described under the following key topics:

Inventory and Analysis of Past Works

This includes an inventory of past construction and maintenance works including retired embankments.

Data Collection and River Surveys

This includes the data requirements for the mathematical and physical modelling studies and for the engineering designs.

Hydrological, Hydraulic and Morphological Studies

The objective of these studies is to obtain a thorough understanding of the hydraulic and morphological characteristics of the Brahmaputra River and to provide the necessary hydrological and morphological design parameters required for the modelling and engineering studies.

Mathematical Modelling Studies

The mathematical modelling studies will support the other river studies in the preparation of a master plan and the design of river training works. The one-dimensional and two-dimensional models will simulate river hydraulics and sediment transport, and provide input to the physical modelling studies and engineering designs.

Physical Modelling Studies

The physical modelling studies will support the design of river training works and preparation of a master plan. These studies are to be undertaken by RRI.

Short-Term Works

In order to implement an immediate rehabilitation of critical sections of the BRE, priority works to be identified on the basis of the threat posed by river erosion. These works will form a part of the Master Plan for the protection of the BRE.

Master Plan for River Training Works

The formulation of a Master Plan for the protection of the BRE from Chilmari to Hurasagar. This will include a phased implementation programme. Detailed designs and tender documents to be prepared for the works to be implemented.

2.2 Additional Instructions from BWDB

The original Terms of Reference for the BRTS were prepared prior to the formulation of the Bangladesh Flood Action Plan (FAP). BRTS now forms Component No.1 of the FAP. The FAP includes the following projects and studies which are of direct relevance to the BRT project:

- (a) North West Regional Study: this study is concerned with the development of the area behind the Brahmaputra Right Embankment.
- (b) North Central Regional Study: this study is concerned with the development of an area which includes the Brahmaputra left bank flood plain, and includes a pilot study on compartmentalisation.
- (c) Brahmaputra Left Embankment (BLE): It is envisaged that existing embankments could be incorporated into a continuous embankment, which would result in confinement of the Brahmaputra flood flows.
- (d) River Survey Programme: extensive survey of the major rivers are proposed under this study since the current lack of flood season data is a major handicap to model studies and design works.

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- (e) Bank Protection Pilot Study: this study will identify suitable methods and materials for bank protection works to be taken in the future.
- (f) River Training Pilot Study: this study, aimed at active flood plain management, is designed to study the various methods of river training and river control and to recommend suitable techniques that may be adopted in Bangladesh.

The Consultants have been instructed by BWDB to review and revise their work programme for the BRTS in the light of the FAP. According to the BWDB letter of instruction, which is included as Appendix B, the Consultants have been specifically asked to:

- Review and update their work plan, manning schedule and work schedule taking note of the relevant components of the FAP
- Review the necessity and the technical viability of various components of the BRTS including the large sectoral physical models

The letter requested that the review and revisions should be incorporated in the Inception Report following which, the GOB would take appropriate action on the recommendations made in the Inception Report.

2.3 Consultants' Response

The outcome of the Consultants' review is described in Section 5 (Method of Approach). The implications in terms of refining the aim and nature of the Master Plan are given in Section 12 (Master Plan). Recommendations for revisions to the activity programme, staff inputs and logistical requirements are presented in Section 13 (Work Programme, Staffing and Logistics).

APPRECIATION OF EXISTING SITUATION

3.1 Brahmaputra River

Within Bangladesh, both the Brahmaputra and the Teesta (its main tributary) are braided rivers. The overall slope of the Brahmaputra is roughly 1 in 15 000 to 1 in 20 000; discharges range from 65 000 m 3 /s (average annual flood) to 91 000 m 3 /s (100 year flood). The mean sediment diameter is roughly 0.2 X 10 3 m and suspended sediment concentrations of up to 1 500 ppm (by weight) have been measured. The discharge is low during the period November to April: peak discharges occur in the June to August period.

During the dry season the channel pattern consists of a network of individual channels contained within the main banks, which are between 5 and 15km apart. These channels are separated by shoals and islands; as the discharge increases with the onset of the monsoon, many of these features are submerged, with considerable subsequent changes in the bed topography resulting from the high rates of sediment transport during the flood season. As the discharge decreases, post-monsoon, sediment transport rates decrease and a new dry-season pattern of channels emerges.

An additional effect of the rising and falling discharges is the changes that are produced in the plan geometry of the individual channels in the braided network. As the discharge increases, the channels tend to straighten their course: as the discharge decreases, they become more sinuous. These unpredictable changes in channel pattern during each annual flow cycle, triggered by the movement and deposition of the various types of bed forms, and by the variation with time of the plan curvature, are instrumental in generating bank erosion.

However, shifts in channel pattern are not the only erosive agency. The alluvium comprising the river flood plain is mainly only loosely consolidated and thus relatively weak; bank collapse is therefore induced by a variety of other factors (such as wind-waves, piping, liquefaction), under relatively quiescent conditions, and on both rising and falling stages of the floods.

In a large and continuously braiding channel like Brahmaputra River, both banks may experience deposition or erosion simultaneously. Its plan and profile may change continuously. Erosion and deposition occur along the bankline and within the river channel: the pattern of alternate bars, braided channels, middle bars and islands experiences large and random changes with time and river stage.

Factors responsible for the continual river bank erosion include the following:

- Rate of rise and fall of river level
- Number and position of major channels active during the flood stage
- Angle at which the flow approaches the bankline

- Amount of scour and deposition that occurs during flood
- Formation and movement of large bedforms (sand bars, chars)
- Cohesion and variability in composition and stratification of the bank material
- Intensity of bank slumping (with or without superimposed wave action)

All these factors may interact and can produce severe changes in the bankline configuration.

At several locations, there appear to be 'node points' which correspond to more cohesive bank materials which have a higher relative stability. Upstream and downstream of these 'node' points, the river bed is wide, shoaly in character and shows lateral bank shifting. The lower the river slope, the less the degree of braiding.

In the reaches considered to be relatively stable (node points south of Bahadurabad, south of Sirajganj and upstream of the confluence), banks may experience migration of about 300m per year. In other sections with banks assessed to be stable during one decade, changes have occurred suddenly during the next decade because of the influence of the downstream migration of large islands on the flow configuration.

The bank erosion in the less stable areas can be considerable. In one instance, erosion of 800m per year was estimated to have occurred over an 8 year period.

Plate 1 is a typical view of the flood plain; Plate 2 is an example of one type of bank failure.

Previous studies of the overall long-term channel stability of the Brahmaputra River, after its radical change of course during the second half of the 18th Century, indicate that the river has steadily migrated westwards, this tendency being attributed to various causes (for instance earthquakes in Bangladesh; large landslides in the upstream course of the Lower Brahmaputra, which increased for many years the sediment load downstream; major siltation processes after strong floods; and subsidence).

There is evidence, that since 1830, there has been a systematic, progressive shift of the river channel to the west, of up to 10km in places. As a result of a channel stability analysis carried out for the Jamuna Bridge Project study, it has been questioned whether the westward shift is still taking place. It remains to be resolved whether the occurrence of bank erosion is purely a random phenomenon or whether there are both random and deterministic components.

3.2 Brahmaputra Right Embankment (BRE)

In order to enable the land on the right bank of the Brahmaputra to be developed for agriculture, designs for a flood embankment were

prepared by Leedshill-de Leuw in 1965; the Brahmaputra Right Embankment (BRE) was constructed in the late 1960's - early 1970's. The embankment is 220km long and extends from Kaunia on the Teesta to the junction of the Hurasagar River with the Brahmaputra (Figure 3.1). The protected area is roughly 230 000ha in extent.

There are gaps in the embankment either where the original work has never been completed or where damage has occurred.

There are significant breaches at Sonali Bazar and Maizbari, where construction is held up by delays in acquiring the land required for the retired embankments. Further north, between mileage 9 and 19, there were (in April 1989) other gaps and regulators still to be constructed at Tambalpur Chara and Chanchia Mirganj.

The embankment geometry is as follows:

Crest width:

nominally 4.3m (7.3m in places)

Crest height:

to retain 100 year flood plus freeboard

allowance of 1.2 to 1.5m

Side slopes:

1 (vertical) : 3 (horizontal)

Distance from

0.8 to 1.6 km

river bank:

When the design was prepared, it was accepted that short reaches of the embankment might have to be rebuilt further inland, at places where bank erosion was threatening the structural integrity of the embankment.

Over the years since its construction, sections of the embankment and some of the river training works have been attacked by the flow in several places. The complete list of these locations is not yet available and it may also change in time, but the field data gathered up to now is summarised in Table 3.1.

Although the erosion of the river bank is a significant factor in the embankment failures that have occurred, the condition of the embankment itself is not satisfactory and this creates additional problems. When embankments have been retired, the construction materials and methods have not always been up to specification: side slopes can be 1:2 instead of 1:3 and the crest width can be less than specified. Lack of resources is a considerable handicap to the provision of effective maintenance. As a consequence the condition of the embankment gradually deteriorates. Erosion occurs as a result of rainfall, wave action, and flow through rat holes: the cross-section is weakened as a result of paths cut into the embankment slopes, and of houses, shops and other ancillary structures that are built on the crest. Conditions typical of those on the top of much of the embankment, are shown in Plates 5 and 6.

A census of the population living on the embankment has not been carried out: based on very limited observations made during the

preliminary stage of the BRE inventory survey, the total number is estimated to be in the range 50 000 to 100 000.

3.3 Brahmaputra Left Embankment (BLE)

Although studies have been made for a continuous embankment on the left bank, which would protect 400 000 ha of agricultural land, such an embankment has not yet been constructed. Separate lengths of embankment, amounting to roughly 90km, have been built, but they do not constitute a continuous barrier against flooding from the Brahmaputra on its left flood plain.

North of the junction of the Brahmaputra with the Dhaleswari, the embankment is virtually continuous. It was breached in a number of places during the 1988 flood; some of the breaches have since been repaired, others are still open. There is another embankment following a second line of defence along the Jhenai River. South of the mouth of the Dhaleswari, there is a much lower degree of protection; however there are some short lengths of embankment on the left bank of the Dhaleswari as well as on the left bank of the Brahmaputra from the Dhaleswari mouth to 10km north of Aricha. The embankment was built in the latter part of the 1980's under the Food for Work Programme. In places it has an inadequate cross-section and the crest is not everywhere sufficiently high to prevent frequent over-topping: there is need for some plan re-alignment, in order to increase the distance between the river bank and the embankment.

The study planned for FAP component No. 3 (North Central Region) is expected to consider alternative solutions concerning BLE but it is not known what length of continuous embankment would be proposed. From the point of view of water management other variants may also be considered. At the most the left bank of Brahmaputra, plus the Old Brahmaputra and Dhaleswari River would be embanked over a total length of about 150 km. On the Brahmaputra River, the embanking of the left bank would start at the mouth of Old Brahmaputra.

3.4 River Training Works on BRE

In the years following the construction of the BRE, various measures have been taken to protect the embankment from damage. In some cases the protection measures have been successful, in others they were unable to avert damage to the embankment, which has then had to be re-constructed further away from the river ('retired'), in some cases, several times over.

Two types of measure have been principally employed. Groynes have been constructed, with the aim of creating cushions of low velocity flow immediately adjacent to the bank and thus reducing the hydraulic stresses there. The other procedure has been to protect an eroding bank against further erosion by covering it with a filter surmounted by a layer of hard material that will stand up to the high velocities adjacent to the bank.

The customery method of bank protection using cement concrete blocks is shown in Plate 3, and a length of retired embankment in Plate 4.

Data on the lengths of retired embankment or of bank revetment are being collected as part of the inventory of past works, which is currently underway.

A complete inventory of the training works on the Brahmaputra has not yet been carried out, but a preliminary appraisal, based on the only information immediately to hand, is that groynes have been (or are to be) constructed at fifteen locations. The locations of the groynes so far identified, are shown in Table 3.2. Details of the groynes and an assessment of their present condition will form part of the Interim Report.

Most of the structures are located in first half of the BRE (Mileage 0-74); a significant fraction of the total number has suffered damage of varying degrees of severity.

All the groynes on the Brahmaputra are comparatively short, extending up to 150m out from the edge of the river channel, and mainly act in isolation from one another (the spacing between adjacent groynes is larger than the usual spacing recommendation of 4 x groyne length). This is a departure from the more usual practice of installing a number of groynes to act in concert.

The groynes consist of an earthen embankment, coated with a layer of hard material. To prevent local scouring of the river bed around the groyne, a layer of hard material, extending out from the groyne (the falling apron), is provided: the distance that the falling apron extends out from the groyne, depends on the amount of scour that is expected. For the Brahmaputra training works, the scour depth is estimated by using the Lacey equation to calculate the regime channel depth, and scaling it up by a factor in the range 1.75 to 2.5 depending on the geometry and orientation of the groyne. The BWDB design guidelines are then applied for determining the detailed geometry of the falling apron.

The size of the revetment material is determined by calculating the mean velocity in the channel and then using a scaling factor appropriate to the particular situation (eg. sharp bend, mild bend, straight channel) to allow for the local velocity. The corresponding revetment size is then determined from design charts produced by such organisations as the California Highways Dept, the US Bureau of Public Roads, and US Corps of Engineers.

A comparison of the design drawings of some of the structures on the Brahmaputra, reveals that there is no standardisation. The falling aprons extend out from the groynes for distances ranging from 12 to 50m at the nose and from 10 to 30m along the shanks. There is also disparity in the lengths of groyne shank that are protected by falling aprons on the upstream and downstream sides: in some cases the lengths are equal, in others, 100 per cent of the upstream side is protected, but only 30 to 40 per cent of the downstream side. The grading of the revetment material is, on the whole, consistent. A typical design for a groyne is shown in Figure 3.2.

The groynes that have been installed on the Brahmaputra have a mixed record: there have been a number of successes eg. Sailbari, Ranigram (design based on model experiments carried out by RRI) and a number of failures where the groynes have been damaged or, in some cases, destroyed.

The causes of failure are difficult to determine because there are so many aspects that can introduce weaknesses and it is not usually possible to carry out a failure analysis when the training works have been destroyed eg. Maizbari groyne.

The current shortcomings in the design of groynes would appear to include:

- Insufficient data on which to base the design, leading to inadequate scour protection, under-size revetment material, or deficient filters
- Poor construction materials and methods.

3.5 North - West Region

The area to the west of the Brahmaputra, bounded by the Teesta on the northern edge and the Ganges to the south, is drained by a number of rivers, the majority of which discharge into the Brahmaputra. Flooding regularly occurs, from a variety of causes, principally;

- Rain falling in the area, accumulating in low-lying parts
- High tailwater levels impeding the outflow from the Hurasagar into the Brahmaputra
- Floods in the Teesta spilling out, on to the flood plains of the Atrai and Karatoa
- Breaching of the Brahmaputra Right Embankment.

Proposals for improving the drainage of this area are to be drawn up under FAP: these could affect the inflow discharges to the Brahmaputra and could require the construction of flow regulators on drainage courses crossed by the BRE.

3.6 North - Central Region

The North - Central Region is bounded by the Old Brahmaputra to the north and east, the Brahmaputra to the west, and the Padma to the south. The area is frequently inundated as a result of direct rainfall, impaired drainage and flooding from the Brahmaputra (in the absence of any embankment there).

The Old Brahmaputra and Dhaleswari rivers act as flood channels for the Brahmaputra; roughly 10 per cent of the flood discharge in the Brahmaputra at Bahadurabad is currently able to flow down these rivers.



The total area of the region is roughly 1200 000ha and in a normal year, 68 per cent of it could be flooded; 80 per cent could be inundated in a severe flood, such as that which occurred in 1988.

Proposals for reducing the extent and frequency of flooding are to be considered; these will include such measures as embankments, control structures, improvements to the internal drainage system. A compartment of 50 000ha could be formed.

The flow in the Brahmaputra during the monsoon season, could be affected by some of these measures, in particular the construction of an embankment on the left bank. This could extend from the Old Brahmaputra to the Dhaleswari, and may confine a greater proportion of the flood flow to the main course of the Brahmaputra than is currently the case.



Table 3.1 Locations Affected by River Damage along the BRE

Location	Embankment Mileage ⁽¹⁾	Damage
Teesta		: ::
Tambalpur	11.40	1350m long cross-bar groyne damaged during 1988 flood
Tambalpur	12.10 to 13.10	Embankment erosion
Dhumaitary	18.00 to 21.00	Bank erosion
Belka	20.75 to 21.00	Bank erosion
Belka	22.75 to 23.00	Bank erosion
Brahmaputra		
Ujanbachagari and Haripur	26.00 to 26.60	Bank erosion
Rydashbari	38.00 to 39.70	Bank erosion: embankment needs to be retired
Kukranat to Baratkhali	48.00 to 51.00	Embankment breaches in 1988 flood
Fulchari	49.00 to 50.00	Bank erosion around Fulchari Railway line
Pakulla	64.90	Cross-bar damaged in 1988 and under threat of erosion at present time
Hasnarpara	66.00 to 67.50	Bank erosion
Antarpara	70.00	Erosion. Extension of cross- bar required
Sariakandi	74.00	Embankment damaged on both sides. Danger of linking between Brahmaputra and Bengali rivers through the embankment
Mathurapara	74.00 to 75.00	Bank erosion, with breach at Deluabari (M.74.00)
Chandanbaisa and Baisakhi	78.00 to 85.00	Strong bank erosion

Table 3.1 Continued

Location	Embankment Mileage ⁽¹⁾	Damage
Maizbari, Sonalibazar, Simla	85.00 to 100.00	Strong bank erosion
Sirajganj	104.00 to 105.30	Bank erosion near Upazilla HQs
Beara	106.00	Extensive damage to the cross- bar by bank erosion during 1988 flood
Khokshabari	120.25 to 126.75	Serious bank erosion and embankment failure since 1988
Jalalpur	124.00 to 125.00	Serious bank erosion since 1988
Bentia	131.50 to 132.60	Serious bank erosion since 1988

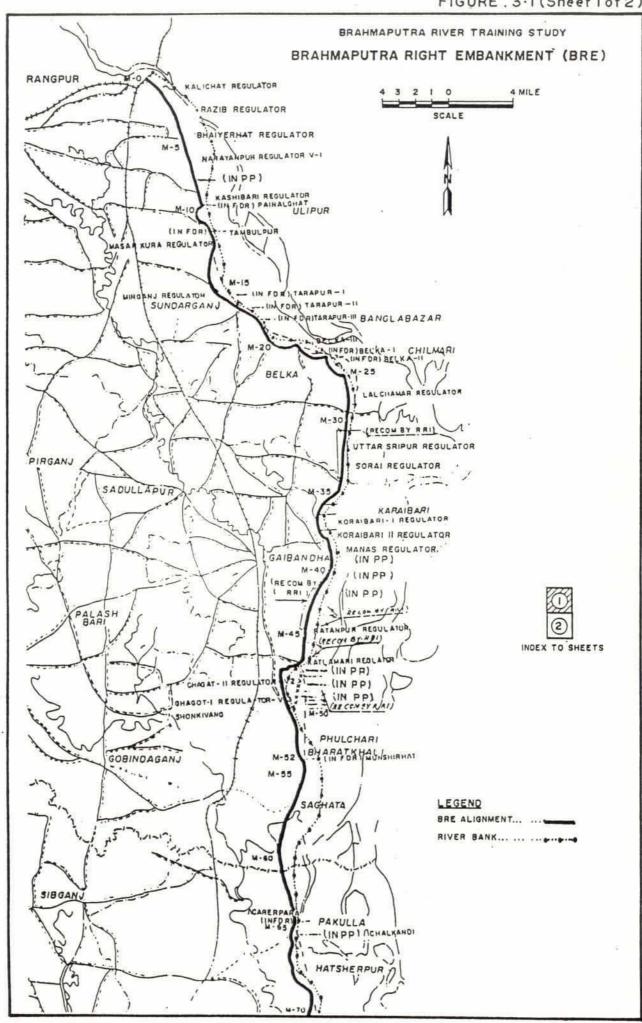
Note: (1) Mileage zero is at Kaunia on the Teesta River

Table 3.2 Location of Groynes on the BRE

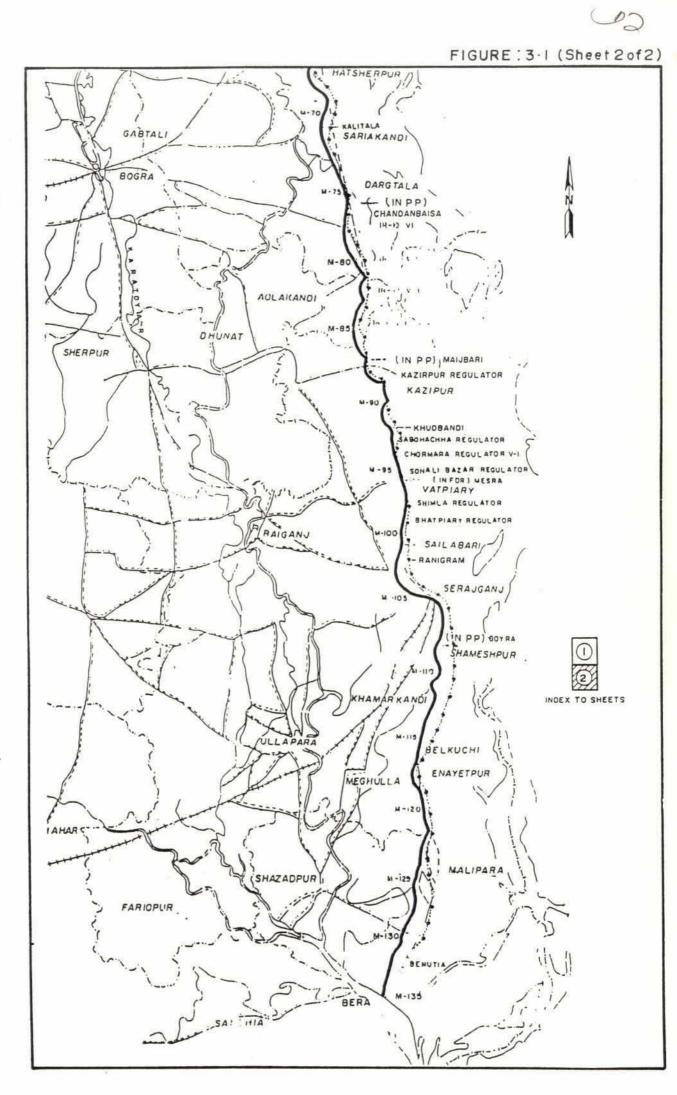
Name	Location	Mileage ^{[1}
n / 1-1-4	Tanata	9.5
Painalghat	Teesta Teesta	11.5
Tambulpur Tarapur ⁽²⁾	Teesta	15.5
Belka ⁽²⁾	Teesta	21.5
Gazaria ⁽²⁾	Brahmaputra	49
Pakulla	Brahmaputra	65
Chalkandi	Brahmaputra	65.5
Hasnapara	Brahmaputra	69
Anterpara	Brahmaputra	70
Kalitola	Brahmaputra	72.5
Deluabari	Brahmaputra	74
Maizbari	Brahmaputra	92
Sailbari	Brahmaputra	104
Ranigram	Brahmaputra	106.5
Beara	Brahmaputra	110

Note:

- (1) These mileage are only approximate and are included solely for the purpose of indicating their relative position along the BRE. The length of the BRE needs to be re-surveyed to take account of the changes in length produced by the various embankment retirements.
- (2) More than one groyne (x-bar) has been proposed or constructed at these locations.

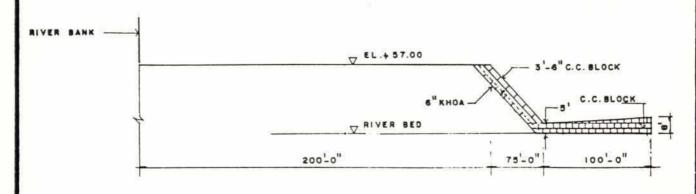


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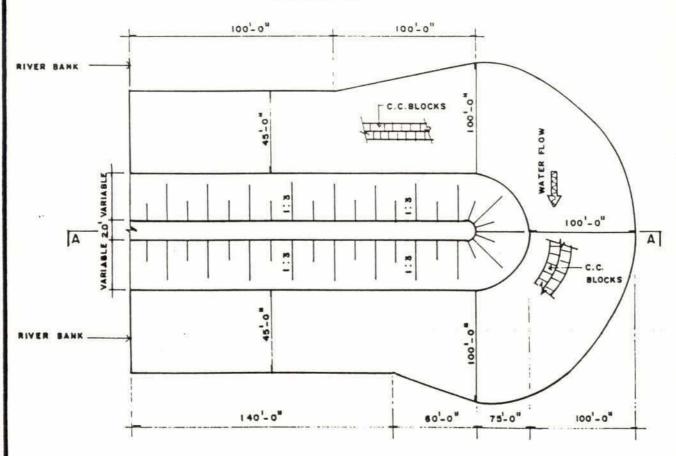


TYPICAL DESIGN OF CROSS-BAR

CONCRETE BLOCKS		
SIZE OF BLOCKS	% TO BE PROVIDED	
21"x 21"x 21"	40%	
18" 18" 18"	40%	
15"x 15"x 15"	20%	



SECTION A-A.



PLAN

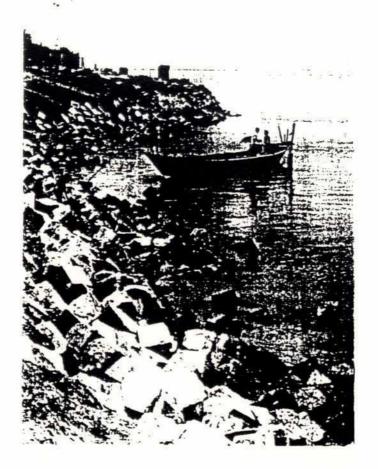


 Brahmaputra left bank near Aricha showing local flood embankment and relatively stable river bank in foreground



Brahmaputra right bank at Deluabari showing eroded river bank in an area of active bank erosion





3. Cast concrete block bank protection at Sirajganj



 Retired BRE at Baishakhi showing line of borrow pits along riverside foot of embankment

 $\widetilde{\mathcal{H}}$



5. BRE inventory survey in progress near Sariakandi



6. BRE near Sariakandi showing an example of settlement on the side slopes of the embankment.

- 4. REVIEW OF AVAILABLE DATA AND PAST STUDIES
- 4.1 Review of Past Studies

During the course of the inception phase, the Consultants have reviewed past studies which relate to the Brahmaputra River and are of relevance to the BRTS. A brief description of the principal topics, observations and results of these studies is given in the following sections.

 Coleman. Brahmaputra River: Channel Processes and Sedimentation (1969)

An important monograph on the river, its channel processes and sedimentation was written by Coleman on the basis of several years of field work and analysis. The monograph covers a wide range of aspects: geological history; channel morphology; river hydrology; bank stability; channel migration; bedforms and flow regimes; bedform and turbulence patterns; stratification of channel deposition; crossbedding and current directions; and fluvial environments.

The study describes the river phenomena and interprets them from the point of view of physical geography and geomorphology, and is a rich source of information. Of direct interest to river engineering problems are Coleman's comments on channel morphology (braiding mechanics), bank stability, and channel migration mechanics. The hydrological and hydraulic data are less detailed.

Coleman reports several observations of relevance to the BRTS:

- (a) The complex nature of its sediment transport regime leads the river to modify the configuration of its channels and islands constantly, sometimes causing the river channels to migrate laterally up to 800m/year over a period of 8 years
- (b) Channel migration is reduced as the percentage of cohesive soil (clay) in the banks increases, while banks rich in silt facilitate bank movement due to their high susceptibility to erosion
- (c) Aerial photographs indicate that during a catastrophic flood, minor flood-relief channels could enlarge to such an extent that a major diversion of the river system could take place. Such events may have been partially responsible in the past for major changes in course by the Brahmaputra River. It is possible that catastrophic floods could introduce in one season relatively large changes that would otherwise take several years to develop under more normal flood conditions.
- (d) The nature of bedforms encountered during a flood cycle and their relatively high rates of movement lead to significant changes along a particular river cross-

section during a period of 24 hours or less. The value of investigation of the hydraulic behaviour of the river using specialized equipment capable of achieving individual sets of measurements within a relatively short time span is therefore clear.

 JICA. Jamuna Bridge Construction Project Feasibility Study Report (1976)

In 1976 JICA (Japan International Cooperation Agency) carried out a feasibility study of the Jamuna River Bridge Construction Project. Volume II of the study deals with river control and Volume VI with geological problems. In addition to specific aspects concerning bridge design at different sites, the study offers a detailed view on the features of Brahmaputra-Jamuna River geomorphology; river morphology; hydrology; and local river control works. Useful field data are also presented including bed sediment granulometry; global roughness of some river sectors; sediment load at Bahadurabad; and flood discharge peaks of various frequencies.

 BWDB/Halcrow. Brahmaputra Multi-Purpose Development Project (1984)

In 1984 the Expert Study Group of BWDB and Halcrow carried out an Engineering Appraisal of the Brahmaputra Multipurpose Development Project. The primary objective of the study was to examine the technical feasibility, including preliminary engineering estimates, for the construction of a barrage on the Brahmaputra River to provide irrigation supplies to the north east and north west regions of Bangladesh.

The study included an assessment of hydrological, geomorphological and geotechnical aspects of the Brahmaputra River. In particular, the following aspects were investigated for the preliminary engineering proposals:

- Flood discharges and flood levels
- Sediment transport
- Geomorphological effects of the barrage
- Geotechnical aspects including seismicity
- River training requirements and scour protection
- Water resources and irrigation studies
- Navigation and environmental issues related to the barrage.
- 4) Hinch et al. Jamuna River 230 KV Crossing Bangladesh (1984)

A 230 KV power transmission line, connecting the east and west networks of the Bangladesh Power Development Board, was

of

installed across the Jamuna in the early 1980s. The line is supported on 11 towers, which are founded on caissons spaced at intervals of 1220m across the river.

The original feasibility study for the transmission line had recommended that it should cross the river in the region of Sirajganj, but a subsequent study by Acres International concluded that the river regime was insufficiently stable in this area and recommended that the crossing be re-located close to the junction of the Jamuna and Ganges rivers. When the detailed studies began it became apparent that the Ganges had recently migrated further north and was threatening to encroach on the selected route for the crossing. An analysis of maps, surveys and satellite photography, led to the conclusion that the migration was part of the normal pattern of movement and did not pose any threat to the transmission line.

The design of the caissons had to take account of general bed scour in the river and local scour around the caissons. The former was calculated using the Lacy equation; the latter was determined from the Laursen equation.

No physical model tests were carried out.

5) BWDB/Halcrow. Common Rivers Study (1986)

The Common Rivers Study carried out from 1984-86 by the Expert Study Group of BWDB and Halcrow, included water resources studies of the Brahmaputra River. These studies included hydrological analysis of the river flows including seasonal patterns, flood flows and low flows, in particular related to future demands for water resources, and optimisation of water resources allocation in Bangladesh.

6) Dhaka University. BRE Evaluation Study (1986)

An evaluation of the BRE was carried out in 1986 by the Department of Economics at Dhaka University; this included a useful appraisal of the condition of the embankment at that time, along with an assessment of the economic benefits which would result from flood alleviation provided by the BRE.

One of the conclusions was that there had been a serious reduction in the area benefiting from the construction of the embankment, but no reasons for the reduction were given. It was estimated that some 100km of embankment had been retired since its construction, and a further 16km in need of immediate retirement were identified. Thus in a period of just over 15 years, roughly 50 per cent of the embankment had been relocated. Active bank erosion was observed over a further 20-30km of river. The construction of groynes at eight sites was recommended.

7) RRI/DHI. Jamuna River Right Bank in the Vicinity of Kaitola Pumping Station (1988)

In 1988, RRI (author: Dr. E. Lates) carried out study of the hydrological and hydraulic features of the Brahmaputra River aimed at updating previous information and clarifying additional questions. This included a review of parts of the existing data from the point of view of river engineering, as well as a more detailed look into the hydraulic behaviour of the river. The results concern the braiding flow regime, and the relationship between bedform changes, liquid and solid discharges, and discharge distribution between the main anabranches on the lower course of the river. The principal conclusions which emerged from this study include:

- (a) The Brahmaputra River in its length from Bahadurabad to Nagarbari reaches braiding conditions only at flood discharges (as defined on the predictor graph by Leopold and Wolman, 1968). During the remaining part of the annual discharge hydrograph the river may find itself in a state between braiding and meandering, which could explain the continuous existence of the anabranches. The two river engineering implications of this result are the possibility of using at lower stages local river training solutions on the anabranches; and the need to carry out hydrological survey measurements in relevant cross-sections at flood discharges or at the beginning of flood recession to gain more insight in the behaviour of anabranches and on the braiding phenomenon itself.
- (b) There are relatively sudden changes of the friction coefficient of the bed in control cross-sections at rising discharges. It seems this happens because bedforms can change from dunes to flat bed and then again to dunes in spite of the fact that the discharge continues to increase. This may happen due to the influence of both solid discharge and braiding trends.
- (c) The distribution of liquid discharges in the flow across the river indicates that about one third of the bankful discharge and of lower discharges are conveyed by the main channel along the right bank.
- MPO/DHI. Surface Water Simulation Modelling Programme: Phase I. (1988)

The first phase of the Surface Water Simulation Modelling Programme (SWSMP) was carried out during 1986 to 1988 by the Master Plan Organization (MPO). The primary objectives of the programme were:

- (a) To develop local capability in surface water simulation modelling
- (b) To develop a fully operational model of the south east region

(c) To develop a structured approach to modelling with a General Model of the whole country.

The General Model comprising the main river systems of the whole country calibrated and verified with data for the 1986 and 1987 hydrometric years. The central part of the General Model includes the Brahmaputra river system. We propose to use this portion of the General Model to provide boundary conditions of the mathematical model for BRTS.

9) RPT/Nedeco/BCL. Jamuna Bridge Project (1989)

The feasibility study of the Jamuna Bridge Project (1986-89) investigated, inter alia, the river training requirements of the proposed brdige.

The study report includes a large range of information, both general and specific, on hydrology, river morphology, river training works, geotechnical investigations in addition to bridge design and other related issues.

The following elements of the study are of direct relevance to the BRTS:

- (a) The processing of hydrological field data and the mathematical modelling study;
- (b) Extensive use of satellite imagery (in combination with available geological and geomorphological data) aimed at obtaining quantitative information on channel changes and bank erosion rate in order to derive geometric parameters of the channels and basic data on bank behaviour;
- (c) Special hydrographic survey during a recent monsoon period (July-November 1987) at several locations, aimed at improving the understanding of scour in channel bends, confluence scour, bedforms and local scour. The results completed BIWTA sounding charts on deepest scour depths and scour at channel confluences, as well as BWDB crosssectional soundings to check on the vertical and horizontal stability of the river and to derive regime equations;
- (d) Combined use of physical scale modelling and mathematical modelling.

The scale model was a movable sand bed model of the Jamuna River reach upstream of the bridge. The purpose of this model was to provide insight into channel processes in a braiding river system like the Brahmaputra and how they can be influenced by river training works for the bridge. The model was not specifically intended to test the layout of the river training works, but rather to give initial design information. The model was also used to investigate the likely number of expected anabranches in the reach under the changed flow conditions resulting from a significant reduction in river

width at the cross-section of the bridge; and their limit positions assuming a fixed right bank at Sirajganj. This type of situation is unlikely to be met at other locations on the Brahmaputra river where river training works are being considered.

A group of models were used in determining the optimum lay-out of the river training works (number and type of structure included); required dimensions of the different elements of the river training works; establishing the design criteria for these elements by gaining more insight into bank erosion tendencies; and investigating channel changes of the braided river system.

10) Ullah. Channel Changes of the Brahmaputra (1989)

In a recent study Ullah (1989) has analysed BWDB cross-section data for the years 1965/66 and 1983/84 to investigate channel changes in the Brahmaputra. His main conclusions were:

- (a) No general trend in the channel movement could be detected.
- (b) The overall channel gradient had increased from 6.74×10^{-5} to 7.99×10^{-5} in that period.
- (c) The cross-sectional area had increased in the lower reaches of the river and had decreased in the upper reaches

4.2 Review of Available Data

The modelling and engineering studies and analyses associated with the BRT study will require topographical, morphological, hydrographic, hydrological, meteorological and agro-socio-economic data as well as data on existing river training works. Relevant data are available from a number of sources, the most important being the Bangladesh Water Development Board (BWDB), Survey of Bangladesh (SOB), Bangladesh Space Research & Remote Sensing Organization (SPARRSO), Bangladesh Inland Water Transport Authority (BIWTA) and the Meteorological Department.

4.2.1 Topographical Data

11:11

The availability of topographical and morphological data relevant to the BRT Study could conveniently be presented in Figure 4.1.

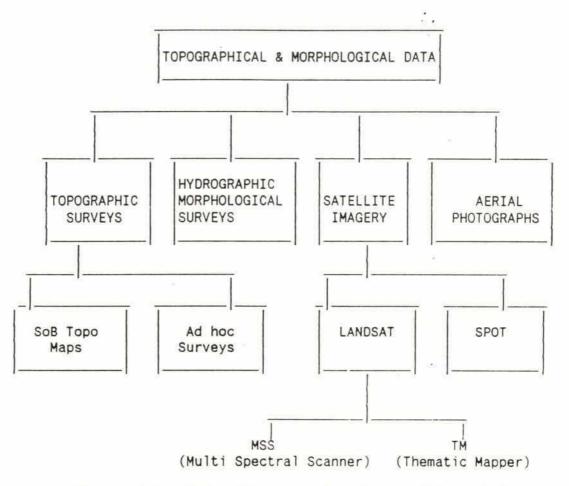


Figure 4.1 Data Structure for Topographic and Morphological Information

The map of Bangladesh (1:750 000) is partitioned to 27 one degree sheets at 1:250 000 (see inset in Fig. C.1); these are numbered 78G, 78H, etc. Each of these maps is partitioned into 16 topographic maps (1:50 000). These fifteen minute quadrangle sheets are based on air surveys verified on the ground; they are numbered 78H-5, 78H-6, etc.. Each is composed of 6 to 9 contour maps (1:15 840, ie. 4 inches = 1 mile and thus referred to as the Four Inch Sheet Series) which were commissioned by WAPDA E.P. and produced in 1963/64 from enlargements of air photos supplemented with ground verification. Some have contour maps at scale 8 inches = 1 mile.

The BWDB also commissions ad hoc surveys for the preparation of base maps to be used in the planning and design of flood control, drainage and irrigation schemes. These provide detailed topographical information within such project boundaries. These maps are of limited value for the BRT Study.

The field divisions within the Bogra Operation and Maintenance (O&M) Circle also carry out ad hoc surveys of the ferry ghats, river training, and bank protection measures. These surveys include cross-sections of specific reaches of the river bank and extend typically 300m into the river. Depth soundings are usually done with a weight lowered from a boat. Other topographical/morphological data prepared by the field divisions include the approximate location (on a base

map of scale 4 inches = 1 mile) of the river bank and BRE at the end of each monsoon season. These maps indicate the reaches of the BRE which are proposed to be retired that year, the alignment of the proposed retired embankment and the cross bars/groynes proposed to be constructed or rehabilitated.

For the correlation and superimposition of topographic and morphological data obtained from various sources, and from data to be collected at various stages of the annual river cycle, it is essential to establish such data on a common co-ordinate system in planimetry and a common datum in hypsometry.

The Survey of Bangladesh (SOB) maintains a set of geodetic bench marks denoted Great Trigonometrical Survey (GTS) points. The BWDB maintains topographic bench marks, denoted WAPDA and now, BWDB bench marks. The GTS datum is mean sea level; the datum for the BWDB bench marks is the 'PWD' datum, which is 0.46m below the GTS datum.

In the hydrographic maps and charts produced by BIWTA, depth soundings are referenced to Chart Datum (CD) which is defined as a "place below which the tide seldom falls" and is consequently not a unique datum. However, CD values could be transformed to PWD datum by obtaining the PWD level corresponding to the CD at that location.

4.2.2 Morphological Data

Cross sections of the Brahmaputra River at fixed locations, 4 miles apart, from the Indian border down to the Ganges confluence have been taken annually by BWDB during the dry season (November to April) from 1965 onwards (see Table C1, Appendix C). In 1986/7, the survey of cross sections was carried out at 1 mile (1.6km) intervals along the river. Figure 5.2 shows the locations of the cross-sections.

These routine surveys are carried out by the field teams of the Morphology Directorate earlier located at Mymensingh and now at Jamalpur. Echo sounders are used for depth measurement. Steering of the boat along the fixed cross-section is by visual alignment with two tall flags on shore, one of which is located on the intersection point of the cross-section line with a base line. Position fixing is by theodolite located at the other end of the base line.

The sections above water level are surveyed and levelled using levelling instruments, staves and a linen tape. Base lines are established on the further bank of each 'char' to enable position-fixing during sounding of the adjacent river channel.

Additional hydrographic survey data are available for specific reaches of the river from echo soundings done by BIWTA using the Decca navigation system for position fixing. Special surveys to assess bend and confluence scour and also to track bed forms and dunes were done in 1987 on a limited scale in the river reach of interest to the proposed Jamuna Multi-purpose Bridge, for the Jamuna Bridge Study (RPT-Nedeco-BCL, 1989).

4.2.3 Satellite Imagery

The resource satellites Landsat and SPOT provide satellite imagery at a resolution of 80 x 80m (MSS) and 30 x 30m (TM) for Landsat Imagery available since 1972, and 20 x 20m (or 10 x 10m depending on wavelengths) for the SPOT-1 imagery available from 1986. A total of 11 Landsat maps (1:250 000) of the Brahmaputra River of bands 4 - 7, dating from February 1973 to February 1988 were selected from a possible total of 640 maps available on film at SPARRSO. The selection was based on quality and cloud cover. Copies were also obtained from SPARRSO of enlargements at 1:250 00 of imagery dated 30 January 1990 for the area selected for detailed river surveys ('Test Area 1' - see section 9.4.2).

Timely availability of Landsat and SPOT imagery is affected by the need to have these ordered from Thailand or India. Digital data of imagery are available in CCT's (Computer Compatible Tapes) for particular scenes/area coverage on hire from SPARRSO; or other CCT's for purchase from Thailand. The time delay in securing these is estimated to be about 2 months. The index to Landsat and SPOT imagery is shown in Figure C.3.

Negatives of recent (1987) SPOT imagery at a scale of 1: 50 000 have been obtained under a project assisted by the Like Minded Group of donors. BRTS expects that these could be borrowed from DANIDA for printing. Landsat imagery is expected to be ordered by the Jamuna Multi-Purpose Bridge Authority from SPARRSO for October 1990, February 1991 and October 1991. BRTS will utilize this imagery in its studies. Additionally, BRTS will require imagery in July 1990 if cloud cover and image clarity are acceptable.

4.2.4 Aerial Photographs

The latest aerial photography covering the entire area dates back to 1983/84. Samples of 1: 50 000 black & white photographs (stereo pairs) show excellent quality; however it was not possible to obtain a satisfactory index map for the flight. An indicative index map of the area of coverage is shown in Figure C.4.

Discussions with the North Central Region Study Team who are assembling a mosaic of the 1983/84 photos lead to the conclusion that a large number of photographs, including areas of the river bed and banks, are unavailable due to security or other reasons. The detailed index map currently under preparation by them will be of considerable assistance in the requisitioning and subsequent assembly into a mosaic of these air photos for the BRT study.

Aerial photographs of the River Brahmaputra and its environs were taken at 1: 20 000 scale in January 1987 by Finnmap for SOB; and an uncontrolled mosaic was compiled at scale 1: 50 000 (approx) for the Jamuna Multi-Purpose Bridge Study. A requisition will be placed with SOB for a copy of this mosaic.

4.3 Hydrological Data

Whilst wind, temperature and some rainfall data are collected by the Meteorological Department, the BWDB maintains a denser network of rainfall stations. Consequently, the main source of hydrometeorological data for the BRT Study will be the BWDB. The Directorate of Surface Water Hydrology I (DSH-I) is responsible for hydrological field work whilst the Directorate of Surface Water Hydrology II is responsible for data storage and processing.

Records of rainfall, water levels and discharge (water and sediment) dating back to 1960 have been stored on magnetic media on the Xenix operating system which is not compatible with the operating system (MS-DOS) used by IBM/PC and its compatibles. Consequently, the computerised data cannot be conveniently accessed for processing using the project computers unless it is first converted using specialized software into IBM/PC compatible format.

There is no summarized list of the data prior to 1960 available. Thus, the preparation of a summary of data available prior to 1960 would require an indent for all available hydro-data from DSH-II and then classification thereof.

Consequently, a summary of only the available computerised data has been prepared, immediate data requirements assessed and these then collected on 'hard' copy. The summaries of 'Collected & Available Computerised Data' for rainfall, daily water level and discharge are shown in Appendix C.

The locations of hydro-meteorological stations within the catchment of the Brahmaputra in Bangladesh are shown in Figure C.8. The locations of water level gauges and of the river discharge/sediment load measurement stations on the Brahmaputra are shown in Figure C.9.

A tentative list of 33 rainfall stations (see Table C1 in Appendix C) were selected as representing the rainfall distribution in the catchment of the Brahmaputra and its tributaries within Bangladesh. Data were collected for the rainfall station at Bogra which is an important rainfall station representative of the Brahmaputra catchment within Bangladesh for the period 1960-1988.

Details of the type and frequency of observation of water level, discharge and sediment along the Brahmaputra River and its major tributaries are summarised in Table C3.

Discharge and sediment measurements of the Brahmaputra are taken only at Bahadurabad for which records are available from 1956.

An effort will also be made to collect flow data for the Brahmaputra upstream of Bahadurabad from the Joint Rivers Commission.

4.4 Agro-Socio-Economic Data

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The implementation of a long term programme of river training and bank protection works for the Brahmaputra River will require a

substantial capital investment. A good understanding of the agrosocio-economic aspects relating to this investment is therefore essential in making an objective assessment of the financial and economic viability of the proposals.

The appraisal of the agro-socio-economic aspects will include a study of the existing situation in the protected areas of the Brahmaputra right bank flood plain. This study will be mainly based on data available from secondary sources, supplemented by information collected during the field survey (see Section 9.5). These secondary data are presently being collected from a variety of sources.

The information required for the study on issues relevant to the socio-economic appraisal is summarised in Table 4.1, below.

A substantial body of knowledge is currently available on many of the above topics from the Bangladesh Bureau of Statistics (BBS), which will prove invaluable in the conduct of the study. In addition, comprehensive agro-socio-economic data are also provided in the 'Evaluation Study of the Brahmaputra Right Embankment' conducted by the University of Dhaka 1986. The data from these sources will also be supplemented by information from other sources, given in Table 4.2.

Information collected from the above sources will not necessarily be up to date, but estimates reflecting the present situation for a number of key parameters would be derived from historical trends identified during the analysis of secondary data. These estimates would then be verified during the field survey (see Section 9.5). The historical time series data would also provide a basis for projecting future agricultural, social and economic development scenarios for the study area.

Table 4.1 Information Requirements for the Socio-economic Appraisal

1

Issue	Information Required
Land Use	 Areas under cultivation, fallow, fisheries (river ponds, beels), forestry and settlements (towns/villages/roads)
	- Areas under different flooding depths
	- Areas under irrigation
Population	- Size and distribution of the population, especially the population currently living on the embankment
	- Population growth rate, urbanisation and migration
	- Economic participation and labour force
	- Literacy rate and educational attainment
	- Household size and distribution
	- Wealth indicators (eg. housing, material goods)
Farm Structure and Land Tenure	- Farm size and distribution
	 Number of owner operators and sharecroppers
	- Types of sharecroping
Agricultural Practices and Crop Production	- Cropping patterns and intensities
	- Adoption of improved seeds
	- Fertilizer and pesticide usage
	- Labour and draught power requirements
	- Irrigation systems (DTW, STW, LLP, traditional)
	- Crop yields and land capability.
Livestock and Fisheries	 Number and distribution of livestock (cattle, buffaloes, goats/sheep, poultry)
	- Production of livestock and livestock products
	- Number of fish ponds, beels etc.

Table 4.1 Continued

- Species of fish - Fish catch in rivers, beels and ponds - Marketed surpluses of agricultural produce - Availability and capacity of processing and storage facilities - Market infrastructure and transport facilities (road, rail, ferry services)
 Marketed surpluses of agricultural produce Availability and capacity of processing and storage facilities Market infrastructure and transport facilities
 Availability and capacity of processing and storage facilities Market infrastructure and transport facilities
storage facilities - Market infrastructure and transport facilities
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- Institutional arrangements
- Availability and effectiveness of extension services
- Credit and input supply systems
- Distribution of inputs
- Disbursement and recovery of institutional credit
- Number and types of schools, hospitals/ dispensaries and family planning clinics
- Availability of public water supply
- Distances from welfare facilities
- Types of non-agricultural activities
- Number and size of economic units
- Forms of ownership
- Income levels and growth rates

- Input prices and wage rates
- Marketing costs (handling, transport and storage)



Table 4.1 Continued

Issue	Information Required
	- International commodity prices
	- Foreign exchange rates
	- Shadow conversion factors
Flood Damage	- Agricultural production losses
	- Damage to infrastructure (houses, shops, schools etc.)
	- Displacement of population
	- Dislocation of agricultural and non-agricultural economics
	 Impact on economic growth rate, investment, foreign exchange earnings savings



Table 4.2 Sources of Economic Data

Source	Topic
BWDB	 Evaluation of benefits from past and on-going FCD/FCDI schemes
BADC	- Seed and fertiliser distribution
	- Uptake of tubewells, LLPs etc.
BARC	- Cropping patterns and intensities
	- Crop yield potential
	- Crop input requirement
Ministry of	- Agricultural extension
Agriculture	- Crop production economics
	- Marketing
Ministry of Livestock	- Livestock and fisheries extension
and Fisheries	- Marketing
Ministry of Food	d - Food procurement, storage and distribution
Master Plan	- National Water Plan
Organisation (MPO) and	- Economic pricing
Planning Commission	- Economic conversion factors
	- Methodological issues re: master planning
SPARRSO	- Land use
BIDS	- Economic impact of 1988 flood
	 Impact of adoption of new agricultural technology
UNDP	- Agricultural Sector Review
	- Bangladesh Flood Policy
World Bank	- Flood Rehabilitation Review
	- Flood Action Plan
	- International Commodity Prices
	- Recent Economic Development



METHOD OF APPROACH

This section of the report covers a review of the Consultants' method of approach as set out in their original proposal for the BRTS. It takes into account the additional instructions from BWDB given in their letter of 19 October 1989 (see Appendix B), and the Consultants' enhanced appreciation of the scope of the project which has emerged during the course of the inception phase.

5.1 Overall Approach

The overall approach of the BRTS is directed towards producing a Master Plan containing phased sets of technically and economically feasible schemes for improving the performance of the BRE by protecting it from structural failure and river erosion. These measures are intended by the TOR to include physical works as well as the identification of the operational and maintenance resources required by these works. The proposed implementation sequence contained in the master plan is to take into account priorities identified during the course of the BRTS, as well as the social and environmental effects of proposed schemes.

As stated in the TOR, recommendations for improving the performance and the protection of the BRE are to be made on the basis of an understanding of the nature of the River Brahmaputra, its braided channel network, and its floodplain. The morphological development of the river is the outcome of interactions between river channel processes, the inherent stability and resistance to erosion of the river banks, and the geomorphology and geophysical character of the flood plain. These interactions influence the rate and extent of erosion along the river banks.

These processes, which are complex in nature, can partly be explained in deterministic terms. They also involve a number of random phenomena, such as the location and formation of chars which strongly influence the resulting flow distribution between the braided network of channels and erosion along the channel sides. An assessment of the overall effect of these processes requires the examination of the historic evolution and behaviour of the river, on a macro level, (taking particular account of the incidence, spatial distribution, and severity of bank erosion), and, on a more local level, the modelling of flow and sediment transport processes.

In view of this, the overall strategy that has been adopted for the BRTS centres on an interrelated set of specialist studies and analyses directed towards improving the understanding of channel processes, flood plain characteristics and the interaction between them. The knowledge thus gained will then be used in the engineering design of river training and embankment protection works. In addition the design of works for the right bank of the Brahmaputra should take into account any works for flood alleviation, flood plain management, and other river training proposed or anticipated for the left bank of the river because of their effect on peak flood levels and sediment discharge along the river course.

The control of river bank erosion by means of engineering works both in the river channel (to influence flow patterns) and along the bank (to enhance bank stability) is necessary to protect the BRE. Combined with this, engineering works are also required to improve the structural integrity of the BRE.

The Consultants' overall method of approach for the master plan is illustrated in Figure 5.1. It comprises the following activities:

- (a) Studies covering overall river channel behaviour, morphology, sediment transport, and discharge characteristics. These studies will focus on the interpretation of data on the historic evolution of the braided river channel and its course.
- (b) Studies directed towards achieving a better understanding of the geotechnical, geophysical and geomorphological nature and characteristics of the river banks and flood plain. These studies will include field surveys covering river bank stability and geomorphological mapping.
- (c) An inventory of the present structural condition of the BRE and river training works; an analysis of past schemes and their performance; and an investigation of the effect on the BRE of proposals for works on the left bank of the river
- (d) Mathematical models to simulate water flow, sediment transport, and river bed changes in order to provide inputs to the physical models and to assist in the conceptualisation and design of river training works
- (e) Physical models to support the conceptualisation and design of river training works
- (f) The data, results and information from all the above will then be synthesised in order to:
 - Establish a broad strategy for the protection of the BRE and the confinement of flood flows along the course of the river
 - Identify critical locations requiring river training, bank protection, and embankment rehabilitation
 - Propose suitable schemes at the above locations, maintaining coordination with other FAP projects
 - Establish engineering design parameters and suitable construction procedures for these schemes
- (g) An appraisal of the agro-socio-economic and environmental effects of the proposed schemes
- (h) The formulation of a Master Plan which will provide a strategy for the protection of the BRE with the phased implementation of schemes.

The above series of activities will be supported by a river survey programme to provide data for the construction and calibration of the mathematical and physical models, as well as for the geomorphological study. Field surveys will also be carried out to collect engineering, geotechnical, and agro-socio-economic data.

There is a need to design and implement short-term priority measures for bank protection, river training works, and embankment rehabilitation, in those areas currently under threat from river erosion. The urgency attached to these works means that their design will have to be carried out as soon as possible, without being able to draw on the results of the specialist studies and mathematical models. Where available however, indicative results from these studies and models will be used. Physical models will be used, to assist, where possible, in their design (see Section 11). The overall approach used in the design of the short-term priority works will be generally consistent with that used for the master plan study.

5.2 Key Issues Affecting the Method of Approach

A number of key issues have emerged during the course of the inception phase which affect the scope of, as well as the methodology and programme required for the BRTS. These issues are described in the following sections, along with proposals for refining the method of approach to take account of them.

5.2.1 Feasible Implementation Rate

The TOR calls for a flexible implementation schedule for the Master Plan which will allow for the phased implementation of permanent river training works, with certain works to be implemented on a priority basis. In establishing a feasible implementation rate, consideration will have to be given to the requirements of the Master Plan works for financial, management, and construction resources, and infrastructure, and their availability. These resources are likely to be constrained by competing demands for investment capital and development resources which will arise from the other components of the FAP. Such constraints may have a strong influence on the feasible implementation rate of the Master Plan.

Furthermore, during the course of the implementation of the Master Plan, the Brahmaputra River system may also be influenced by natural and man-made changes (such as environmental changes in the catchment and proposed works for river regulation and water transfer) which are beyond the control of the Master Plan and its implementing authority. In order to accommodate such changes, the Master Plan should be flexible in detail whilst directed towards achieving an overall defined aim. This points to an evolutionary approach to master planning rather than the drawing up of a static and definitive plan that is able to be executed without further amendment irrespective of the rate of implementation actually achieved.

The Consultants' interpretation of the scope of the Master Plan has been defined to reflect the above, and is described in detail in Section 12.

5.2.2 Flood Alleviation Works on the Left Bank

A continuous flood alleviation embankment, the BLE, has been proposed for the left bank flood plain of the Brahmaputra. Its design height and alignment will affect the design height for the BRE, and containment by it, of flood flows and sediment transport will influence the morphological behavior of the river.

The effect of such works should be taken into account in formulating a Master Plan for the BRE, as discussed further in Section 10.3.

5.2.3 Geomorphological and Geotechnical Studies

The technical note included with the request from BWDB (Appendix B) to review the Consultants' study methodology, lists a number of causes of embankment and river bank failure.

Particular attention is drawn to mechanisms such as piping through the sub-soil and wave attack during high stages which were not specifically mentioned in the TOR.

With regard to river bank stability, groundwater flow back into the river during falling stages is identified as an additional failure mechanism to be considered in the assessment of erosion potential.

These mechanisms need to be considered alongside the other causes of embankment failure mentioned in the TOR, and the scope of the geomorphological and geotechnical studies have been reviewed accordingly. The Consultants' recommendations arising from this are as follows:

- (a) The scope of the geomorphological and geotechnical studies should be increased. This will include additional geomorphological data collection and additional geotechnical investigations along the BRE as well as both banks of the river.
- (b) In addition to the data base of the BRE inventory survey, data bases of geomorphological and geotechnical data will also be created.
- (c) The inputs of the expatriate Geomorphologist and Geotechnical specialists should be increased to supervise the above activities.
- (d) An expatriate Data Base Analyst/Hydraulic Engineer should be included in the study team to be responsible for the geomorphological data analysis.

The implications of this in terms of the project programme and staff inputs are given in Section 13.

5.2.4 Data Management

The variety and amount of data that will be collected during the course of the study is best catalogued, stored and analysed using

data bases. The development and management of data bases is important to the effective and efficient use and interpretation of project data. It is necessary to make adequate provision for specialist (and logistical) inputs for the collection, organisation and analysis of the large volume of data to be collected during the BRTS project. The expatriate staff inputs have therefore been revised to include an input by a Data Base Analyst, as described more fully in Section 13.

5.2.5 The Role of Mathematical and Physical Modelling

During the course of the inception phase, the Consultants' Team have reviewed the role and phasing of the mathematical and physical modelling.

As pointed out in the technical note accompanying the BWDB letter, the mathematical models do require extensive river channel data for their calibration. These data requirements have been assessed in detail (see Section 9). As a consequence we have increased the input of the Field Engineer and determined the logistical support necessary to enable data collection to proceed within the time scale of the study as specified in the TOR.

The technical note expressed reservations regarding the limitations inherent in the mathematical modelling of a braided river. Our overall approach, set out in Section 5.1, reflects the view that the modelling (both mathematical and physical) forms part of an combination of specialist studies integrated (including geomorphology, river engineering and soil mechanics) all of which are directed towards obtaining a better understanding of the behaviour of the river and the nature of the erosion process. Implicit in this is the view that no single activity will provide sufficient information on its own to significantly improve the design basis of the master plan schemes, and that an integrated set of studies is required to achieve this. Such an approach combines the insight into the deterministic processes obtained from mathematical modelling with an appreciation obtained through the complementary specialist studies of the stochastic processes influencing channel morphology and bank erosion.

We have also considered the role of the large sectoral models within the overall scope of the BRTS, along with their technical and operational feasibility. Our recommendations are that they be replaced with a set of schematic and (local) partial models directed towards a more detailed hydraulic analysis of alternative solutions and the influence of different design parameters. This will provide results which complement those from the mathematical modelling studies more adequately. Furthermore the costs and logistical problems of setting up large scale mobile bed models in open spaces are avoided as described in Section 8.

5.2.6 Increased Emphasis on Multidisciplinary Planning and Design

The planning and design of river training works, for implementation within the context of the Master Plan, is the final project output. The multi-disciplinary activities to be carried out during the BRTS will therefore have to be managed and directed towards achieving this

aim, whilst taking full account of the other FAP study programmes and the coordination required between BRTS and the other FAP components (see Section 5.3 below).

It is therefore recommended that the Design Engineer, to whom the responsibility for coordinating the outputs of the various project studies naturally falls, should take on the role of Team Leader. As discussed in Section 13, provision should be made to extend the time input of the Team Leader/Design Engineer.

This revision will also enable the Physical Modelling Specialist (who is the current Team Leader) to concentrate on the physical modelling studies which will require him to spend significant periods of time at RRI in Faridpur.

5.2.7 Approach to the Economic Appraisal of the Master Plan

The costs of river training, bank protection and embankment refurbishment works will have to be linked with a full evaluation of both direct and indirect benefits of flood alleviation and bank protection. These should also take into account the benefits that the works will bring to the regional water resource and agricultural development including projects identified as components of the FAP.

The implication of this is that the Master Plan can be used to provide a framework for facilitating the funding of one or more integrated development projects which will include river training and flood alleviation works, as well as water control, drainage, agriculture and fisheries development in adjacent areas. This issue is discussed more fully in Section 6.4.

5.3 Integration with the Flood Action Plan

It is now important and necessary to co-ordinate the BRTS programme and activities with other components of the FAP. The influence of the FAP components can be broadly classified into two categories:

- Components which will have a direct influence on the components of the BRTS Master Plan
- Components which could provide information for or directly benefit from the BRTS activities

The main reason to distinguish between the two types of influence is that it is necessary for the BRTS programme to be closely co-ordinated with those aspects of the FAP components which will directly influence the Master Plan.

The need for co-ordination and integration of the BRTS with the FAP components in the second category depends on the degree of mutual benefit that can be derived from these components and on their programmes.

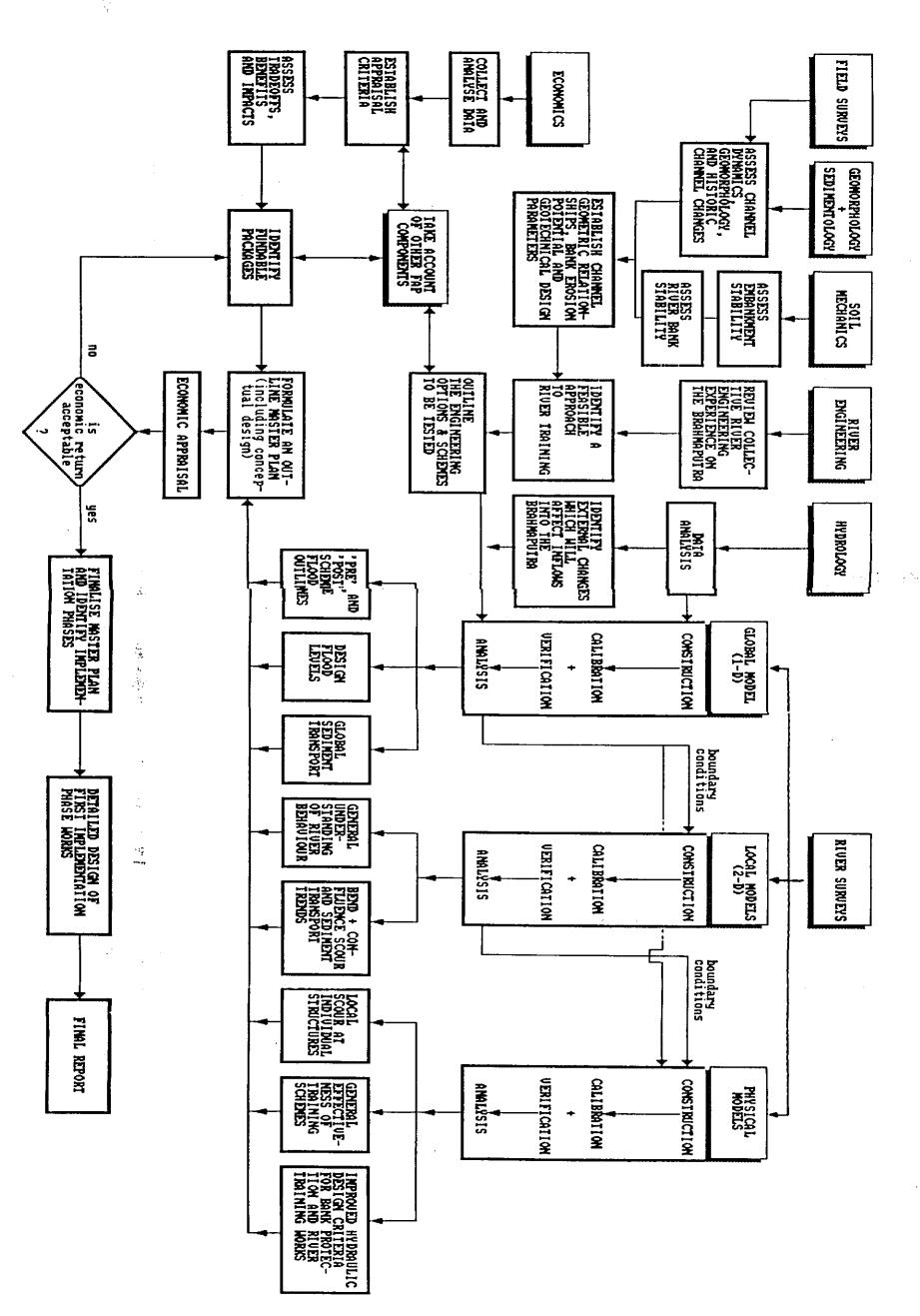
As described in Section 2.2, the additional instructions received from the BWDB identified six components of the FAP with which the BRTS should be co-ordinated. As discussed in Section 10, it is



considered that the BRTS should not only co-ordinate with these components but also take into consideration the other environmental and agro-socio-economic components which address common issues.

The studies to investigate the proposed confinement of the Brahmaputra River by the construction of a continuous left embankment would need to be closely linked to the BRTS. The BLE would have an influence on the confined flood water levels in the river as well as its morphology and thus influence the Master Plan for the river training works for the BRE. The BRTS activities have accordingly been extended to support the planning and design studies of the BLE. Recommendations for the scope of these activities are given in Section 10.3.

Meetings held with the BWDB, the FPCO and other concerned organisations including the study teams for FAP 2 and FAP 3, during the inception phase have confirmed the need to revise and the extend the BRTS programme to integrate with the FAP, and that this integration should include studies for the proposed BLE.



BRAHMAPUTRA RIVER TRAINING STUDY

Figure 5.1



RIVER AND SPECIALIST STUDIES

6.1 Hydrology

The hydrological studies will form an essential requirement in understanding the morphological and drainage characteristics of the Brahmaputra river system in Bangladesh. These studies will be based on the hydrological data available for the river system and the rainfall and climate data available for the adjacent North West Region and North Central Region drainage areas.

A review of past hydrological studies for the Brahmaputra River is currently in progress. This includes the studies undertaken in connection with the Brahmaputra Multipurpose Development Project (1986) and the Common Rivers Study (1986). The former included an analysis of high water level and flood flows, whilst the latter study was particularly concerned with low flows during the dry season.

The hydrological studies will also provide information for the geomorphological studies and the modelling studies, including the following:

- (a) River flow and water level characteristics, including seasonal patterns and tributary flows
- (b) Sediment transport characteristics based on available data
- (c) Rainfall characteristics of the adjacent areas
- (d) existing drainage characteristics of the adjacent areas.

The mathematical and physical model simulation studies will be undertaken for a range of design flows. The hydrological studies will, therefore, include the determination of seasonal and event-based flows and water levels corresponding to different return periods. This will also include the determination of inflows from the major tributaries draining to the Brahmaputra River from the North West Region. Changes in the drainage patterns as a result of proposed developments in this area will also need to be taken into account.

The hydrological study activities may, therefore, be summarised as follows:

(a) Data Collection

- Review and collection of relevant data
- Establishing the hydrology data base
- Verifying data quality by necessary field checks and analysis.

(b) Basic Analysis

- Analysis of water level, discharge and sediment data to determine general hydrological characteristics of the Brahmaputra River
- Analysis of rainfall and climate data in the North West and North Central regions to determine their general characteristics
- Definition of drainage characteristics of the North West and North Central regions.

(c) Analysis for Modelling Studies

- Ten-day river flows and water levels corresponding to different return periods
- Analysis of monsoon flow and water level hydrographs
- Estimation of tributary water and sediment inflows for different return periods, and outflows down the distributaries.

(d) Recommendations for Additional Data Collection

- Assessment of additional data required for the BRTS
- Assessment of long-term data collection needs
- Proposals for the institutional and logistical requirements to enable the long term collection of data.

The hydrological analysis will be carried out with the assistance of a suite of computer programmes available with the Consultant.

6.2 Geomorphological Studies

The geomorphological component of the study has two main functions: to provide quantitative data about the river channel geometry and its variation with time; and to provide guidance in the assessment of the long-term effects of the river training works on channel morphology.

Three major areas of study are envisaged: channel geometry and dynamics; geomorphological and geophysical aspects of the flood plain; and historical channel changes.

6.2.1 Channel geometry and dynamics

The objective of this area of the study is to enable predictions to be made on the likely effects of future training works on the morphology of the river and to obtain a greater appreciation of the evolution of the channel patterns.

The general approach will be to use existing data on the planform and geometry of the river and its channel, supplemented by field

data collection in areas of particular importance and geomorphological sensitivity.

Literature searches will be conducted to gather information from previous academic studies.

Field data will be collected, using a river bank data logging procedure appropriate to the nature of the river bank geometry and material found on the Brahmaputra.

Data analysis will include the application of regime type theory for local and downstream hydraulic geometry. Bend flow theory and modelling will be utilised for bend scour and migration prediction. Sediment transport and flow resistance equations will be employed for bedform prediction and the computation of sediment transport rates.

There are two principal features of the channel pattern that are of vital concern. The first is geometric characteristics such as the width, depth, bend radius, and wavelength of anabranch channels. The other is the nature of development of such channels; and whether bank attack occurs most frequently in certain limited areas or more or less at random along the whole length of the BRE.

The Brahmaputra shifted to its present course, some 200 years ago. Surveys were carried out subsequently, but not at frequent or regular intervals. The resulting maps are, in the main, at a scale of (roughly) 1 inch to 1 mile. This old mapping was not considered when the plan-form analysis was carried out for the Jamuna Bridge study, because of doubts about its accuracy. It is intended to look again at this question of reliability, using whatever copies of the old maps can be obtained. If the conclusion is that it can be used with a fair degree of confidence, the bank-line movement since the mid-19th century, can be traced.

The mapping was carried out relatively infrequently so it will provide only an overall view of the rate and trend of bank-line movement. A more detailed picture will be revealed by the satellite imagery and the aerial photography that has been carried out. Post-1973 Landsat maps, at a scale of 1:250 000, have been obtained and will be analysed, to provide the data on plan form characteristics and plan stability, which will be required when designing the training works. Where available and if possible, aerial photography that will also be used in the analysis.

Methods have been developed for characterising braided rivers, for example that of Howard, Keetch and Vincent (1970). Such methods will be employed, where appropriate, as an aid in determining whether the river characteristics change with time or with distance along the river. The standard cross-sectional surveys carried out by the BWDB, since the mid-1960s, will also be a source of information on the changes that have taken place. The conclusions from the cross-section analysis can be compared with those obtained from the satellite imagery and aerial photography.

There are many reasons why bank erosion takes place: direct attack by high velocity currents; seepage pressures during flood recession;

undercutting by river bed or wave erosion; weak material; and liquefaction. The bank stability along the length of the river will be assessed on the basis of field inspection and tests to determine the strength parameters of the bank material. Bank stability models that have been developed in the course of previous investigations of similar problems will be applied, where possible, using field data.

If a correlation can be developed between the locations of previous bank failures and the nature of the bank material, it will enable the risk of future failures to be assessed for individual reaches of river bank. The possibility of developing such a predictive method will be examined.

6.2.2 Geomorphological and Geophysical Aspects - Historical Channel Changes

The objective of these two areas of the study is to predict the long term channel changes.

One of the options that will be considered in the study is the feasibility of converting the braided river by comprehensive set of river regulation works into a single thread channel. Although this would not completely eliminate the need for localised river training works, it would remove some of the unpredictability of erosion and channel movement, that is a feature of a braided river.

Another aspect that will be examined is the effect of reducing the overall width within which the river is free to generate its braided pattern, such as is being proposed at the Jamuna Bridge crossing.

The geomorphological/geophysical component will rely on existing maps and information supplied by BWDB and BIWTA plus data from the literature and field reconnaissance. Topographic maps will be used to define the flood plain and drainage pattern, and superficial geology. Rainfall maps will be used to assess the distribution of precipitation.

There are two types of long term development that need to be considered. One is a major shift, such as occurred 200 years ago, when the Brahmaputra forsook its historic course. The other type is a less radical development and comprises relatively minor (albeit potentially still damaging) movements in the individual channels making up the braided network.

The prospect of the former type of shift will be examined, using data derived from an analysis of exiting topographical and geomorphological maps as well as previous geomorphological studies of the area. Seismic data will also be analysed. Site visits will be made and soil testing will be carried out.

An assessment of the changes in channel morphology following the construction of training works constructed as part of the short term measures (Section 11), will also be made, based on a similar approach to that described above.

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6.3 Geotechnical Studies

Geotechnical aspects are closely related to the security of the BRE and the damage causing mechanisms. Damage to the BRE can have a variety of causes including:

- Seepage through the embankment can produce piping
- Wave attack can result in erosion
- Weak material or poor construction can lead to structural failure in the saturated state
- Erosion of the adjoining flood plain can undermine the embankment
- Poor maintenance, particularly in reaches where embankment slopes are inhabited, could lead to weakening of the BRE
- The effect of ground water flow into the river during falling river stages may be a damage-causing mechanism in certain soils. However, this phenomenon needs to be investigated.
- The river banks themselves are prone to fail for much the same reasons as described above, such as piping, wave attack, oversteepening of slopes, under-cutting, liquefaction etc.

All of these failure mechanisms are intimately linked to the strength of the bank or embankment material: thus the geotechnical studies have an important role to play in the design of the training works.

The geotechnical studies fall under two main headings; those relating to the embankment and those concerning the river banks.

The studies concerned with the embankment will examine the methods used to design and construct them, as well as the materials, and will include an assessment of:

- Available data and past reports
- Performance of existing works
- Studies of past breaches
- Appraisal of current geotechnical design standards
- Specifications for additional investigations
- Seismic studies
- Testing of materials
- Recommendations for geotechnical design parameters
- Location of suitable bank-fill material.

The studies related to the river bank stability will assess the causes of failure and will suggest measures for stabilising the banks Geotechnical design procedures for river training works will be recommended. The need for filter layers beneath bank revetment, particularly the revetment lying below low water level, will be assessed; and methods for designing the filter will be recommended.

The geotechnical inputs of the expatriate and local Geotechnical specialists will have to be increased to undertake these studies which would also involve close co-ordination with the geomorphological studies.

With regard to the geotechnical investigations for the BRE, the right bank and left bank, we recommend that these are undertaken by BWDB according to specifications drawn up by the Geotechnical specialist. These investigations will be necessary to satisfactorily complete the geotechnical studies including assessing failure mechanisms and determining design parameters.

6.4 Agro-Socio-Economic Studies

In the UNDP funded Bangladesh Flood Policy Study (May 1989), it was strongly recommended that flood protection measures should be integrated with the economic development of the protected areas. It was envisaged that their approach would lead to the successive implementation of projects in which 'flood protection is provided in conjunction with area development, including irrigation, drainage, promoting increased agricultural productivity as well as fish culture and agricultural processing'.

This argument for an integrated approach was further endorsed by the World Bank's 'Action Plan for Flood Control' which suggested that the 'economic justification of flood control rests more on the enhancement of land use rather than on the reduction in flood damage'. The World Bank report also concluded that 'embankments must be seen as elements of a comprehensive water control system planned and designed to modify the water regime in the interests of more profitable land use in an environmentally sound manner'.

The Consultants fully support this view and consequently propose adopting a more comprehensive approach in their financial and economic appraisal of BRE river training and bank protection schemes. In addition to determining the direct benefits from flood protection (eg. reduction in agricultural losses, avoiding loss of life and damage to infrastructure etc.), the Consultants would also provide an assessment of the agricultural development potential within the protected areas, as well as the social and environmental implications of alternative investment strategies. It is clear that this approach will also have to take into account any proposed investments relating to drainage and water control in the area protected by the BRE. A schematic diagram of the method of approach to be adopted for the agro-socio-economic studies is presented in Figure 6.1.

It should also be emphasised that by adopting an integrated approach to the agro-socio-economic studies, the Consultants will provide a direct link with other components of the Flood Action Plan (FAP). The

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analysis and conclusions given in the North West Regional and North Central Regional Studies will clearly provide an important input into the assessment of the development opportunities which would enhance the economic value of the protection works for the BRE, and the construction of a BLE.

In addition, the findings and recommendations generated by the following FAP supporting studies will provide valuable information during the assessment the agro-socio-economic implications of various investment strategies:

- FCD/FCDI Agricultural Review
- Fisheries Study and Pilot Project
- Land Acquisition and Settlement Study
- Environmental Study.

The data collection and analysis undertaken in the BRT studies will also be of use to other studies in the FAP programme. Every effort will be made to ensure that the output from complementary FAP studies is taken fully into account through the establishment of formal coordination/liaison links.

6.4.1 Preliminary Analysis

On the basis of the field survey (see Section 9.5) and the analysis of secondary data, an assessment of the agricultural development potential will be prepared. This assessment will examine the potential for changes in agricultural practices, cropping patterns/intensities and crop yields for varying degrees of water control (including irrigation from both groundwater and surface water sources). Both the opportunities and constraints to agricultural development will be determined with a view to identifying alternative 'with project' development scenarios. In addition, the scope for the improvement and expansion of rural industries will also be considered. This assessment will therefore provide the basic physical parameters required for an evaluation of the financial and economic benefits of the proposed investments in flood control and drainage.

A financial analysis will primarily be undertaken to determine the likely financial implications of the proposals on households within the study area. As household incomes are governed by market prices for production inputs and outputs, all prices used in this analysis will be expressed on this basis. Financial gross margins for all major enterprises (farm and non-farm) will be derived for both the 'with' and 'without' project situations, and will be subsequently used to determine the incremental net returns to different households.

Furthermore, the impact of the proposed developments on income distribution and employment opportunities in both the agricultural and non-agricultural sectors will also be examined, with special emphasis on the prospects for the poorer more disadvantaged groups within the community. Initial estimates of the economic benefits

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generated by the programme will also be made during this phase of the study. It will, therefore, be necessary to derive a set of economic prices which reflect the 'opportunity cost' of the resources used. For goods traded internationally, import and export parity prices will be derived. For non-traded goods, the economic prices will be obtained by the application of standard and specific conversion factors used by MPO and the Planning Commission.

In the estimation of economic benefits an incremental approach will be adopted, which contrasts the future 'without' and future 'with' project situations. A series of incremental benefit streams will then be generated reflecting alternative development options. The direct and tangible economic benefits will mainly be generated through:

- Improvements in agricultural production
- Growth in the economic activity of the non-agricultural sector
- Increases in livestock and culture fisheries production
- Decrease in the flood damage to infrastructure
- Decrease in crop and livestock losses due to flood and drought
- Prevention of damage to towns and villages the displacement of people due to bank erosion
- Reduction in the cost of rehabilitating and retiring the BRE
- Increasing the stability of ferry ghat location

In addition, an attempt will also be made to assess the indirect benefits that could be attributed to flood protection and drainage. These indirect benefits would include:

- Reducing the long term costs that can be attributed to underinvestment in improved agricultural technology because of the risk of loss through flooding
- Mitigating the macro-economic losses caused by a dislocation in communications and economic activity which results in a reduction in economic growth and investment
- increasing foreign exchange earnings/savings
- improved nutritional status of the population
- improved communications and transport resulting from the infrastructural developments
- increased production and marketing of farm inputs and outputs.

These benefits, would, however, be offset by the social and environmental costs associated with land acquisition/resettlement. These costs will also have to be taken into account in the analysis.

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Of particular significance in the context of the BRE is the likely social impact of having to move those people who have established permanent settlement along the embankment in order to carry out refurbishment or strengthening work. There are estimated to be of the order of 100 000 people currently living on the BRE. In order to enable an assessment of this social impact it is proposed that the local staff input allocation be increased to allow for an input by a sociologist to carry out a study of this problem.

This evaluation of benefits does assume that in the future 'without project' situation the present methods of rehabilitating and retiring the BRE will continue. It may, also be worthwhile to estimate the benefits of a more pessimistic scenario in which an increasing number of major breaches in the embankment begin to occur, resulting in significant losses in terms of the displacement of population as well as agricultural and infrastructural damage. Examination of the history of the BRE will show if there is a trend in flood damage resulting from inadequate maintenance. Particular account will also be taken of the consequences of large scale changes in river course that might follow the opening up of new flow channels in areas of high erosion potential. If a distinct possibility that this may occur is identified, this will be taken into account in the 'without project' scenario.

6.4.2 Evaluation of the Master Plan

An essential component in the formulation of the Master Plan is the economic analysis of the proposed sets of integrated schemes, each reflecting particular investment strategies, over the planned economic life of the schemes. The costs and benefits of alternative investment strategies will, therefore, be subjected to an economic appraisal in line with the procedures adopted by the international funding agencies.

Financial cost estimates for proposed civil works will be derived from the engineering designs using standard unit rates for similar current and recently completed works. Cost estimates for river training and bank protection works will be obtained from the BRTS, while costs relating to area development will be provided by the North West Regional Study. The costs of additional engineering services and operation and maintenance will also be included in the project cost estimates. These financial costs will be converted to economic costs by applying the appropriate conversion factors, used by MPO and the Planning Commission, to the various cost components. The estimation of the economic benefits that can be attributed to the alternative investment strategies has already been discussed in Section 6.4.1.

After determining the cost and benefit streams of various options, the incremental net project benefit would then be derived. This incremental net benefit stream would then be subjected to discounted cash flow techniques in order to estimate the Economic Internal Rate of Return (EIRR) and the Net Present Value (NPV) at the prevailing opportunity cost of capital. In addition, the Net Present Value Ratio (NPVR), ie. NPV in shadow prices divided by the PV of capital expenditure in market prices, will also be calculated. Sensitivity

analysis will also be undertaken on the alternative investment scenarios to assess the impact on economic viability to adverse and/or positive changes in the cost and benefit streams, and delays in project implementation.

This analysis would, therefore, provide a guide to the suitability of the various strategies for funding by the GOB and international donor agencies based on purely economic criteria. It is, however, also important to assess the various options with regard to their social and environmental implications.

Social benefits would be derived from increasing household income and creation of employment opportunities (particularly for disadvantaged groups), greater provision of public welfare facilities, and preventing the displacement of people due to bank erosion. Land acquisition and resettlement would, however, be evaluated as a social cost. Similarly, the movement of people presently settled on the embankment would also be taken into account. The FAP study on Land Acquisition and Settlement would provide valuable information during the estimation of these social costs.

After screening the alternative scenarios according to economic, social and environmental criteria (discussed in Section 6.5), as well as the technical merits and consequences, recommendations will be presented to the BWDB for their consideration prior to finalising the most suitable strategy. A phased investment schedule will then be prepared with due regard to the time required arrange funding, and the limitations in the fiscal, administrative, and technical implementation capacity.

In this context, it is important to note that the Master Plan can be used to provide the framework to facilitate the funding of one or more integrated development projects which comprises river training and embankment protection works, water control and drainage systems, together with agricultural and fisheries development within a defined area; as a fundable package. The identification of 'fundable packages' (which are technically, economically, socially and environmentally sound sets of development schemes) will be one of the main results of the agro-socio-economic studies.

6.5 Environmental Studies

There has been considerable concern that flood control and drainage works, together with agricultural development within the flood protected areas, could have an adverse impact on capture fisheries, soil fertility, groundwater recharge, health and wildlife. The consultants are very aware of the importance of taking environmental effects into account during the planning process.

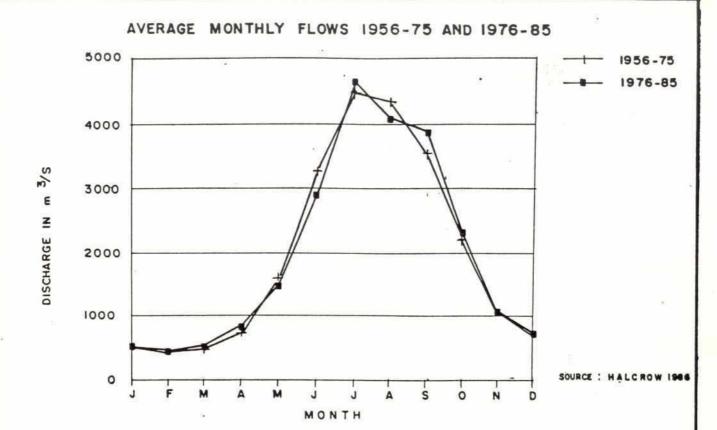
A primary objective of the strengthening of the BRE is to engender a favourable environmental impact through mitigation of the harmful effects of inundation from overbank flooding on human lives, crops and infrastructure. However, floods are often said to deposit fertile sediment on inundated land and the construction of embankments would prevent this from occurring. But in the case of the right bank of the Brahmaputra, the BRE is extant and the effects of its strengthening

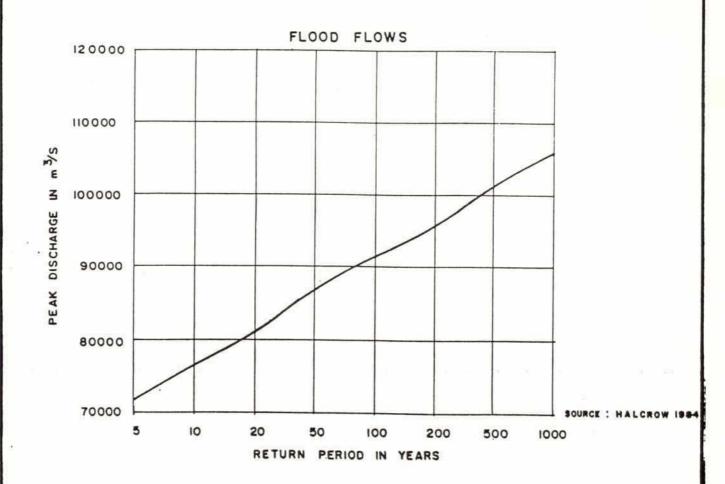
would not include any measurable impact on the frequency or extent of inundation of the land behind it. It is also noted that a problem which is encountered when a weak section of the BRE breaches, is the loss of land quality due to deposition of sand and silt following flooding. The strengthening of the BRE would minimise adverse impacts due to such flood inundation.

Whilst flooding contributes to groundwater recharge, it is also to be recalled that the bunded and levelled agricultural land behind the BRE functions as a very effective detention flood basin during the flood season due to heavy rainfall in the local catchment. Consequently the contribution of flooding to groundwater recharge needs to be evaluated in this context.

Information relating to the possible environmental impact of the proposed works, envisaged under the various FAP options, will mainly be obtained from those studies which have a specific responsibility to undertake environmental impact assessments (EIA). For example, the NW Regional Study will be able to provide information on the likely environmental impact of improved drainage and agricultural development in the area protected by the BRE. Similarly, the Fisheries Study will provide a guide to effects of the BRT civil works on the nature and diversity of fish population, as well as fish production in the Brahmaputra River. In the evaluations of past and on-going FCD/FCDI projects, the Agricultural Review will also undertake EIAs, thereby providing further insights into likely environmental effects in the BRE study area. Furthermore, the FAP's Environment Study will be able to identify the environmental issues of major concern and assist in the appraisal of likely environmental effects in the BRE study area, as well as recommend ways of mitigating any adverse impact.

Through good co-ordination and liaison with the relevant FAP studies, any possible adverse environmental impact related to BRE proposals can be highlighted and given full consideration during the preparation of the Master Plan.





BRAHMAPUTRA AT BAHADURABAD

7. MATHEMATICAL MODELLING

7.1 General Approach

The main objectives of the mathematical modelling studies within the overall scope and objectives of the BRT Studies are given in the TOR as:

- To simulate the movement of water, sediment and the river bed in order to gain a better understanding of the River Brahmaputra system
- To provide input parameters and boundary conditions for the physical models
- To predict the consequences of potential river training schemes on the river morphology
- To simulate flow over the embankment during overtopping or through the embankment following breaching.

The above objectives will be investigated using an integrated combination of mathematical and physical modelling carried out in conjunction with specialist studies covering fluvial morphology, sedimentology, river engineering and soil mechanics. The results from these models will be combined with an assessment of the potential for longer-term morphological change in the river channel provided by the specialist studies.

The mathematical models will be set up using one-dimensional (1-D) as well as two-dimensional (2-D) numerical systems. Each of these systems is better suited than the other to addressing particular issues within the overall set of objectives of the mathematical modelling studies. The combined use of the two types of mathematical model, in conjunction with the physical model, has therefore been designed to provide outputs which will be complementary to one another.

The general approach to the mathematical modelling will be to set up a 'global model' (1-D) covering the Brahmaputra between Chilmari and the Ganges confluence; the Teesta up to Kaunia; and parts of the right and left bank Brahmaputra flood plain as required. The 2-D system will be used to set up a series of local models of reaches of particular importance or interest.

A detailed description of the 1-D and 2-D models and their proposed scope and application is given in Sections 7.3 and 7.4 below. The scope of physical modelling in this study is discussed in Section 8.

7.2 Data Availability

The different types of data required for the mathematical modelling studies fall into the following main categories:

(a) Historic river discharges and water levels

- (b) River channel cross sections
- (c) Flood plain topography and drainage channels
- (d) Historic flood patterns in depth, duration and extent
- (e) Sequences of aerial photographs, satellite images, and maps from which changes in the course of river channels with time can be assessed
- (f) Bed-topography (small-scale as well as large-scale) with information on the variability of the bed through one year taken at the following times:
 - at rising stage
 - at falling stage
 - at low stage
- (g) Flow patterns in relation to the three stages of flood described above with data on the distribution and direction of flow over the whole cross-section of the river, and associated water levels
- (h) Sediment load: this should comprise vertical distribution of wash load and suspended load as well as measurements of bed load
- (i) Bank line movements: the erosion of the river banks in the test area selected for calibration of the 2-D model should be surveyed during the flood season and in the period of falling stage after the flood.

A full description of available data and sources is given in Section 4 and Appendix C.

The calibration data for the 2-D model will be collected during the course of the river survey programme described in Section 9.

7.3 One Dimensional (1-D) Modelling

The 1-D modelling will be carried out using the 'Mike 11' numerical modelling system developed by DHI. Mike 11 is a successor to 'System 11' which is currently being used by SWSMP who are currently in the process of transferring their 'General' and regional models from 'System 11' to 'Mike 11' (SWSMP, 1990).

The 'Mike 11' modelling system has been selected for use on the BRTS for three main reasons:

- It is an established general purpose open channel flow modelling system
- It is suitable for the range of applications envisaged for the 'global model' on the BRTS

 It is compatible with the modelling system used by SWSMP and therefore offers a consistency of approach with SWSMP and other studies using their models.

The technical capability of Mike 11 includes:

- A hydrodynamic core module which is capable of simulating unsteady flows in a network of open channels
- A sediment transport module which is able to use the results of the hydrodynamic computation.

The hydrodynamic module has been developed on basis of 'System 11' and is an implicit, finite difference model for unsteady flow computation based on the Saint Venant equations of conservation of mass and momentum. The model can describe subcritical as well as supercritical flow conditions through a numerical description which is altered according to the local flow conditions (in time and space).

Additional computational modules are included for the description of flow over hydraulic structures, including the facility to describe the operation of hydraulic structures. The formulations can be applied to looped networks and to quasi two-dimensional flow simulation on flood plains.

'Mike 11' can be applied to vertically homogeneous flow conditions extending from steep river flows to tidally influenced estuaries. The system has been used in numerous engineering studies around the world.

The non-cohesive sediment transport module can be used in conjunction with three different models for the calculation of the sediment transport capacity and alluvial roughness. This module requires output from the hydrodynamic module in terms of discharges, cross sectional area and hydraulic radii.

The sediment transport module is run serially with the hydrodynamic module. It is based on a simple routine considering the net sediment transport between neighbouring grid points in each branch for estimating the general erosion or deposition during the simulation period.

The 1-D model can be used to investigate the effect, in terms of river water levels and section average velocities along the length of the Brahmaputra, of:

- (a) Inflows to the river system and outflows from it for flood events of different frequency or return period
- (b) Changes in the relative distribution of flows between the main river channel(s) and its distributaries such as would result from the implementation of certain FAP components
- (c) Changes in sediment transport rates

- (d) Backwater effects following the construction of major works (eg Brahmaputra Barrage) or increased flood peaks down the Ganges
- (e) Engineered changes in cross-section geometry of the river channels
- (f) Variation in channel roughness due to changes in bedform.

The 'global model' will be applied to modelling flood plain flow due to natural flooding and flooding that occurs as a result of overtopping of the embankment. For this purpose, the flood plain can be represented as a quasi two-dimensional network of channels and interconnected flood cells. The typical size of flood plain cells may be of the order of 20-25 km².

In this way the 'global model' will simulate flood patterns and river water levels for cases 'without' and 'with' flood alleviation works on the river bank. By comparing the 'without' and 'with' scheme flooding, the benefits of flood alleviation can be determined. These benefits can then be compared with the costs of the schemes as part of their economic appraisal.

The 'global model' can also be used to obtain indicative values for general scour along the Brahmaputra resulting from different degrees of flood confinement. However, a much more detailed indication of scour in specific reaches will be provided by the System 21 (2-D) local models as described in Section 7.4. below.

A schematisation where the channel network follows the braiding pattern of the main channels will be tested and used if found to be significantly more accurate than using a more simple representation of single-channel cross-sections. Smaller channels will in any event be lumped together. Computational nodes (cross-sections) will be located with an average spacing of 3 to 4 km.

A flexible approach to the schematisation of the 'global model' will be maintained to enable account to be taken of aspects of the river system as they become apparent during the course of the study. The intention is however to retain overall compatibility with the layout of the SWSMP General Model since this model will be used to determine the boundaries of the 'global model'. To assist in this, it is recommended that a copy of the SWSMP General Model be transferred to the BRTS and mounted on one of its project computers. The model will be maintained and updated in collaboration with the SWSMP.

Observed sets of flow, stage, and flood pattern data for recent flood events of different return period will be used for the calibration and verification of the 1-D model at high stage. Inbank flows will be used for the calibration of the model at low stages, and the model will then be tested by simulating a complete annual flow cycle.

7.4 Two Dimensional (2-D) Modelling

In the present study, (2-D) mathematical models of selected reaches of the Brahmaputra will be established using 'System 21'. 'System 21' is an un-steady two-dimensional integrated hydrodynamic and sediment transport modelling system developed by DHI.

'System 21' has been selected for use on the BRTS for the following principal reasons:

- It is an established, general purpose 2-D modelling system
- The modelling system allows a description of the water flow velocity vectors to be combined with a description of sediment transport processes in order to simulate the dynamic changes of the river bed - this is important to enhancing the understanding of the behaviour of a braided river
- It can utilise a traditional rectangular or an orthogonal curvilinear computational grid, which makes it particularly well suited for application in braiding rivers.

The 'System 21' modelling system consists of the following components:

- An elliptic grid generator
- A hydrodynamic stage
- A transport dispersion stage
- A sediment transport stage
- A module for updating of the bed topography.

The elliptic grid generator computes a curvilinear orthogonal computational grid, which is utilized by the remaining stages of the modelling system. Input to the grid generator is the cartesian co-ordinates of the model boundaries and a weight function. With the weight function the grid can be twisted in such a way that the grid density can be increased in areas of particular interest. Amongst others, the water depth can be used as weight function, so that the grid density increases in the deeper parts of the river.

The hydrodynamic stage simulates the water level variations and flows which are resolved on a rectangular or curvilinear computational grid covering the area of interest when provided with the bathymetry, bed resistance co-efficients, wind field, and boundary conditions.

The system solves the Saint Venant equations of continuity and conservation of momentum in two horizontal directions using implicit finite difference methods.

The transport-dispersion stage of System 21 simulates the spreading of suspended sediment in an aquatic environment under the influence

of fluid transport and associated natural dispersion processes. In a similar way to the hydrodynamic stage, the concentration of suspended sediment is calculated at each point of a computational grid covering the area of interest. Information on the flows and water depths at each point of the grid, are provided by the hydrodynamic stage. Other data required includes sediment concentrations and discharges at tributaries and distributaries, together with concentrations at boundaries.

The sediment transport module can be operated in two ways. The module can be used to simulate the dynamic development of sand dunes and their associated hydraulic resistance. Alternatively, or in addition, the model can be used to simulate the magnitude and direction of the sediment transport in the two-dimensional computational grid. The sediment transport model and the module for updating the bed topography due to erosion or sedimentation are integrated with the hydrodynamic model so that feed back due to change of hydraulic resistance of bed topography are automatically taken into account.

The flow in a braided river such as the Brahmaputra is strongly curved giving rise to secondary (or spiral or helical) flow. The secondary flow is directed towards the centre of curvature close to the channel bed and outwards in the upper part of the flow. This flow pattern has a significant impact on the sediment transport direction and hence on the bed topography development in the river. The effect of secondary flow is included in both the suspended and the bed load calculation. The effect of gravitational forces on sloping beds is also included in the bed load transport calculations.

7.4.1 Application

The purpose of the 2-D models is to help predict short-term large scale morphological development assuming 'worst case scenarios' to derive some of the design criteria for the river training measures. The model will also provide insight into the processes in a braiding river and in that way will assist in the extrapolation from the available field data to evaluate the effects of river training measures.

The model can be employed in several ways within this study:

- (a) To predict bend and confluence scour during extreme floods and hence improve the design basis for river training works
- (b) To analyse the impact of various river training measures and to compare alternatives. River training measures such as groynes will have both a local effect and a more general influence on the distribution of flow and sediment transport between individual braiding channels.
- (c) By analysing 'worst case scenarios' on the locations most severely exposed to bank erosion so that suitable design parameters can be determined.

Key parameters in the morphological development of braided rivers are the distribution of flow and sediment transport between the individual channels of the braided rivers and the bank erosion rate. Both the flow and sediment distribution as well as the bank erosion rate and pattern will depend strongly on the actual discharge variation on the river. Formation of new channels in a braiding river normally takes place during severe floods. In order to predict the morphological development in the longer-term it would therefore be necessary to know the actual discharge variation in advance. Thus, the longer-term morphological development of a braided river is dependent, to a large extent, on stochastic processes. Consequently, the two-dimensional models cannot be used directly in predicting the long term development of the river morphology, but they will be used in conjunction with the output from the geomorphological studies in order to assess the longerterm trends in river morphology and determine 'worst case scenarios' so that suitable design parameters can be determined.

The general modelling strategy is to set up and calibrate the model in detail for one selected test area in order to build up confidence in the model performance and improve the understanding of the processes in the river. Subsequently, the model will be applied to selected reaches where river training measures are planned.

The area selected for calibration of the model extends from upstream of the Ranigram Groyne to downstream of the proposed site for the Jamuna Bridge crossing. This area has been selected because it is the most intensively surveyed reach of the Brahmaputra River (as a consequence of studies for the Jamuna Bridge Project) with a certain amount of relevant data, and mapping already available.

7.5 Implications of the Flood Action Plan

The modification of the BRTS in response to integration with the other FAP components means that the schematisation used in the models would need to be sufficiently flexible to allow the models to be modified to represent relevant FAP components. Of particular importance are those components which will directly affect inflows to and outflows from the Brahmaputra as well as design embankment heights, alignments, and the construction of control structures.

The following additional requirements for the modelling studies may arise from the FAP:

- (a) The inflow boundaries of the 'global model' may have to take account of possible changes to the distribution of flows in the surface water system arising from North West Regional Study (FAP Component No 2)
- (b) The schematisation of the 'global model' on the left bank flood plain of the Brahmaputra (using a quasi 2-D representation) may have to be extended to reflect the possible changes to the flood plain flows such as would result from the construction of a Brahmaputra left embankment

or follow on from the results of the North Central Regional Study (FAP Component No 3)

- (c) The possible changes in flow distribution between the Brahmaputra and its distributaries arising from FAP Component No 3 will affect the location of and stage-discharge relationships at the downstream boundaries of the model. The area covered by the 'global model' may, therefore, have to be extended to include parts of the left bank distributary network (as has been done in the SWSMP General Model) and downstream of the Brahmaputra-Ganges confluence.
- (d) The degree of detail of the schematisation of the braided channel of the Brahmaputra represented in the local (2-D) models will have to be sufficiently flexible to incorporate schemes arising from the River Training/AFPM Pilot Project (FAP Component No 22). The underlying philosophy of this component would seem to be an attempt to control the flow distribution in the various branches of the braided channel network, intervening, where necessary to prevent channels developing which might eventually attack the river banks.

Integration with FAP will, therefore, extend the scope of the mathematical modelling studies, with the probable effect of increasing their complexity, data requirements and overall duration.

Given that the modelling (mathematical and physical) lies on the critical path of the BRTS study programme, these extensions will directly affect the overall timetable of the study. As such the modelling programme as well as the study timetable would be sensitive to delays in one or more of the related FAP components. It is important to maintaining adequate progress on the BRTS that adequate coordination with FAP components is achieved so as to minimise delays to the BRTS programme.

The mathematical modelling programme may benefit from the increased availability of data from FAP Component No 16 (Topographic Mapping) and FAP Component No 24 (River Survey Programme). These components are currently insufficiently far advanced to be able to predict their likely benefit to our own data gathering programme. The BRTS activity programme has, therefore, been devised on the assumption that there will not be any data contributions from these FAP components.

8. PHYSICAL MODELLING

8.1 General Approach

The natural direction of flow in the Brahmaputra is controlled predominantly by bank slumping during the rising stage and by the formation of sand bars which deflect the course of existing and new channels after the flood starts subsiding. The process is continuous along the entire river, with large differences in flow direction at any one section, as illustrated by the variation in angle of flow velocity (Figure 8.1). The highest values of the variation angle occur where the distance between river banks is greatest and the bed contains the highest number of sand banks and islands. The lowest variations are met in narrow channels, with areas of deep scour.

The high variability of the direction of the approach velocity in the Brahmaputra reflects the stochastic nature of flow changes and exists also in the river channel along the right bank, which represents the contact front with the mass of river flow. In practice, this means that the tests and studies on hydraulic scale-models, which are one of the key inputs of the project, will need to be designed and carried out, bearing in mind the respective variability of the direction of approach velocity in the vicinity of bank protection and river training works.

The TOR specified two long sectoral river models and six sectional models, plus the mathematical modelling of the Brahmaputra from the border with India up to the junction with the Ganges.

Sectoral models (scales 1:500 to 1:1 000 horizontal, 1:100 to 1:200 vertical) were to reproduce the overall braided flow of very long river sectors and the full river width. The two sectoral models were supposed to cover together the total length of Brahmaputra in Bangladesh. Their use would have been mainly to provide hydraulic data (liquid discharges, flow velocities, water levels) for the study of bank protection and local river training works on the right bank channel. Another objective was to get information about the influence of successive groups of works (groynes, x-bars, etc). on the flow and channel bed.

Sectional models (scales 1:200 to 1:500 horizontal, 1:40 to 1:100 vertical) were intended to reproduce the overall braided flow and the full width of shorter river stretches at larger scales than the sectoral models. They were expected to provide data on discharge distribution, flow velocities and water levels among the component channels of the network. The sectional models were supposed to enable bank protection and river training solutions to be developed for design use. Both types of models would be distorted and would behave like fixed bed models even with loose boundaries (sand). The actual shear stress at bed level will not reach the critical threshold without strong geometrical distortion, which will affect the correct simulation of scour evolution and its ultimate depth.

As mathematical models will provide the relevant hydraulic and morphological data (water levels, velocities, scouring and deposition, solid transport) for local physical modelling in

different locations along the main channels of the braided river network, there is no longer any justification for the long sectoral models because they do not offer better accuracy than the mathematical models of the respective river reaches. Moreover, sectoral scale-models are difficult to operate due to their size.

Since the mathematical models will give the water levels, discharges and sediment transport conditions in the channels of the river network, it is no longer necessary to use sectional scale models of the network, which could give similar results to the mathematical model, albeit less accurately. Furthermore, they would also impose inconvenient geometric scales for the study of flow conditions around bank protection and river training works.

Therefore, instead of two sectoral and several sectional scale-models, an increase in the number of local/partial models is recommended.

Local hydraulic scale-models (scales 1:60 to 1:100, non-distorted) will reproduce only the necessary length of the channel where bank protection and river training solutions are required. The model will be provided with the necessary hydrological and hydraulic data from field measurements and mathematical models, and will be designed at a large enough scale to offer reliable results.

Partial hydraulic scale-models (scales 1:40 to 1:60, non-distorted) cover only part of the river bed where active bank protection works and local river training works (groynes, x-bars etc.) are placed, in order to study at larger scale, detailed design elements. Such models will reproduce both the structures and the relevant flow velocity field characteristics. It is also expected to use local/partial schematic models which hydraulically represent limit-states with regard to the influence of certain parameters (ie. 'worst case scenarios'). The local/partial models, both for the study of individual cases of structures/works or for limit-states, will be designed for specific problems such as:

- (a) Local studies of the hydraulic behaviour and efficiency of spur/groyne/cross-bar groups of impermeable/permeable type in given channel locations
- (b) Local study of channel branches or junctions provided with river training works for controlling their stability and behaviour
- (c) Detail studies of the hydraulic efficiency of structure elements in different conditions of flow approach. Such elements could include: shape of groyne nose; behaviour of the falling aprons; possibilities of reducing the size and intensity of vertical eddies and rollers close to the nose; possibilities of shifting the maximum scour depth far away from the nose of the groyne; likely configuration of the scour hole area; longitudinal scour at the toe of bank/embankment slope protected with different types of revetment etc

to

- (d) Studies on 2-D scale-models of wave action on embankment crosssections during high stages or flood overspilling of the embankment crest
- (e) Investigation of the possible use of traditional structures to control and train branches/junctions of channels (for instance by applying permeable structures, or using submerged sills, bandals etc)
- (f) Monitoring of existing/newly built bank protection and river training works, to compare their behaviour in prototype and model.

Model tests and studies (a) and (b) give answers to the design of new bank protection and river training solutions by means of 'local models' which reproduce channel reaches and the respective works

Model tests and studies (c), (d), (e) and (f) provide elements to improve the existing level of the hydraulic design concerning bank protection and local river training works, using local/partial models. The position of physical models within the project strategy for modelling studies is shown in Figure 5.1.

The scale-model analysis of bank protection and local river training for the short-term measures (see Section 11) represents a special programme in the tentative schedule. Due to the strict limitation of the available time (August 1990-March 1991) for such tests, in order to check alternative design solutions and the final one, the number of priority locations expected to be studied till end of March 1991 could not exceed five or six cases. Afterwards, other important cases will also be analysed if time permits.

8.2 RRI Facilities and Activity

According to the ToR, the programme of physical modelling works was envisaged to be developed partly at RRI Faridpur and partly in Dhaka. Since RRI was completely moved to Faridpur in mid-1989, all the tests and studies on hydraulic scale models for the BRTS will be undertaken in Faridpur. The work will be done by the staff of RRI on contract basis, under the supervision of specialist BRTS staff, who will also plan the physical modelling programme and design the models. The existing hydraulic research facilities at RRI in Faridpur consist of two main components as illustrated in Figure 8.2.

The first component is a large open-air river model platform (260m \times 120m), with its own pump house, water supply, recirculation canals and storage pool. The platform is provided with a deep sand bed (sand diameter = 0.22mm) and is subdivided in 9 independent compartments, of which 3 are 125m \times 40m and 6 are 60m \times 38m.

Completion works are currently under way and will continue till around the end of August 1990. The total available discharge is 0.5 m³/s, but it could be increased by installing more locally manufactured single stage pumps. During the monsoon season, weather conditions impose constraints on the tests since the models require protection against both wind and rain. These are at present

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limitations which need to be settled in order to avoid delays in the modelling activity.

The second component is a hydraulic model hall under construction, expected to be completed by mid-to late-1991. The hall (95m x 28m) will be provided with its own closed hydraulic circuit of clear water and will have enough room for a shallow water wave basin (approx. 47m x 24m), river models (2 x 10m x 50m or 1 x 20m x 50m) and glazed flumes (4m x 50m). The likely total discharge in the closed circuit (collecting channels under hall floor - lower tank - pumps - elevated tanks - perimetral feeder - models and stands - collecting channels) is expected to be up to about 1.8 m³/s, if two-stage imported pumps are procured. The use of local pumps would limit the height of the water level in the upper tank and also the discharge. There would also be the inconvenience of a very large number of delivery pipes to supply enough discharge to the upper tank (one delivery pipe for every 0.1 m³/s). Considering the existing RRI construction programme and its planned financing, it is expected that the completion date will be met. Possible reductions in allocated funds would affect the implementation and generate bottlenecks.

The activity of RRI as specialized national institute in the field of river hydraulics and hydraulic engineering is well known and acknowledged. For many years the institute has solved a large number of applied problems for bank protection and local river training works on different rivers including the Brahmaputra.

At its new home in Faridpur, RRI will be strongly placed to increase its research potential and know-how. It is felt that the collaboration between RRI and BRTS will be a benefit for both parties.

8.3 Physical Modelling Programme

The tentative schedule (bar-chart) of the BRTS physical modelling programme of tests and studies is shown in Figure 13.1.

Scale models will use, as mentioned earlier, hydraulic data furnished by the mathematical models for the locations where bank protection and/or river training works are envisaged. These input data are expected to comprise mainly boundary conditions (water levels, velocity and sediment transport distribution in relevant cross-sections, free surface slope), but may also include morphological changes (erosion and deposition in sectors of the main channels of the river system, channel migration).

The main types of bank protection and river training works expected to be used, depend on factors such as hydraulic efficiency, inservice life, cost, limitations in types and quantities of building materials, execution technology, available duration of construction period.

Two main types of river training and bank protection works are expected to be used in practice:

(a) Groynes and revetments on the river bank

(b) River training works in the braiding channel network, aimed at controlling the local distribution of liquid/solid discharge at key locations

Local river training works in the braiding network could be effective when used for the closure of a channel threatening the bank/embankment, or for keeping open a channel that is diverting flow away from the bank. However such works are likely to be expensive and their efficiency may be affected by the random behaviour of the active braiding river system: they merit further investigation.

Taking into account the aspects already discussed in Sections 3, 5 and 8.1, the hydraulic scale-model tests and studies will have to provide answers to problems such as:

- The length and spacing of groynes which will prevent the braided channels from attacking the river bank or the groynes
- The effects on a group of groynes of variations in the channel geometry and in the approach angle of the currents.
- Scour evolution along the toe of a flood embankment or along the river bank (revetment)
- Behaviour of bank or embankment under wind-wave action, either with or without overspilling of the crest: in certain areas, erosion produced by wind-waves is a serious problem during floods.

Scale model tests will give answers to matters such as:

- The influence of groyne/cross-bar geometry (bank, nose) on the local velocities around the structure; scour characteristics and potential scour area to be protected by falling apron (hole configuration, apron size and effectiveness).
- The maximum likely scour depth (tests with 'clear water', mobile-bed models ie. tests without general sediment transport); calibration of constants in the best existing scour depth equations for use on Brahmaputra.
- Limit cases of groyne and revetment behaviour in braiding main channels (change in bend curvature, char approaching a groyne group, bank revetment or groyne attacked by oblique approach velocity etc.)
- Development of guidelines for the hydraulic design of bank protection and local river training works.

The degree of bed mobility of the hydraulic scale-models is important for several reasons, such as fidelity in reproducing the flow phenomenon and its effects, the time required for testing, the costs of model tests, availability of suitable granular bed material, the need to recirculate solid discharge along with the liquid discharge.



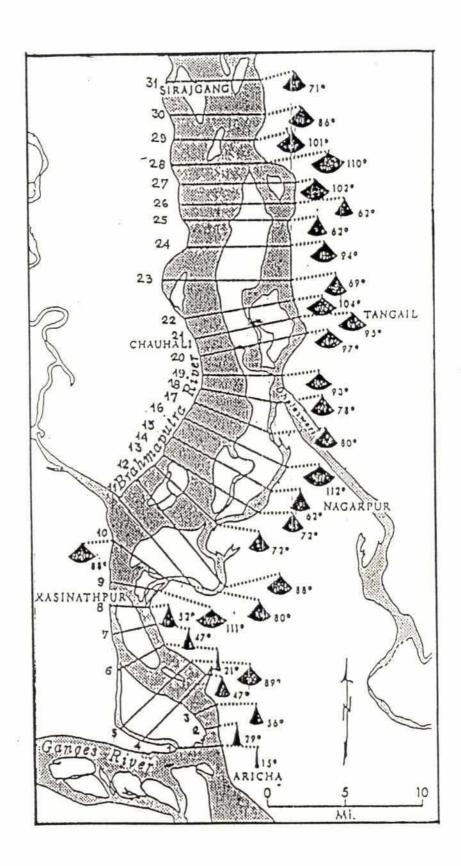
Fixed-bed models reproduce only the hydrodynamics of the flow and therefore they can offer only limited information.

Semi-mobile bed models ie mainly fixed bed, but with relevant areas of the bed consisting of granular loose material, (for example in the groyne scour area or at the toe of the revetment) can be used as undistorted local or partial models.

Live-bed (mobile-bed) models using sand as granular bed material need to be either at very large scale if undistorted, or to be distorted (geometrically or slope exaggerated), in order to achieve bed material mobility. When using light granular material, such difficulty could be avoided, but the cost of this material is very high and the expenditure could substantially exceed the budget provisions.

Semi-mobile models, either with or without sediment re-circulation represent the most viable option for most of the experimental studies.

VARIATIONS IN CURRENT DIRECTIONS FROM GENERAL FLOW PATTERN



DATA COLLECTION AND RIVER SURVEYS

9.1 General Approach

Data collection will include both field data collection and the extraction of data from published (and unpublished) sources. In both processes, data collection will be focussed on the actual requirement of data for each aspect of the study; mathematical modelling; physical modelling; engineering; geomorphology; and economics.

The general approach to data collection is set out in the flow chart below

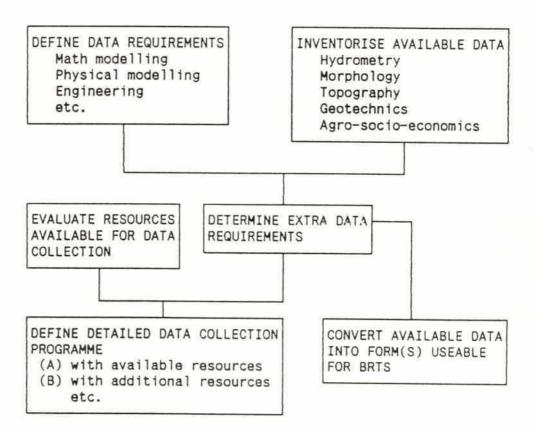


Figure 9.2 General Approach to Data Collection

The collection of data associated with the requirements as defined above falls into two broad procedures:

- Collection of existing maps and data
- Field data collection

Data requirements, both from available sources and from special surveys to be carried out under the BRTS, are listed in Table 9.1 and are illustrated on Figure 9.1.

9.2 BRE Inventory Surveys

The BRE comprises the embankment itself and the protective measures - groynes, x-bars and bank revetment - installed to stabilise the river bank. The proposed inventory surveys cover all these components

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but at a level of detail appropriate to each. The outline scope and extent of the inventory survey is given below:

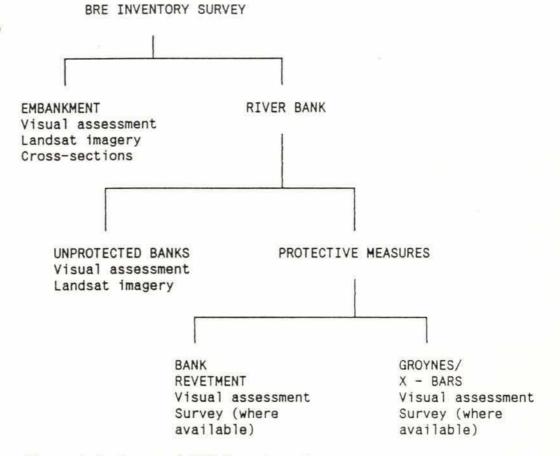


Figure 9.3 Scope of BRE Inventory Survey

9.2.1 Earthen Embankment

The inventory survey of the earthen embankment itself comprises three separate procedures:

- (a) Determination of the condition of the embankment by visual inspection
- (b) Determination of the alignment of the embankment in plan through 1:25 000 scale Landsat imagery correlated with the alignment indicated by the Bogra O&M Circle on 4 inches = 1 mile base maps, and
- (c) Detailed levelling of the embankment (cross-sections) in reaches which may require strengthening.

The visual assessment would include the assignment of parameters, in as objective a manner as is feasible for each of the following aspects:

 Top width and surface condition of crest; viewed also as the access road for O&M operations



- Condition of the slopes, both river-side & country-side
- Encroachment on embankment by villagers
- Any special features.

9.2.2 Unprotected River Bank

The visual assessment of the unprotected river bank reaches would necessarily be much less detailed than of the embankment itself and would primarily be aimed at: identifying reaches which have failed; and classifying reaches according to the potential for failure through known failure mechanisms. Thus the visual assessment would include:

- Bank height and slope (qualitative)
- Type and extent of failure observed
- Areas likely to fail and probable mode of failure

The bank line itself vis-a-vis the BRE will be defined using Landsat imagery.

9.2.3 Bank Revetment

The assessment will gather data on the present condition of the bank revetment, such as:

- Location, age, extent
- Type (cc blocks, brick blocks etc)
- Size of material and thickness of layer
- Evidence of filter layer
- Condition (signs of slumping, areas where revetment thickness is thin or non-existent).

The condition of the revetment below water level can only be assessed if up-to-date surveys of the river banks and bed, are available.

9.2.4 Groynes and X-bars

Data will be assembled on:

- Reason for constructing groyne or X-bar
- Location, length, orientation, age
- Details of geometry (crest width, elevation, side slopes)
- Type, size and dimensions of revetment (both slope and falling apron)
- Evidence of filter

- Condition of revetment (same criteria as for bank revetment)
- Effectiveness (further bank erosion prevented, deposition of sediment up or downstream).

The condition of the falling apron can only be assessed if up-to-date bed surveys are available.

9.3 BLE Inventory Survey

The BLE as it exists is not comparable in extent or importance to the BRE. However, an embankment does exist on some part of the left bank; and the unprotected river bank itself is subject to river action in several reaches.

Consequently an inventory survey of the river bank will be conducted as for the right bank; the inventory survey of the earthen embankment would comprise:

- (a) Determination of the condition of the embankment by visual inspection, and
- (b) Determination of the alignment of the existing embankment in plan using 1:50 000 SPOT imagery.

9.4 River Surveys

River surveys will constitute the most demanding component of data collection. River data are being collected primarily to calibrate the 2-D mathematical model (System 21) and for simulation studies associated with both the 2-D local models and the 1-D (Mike 11) 'global model' of the Brahmaputra River. Some river surveys will also be associated with data requirements for physical modelling and engineering studies, particularly in the vicinity of existing or proposed river training structures and also for the measurement of bend and confluence scour. The river surveys to be carried out for these purposes are organized into separate exercises as follows:

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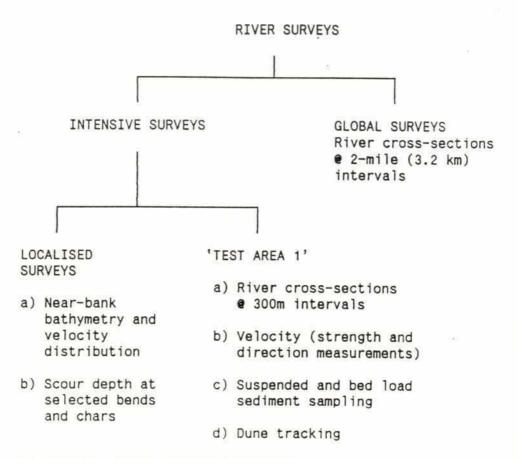


Figure 9.4 Scope of River Surveys

9.4.1 Localised Surveys

These would be carried out during the falling stage of the river (Nov-Jan) from propeller-driven 'country' boats using echo-sounder and current meter. Position fixing will use land survey methods for near-bank surveys, and baseline and theodolite tracking for the scour depth surveys. A total of about 8 locations are planned.

9.4.2 'Test Area 1' Surveys

Test Area 1 comprises a river reach extending 12km south from Sirajganj. To the hydrographer, the morphology of the Brahmaputra River is characterised by subaqueous sand banks which hinder boat movement along a fixed line and by large chars which hinder both the movement of boats and the visibility of shore stations. These impediments impose constraints (directly) on the type of position-fixing instrument to be utilised; and (indirectly) on the hydrometric instruments to be used, if measurements are to be carried out within a short enough time period such that the river discharge does not change significantly during the period of survey.

River surveys within Test Area 1 are to be carried out at 3 stages of the annual river cycle: at rising stage (June/July); falling stage (Oct/Nov); and at low stage (Feb/Mar). The detailed scope of work in Test Area 1 is given in Appendix D.

Within Test Area 1, the total (approximate) number of measurements required to be carried out (summarized from Table D.1) is as follows:

- Length (of cross section) to be echo-sounded = 300km

No. of velocity measurements = 300nos. (strength + direction)

- No. of suspended sediment samples = 60

No. of river bed samples = 20

The size and draught of boats, the propulsion mechanism and the effectiveness of anchoring are all important considerations for vessels to be deployed for river surveys in Test Area 1. For the monsoon surveys (ie. during the rising stage of the river) the hydrographic survey vessel, M V Anwesha attached to the Dutch aided Land Reclamation Project (LRP) will be utilised. The vessel carries two tenders (or daughter boats) also equipped with Decca navigation facilities and the capability to carry current meters and sediment sampling equipment in addition to an echo-sounder.

As there is little experience in river surveys of the Brahmaputra during the monsoon period, it is not possible to predict the capability of steering the 'daughter' boats along a required cross section or of being able to be anchored at a required grid point (within an acceptable drift) for taking velocity measurements and/or sediment samples. The mother vessel has a draught which would not permit it to approach the edges of chars or even areas outside the deep channels where sand banks can form just below the surface. Nevertheless the Consultants expect to achieve a sufficient degree of accuracy of measurement to meet the data requirements of the mathematical modelling.

It is recognised that the availability of M V Anwesha for the postmonsoon round of surveys — from October to December during the falling river stage — is uncertain. However, data requirements for the 2-D mathematical model requires recording the bathymetry and flow conditions at the same locations as for the monsoon surveys. Whilst 'country' boats ply the river during this period, they are poorly suited to carry winches capable of handling current meters and sediment sampling equipment which require to be weighted down with up to 100kg of ballast. Consequently, an adjustment would need to be made to engage suitable vessels from BIWTA or re-assign BWDB boats from other projects to the BRTS or purchase boats from other sources.

Bed-form tracking will be carried out at 3 stages of the annual river cycle referred to. This involves the continuous sounding of the bed-form on three lines (tracks) each about 3 km long (see Fig. D.1 for location) for 5 successive days, twice daily. The need to ensure that the same track is traversed each time necessitates position-fixing accuracy of a high order. This rules out the Decca or GPS navigation systems and requires a micro-wave positioning system with at least two suitably located shore stations providing continuous navigation information.

9.4.3 Global Surveys

'Global' surveys are the river cross-section surveys at 2-mile intervals from the Indo-Bangladesh border down to the Ganges confluence, with additional (perhaps 10 nos.) cross-sections to define node points for schematisation of the MIKE 11 model. These surveys are expected to be carried out during the November-April period by the BWDB Morphology Sub-division within the routine annual river survey programme.

9.5 Agro-Socio-Economics

The secondary data currently being collected (see Section 4.4) will provide the basic quantitative information necessary to undertake a financial and economic appraisal of the proposed civil works. It is however, very important that these data are complemented by more qualitative information gathered during an agro-socio-economic survey of the study area.

The primary objectives of the field survey would be to:

- (a) Verify the key parameters identified during the analysis of secondary data, eg. land use, population, crop areas, crop yields, output/input prices.
- (b) Provide a greater understanding of farmers' perceptions and attitudes to floods, embankment strengthening, adoption of improved agricultural technology, drainage, irrigation and agricultural support services (extension, input and credit supply).
- (c) Identify the relative importance of the major constraints to agricultural development, eg. farm size/land tenures, labour, input/credit supply, extension, marketing, irrigation, drainage, and risk of flooding.
- (d) Assess the development opportunities within the study area with particular regard to agriculture (including irrigation) and fisheries.
- (e) Identify the potential adverse social and environmental implications of the proposed works such as land acquisition and resettlement, reduction in capture fisheries, and possible effects on soil fertility.
- (f) Determine the social and economic implications of moving people off the BRE to enable its refurbishment
- (g) Determine the likely future developments within the nonagricultural sector as well as infrastructural developments such as roads and public welfare facilities.

The field survey will be conducted by the two Agro-Socio-Economists using qualitative data collection techniques assisted by a Sociologist. Data collection will mainly be based on:



- Focussed group interviews with farmers and other groups affected by the BRE
- Structured interviews with 'key informants' (eg. government officials, extension workers, local leaders, and traders).

The field survey will cover all the areas in the flood plain benefiting from the Brahmaputra Right Embankment, but will place greater emphasis on those areas which are likely to be more directly affected by the implementation of the proposed works. In addition, attention will also be given to the 'char lands' lying within the river course, and the problems associated with settlement on the embankment itself.

On the basis of the information gathered during the field survey, together with the analysis of secondary data, an appraisal of the agro-socio-economic conditions currently prevailing within the study area will be undertaken.



Table 9.1 Data Requirements and Source

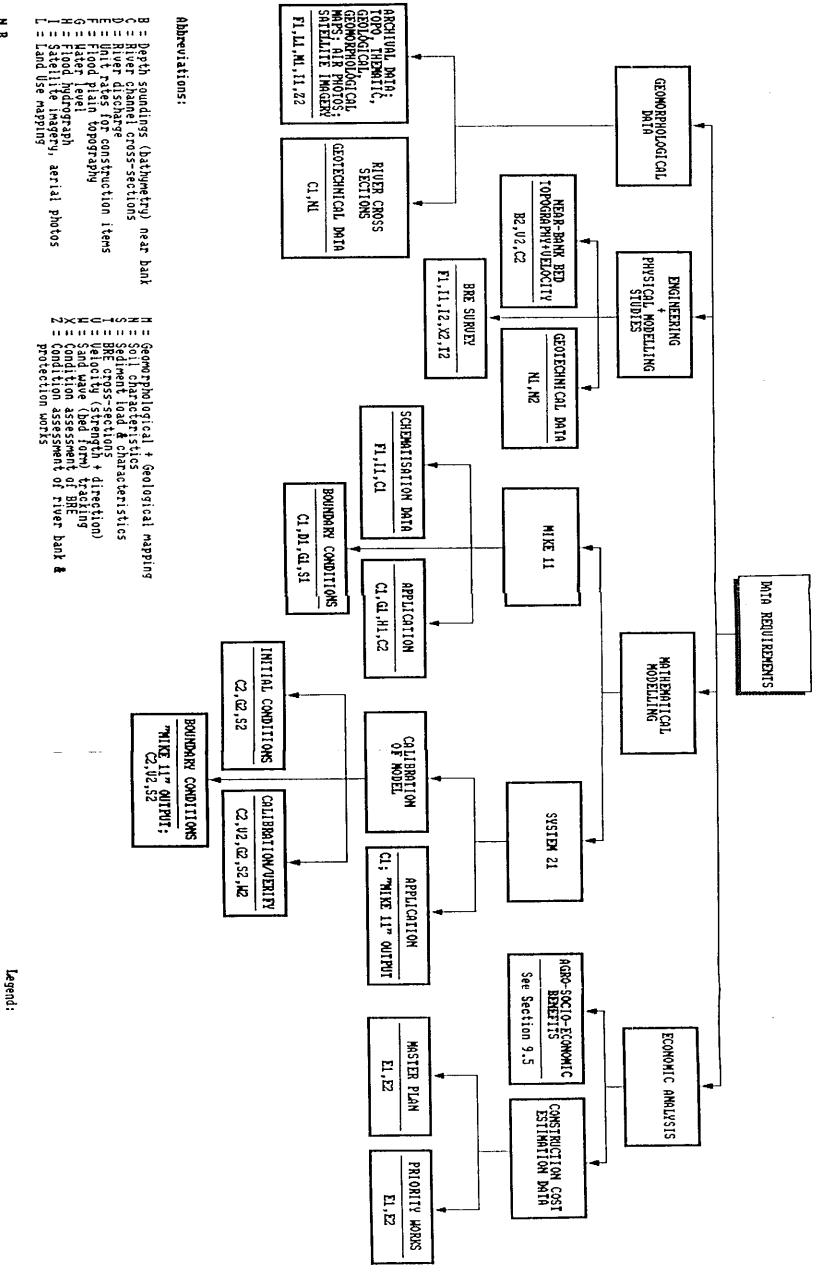
Study	Required data type							
activity	Description		Code ⁽¹⁾	Main sources				
Geo- morphology	a)	Archival Data		SOB, other GOB & UK sources				
		Topo maps Thematic maps	F1 L1	SOB, BWDB Soil Survey of Bangladesh, BWDB,MPO				
	d)	Geological/ Geomorphological maps	M1	Geological Survey of Bangladesh, BWDB, MPO				
	e)	Satellite Imagery/Aerial Photos	I1	SPARRSO				
Engineering and Physical Modelling	a)	Near-bank bed & bank topo- graphy	B2 B2	BRT Study Team Bogra O&M Circle				
Studies	b)	Near-bank velocities	V2	BRT Study Team				
	c)	Soil charac- teristics associated with river banks	N1 N2 N2	RRI (Faridpur) BRT Study Team Groundwater Circle (GWC)				
	d)	BRE alignment	F1 I1 I2	Bogra O&M Circle SPARRSO (1:25 000) SPARRSO (1:25 000)				
	e)	Condition Assessment of BRE	X2	BRT Study Team				
	f)	Cross-Sections of BRE	T2	BRT Study Team				
*	g)	Condition Assessment of river banks & protection works	Z2	BRT Study Team				
	h)	Soil Strength Characteristics	N1 N2 N2 N2	RRI (Faridpur) BRT Study Team Groundwater Circle RRI (Faridpur)				

Table 9.1 Continued

Study	Required data t							
activity	Description	Code ⁽¹⁾	Main sources					
Mathematical Modelling (1-d)	a) Schematisatio Data	n I1 F1	SPARRSO (1:250 000) BWDB SWSM Project					
	b) Boundary Conditions	C1	BWDB River Cross- Sections pre-1990					
		D1 G1 S1	BWDB BWDB BWDB					
	c) Simulation Da	ta H1 G1 C1	BRT Study Team BRT Study Team BWDB River Cross- sections					
		G2 G2 S2	BRT Study Team BRT Study Team BRT Study Team					
Mathematical Modelling (System 2-d)	a) Schematisation Data	11 C2	SPARRSO (1:25 000) BRT Study Team (1: 10 000)					
	b) Calibration Data	V2 S2	BRT Study Team (1: 10 000) BRT Study Team BRT Study Team					
	c) Simulation Dat	C1 C2 H1 G2 G1	BWDB (1990 Surveys) BRT Study Team BRT Study Team BRT Study Team BRT Study Team					
Economic Analysis	a) Agro-socio- economic benefits		BRT Study Team					
	b) Construction Cost	E1	BWDB					
	(Priority Work	(s) E2	BRT Study Team					
	c) Construction Cost (Master Plan)	E1	ICB Tenders (Overseas)					
		E2	BRT Study Team					

Note: (1) See Figure 9.1 for code definitions

DEFINITION OF DATA REQUIREMENTS



Subscripts "1" and "2" are attached (where appropriate) to indicate as followes:

← Data Type/Activity

Specific Data Requirement(s) associated with activity/data type

 n1 n n historical data (or data routinely collected by BHDB) n2 n data to be collected specifically for the BRT Study

C1 = River cross-sections done by BMDB C2 = River cross-sections to be obtained from BRT River Surveys

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10. CO-ORDINATION WITH THE FLOOD ACTION PLAN

10.1 Related Components

The FAP, covering the five year period 1990-95, is the first of several stages in a strategy for the development of a comprehensive system of flood control and drainage works designed to meet GOB's long-term objectives to provide a permanent solution to the recurrent flood problem. The BRTS project forms a key component within the FAP. The need to integrate with other relevant components of the FAP is therefore an essential aspect of the BRTS scope of work and programme.

The main links between the BRTS and the FAP were identified in the additional instructions received from BWDB (Appendix B). Discussions with BWDB, FPCO and other groups involved in specific FAP components have confirmed the relevance of these additional components.

The related components and the perceived links are given in Table 10.1. A brief description of the components are in Appendix E.

10.2 Co-ordination Strategy

A strategy to co-ordinate the BRTS programme with relevant FAP components will be particularly dictated by the timing of the respective study programmes. Since the main studies of these components have yet to commence, it is difficult to formulate a definitive programme for co-ordination. However, the need for co-ordination is recognized in principle and the BRTS programme will be reviewed after the other FAP component studies commence.

It is, therefore, recommended that the BRTS programme be reviewed at the First Interim Report stage in February 1991. Since the other FAP component studies are programmed to commence later this year, this stage would be an opportune time to consider the detailed co-ordination strategy.

The co-ordination strategy should take into account the following aspects which are identified in Section 5.3:

- Influence of other FAP components on the Master Plan for river training works to protect the BRE
- The BLE studies and the effects of river confinement
- Interaction with conceptual design of the River Training and Bank Protection Pilot projects which should benefit the Master Plan designs
- Interaction with the agro-socio economic components which are expected to address key issues such as land acquisition, resettlement and benefits from FCD/FCDI projects
- Environmental effects of BRTS proposals, and issues relating to fisheries, which can be assessed in conjunction with information from other FAP components.

Thus, an overall co-ordination strategy based on the following is recommended:

- Incorporation of results from relevant FAP pilot studies in the design of Master Plan works
- (b) Implementation phases of the Master Plan should aim to be compatible with those of the related FAP components
- (c) There should be consistency of approach between related FAP components on economic, environmental and social issues.

10.3 Brahmaputra Left Embankment Studies

The formulation of the Master Plan and the design of works for the right bank of the Brahmaputra should take into account any works for flood alleviation, flood plain management and river training proposed for the left bank of the river. Such works will influence the height of peak flood-water levels and sediment transport characteristics of the river through the confinement of flood flows and sediment discharge along the river course. This in turn will influence the morphological behaviour of the river.

A continuous flood alleviation embankment (the BLE) has been suggested for the Brahmaputra left bank. If such an embankment is built, its design height and its alignment will influence the design height for the BRE. The Master Plan study of the BRE would therefore be incomplete without taking full account of developments on the left bank. In addition any changes in river morphology resulting from the construction of the BLE and associated river training works will affect the design conditions for the BRE river training works.

The BRTS team is well equipped, in terms of the specialist skills it has mobilised and the mathematical modelling it will be carrying out, to undertake a series of tasks which will enable the BRTS to take into consideration possible developments on the left bank.

It is therefore recommended that the BRTS programme should include the following additional activities for the BLE study:

- (a) Mathematical modelling (using the 1-D model) to help determine a suitable alignment and crest level for the BLE; and to assess the tradeoff between embankment height and distance from river and the influence of this on the design height of the BRE and on the design of any training works.
- (b) Preliminary inventory survey of existing BLE
- (c) Inventory survey of the left bank with particular reference to erosion hazard
- (d) Identification of potential erosion areas with respect to the BLE and identification in outline of measures for protection works

(e) Preparation of terms of reference for physical modelling studies and related engineering studies for the design of river training works for the BLE.

An allowance has been made in the revised BRTS activity programme and staff inputs (Section 13) for items (a), (b) and (c). Items (d) and (e) would require an extension of the geomorphological, geotechnical and river engineering inputs, the extent of which will be determined by the Geomorphology/Geotechnical Specialists and presented in the First Interim Report.

The above items exclude activities connected with the design of the BLE and river training works for the BLE, which will need to be considered during the formulation of the Master Plan so that the full effect of proposals on the left bank can be taken into account.

Table 10.1 Schedule of Links with Related FAP Components

FAP	No. Name	Relation to BRT
(2)	North West Regional Study	a) Changes to inflows to the Brahmaputra from the NW area
		b) Development of the NW area is linked to the security of BRE
(3)	North Central Regional	 a) Changes to drainage in the NC study area including the Brahmaputra distributaries
		b) Confinement of the Brahmaputra River by the construction of BLE and the consequent effect on the design parameters of the BRE
		 c) Studies for the BLE including river training requirements
(12)	FCD/I Agricultural Study	 a) Impact of BRE on agricultural development of the NW area
(16)	Environmental Study	 a) Environmental issues relating to BRTS
(17)	Fisheries Study	 a) Effect of Brahmaputra River confinement on fisheries
(20)	Compartmentalisation Pilot Project	 a) Effect of pilot project at Sirajganj on BRE
(21)	Bank Protection Pilot Project	a) Bank protection methods for BRE
(22)	River Training/AFPM Pilot Project	a) River training methods for BRE
		b) AFPM methods applicable to Brahmaputra River.
(24)	River Survey Program	a) Long-term river survey programme for Brahmaputra

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11. DESIGN OF SHORT-TERM MEASURES

11.1 General Procedure

The terms of reference call for schemes to be designed for early implementation in areas where the BRE is threatened by river bank erosion at the present time. The areas under attack have not been specified, so the first task will be to identify them. They will then be grouped into a number of categories of differing degrees of urgency: schemes for protecting the various localities will then be drawn up.

Appropriate design data will be gathered from a variety of sources, including physical models: site surveys will be carried out. Detailed design drawings and tender documents will then be prepared.

11.2 Data Collection

In order to allow the physical model testing to begin sufficiently early for the results to be incorporated into the design of the short term works, the selection of sites will have to be made before the BRE inventory survey has been completed. A list of potential sites will be drawn up, following discussions with engineers in the BWDB divisional offices and visits to sites that are considered to be the most critical.

Following this, the data will be evaluated and the various locations will be given a priority ranking. In the time available it will not be possible to use any sophisticated method for evaluating the relative importance of the different locations. However, the Consultants recommend that an appraisal of the vulnerable locations is undertaken using an objective screening approach to classify them according to selected broad criteria. The Consultants also recognise that the BWDB field divisions have identified many of the critical points where emergency or priority works are required.

11.3 Selection and Ranking of Priority Works

On the basis of the information already available, there are three sites where the need for urgent protection works is clearly established. These are Beara, Sariakandi and Fulchari. Survey data are already available for these three sites, so that physical modelling for these locations can start almost immediately.

It is proposed to select other areas for priority works on the basis of the following broad criteria:

- Nature, rate and extent of the river bank erosion
- Risk and consequences of a breach to the BRE
- Type and capital cost of protection works

An assessment of the nature and extent of river erosion will identify the areas of agricultural land being eroded, the number of villages, towns and important communications infrastructure under immediate

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threat, and the number of people likely to be displaced. An estimate of the rate of erosion will be made.

The risk and consequences of breaching the BRE will be assessed at each location. Since the 'global model' will not be sufficiently advanced to enable flood simulation at the selection stage of priority works, a qualitative estimate of the probable crop and livestock losses, and damage to villages, towns, and infrastructure, will be made. The size of population affected by a possible breach will also be estimated. In addition, other more site specific factors will also be taken in account, such as the possibility that the diversion of flood flow following a breach might cause a partial change in the river course (as for example at Sariakandi, where roughly 1km now separates the Brahmaputra and Bangali rivers).

The type of protective measures, together with an estimate of the capital cost and the length of time required for construction, will be considered in the selection procedure alongside the availability of construction resources to implement such measures.

The population displaced by the protective measures, as well as the agricultural area and settlements lost to the civil works will also be assessed.

It is hoped that this qualitative assessment will provide an adequate framework for selecting the most suitable schemes for immediate design and implementation, and ranking these in order of priority. Weighting factors that reflect the relative importance of the selection criteria may have to be applied to assist this ranking procedure.

A proforma 'decision matrix' of the type that could be used in the selection and ranking of the priority works is given in Table 11.1. It is envisaged that the selection and ranking of priority works will be undertaken between June and August 1990. Consultation with the BWDB including field divisions will form an important element in this appraisal. The findings and recommendations will then be submitted to the BWDB for review and approval.

11.4 Measures to be Adopted

Having determined the order of priority, the next stage will then be to draw up protection schemes for the different locations. At the present time, it is not possible to be precise about the measures that will be adopted, but they will comprise a mixture of training structures, bank revetment, and bank retirement. Although it is stipulated that the priority measures have to be incorporated into the master plan, it will be difficult to do this when the master plan has not, at such an early stage, yet been formulated. This requirement will, however, be borne in mind when the priority works are being planned.

11.5 Design Procedure

The principal data that will be required when designing the works are:

- Details of the bed topography '
- Water levels, discharges, and velocities at dominant discharge, as well as at more infrequent floods, for particular reaches of river
- Depths of local scour at the different types of engineering works, of general scour in the adjacent channel, of bend scour, and of confluence scour
- Soils information

These data will be obtained from a variety of sources, including field surveys, physical model tests and a search through the technical literature. The mathematical models will still be in the development phase, so they will not be capable of producing any data for designing the priority works.

11.6 Preparation of Contract Documents

Following the completion of the detailed design, working drawings and tender documents will be prepared. The number of locations at which work will be carried out, cannot be specified until the preliminary field investigation has been completed and the scale of the problem assessed. The final selection will be made in consultation with the BWDB, but will have to take account of the resources that are available in the contract for consultancy services; also the funding that will be provided for construction of the works.

11.7 Implementation

Tenders for the construction of the works will be floated and awarded by the BWDB, who will also be responsible for the supervision and contract administration. The Consultants will maintain a watching brief during the actual construction in order to appraise the techniques that are used by the contractors. This will allow an appraisal of current construction methods and practices so that account can be taken of these in forming recommendations for adoption in the works to be built under the Master Plan.



Table 11.1 Proforma for Selection and Ranking of Priority Works

	lection	Site				Erosion
cr:	iteria		Α	8	\$ С	etc
1)	Direct consequences of river erosion in terms of:			a		
	People at risk					
	Agricultural land at risk					
	Villages at risk					
	Towns at risk					
	Infrastructure damage					
2)	Likelihood of a breach in the BRE			1	×.	1
3)	Consequences due to flooding, of not being able to repair or retire the BRE before the next flood occurs					
	Crop and livestock losses					
	Villages damaged					
	Towns damaged					
	Infrastructure damaged					
	Number of people affected					
4)	Protection works required			1		
	Type of works					
	Capital cost					
	People to be displaced					
	Land acquisition					
5)	Other important considerations	1		1		1
	Could a permanent change in river course result ?					
	Are centres of administration or communication links at risk ?					

12. MASTER PLAN

12.1 Overall Strategy

In the TOR the aim of the Master Plan is described as 'the containment of the river (Brahmaputra) from Chilmari down to the confluence with the Hurasagar'. It should include 'recommendations for the type and layout of river training works aiming to provide a permanent protection of the BRE'. The Master Plan is thus envisaged as an overall plan for river training, along the BRE, which, when fully implemented will provide protection to the BRE from bank erosion. In addition the BRE is to be rehabilitated where necessary to provide flood protection to the right bank area by containing or confining flood flows along the river course.

Specific problem areas are also to be considered. These include advice on the permanent location of ferry terminals, and the effect, elsewhere on the river, of proposed measures to fix the position of the river course at particular locations. An example of such an area would be the site of the proposed Jamuna Bridge crossing.

Alternative Master Plan schemes are to be examined, before making the final choice. A necessary consideration in this selection procedure will be the economic appraisal of the alternative schemes in terms of their effects on related development activities (drainage, irrigation, agricultural and general development) promoted by other FAP components (as discussed in Section 6.4).

The programme for the progressive implementation of the Master Plan should reflect those priorities that become apparent during the course of the BRTS. In deriving the implementation sequence it is considered that adequate consideration should be given to the requirements for and the availability of financial, management, and construction resources for the implementation and subsequent maintenance of the selected schemes. These resources are likely to be constrained since competing demands for investment capital and development skills will arise from the other components of the FAP.

A phased implementation of the Master Plan is therefore realistic in terms of effective resource allocation. Each phase of works should respond to specific needs identified at the time of planning, whilst being technically sound, economically feasible, and for which adequate implementation resources exist. The measures would be linked, where necessary, to other components of the FAP.

Beyond the initial phase, flexibility is required. Changes may occur to the river during the period between the submission of the Master Plan report and the completion of the first phase of works. Such changes may alter the relative priorities between the remaining areas to be protected. The opportunity to monitor the construction of these schemes and evaluate the behaviour of the river in their vicinity will allow improvements in the cost effectiveness and efficiency of the design and implementation of the works in the subsequent implementation phase.

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In the longer term, changes in the behaviour of the river may arise from a number of causes including environmental factors affecting run-off and sediment yield from the Brahmaputra catchment areas, changes in flow management on the Brahmaputra River system; and redistribution of river flow following the full implementation of the Flood Action Plan. Developments in 'active flood plain management' may also have taken place. The Master Plan will therefore need to evolve with time to take such factors into account.

Thus the Master Plan will, in concept, need to be :

- Responsive to changes in needs and priorities
- Flexible in terms of the selection and design of the schemes that make up each implementation phase
- Evolutionary, whilst directed towards the overall aim given in the TOR.

12.2 Influence from Flood Action Plan

The Master Plan will be influenced by the related components of the FAP which are described in Section 10. The nature of this influence will depend on the types of proposals resulting from the FAP studies. In particular, the North West Regional Study and the North Central Regional Study which concern the drainage and flood control of areas adjacent to the Brahmaputra will have a direct influence on the Master Plan.

The possible confinement of the Brahmaputra River on its left bank by means of a continuous embankment has been partly included in the North Central Regional Study. Since the long-term strategy of the FAP is to investigate the confinement of Brahmaputra River, the BRTS study should undertake the necessary additional studies to investigate the BLE and the effects of total confinement of flood flows on the BRE.

It is necessary that the Master Plan is consistent with the fundamental concepts of the FAP with regard to a long-term flood control strategy for Bangladesh. This includes the following key items:

- (a) The results from relevant FAP pilot studies should be incorporated in the Master Plan. In particular, the River Training Programme, the Bank Protection/AFPM Programme and the Compartmentalisation Programme.
- (b) Agro-socio-economic and environmental aspects relating to the BRTS and incorporated in the Master Plan should be evaluated in a manner consistent with the relevant FAP components
- (c) The phased implementation programme to be adopted for the Master Plan should be compatible with the FAP implementation programme.

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The FAP is based on the fundamental concept of phased implementation which includes a strategy of early design and implementation of priority items which are identified during the initial study stages. This strategy is entirely consistent with the recommended approach to the BRTS Master Plan which envisages that the detailed design of short-term priority measures will be implemented at an early stage in the project.

12.3 Scope of Master Plan

A phased implementation of the Master Plan scheme is envisaged. Within this context the output from the BRTS would be directed towards providing:

- (a) An overall strategic plan which identifies in broad terms the various river training, bank protection, and BRE refurbishment measures considered to be appropriate for given areas of the right bank of the Brahmaputra.
- (b) Recommended implementation phases, with each phase comprising a set of technically sound, economically viable, and socially and environmentally acceptable outline schemes coordinated with the FAP.
- (c) Designs to tender document level of the initial phase of works for immediate implementation - accompanied by an investment and implementation schedule which takes into account logistical and funding constraints.
- (d) Assistance with the BLE studies as described in Section 10.3.
- (e) Recommendations on proposed solutions for particular problem areas such as ferry terminals and an appraisal of river training works designed outside the framework of the BRTS such as those forming part of the Jamuna Bridge crossing.
- (f) Recommendations for the establishment of a monitoring programme so that the effectiveness of the works implemented under the initial phase can be evaluated.
- (g) Recommendations on establishment of the physical and engineering infrastructure (eg depots, plant, access roads, personnel, labour, etc.) necessary for the works described in (c) above.

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WORK PROGRAMME, STAFFING AND LOGISTICS

13.1 Revised Work Programme

The BRTS work programme has been reviewed and revised to accommodate the following:

- (a) The delayed start to the project (the project was originally expected to commence in August/September 1989)
- (b) Additional instructions received from the BWDB which may be summarised as follows:
 - the BRTS programme is to be co-ordinated with other relevant components of the Flood Action Plan
 - to review the technical approach to various components of BRTS.

All these aspects have been carefully considered in the light of the appreciation of the project gained from the inception phase activities. A revised work programme which accommodates the original Terms of Reference and takes account of the additional instructions is recommended.

The revised work programme is shown in detail in Figure 13.1. It is scheduled over the original 3-year project period, but includes the following important revisions:

- (a) Data collection and river surveys are programmed to continue up to end of the dry season period 1990-91.
- (b) Data collection and bank erosion studies will include the left bank as part of the BLE studies.
- (c) Geomorphological, fluvial and geotechnical studies will be enhanced and continue up to the drafting of the Second Interim Report (ie month 20).
- (d) Mathematical model studies will include simulations for the BLE.
- (e) The physical model studies will exclude large sectoral and sectional models, but will include additional local and partial models.
- (f) Since full site surveys for the priority locations cannot be carried out until the 1990-91 dry season, the detailed designs of the short-term works cannot be completed before August 1991.

The scheduling of key project activities is summarised in Table 13.1. This programme of activities assumes that necessary steps will be taken to ensure completion of the main experimental hall at RRI by July 1991 so that the master plan physical modelling studies can commence on time. Since the modelling studies lie on the critical path of the BRTS programme, any delay beyond July 1991 in completing

the experimental hall could delay the completion of the whole study. It is proposed that progress on the construction of the modelling hall be kept under continuous review so that any likely delay in completing the hall can be responded to in good time.

Table 13.1 Schedule of Key Project Activities

Act	ivity	Project Period (months)
1)	Data collection and river survey:	
	 Inventory surveys, river surveys Geomorphological, fluvial and 	3-15
	geotechnical studies	4-22
	- Developing data bases	3-20
2)	Mathematical modelling	3-22
3)	Physical modelling	2-25
4)	Priority works	3-18
5)	Master Plan	3-34
6)	Training	1-36
7)	Key Reports:	
	- Inception	3
	- First Interim	13
	- Second Interim	22.
	- Draft Final	33
	- Master Plan	34
	- Model Studies - Data Base	35 36

Note: March 1990 is month No. 1

13.2 Staffing Schedule

The staffing schedule has been revised to accommodate the revised work program. The enhanced scope and objectives of the project will require an increased input of expatriate and local staff. The revised input totals are as follows:

Expatriate - 138 months

Local - 218 months

The revised staffing schedule is shown in Figure 13.2.

The reasons for these revisions, including the recommended increases, are described in the overall method of approach in Section 5 and the FAP co-ordination in Section 10. The following is a summary of the primary changes and their justification:

Team Leader

The planning and design of embankment protection and river training works is the ultimate project output from the BRTS. reasons already described in Section conceptualisation and design process leading up to the formulation of the Master Plan relies on a series of interactive multi-disciplinary studies which need to be actively coordinated and interfaced. The emphasis on multidisciplinary planning and design is further increased through the required interaction between the BRTS and other FAP components. The role of synthesis and coordination of project studies, combined with the need for interaction within the FAP, requires the full time input by the Team Leader in the BRTS office in Dhaka. Furthermore, it requires a Team Leader who would actively steer the multi-disciplinary studies towards the definition of design methods and parameters for the Master Plan.

We therefore recommend that the role of Team Leader be combined with that of the expatriate Design Engineer, who would in any event be responsible for the synthesis of outputs from the various multi-disciplinary activities. This arrangement will enable effective coordination of these activities and the required liason with other FAP studies.

This change will also allow the Physical Modelling Specialist (current Team Leader) to devote his time to the important physical modelling which will require close coordination with RRI including spending significant periods of time at Faridpur. He would also be able to assist more effectively with any RRI research activity linked to the BRTS model studies.

In order to be effective, it is considered that the Team Leader/Design Engineer should provide a continuous input of 28 months from August 1990, and that the input of the Physical Modelling Specialist could, as a consequence, be reduced to 30 months.

Mathematical Modelling Team

As a consequence of the increase in computing activities that will result from the inclusion of the BLE studies within the scope of the BRTS work, and the extensive data base construction and analysis that will have to be carried out, we recommend that the staff inputs of the Mathematical Modelling Team be revised.

We consider that the best allocation of staff inputs would be for the Mathematical Modeller/Computational Hydraulics Engineer to provide an overall supervisory role in the mathematical

modelling and computing studies by means of regular periodic inputs. The reduction in his total input will then allow an increased input of the System Engineer to provide an enhanced level of mathematical modelling support.

In addition, we would strongly recommend that an additional post of Data Base Analyst/Hydraulic Engineer be created to undertake the following tasks:

- (a) Development and management of the data bases required to store the extensive data collected from the field programme and other sources. These data bases will cover:
 - BRE inventory survey
 - BLE inventory survey
 - geomorphological data base for right bank
 geomorphological data base for left bank
 - geotechnical data base
 - agro-socio-economic data base
- (b) Analysis of geomorphological data according to procedures set up by the Geomorphologist and the Geotechnical Specialist.
- (c) Participation in the mathematical model simulation studies.

We recommend that the Data Base Analyst/Hydraulic Engineer provides a continuous 14 month input from October 1990.

In order to provide the back-up to service this increased computing load, we are proposing that the inputs of the two local programmers should be increased.

The revised total input from the Mathematical Modelling Team would thus be 34 man-months (expatriate) and 54 man-months (local) made up as follows:

Expatriate

Mathematical Modeller/ Computational Hydraulics Engineer	10 man-months
Data Base Analyst/Hydraulic Engineer	14 man-months
System Engineer	10 man-months

Local

Mathematical Modelling Engineer	18 man-months
Programmer - 1	18 man-months
Programmer - 2	18 man-months

3) Data Collection and River Surveys

The primary data collection and river survey programme is scheduled to continue until May 1991. We therefore recommend that the input of the expatriate Field Engineer/Water Resources Engineer should be increased.

Consultants also recommend that the expatriate Instrumentation Specialist's input be increased to accommodate this river survey programme.

The revised inputs would be:

Field Engineer/ Water Resources Engineer

13 man-months

Instrumentation Specialist

5 man-months

4) Geomorphological, Fluvial and Geotechnical Studies

The original inputs for these activities are inadequate to carry out the extensive programme described in Section 6. The Consultants therefore recommend an increase in these specialist inputs as follows:

> Geomorphologist River Hydraulics Specialist) 5 man-months Geotechnical/Seismic Expert)

Sedimentologist

3 man-months

5) Agro-Socio-Economics

The problem associated with the resettlement of families who have now settled on the BRE need to be investigated by a sociologist to ensure that resettlement measures are designed to be effective whilst being sensitive to the social issues involved. The Consultants therefore recommend that a local Sociologist be included in the team. An increase in the inputs of the expatriate and local agro-socio-economists in response to the data collection and analysis required to integrate the agro-socio-economic study with the relevant components of the FAP is also recommended.

Expatriate Agro-Socio-Economist 4 man-months

Local Agro-Socio-Economist 7 man-months

Local Sociologist 2 man-months

A summary of the primary responsibilities/tasks of the key expatriate and local personnel are summarised in Tables 13.2 and 13.3 respectively. These tables show the recommended revised inputs.

13.3 Logistics

We have reviewed the logistics and the funds required for the data collection and river surveys in the light of the following:

- A better appreciation of the logistics required for these activities gained during the inception phase
- The increased geomorphological and geotechnical data requirements
- The data and survey requirements for the BLE studies.

The programme for data collection and river surveys is described in Section 9, and the revised programme of work is shown on Figure D.2 (Appendix D).

According to the original Terms of Reference and the Contract for Consultancy Services the data collection and surveys were to be undertaken as follows:

- BWDB will undertake routine surveys
- The Consultants will arrange for additional surveys and data collection
- BWDB will provide the boats, hydrological equipment etc. required for the surveys
- RRI will undertake testing of sediment samples at their laboratory.

The funds where made available in the Consultants' contract will be used for the proposed data collection programme on the BRE, on the right bank and for specific additional river surveys. We recommend that the BWDB undertake the global river surveys. However, in view of BWDB's heavy commitment on on-going projects, we recommend that additional funds be provided to the Consultant for geotechnical investigations and for BLE data collection.

River Surveys

The recommended scope, responsibility and supporting equipment required for the river surveys is shown in Table 13.4.

Table 13.4 River Surveys

Surv	vey activity	Responsibility	Supporting equipment
1)	Test Area 1 (2-D model)		
(a)	River x-sections plus hydrological measurements during monsoon (1990), post monsoon (1990), and dry season (1991)	Consultant	*Boats with Decca navigation and hydrometric equipment
(b)	Land surveys during monsoon	Consultant	-
(c)	Land surveys during post monsoon and dry season	BWDB	-
(d)	Bed form surveys during post-monsoon, dry season and pre-monsoon	Consultant	Boats with position fixing and hydrometric equipment
(e)	Laboratory analysis of samples	RRI	-
2)	Global River Survey dry season x-sections	BWDB	·

Note: * This has been arranged by BWDB for the monsoon survey.

2) Detailed Site Surveys

Detailed site surveys for physical modelling and engineering are to be undertaken by BWDB with specifications drawn up by Consultants.

3) Inventory Survey and Geomorphological Data Collection

Recommendations regarding the division of responsibility for the inventory survey and geomorphological data collection are shown in Table 13.5.

Table 13.5 Inventory Survey and Geomorphological Data Collection

	Item	Responsibility
1.	BRE Inventory Survey	Consultant
2.	Right Bank Condition Survey	Consultant
3.	Selected X-Sections on BRE	BWDB
4.	BLE Inventory Survey	Consultant
5.	Left Bank Condition Survey	Consultant

Geotechnical Investigations

Geotechnical investigations will be required for the BRE, the right bank and left bank of the river. The investigations will include site and laboratory tests. The extent and specifications will be defined within the next 3 months, but are expected to include a total of about 50 locations on the BRE and right bank and about 25 on the left bank.

We recommend that additional funds be provided to the Consultants for these investigations to be executed through suitable agencies.

The carrying out of dry season river cross-section surveys from the Indo-Bangladesh border to the Ganges confluence is a routine function of the Directorate of Morphology. In various years, the most recent being 1986/87, the surveys were carried out at 1-mile intervals. The requirement under Global River Surveys, above, is for dry season cross-sections at 2-mile intervals. It is our assessment that the BWDB morphology sub-division at Jamalpur will be able to complete the required 75 cross-sections in the dry season of 1990/91 if the project makes arrangements for payments during holidays, longer working hours, etc.

Whilst the only practical arrangement for the execution of the Global River Surveys is via BWDB, the BRE cross-sections and longitudinal survey could be sub-contracted to competent private sector survey firms under the supervision of the Consultant using funds provided by BWDB. A similar arrangement would also be feasible for the site surveys for the physical model studies and for geotechnical investigations. An alternative would be for RRI to undertake these surveys and investigations if they have the resources.

In order to undertake the enhanced work programme effectively and to schedule the following additional logistics will be required:

(a) Vehicles

1 additional 4-WD vehicle for 12 months

1 additional 4-WD vehicle for 6 months

1 additional Saloon car for 12 months

The additional 4-WD vehicles are required to cope with the intensive field programme scheduled for the period September 1990 to May 1991, as well as to have the use of a field vehicle until the end of the field program for the Master Plan studies.

We recommend that an additional saloon car should be provided as the Physical Modelling Specialist and Research Engineers will need to make frequent visits to RRI in Faridpur in connection with the physical modelling studies. This is not adequately allowed for in the present transport provisions in the Contract.

(b) Boats

The BWDB is aware of the difficulty in obtaining suitable boats for the river surveys. A suitable boat has been obtained by the BWDB for the monsoon surveys in June 1990, but it is unlikely that this will be available for post-monsoon and dry season surveys.

The prospect of hiring boats from the BIWTA should be considered.

We therefore recommend that two boats (with hydro-jet propulsion and with provision for installation and operation of hydrographic/hydrometric survey equipment) are purchased for this study which can later be used for future Brahmaputra river surveys. Detailed specifications for the boats will be supplied by the Consultants.

(c) Technical Support Staff

We recommend that 2 additional junior engineers are included in the Consultants' team to assist with the intensive data collection and river survey program scheduled during the next 12 months.

Table 13.2 Expatriate Staff Inputs (Revised)

Post		Resp			ended d Input nonths)
1)	Team Leader/ Design Engineer	b) c) d) e)	Overall project management Co-ordination of activities Liaison with client and othe agencies Co-ordination with FAP Design of engineering works Master plan	r	28
2)	Physical modell- ing Specialist	b)	Physical modelling studies Co-ordination with RRI Assisting with engineering designs and master plan		30
3)	Math. Modeller/ Computational Hydraulic Engineer		Supervision of mathematical modelling studies Supervision of data base and	alyses	10
4)	Hydraulic Engineer/Data Base Analyst	b)	Development of data bases and analyses Geomorphological data prepart and processing Mathematical model simulation	ation	14
5)	System Engineer	a)	Development and calibration mathematical models	of	10
6)	Hydrologist	a)	Hydrological studies		4
7)	Field Engineer/ Water Resources Engineer		Field data collection River surveys		13
48)	River Training Expert	a)	Planning and design of river training works	-	11
9)	Technical Direc- tor Computationa Hydraulics		Maintaining technical stands Advising on computational hydraulics	ards	1
10)	Instrumentation Specialist	a)	River survey equipment		5
11)	Agro-Socio- Economist	a)	Economic analysis		4



Table 13.2 Continued

Post		Responsibility/Tasks	Recommended Revised Input (man-months)
12)	Sedimentologist	a) Sediment module in mathemat model b) Advising on sedimentology	ical 3
	Geomorphologist River Hydraulics Specialist	a) Geomorphological studies a) Fluvial/geomorphological studies))) 5
15)	Geotechnical Specialist	a) Geotechnical studies)
		TOTAL	138

Table 13.3 Local Staff Inputs (Revised)

Post	F	esponsibility/Tasks Revise (man-m	d Input
1)	Senior Research Engineer	a) Physical modelling studies b) Assisting with the design of river training works	21
(NG2)	Research Engineer	a) Physical modelling studiesb) Assisting with the design of river training works	21
0/R 3)	Mathematical Modelling Enginee	a) Mathematical model studies	18
(964)	Programmer - 1	a) Assisting with mathematical model studies b) Assisting with data base analyses	18
5)	Programmer - 2	a) Assisting with mathematical model studiesb) Assisting with data base analyses	18
6)	Hydrologist	a) Hydrological study	12
7)	River/Hydrogra- phic Surveyor	a) River surveys	16
8)	Senior River Engineer	a) River bank characterisationb) River studiesc) Planning and design of engineering works	20
9)	Hydraulic Struc- ture Design	a) Design and tender documents for river training worksb) River bank characterisation	18
10) Hydraulic Struc- ture/Design Engineer	a) Design and tender documents for river training worksb) River bank characterisation	15
11) Instrumentation Specialist	a) River survey equipment	1.5
12) Agro-Socio- Economist	a) Economic analysis	7
13) Sociologist	a) Sociological investigations	2
14	Specialist	a) Geotechnical studies	3.5

Table 13.3 Continued

Post	L	Responsibility/Tasks	Recommended Revised Input (man-months)
15)	Transport Specialist	a) Transport studies	2
16)	BUET Advisory Group	a) Advise on project studiesb) Assistance with specialist studiesc) Training))) 25
		TOTAL	218

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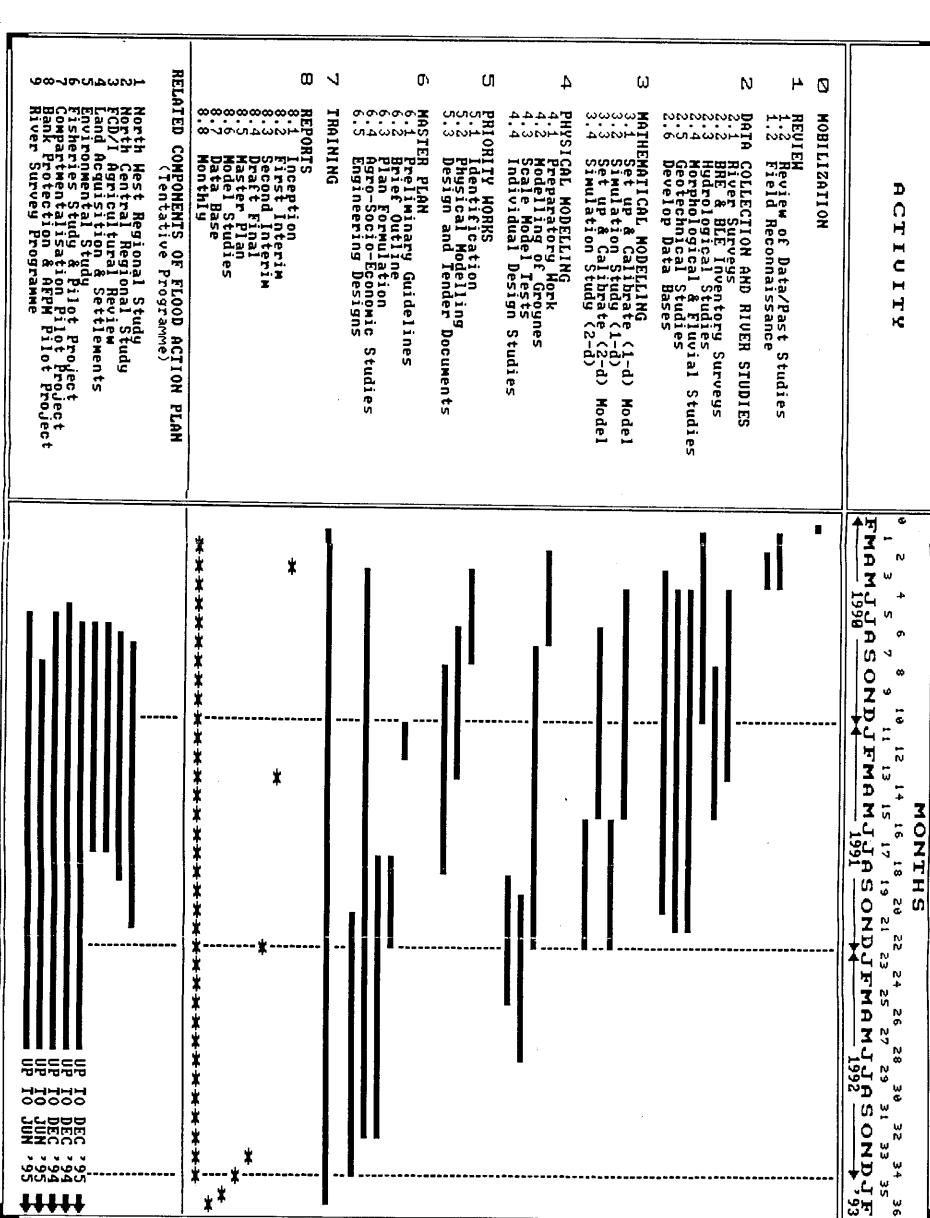
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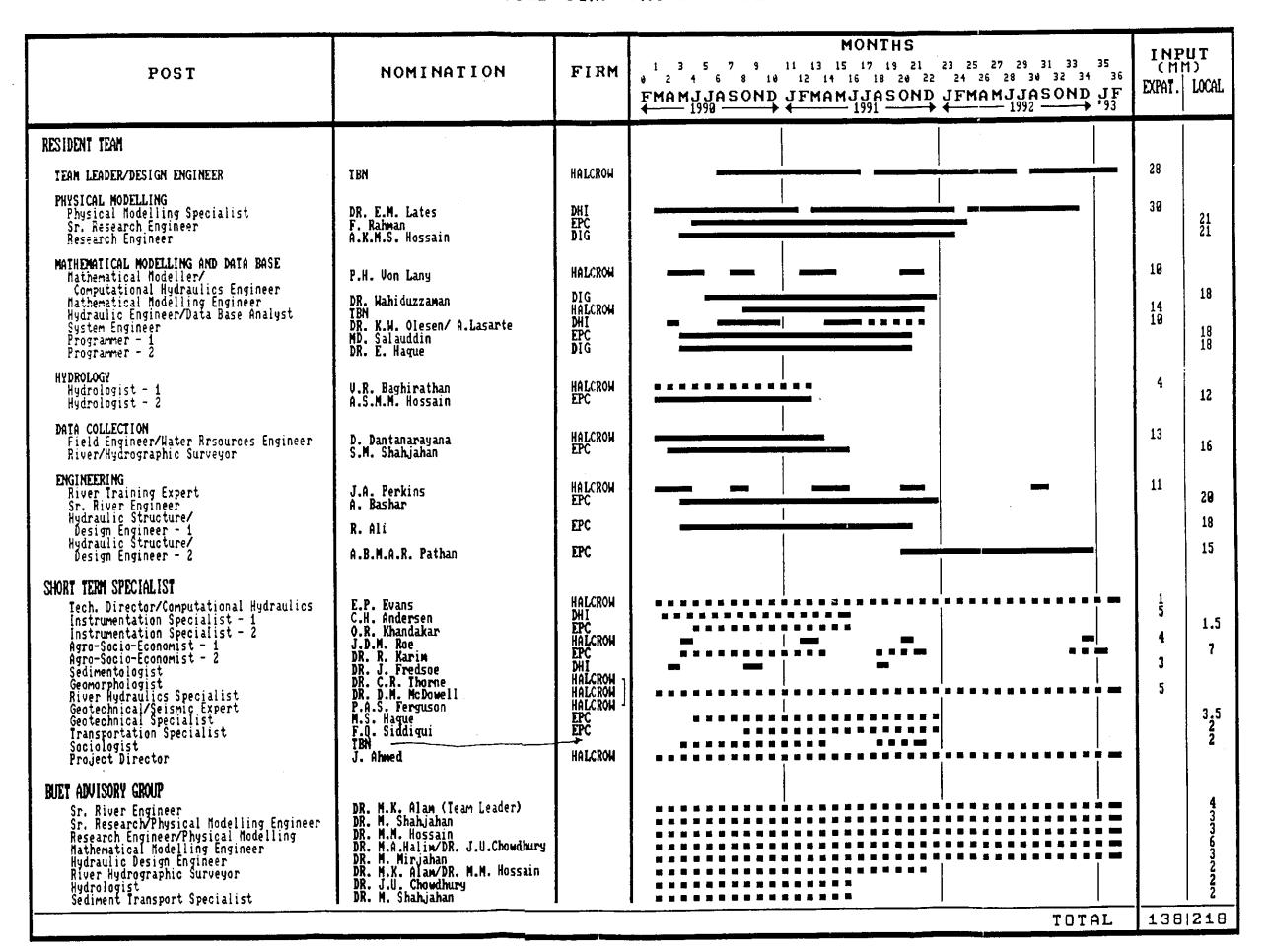
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REVISED STAFFING SCHEDULE



APPENDIX - A

Professional Staff Inputs and Organisations Contacted during the Inception Phase

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A. PROFESSIONAL STAFF INPUTS AND ORGANISATIONS CONTACTED

A.1 Professional Staff Inputs - Inception Phase

Professional staff inputs during the inception phase are listed below:

Name	Position	Firm	Input
Expatriate			
F.P. Evans	Technical Director	Halcrow	Visit
E.M. Lates	Team Leader/ Physical Mod. Sp.	DHI	Full time
J.A. Perkins	River Training Expert	Halcrow	-do-
J. Fredsoe	Sedimentologist	DHI	Short term
D. Dantanarayana	Field Engr./Water Resources Engineer	Halcrow	Full time
V.R. Baghirathan	Hydrologist	Halcrow	Part time
C.H. Andersen	Instrumentation Specialist	DHI	Short term
A.E. Lasarte	System Engineer	DHI	Full time
P.H. von Lany	Mathematical Modeller/ Computational Hydraulic Engineer		-do-
J.D. Roe	Economist	Halcrow	Short term
Local			
A.S.M.M. Hossain	Hydrologist	EPC	Full time
S.M. Shahjahan	River/Hydrographic Surveyor	EPC	-do-
A.K.M.S. Hossain	Research Engineer	DIG	-do-
R. Ali	Hydraulic Structure/ Design Engineer	EPC	-do-
E. Haque	Programmer	DIG	-do-
A. Basher	Senior River Engineer	EPC	-do-
R. Karim	Agro-Socio-Economist	EPC	Part time
Md.S. Khan	Programmer	EPC	Full time

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A.2 Organisations Contacted

The main organisations of GOB, the Directorates and field divisions of BWDB, the World Bank and the international missions with which official meetings were held by the members of the BRTS team during the inception phase, are listed below:

Bangladesh Water Development Board (BWDB)

- Mr. Shamsur Rahman, Chairman
- Mr. S.M. Zakiul Alam, Member, Planning
- Mr. Mobinuddin Chaudhury, Member, O&M (Retd.)
- Mr. A. Barik Bhuiyan, Member, Implementation
- Mr. Aminul Islam Bhuiyan, Secretary
- Mr. M.A. Razzaque, Chief Engineer, Planning
- Mr. Syed Anwar Yusuf, Chief Engineer, Hydrology
- Mr. Md. Khaliquzzaman, Director Planning (General) (Retd.)
- Mr. Lutfur Rahman, Director Planning (General)
- Mr. Syed Shahadat Hossain, Director Surface Water Hydrology I
- Mr. Anwarul Kader, Director River Morphology
- Mr. Gazi, Director, Economic Planning Unit
- Mr. Aowlat Hossain, SEN Bogra O&M Circle
- Mr. M.M. Nabi, XEN Sirajganj
 - Mr. Altaf Hossain, XEN Bogra
- Mr. Abdus Sattar, XEN Gaibandha
- Mr. Mohiuddin Farouque, XEN (Morphology), Jamalpur

River Research Institute, Faridpur (RRI)

- Mr. Wazed, Director-General (Retd.)
- Mr. Samsul Hoque, Director-General
- Mr. T. Hossain, Director Research (River Hydraulics)

Flood Plan Co-ordinating Organization (FPCO)

- Mr. Nurul Huda, Chairman
- Mr. Nurul Huq, Chief Engineer
- Mr. Ashfaque-e- Azam XEN
- Mr. M. A. Khaleque XEN
- Mr. Imaduddin Ahmed XEN

Space Research and Remote Sensing Organization (SPARRSO)

- Dr. A.A. Ziauddin Ahmed, Chairman
- Dr. M.A.H. Pramanik, Director
- Mr. M.A. Jabbar, Principal Scientific Officer
- Mr. M.A. Kalam, S.O.

Bangladesh Inland Water Transport Authority (BIWTA)

- Mr. Abu Henna, Director, Hydrography
- Mr. Abul Mokarram, Jt. Director, Hydrography

Master Plan Organization (MPO)

- Dr. K.M. Mustahidur Rahman, Economist
- Dr. Q. Shabuddin, Economist
 - Mr. Murshed Ahmed, Economist
- Dr. David Suie, Economist
- Dr. J.A. MacDonald, Team Leader, SWSM Project

Jamuna Multi-Purpose Bridge Authority (JMPB)

- Mr. Shamsul Haque, Director (Tech) & Chief Engineer

Bangladesh University of Engineering Technology (BUET)

- Dr. M.K. Alam
- Dr. A. Hannan
- Dr. A. Nishat
- Dr. Halim

World Bank (RMB)

- Mr. Jan Pruntel, Senior Irrigation Engineer
- Prof. Van Ellen, Member, World Bank Mission on FAP
- Mr. G. Schokman, Consultant
- Mr. Bill Smith, Consultant

European Economic Commission (EEC) Mission on the Flood Action Plan (FAP) River Survey Component

- Mr. Sean Doyle, Acting Head of Delegation
- Mr. Daan Gersie, Team Leader
- Mr. Georges Varet
- Mr. Shamsuddin Khan

EEC Mission for the North Central Regional Study

- Mr. Jean-Marie Lacombe, BCEOM Resident Representative
- Mr. Bernard Caussade, Hydraulic Engineer

ODA Mission for NW Regional Study (FAP)

- Mr. Bryan Bennell, Team Leader
- Mr. Paul Balogan, Economist
- Dr. Nigel Wolmsley, Hydrologist/Modelling Specialist

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APPENDIX - B

Additional Instructions From BWDB

Office of the Chief Englacer, Hanning, BWDB, Dhaka.

Nahn 1 mu lottius

No. P-420/CEP/1606

Dated

19. 10. 1989 1. 7. 96 Bungla.

The Team Leader, sir william Halcrew & Partners Ltd., House No.54, Block-E, Read No.10, Banani, Dhaka. HALCROW

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2 1 OCT 1989

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PILE HBD PRT CON

Sub: - River Training Studies of the Brahmaputra River (Credit No. 1870-BD).

plicom + DAI

Ref: - This Office Nemo No.CEP-429/82/1330(5) dt. 9. 9. 89

Dear Sir,

that a meeting was held on 4. 10. 89 in the Ministry of Irrigation, water Development & Flood Control to discuss the technical note given by Prof. Van Ellen of the Netherlands on the TOR of Brahmaputra River Training Studies (RTS) under the Chairmanship of Syed Shamim Absan, Secretary, Ministry of Irrigation, W.D.& F.C.

Professor Van Ellen, a member of world Bank Flood Missien, an his technical note highlighted some areas and issues which appeared to have a degree of overlap as well as complementary between the RTS and the action Plan being drawn up under the Flood Master Plan. He suggested to defer the development of physical a mathematical models to a later stage.

The meeting discussed in details the views expressed by Prof. Eller and the following decisions were taken :-

- i) The RTS would commence in its present form without any further delay.
- Nember (O&N), BwDB, Prof. M. Shahjahan & Prof. Ainun Nishat of Water Resources Engineering Deptt., BLET formed to examine Prof. Ellen's technical note and to prepare a draft suggesting deletion & addition of stems of works in the light of the scope of work identified for the Resonanting in the Action Plan.

- iii) The consultant would examine this note and deal with the issues in the note in its Inception Report.
- iv) GOB would take apprepriate action on the recommendation of the Inception Report.

As per decision of the Ministry the technical committee prepared guidelines for making necessary changes in the work plan and methodology of the BRTS. The guidelines are enclosed for information and necessary action (Appendix - A).

As per the guidelines you are requested to incorporate suitable changes in work plan, manning schedule & work schedule and place them for consideration by appropriate quarter through the Inception Report which is due within three menths from the commencement of work.

You will please centact the undersigned if you require any clarification.

Thunking you,

Encle: As stated.

Yours faithfully,

(Mabinuddin Chaudhury) Chief Engineer, Planning, BWDB, Dhaka.



GUIDELINE REGARDING UPDATING OF WORK PLAN AND METHODOLOGY BRAHMAPUTRA RIVER TRAINING STUDIES

- 1. Since the submission of the technical proposal for the Brahmaputra kiver Training Studies (BKTS), some major works have been carried out towards preparation of Flood Action Plan(FAP) for Bangladosh, a major component of which will be construction of embankments on both sides of the Brahmaputra River. Therefore, BRTS will be of direct relevance to the FAP. The Flood Action Plan proposes " controlled flooding" which will require a sories of control structures along the ombankments. Further, the FAP proposes "Active Flood Plain Management" which would require river training works and controlling the flow of the Brahmaputra through a much narrower channel than the present day width. The FAP proposes to undertake the following projects and studies that are of direct relevance to the BRTS:
 - (a) NW Regional Study: This study would outline the development of the area behind the Brahmaputra right embankment.
 - (b) Strengthening of Bruhmuputra Right Embankment(BRE): This study would recommond strengthening of BRE and measures which would include river training works, bank protection and reconstruction of reaches of embankment.
 - (c) North Central Regional Study: This study would recommend the development of the area behind Brahmaputra left embankment and undertake pilot study on compartmentalization.
 - (d) Brahmaputra Left Embankment(BLE): It is envisaged that existing embankments be incorporated into a continuous embankment. This would result in confinement of the Brahmaputra flows.
 - (e) River Survey Programme: Extensive survey of the major rivers are proposed under this study. Absonce of flood season data is a major battlenock in model studies and design works.
 - (f) Bank Pretection Pilot Study: To recommend suitable methods and materials for bank protection works to be taken up in future, this study is envisaged. If necessary, new techniques will be developed and protetype and pilot experiments will be carried out. Bank protection works are expensive and development of cost

effective methods will be aimed ut.

- (g) River Training Pilot Study: This study aimed towards active flood plain management, is designed to study the various methods of river training and river control and to recommend suitable techniques that may be adopted for other areas of Bangladesh also. Effective control on flow pattern and flow path will allow proper channel regulation as well as reclamation of flood plain for productive utilisation.
- 2. It is expected that the studies and projects envisaged in the initial phase of FAP will be completed in five years. Activities under FAP will be reviewed every two years and action plan for next five years will be finalised.
- update the work plan and methodology taking note of the proposed studies under FAP. Horeover, they may be requested to review the necessity as well as technical viability of various components of BRTS e.g. large sectoral physical model this model (in two segments) is envisaged to be a mobile bed model and simulation of morphological behaviour of the Brahmaputra will be highly questionable. As such the consultant needs to maintain close liasion with FAP studies and cooperate and collaborate with them.

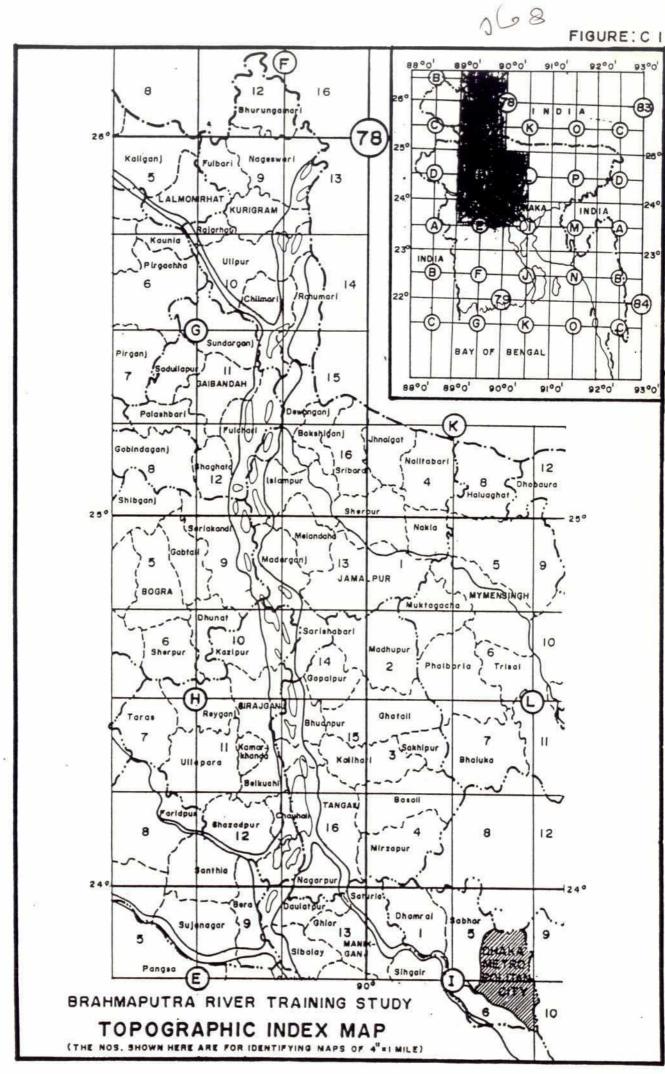
C. TOPOGRAPHICAL & HRDROLOGICAL DATA AVAILABLE

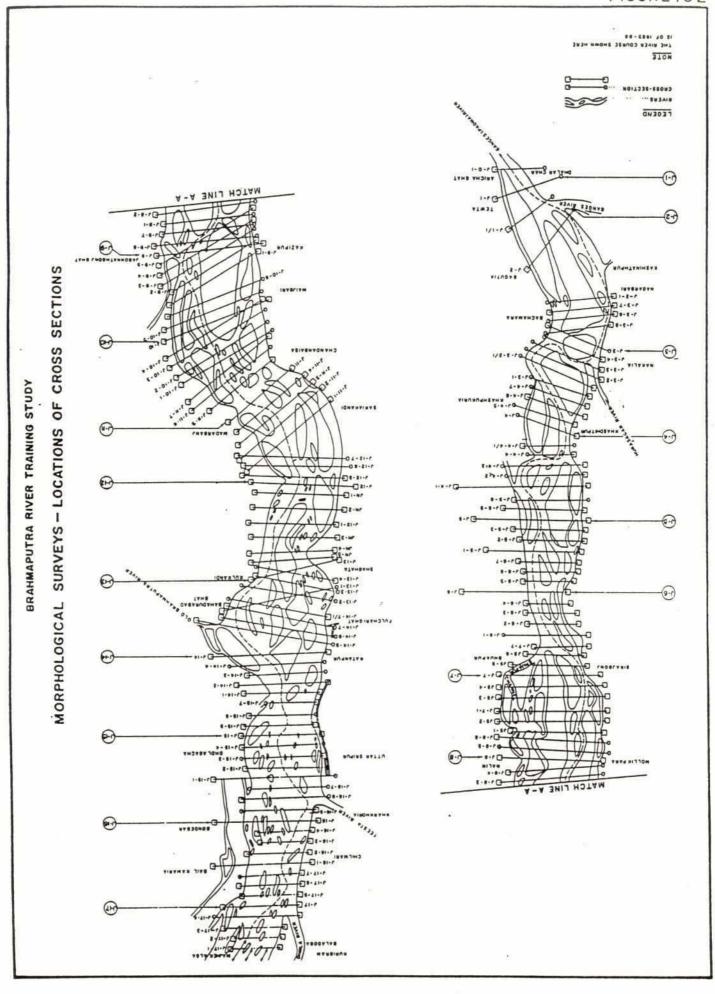
C.1 Figures

- C1 Topographic Index Map
- C2 Morphological Surveys Locations of Cross Sections
- C3 Index to Landsat & SPOT imagery
- C4 Index to Aerial Photographs
- C5 Rainfall Data Available/Collected
- C6 Daily Water Levels Available/Collected
- C7 Discharge Measurements Available/Collecte
- C8 Location Map Rainfall Stations
- C9 Location Map Water Level Gauges & Discharge Measurement Stations
- C10 Schematic Diagram Water Level Gauges & Discharge Measurement Stations

C.2 Tables

- C1 Statement of River Cross-Section Surveys by BWDB (Source: Directorate of Morphology, BWDB)
- C2 List of Selected Rainfall Stations
- C3 List of Selected Water Level & Discharge Measurement Stations





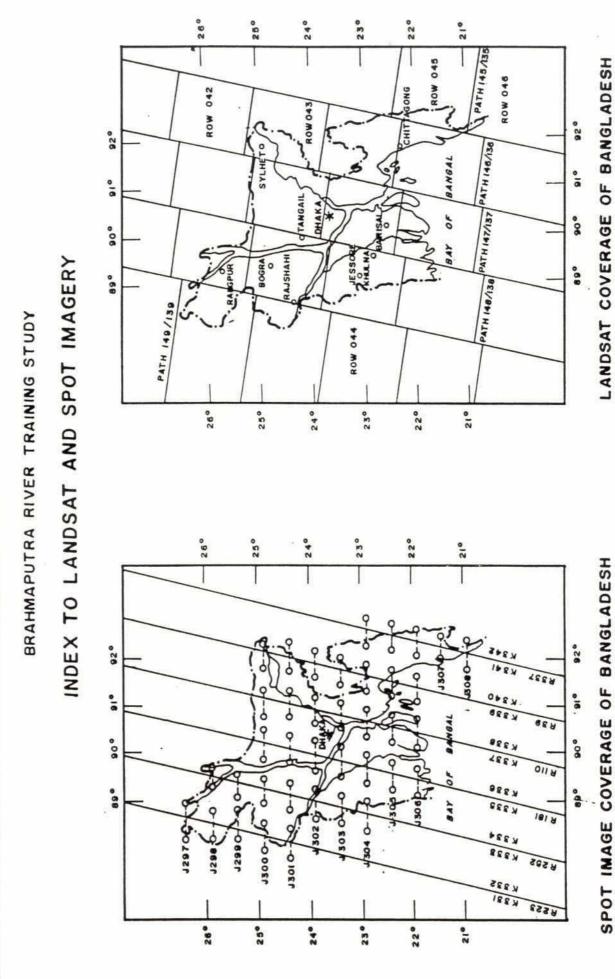
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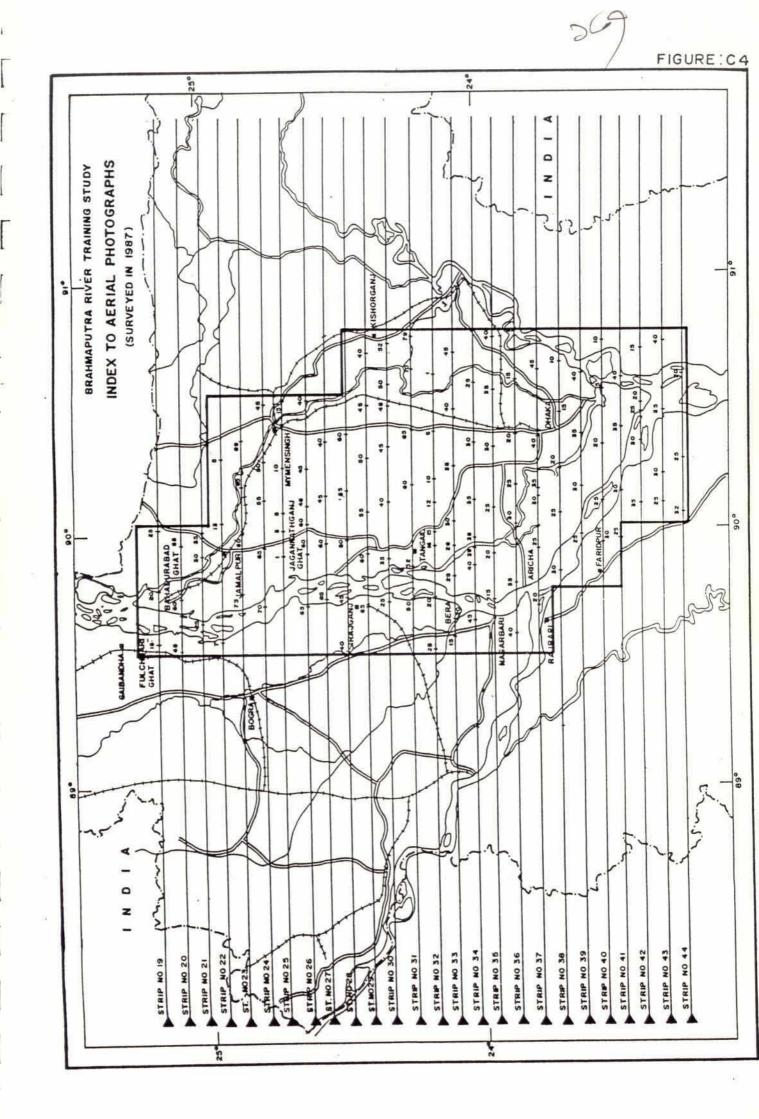
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SCALE: 1: 6000,000



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	132 - Manmathpur (N T) 132.5 Joypurhat (N T) 133A Tajnagor (N T) 133 Naogaon (N T)	
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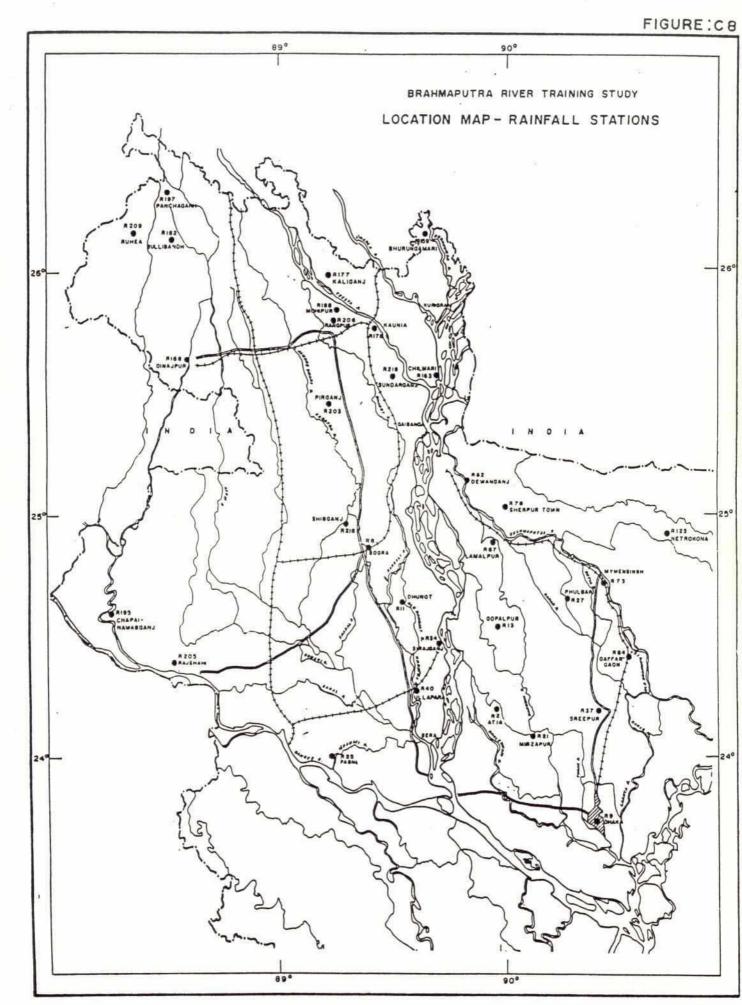
* Computerized Data Collected + Computerized Data Available (to be collected)

BRAHMAPUTRA RIVER TRAINING STUDY DISCHARGE MEASUREMENT AVAILABLE AND COLLECTED DATA

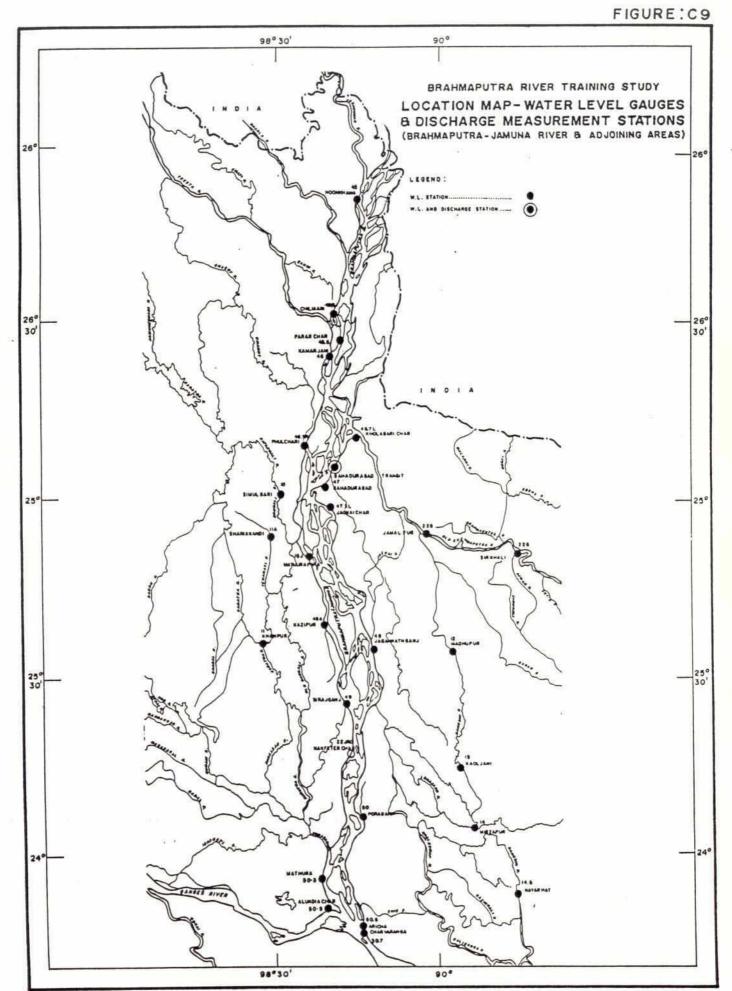
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	132.5	Joypurhat (N T)																								
THENAI	133	Naogaon (N T)										***				****		*00.0*				##J		UNTO	**	
	134A	Bangshi Bridge (N T)																								
14	134	Jukerchar (N T)					• ••	**	**	**	* *	**	* *	• •				•			٠.			• ••	**	33
	1348	Off-take of Jhenai (N T)																								
CURLITON - A	TRAI -	GUR-GUMANI - HURASAGAR																								
	140	Panchagarh (N T) Khan Sama (N T)		**	** *																707					98
		Bhustr Bandar (N T)					**												3						***	ř.
	145	Hohadebour (N T)									••			••											**	Œ.
	146	Rasulpur (N T)																								
	147	Atrai (N T)		**	** *			**	**	**		**	**	**	** *											
		Singra (N T)																						• ••	**	
	148	Chanchkari (N T) Astamanisha (N T)																								
		Gumant Rly Bridge (N T)		**					* **	**	**	++	**	**	** *											
	151	Baghabari (N T)																								
MARKHURIA	156	Parbatipur (N T)																								
	150	Parbacipur (H 1)																								
OLD BRUHUP	TRA																									
	224	Off-take of Bangshi																								
	***	(Jhenai: N T)																								
	227	Off-take of Sutia (N T)																								
	228	Hymensingh (N T)								**														+ ++		
		Hymensingh (N T) Bhairab Bezar (Rly		**	1000		011000	5 50		1,500		2.5	7.70	05.00												
		Bridge; T)																								
TEESTA	201 -	R Dalla (N T)															- 09							+ ++		
	291.5	Doni (N T)																								
Co.	*****	Gaddimart (N T)																								
	292																	4 60					4 1 4		. +	
	292 294	Kaunta (H T)	** ** ** **	8	9	** *	+ +	+ +	+ ++	**	**	**	**	**	**		•	**	**	**	**	" '				5
TURAG					••				• ••					**			•									

Legend: • 'Computerized Data Collected .
• Computerized Data Available (to be collected)

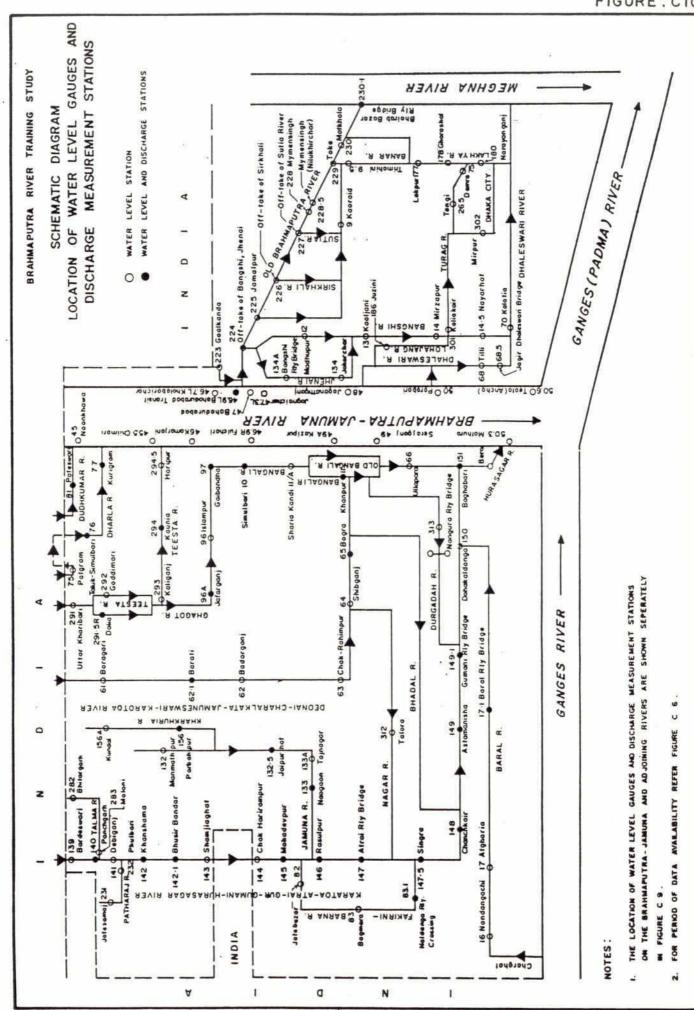
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TABLE C1: STATEMENT OF RIVER CROSS-SECTION SURVEY BY BWDB

BRAHMAPUTRA-JAMUNA RIVER

Year	Description of Cross-Section as per programme	No. of	Approx. Interval (mile)	C.S.
1964-65	Between Aricha & Indo-Bangladesh border C.S. No. J-0-1 to J-17	17	8	17
1965-66	Between Aricha & Indo-Bangladesh border C.S. No. J-0-1 to J-17	34	4	34
1966-67	Between Aricha & Indo-Bangladesh border C.S. No. J-0-1 to J-17	34	4	34
1967-68	Between Aricha & Indo-Bangladesh border C.S. No. J-0-1 to J-17	34	4	34
1968-69	Between Aricha & Indo-Bangladesh border C.S. No. J-0-1 to J-17	34	4	34
1969-70	a) Between Aricha and Bahadurbad C.S. No.J-0-1 to J-12	24	4	24
	b) Near Bahadurabad C.S. No. J-12-4 to J-13	9	1	9
	c) Between Bahadurabad and Teesta outfall C.S.No. J-13-8 to J-15-1	48	1/2	48
	d) Between Teesta outfall and Chilmari C.S.No.J-16-7 to J-16-1	8	1	8
	e) Above Chilmari C.S. No. J-17	1	4	1
	Sub-Total 1969-70	90		90
1970-71	a) Between Aricha and Bahadurabad C.S. No. J-0-1 to J-12	24	4	
	b) Near Bahadurabad C.S. No. J-12-4 to J-13	9	1	-
	c) Between Bahadurabad and Teesta outfall C.S.No. J-13-8 to to J-15-1	48	1/2	S

Year	Description of Cross-Section as per programme	No. of	Interval	No. of
	d) Between Teesta outfall and Chilmari C.S. No. J-16-7 to J-16-1	8	4	3
	e) Above Chilmari C.S. No. J-17	1	1	1
	Sub-Total 1970-71	90		4
1971-72	 a) Between Aricha and Bahadurabad C.S. No. J-0-1 to J-12 	24	4	24
	b) Near Bahadurabad C.S. No. J-12-4 to J-13	9	1	-
	c) Between Bahadurabad and Teesta outfall C.S. No. J-13-8 to J-15-1	48	1/2	35
	d) Between Teesta outfall and Chilmari C.S. No. J-16-7 to J-16-1	8	1	8
	e) Above Chilmari C.S. No. J-17	1	4	1
	Sub-Total 1971-72	90		68
1972-73	a) Between Aricha and Bahadurabad C.S. No. J-0-1 to J-12	24	4	21
	b) Near Bahadurabad C.S. No. J-12-4 to J-13	9	1	9
•	c) Between Bahadurabad and Teesta outfall C.S. No. J-13-8 to J-15-1	48	1/2	48
	d) Between Teesta outfall and Chilmari C.S. No. J-16-7 to J-16-1	8		•
	e) Above Chilmari C.S. No. J-17	1	4	8 1
	Sub-Total 1972-73	90		87

Year	Description of Cross-Section as per programme	Total A No. of I C.S. (nterval	C.S.
1973-74	a) Between Aricha and Bahadurabad C.S. No. J-0-1 to J-12	24	4	22
	b) Between Bahadurabad and Chilmari C.S. No. J-12-4 to J-16-1	41	1	41
	e) Above Chilmari C.S. No. J-17	1	4	1
1974-75	Between Aricha & Indo-Bangladesh border C.S. No. J-0-1 to J-17	34	4	34
1975-76	a) Between Aricha and SirajganjC.S. No. J-0-1 to J-4	8	4	8
	 b) Between Jagannathgonj and Indo- Bangladesh border C.S.No. J-9-1 J-17 	17	4	17
	Sub-Total 1975-76	25		25
1976-77	Between Aricha & Indo-Bangladesh border C.S. No. J-0-1 to J-17	34	4	34
1977-78	Between Aricha & Indo-Bangladesh border C.S. No. J-0-1 to J-17	34	4	34
1978-79	Between Aricha & Indo-Bangladesh border C.S. No. J-0-1 to J-17	34	4	34
1979-80	Between Aricha & Indo-Bangladesh border C.S. No. J-0-1 to J-17	34	4	34
1980-81	a) Between Aricha and Bahadurabad C.S. No. J-0-1 to J-13	94	1	94
ū	b) Between Bahadurabad near Fulchar Cross Dam site and Teesta outfal C.S. No. J-13-11 to J-14-8/2		1	15
	c) Between Teesta outfall and Indo- Bangladesh border C.S. No. J-14-8 to J-18-3	34	1	34
	Sub-Total 1980-81	143		143



Year	Description of Cross-Section as programme	No. of	Interval	
1982-83	Ni1	_	_	-
1983-84	Between Aricha and Noonkowa Indo Bangladesh border from C.S. No. J-0-1 to J-17-1	34	4	34
1984-85	-Do-	34	8	17
	Between Bir Bangabari, U/Z Islampur & Goaldoba, Islampur Jamalpur at barrage site C.S. No. JN-1 to JK-5 = 6 Nos. (6 Nos. x 4 rounds)	24	1.34	24
1985-86	a) At Serajgonj C.S. No. JS-1 to J-6 = 8 Nos.	8	1	8
	b) JN-1 to J-5 = 6 No.s (6 Nos. x 3 round)	18	1.34	18
1986-87	a) As in 1984-85 C.S. No.JN-1 to JN-5 = 6 Nos. (6 Nos. x 2 rounds)	12	1.34	12
	b) Between Aricha & Noonkowa C.S. No. J-0-1 to J-17-1	126	1	126

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Table C2 List of Selected Rainfall Stations

No.	Name of Station	Location
R-2	Atia	Tangail
R-6	Bogra	Bogra
R-9	Dhaka	Dhaka
R-11	Dhunot	Bogra
R-13	Gopalpur	Tangail
R-21	Mirzapur	Tangail
R-25	Pabna	Pabna
R-27	Phulbari	Mymensingh
R-32	Sarishabari	Jamalpur
R-34	Sirajganj	Pabna
R-37	Sreepur	Dhaka
R-40	Ullapara	Pabna
R-62	Dewanganj	Jamalpur
R-64	Gaffargaon	Mymensingh
R-67	Jamalpur	Jamalpur
R-73	Mymensingh	Mymensingh
R-78	Sherpur Town	Jamalpur
R-123	Netrokona	Mymensingh
R-159	Bhurungamari	Rangpur
R-162	Bullibandh	Dinajpur
R-163	Chilmari	Rangpur
R-168	Dinajpur	Dinajpur
R-177	Kaliganj	Rangpur
R-178	Kaunia	Rangpur
R-188	Mohipur	Rangpur
R-195	Chapai-Nawabganj	Rajshahi
R-197	Panchagarh	Dinajpur
R-203	Pirganj	Rangpur
R-205	Rajshahi	Rajshahi
R-206	Rangpur	Rangpur
R-209	Ruhea	Dinajpur
R-216	Shibganj	Bogra
R-218	Sundarganj	Rangpur

Note: For available data period refer Figure C5.

Table C3 List of Selected Water Level and Discharge Measurement Stations

River	No. and	Name of Station	Obser- vation
BANGALI	40	Simulbari (N T)	G D
	10	Sharia Kandi (N T)	G
	11A	Khanpur (N T)	G D
	11	Knanpur (N 1)	
BANGSHI	40	Madhupur (N T)	G
	12	Kaoljani (N T)	G
	13	Mirzapur (N T)	G D
	14	Nayarhat (T)	G D
DADAL	14.5	najarnac (1)	
BARAL	16	Nandangachi (N T)	G
	17	Atgharia (N T)	G
	17 1	Baral Rly. Bridge (N T)	G D
BRAHMAPUT	TRA - JAMU		
	45	Noonkhawa (N T)	G
	45.5	Chilmari (N T)	G
	45.6	Chilmari (N T) Pararchar (N T)	G
	46	Kamarjani (N T)	G
	46.71	Kholabari Char (N T)	G
	46.7R	Kristomoni Char (N T)	G
	46.9L		G D S
	40.02	N T)	
	46.9R	Fulchari (Transit; N T)	G
	47	Bahadurabad (N T)	G
	47.3L	Jognai Char (N T)	G
	47.3R	Patilbari Char (N T)	G
	48	Jagannathganj (N T)	G
	49A	Kazipur (N T)	G
	49	Sirajganj (N T)	G
	50	Porabari (N T)	G
	50.3	Mathura (Nagorbari; N T)	G
	50.5	Alukdia Char (N T)	G
	50.6	Teota (N T)	G
	15J	Mathurpara (Milanpur; N T)	G
	50.7	Charvaranga (N T)	G
	22 JR	D Nakfater Char (N T)	G D

Table C3 (continued)

River	No. and	Name of Station	Obser- vation
DEONAI - CH	ARALKATA	A - JAMUNESWARI - KAROTOA	
	61	Boragari (N T)	G
		Badarganj (N T)	G
		Barati (Road Crossing; N T)	G D
		Chak-Rahimpur (N T)	G
	64	Shibganj (N T)	G
	65	Bogra (N T)	G D
	66	Ullapara (Rly Crossing; N T)	G D
DHALESWARI			
		Tilli (N T)	G
	68.5	Jagir (Seasonal:	G D S
		Dhaleswari bridge; N T)	
DHARLA			
		Patgram (N T)	G D
		Taluk-Simulbari (N T)	G D
	77	Kurigram (N T)	G D
DUDH KUMAR	2.4	Data and AN Th	G D
47	81	Pateswari (N T)	G U
FAKIRNI BAR	RNAI		
	00	lata Barar (Off take of	G
	82	Jote Bazar (Off-take of	u
	0.0	Atrai; N T)	G
		Bagmara (N T) Naldanga (Rly Crossing;	G D
	83.1	N T)	d D
GHAGOT		N 17	
GHAGOT	964	Jafarganj (Road Crossing	G D
	307	: N T)	
	96	Islampur (N T)	G
	97	Gaibandha (N T)	G D
ICHAMATI (S	Spill fr	rom Ganges)	
	126	Pabna (N T)	G
	127	Ataikula (N T)	G
JAMUNA		1122112	
om our	132	Manmathpur (N T)	G
	132.5		G D
	133A	Tajnagor (N T)	G
	133	Naogaon (N T)	G D
JHENAI	n energies	THE PARTY OF THE P	
	134A	Bangshi Bridge (N T)	G D
	134	Jukerchar (N T)	G D
	134B	Off-take of Jhenai (N T)	G D

Table C3 (continued)

River			Obser- vation
KARATUA -	AIRAI -	GUR-GUMANI - HURASAGAR	
	139	Bardeswari (N T)	G
		Panchagarh (N T)	G D
		Debiganj (N T)	G
		3807 Table 10 Table 1	G D
		Bhusir Bandar (N T)	G D
		Shamjhiaghat (N T)	G
	144	Chak Hariharpur (N T)	G
	145	Mohadebpur (N T)	G D
	146	Rasulpur (N T)	G D
	147	Atrai (N T)	G D
	147.5	Singra (N T)	G D
	148	Chanchkari (N T)	G D
	149	Astamanisha (N T)	G D
	149.1	Gumani Rly Bridge (N T)	G D
	150	Dohakoladanga (N T)	G
	151	Baghabari (N T)	G D
KHARKHURIA		bagilabar i (ii i)	u b
MIAMMONIA		Kundal (N.T)	G
	156	Kundal (N T) Parbatipur (N T)	G D
LOHAJANG	100	rarbacipar (ii 1)	u u
LOTINOPHIG	186	Jugini (N T)	G
		3.25 111. 111	
OLD BRAHMA	PUTRA		
	223	Goal Kanda (N T)	G
	224	Off-take of Bangshi	G D
		(Jhenai; N T)	
	225	Jamalpur (N T)	G
	226	Off-take of Sirkhali (N T)	G
	227	Off-take of Sutia (N T)	G D
	228	Mymensingh (N T)	GDS
	228.5		GDS
	229	Toke (S T)	G
	230	Motkhola (S T)	G
	230.1		G D
		Bridge; T)	
PATHRAJ			
	231	Jote Samas (N T)	G
	232	Phulbari (N T)	G
TALMA			
	282	Bhitargarh (N T)	G
	283	Molani (N T)	G

Table C3 (continued)

River	er No. and Name of Station		Obser- vation			
TEESTA						
	291 Uttar Khor		G G D	r.		
	291.5R Dalia (N T 291.5L Doani (N T		G D			
	292 Gaddimari		G D			
	293 Kaliganj (G			
	294 Kaunia (N		G D	į		
	294.5 Haripur (N	(15)	G			
TURAG						
	301 Kaliakoir	(N T)	G D			
	302 Mirpur (S	T)	G D	ì		
 Note:	G Water Level	Gauge				
	D Discharge M	leasurement				
	S Suspended S	Sediment Concent	ration			
	T Tidal					
	N T Non-tidal	7 W E				
	S T Slightly Ti	idal				

For available data period refer Figure C6 and C7.

APPENDIX - D

River Surveys



D. RIVER SURVEYS

D.1 Scope of Work - General

(a) Intensive data collection in one test area (approx. 10km wide x 12km long) to measure velocity, depth and sediment loads on a close grid. Test Area 1 includes the proposed Jamuna Bridge site south of Sirajganj (see Figure D.1).

To carry out the above measurements at three different stages of the annual river cycle.

- (b) Bed form tracking along 3 parallel lines of length 3km each oriented in the direction of river flow, within the Test Area 1 (see Figure D.1).
- (c) River cross sections at approx. 3km intervals from the Indian border to the confluence of the Ganges with the Brahmaputra, a total of some 75 cross-sections.

D.2 Detailed Scope of Work

A detailed scope of work is presented in the following table so as to give an indication of the intensity of measurements of depth, velocity and sediment loads which would require to be carried out for the calibration/verification and the application of a mathematical model incorporating hydrodynamic and sediment transport modules.

The figures within parenthesis in each cell in the table refer to the total numbers of measurements (of the relevant type) to be taken at each survey location at each stage of the annual cycle.



	Stage of Ann	ual Cycle					
Survey			Depth	Velocity	Suspended	Bed load	Measure-
Location		NC/ND	NC/NG/NV	NC/NG/NS	NC/NG/NB	stages	
1)	TEST ARE	A 1	33/16	12/10/2	6/5/2	5/4/6*	F
			(= 528)	(= 240)	(= 60)	(*but mixed (= 20)) FS LSA
2)	OTHER RI	[VER	70/20 (=1400)	NIL	NIL	NIL	LSA
3)	BED FORM	4					
500.F	TRACKING		3/conti-	3/3/8	3/3/8	3/4/1	FS
	(3 lines 3 km lo		nuous	(= 72)	(=72)	(= 12)	LSA
	ND	-	(avera	ige)(bed so	ndings in eacounding along the line is	continuous feasible)	lines whe
	ND	-	(avera	age) (bed so	ounding along	continuous	
	NG		measur section	rements ar on (average		e on each ri	ver cros
	NV	-			measurement with depth s		grid poin
	NS	-	colle	of suspend cted at each ity measur	led sediment ch grid point ement	load sampl t, simultane	les to b ously wit
	NB	(c=)(, simulta	oles to be coneously wit		
	F	-	Durin	g flood (r	ising stage)		
	FS	_	Falli	ng stage a	fter flood		
	LSA	_	Low s	tage after	flood peak		

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D.3 Logistics

The degree of usefulness of river survey data for successful calibration of the 2-D model is governed by a set of specific ('ideal') requirements. The equipment and support facilities which would be necessary to meet the ideal data requirements are set out below:

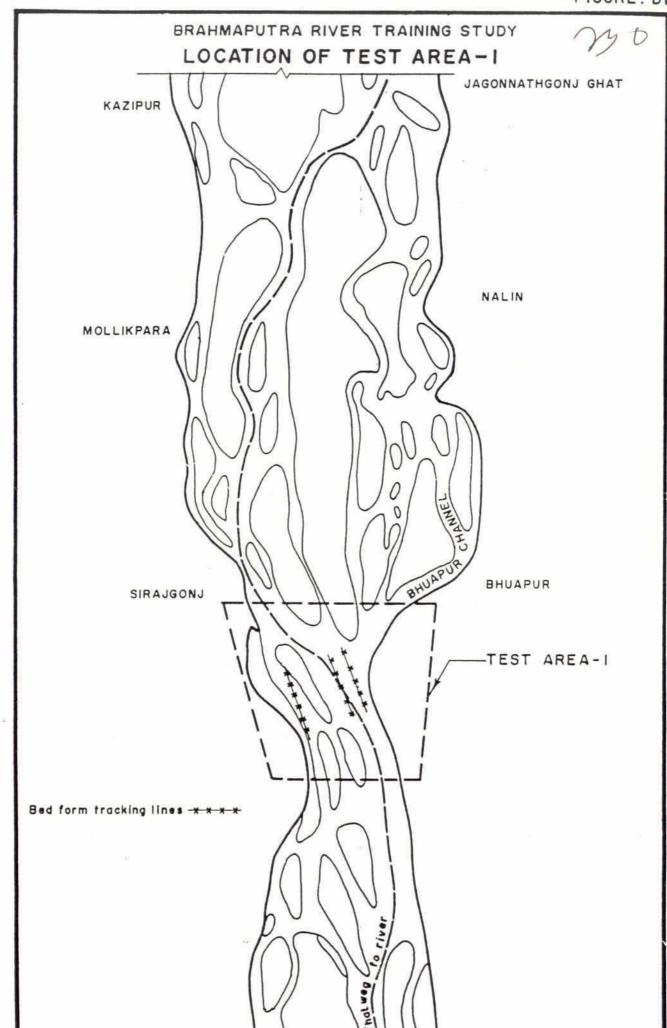
Red	quirement	Corresponding equipment characteristics & support facilities (*)
a)	Measurements along each cross-section (CS) of the	Position fixing equipment independent of ground stations
	Measurements along each cross-section (CS) of the river to be carried out a quickly as possible 'Instantaneous' picture or river reach to be modelled Velocity, sediment load and bottom topography at the same location The same measurements to be repeated at the same	A companion boat with shallow draught to take measurements at shoals, edges of chars etc.
b)	'Instantaneous' picture of river reach to be modelled	Fast boats with (ground station independent) position fixing and navigation equipment; self-recording electronic hydrometric equipment
		More than one fully equipped survey team working simultaneously
		Robust equipment requiring minimum maintenance
		General logistical support for accommodation & meals preferably on board vessels
c)		Boats which could drop and weigh anchor quickly
d)	The same measurements to be repeated at the same locations at different times of the year	Accurate position fixing equipment

(*) Does not include special arrangements for monsoon surveys (eg. heavy anchors & two engines for steering the boat on course and for remaining stationary during measurements; communication facilities with the mother boat during an emergency; sheltered work areas and motorised winches for velocity and sediment measurements in rainy weather, etc.)

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D.4 Work Programme

The proposed work programme for river surveys and other field data collection is given in Figure D.2.





BRAHMAPUTRA RIVER TRAINING STUDY

BRAHMAPUTRA RIVER & EMBANKMENT SURVEYS

REVISED WORK PROGRAMME

ACTIUITY	UNIT					M	ON	THS	3				
HCTTOTT	UNII	M A	М	J	J A	S	0	И	D	J	F	M A	M
A. REVIEW OF DATA/SURVEYS			-									,	7
B. PROGRAM & SPECIFICATIONS FOR DATA COLLECTION		_		•									
C. RIVER SURVEYS													
C.1 GLOBAL SURVEYS	75 CSS							_					
C.2 IEST AREA 1 o Ground Control o Monsoon Surveys (Rising Stage)	30 BMM 3 MASIS 120 km²												
o Falling Stage Surveys o Low Stage Surveys o Data Preparation/Lab. Analysis	120 km² 120 km²		AR	RANG	FOR	VESSE	LS		_			_	
C.3 DUNE TRACKING	3 x 3 km						•	-		-	ı		-
C.4 MEAR-BANK SURVEYS o At River Training Structures o For Confluence/Bend Scour	8 nos. 2 locs.)				I		
D. BRE INVENTORY SURVEY													
D.1 EARTHEN EMBANKMENT o Visual Assessment o Alignment (Sat. Imagery) o Cross Sections o Geotech. Investigations o Data Base Construction	240 km 240 km 500 nos. 50 nos.	-	-	-	1			2 1	_			_	
D.2 RIVER BANK o Visual Assessment o Geotech. Investigations o Data Base Construction	240 km 30 nos.			-					_	•			
D.3 PROTECTIVE MEASURES O Visual Assessment O Detailed Surveys(See C, 4 above)	40 locs.			•			-	_					
E. BLE INVENTORY SURVEY													
E.1 EARTHEN EMBANKMENT o Visual Assessment o Alignment (Sat. Imagery) o Geotech. Investigations o Data Base Construction					3) 			-					
E.2 RIVER BANK o Visual Assessment o Geotech. Investigations o Data Base Construction				-						•			

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APPENDIX - E

Summary of Terms of Reference For FAP Components

- E. SUMMARY TERMS OF REFERENCE FOR RELATED FAP COMPONENTS
- E.1 North-West Regional Study (FAP No. 2)

For FAP component No. 2, concerned with the north west region, located on the right bank of the Brahmaputra, three activities have been identified. These are a Regional Drainage Study, NW Diversion Drain and NW Interceptor Drain.

The central and southern parts of the region suffer regularly from flood due to drainage congestion at the outfall of the Hurasagar river which is the outlet of the entire flow of the Atrai-Karatoya-Hurasagar system. Parts of the region also suffer from overbank spillage of flood flows from the major regional rivers, viz., the Dharla, the Dudhkumar, the Mohanonda, the Teesta, the Atrai, etc. Floods on the eastern part of the region are caused by frequent failure of the Brahmaputra Right Embankment (BRE). Improvement and strengthening of BRE is being undertaken as FAP component No. 1. For improvement of drainage and flood alleviation, the FAP proposal outlined a major drain from near Dinajpur with an outlet in the Brahmaputra, following the Karatoya valley which would intercept the headwaters of the Atrai. The FAP also outlined a diversion drain which would connect the lower course of the Atrai to the Ganges following the Shib-Barnai valley. The regional drainage study will examine various alternatives and identify the most suitable pattern of future water control development in the area using the compartmentalisation concept and firm up the aforementioned drainage proposals as priority projects for the area for early project preparation and implementation.

E.2 North-Central Regional Study (FAP No. 3)

The left bank of the Brahmaputra has high priority for flood control and drainage. About 8 000 sq km of low-lying land bounded by the Brahmaputra, Old Brahmaputra and Dhaleswari rivers are vulnerable to flooding. The flooding of this area (the North Central Region) is caused by rainfall, drainage congestion and spillage from minor rivers and from the Brahmaputra itself. Existing embankments are not effective against major river floods because of inadequate sections, gaps and bank erosion; drainage is impaired by numerous road embankments and restricted waterway sections.

The Action Plan has attached high priority to flood control and drainage on the left bank of he Brahmaputra under component No 3, and identified three specific activities under this component:

- North Central Regional Study
- Brahmaputra Left Embankment (North)
- Brahmaputra Left Compartment (North)

An overall study of flood control and drainage will be undertaken as the first step. The existing embankments are not effective against major river floods because of inadequate sections, gaps and bank erosion: drainage is impaired by numerous road embankments and restricted waterway sections. The study will examine various

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alternatives and establish the most suitable pattern of future water control development.

Strengthening of existing embankments, constructing new ones, building appropriate embankment structures for controlled flooding drainage, remodelling the main drainage systems compartmentalisation would be the main physical features of the regional plan. Two of the major components identified in the Action Plan for early implementation are the northern section of the Brahmaputra Left Embankment (about 80 km) and compartmentalization of the area it would protect (about 50 000 ha). These priority projects would be confirmed by the Regional Study so that project preparation and early implementation can proceed.

E.3 FCD/I Agricultural Study (FAP No. 12)

A review of FCD and FCDI projects is needed in order to learn from previous experience and to provide an input to the planning of the proposed system of embankments and compartments under the Action Plan.

The aims of the Review would be :

- To assess the impact of FCD and FCDI on agriculture
- To assess the agricultural, economic, social and environmental impacts of FCD and FCDI projects and the extent to which technical and other project objectives have been achieved
- To identify constraints to effective project management and to recommend ways in which project design, operation and maintenance can be improved to increase agricultural and other benefits from the projects
- To develop a methodology to be used in subsequent feasibility and evaluation studies under the Action Plan.

E.4 Environmental Study (FAP No. 16)

Concerns have been expressed that construction of embankments and modification of natural flooding regimes, together with intensification of agriculture and expansion of infrastructre within flood protected areas, could have adverse impacts on soil productivity, fisheries, groundwater recharge, health and wildlife. In order to meet these concerns, environmental impact assessments (EIA) need to be made as an integral part of water control projects so that, to the extent possible, adverse environmental effects are avoided in the design, execution and operation of projects. Additionally, provision needs to be made for longer-term environmental impacts to be monitored so as to identify any adverse trends and propose practical remedies.

During the first phase of the Action Plan, the following activities will be undertaken to develop an EIA programme:

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- Identify environmental issues in flood control development in Bangladesh through literature review, field visits to completed flood control projects and consultation with relevant research and development institutions
- Prepare guidelines for EIA of flood control and drainage projects to be used in the regional, pilot and feasibility studies included in the Action Plan
- Identify institutions and consulting firms competent to conduct EIA studies and assess their capacity to undertake the required studies
- Assess needs for training Bangladeshi nationals in EIA methodology
- Organise seminars/training workshops to elicit and propagate available knowledge and experience regarding environmental impacts of development activities in flood control projects.

E.5 Fisheries Study (FAP No. 17)

Despite the obvious value of fishery to the national economy, essential information on migratory and feeding behaviour, reproductive biology, and critical habitat requirements of even the most economically important fish has been poorly researched. Due to weaknesses in the data base, accurate estimation of the impact of embankments on the deltaic fishery cannot be reliably estimated. Accordingly, it is proposed to include the following studies and pilot project in the Action Plan:

- Study of fish and shrimp production in selected floodplain water resource systems to be affected by embankments
- Determination of the social and economic benefits for the fishery and fishing sector in the floodplain areas
- Evaluation of migratory movements, population, location of spawning grounds, and economic importance of Hilsa and major carps
- A pilot project to develop fish stocking and impact mitigation measures to ensure continued high levels of fish production from the floodplain areas.

E.6 Compartmentalisation Pilot Project (FAP No. 20)

The overall objective is to establish appropriate water management methods for the development of protected areas so that criteria and principles for design, implementation and operation can be made available for the Action Plan. Specifically this will entail the testing of the compartmentalisation concept in the field under real operating conditions, addressing all the relevant socio-economic, institutional and environmental issues, and trying out water control works and water management systems.

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The project is divided into three components: Tangail Pilot Project, Sirajganj Pilot Project and Jamalpur Pilot Study (see Figure 10.1).

On the left bank of the Brahmaputra, the selected pilot area covers about 10 000 ha surrounding the district town of Tangail. Lying between the Dhaleswari and Pungli rivers, this pilot area is well defined by a horseshoe embankment on the west, north and east sides and by a village road in the south. The existing embankment provides some protection from river flooding and some degree of controlled flooding from inlet sluices, but what drainage exists is uncontrolled. Irrigation from deep and shallow tubewells for boro rice cultivation has become widespread; however, the transplanted aman rice crop is constrained by the fear of floods and by impeded drainage. The problems to be examined in the selected area are fairly typical of those experienced in the centre and north of the left bank flood plain.

By contrast, the right bank flood plain has been protected by a major embankment for the past 20 years. Despite periodic breaches, particularly in 1988, the area has developed an intensive cropping system with sugarcane and vegetables on the higher and sandier land and with transplanted aman and boro rice on the relatively low land, the latter irrigated mainly from shallow tubewells. The main constraint on crop production appears to be inadequate drainage which is delaying the transplanting of the aman crop. The drainage problem increases to the south, especially towards the Hurasagar mouth. The area identified for the right bank pilot project is between Sirajganj and Kazipur. The eastern boundary is formed by the Brahmaputra Right Embankment. The western boundary will probably be between the Bangali and Ichhamati rivers, but further field work is required to define the location and extent of the project area.

E.7 Bank Protection Pilot Project (FAP No. 21)

Protection from bank erosion by construction of revetments or by diverting the undercutting flows by the building of groynes is expensive. The protection of Chandpur and Sirajganj towns has demonstrated how difficult and expensive the task can be. Despite its problems and cost, effective bank protection will be required for key towns, areas and strategic installations. It is therefore necessary to establish the most economic, appropriate and effective methods of bank protection. A pilot project is therefore to be set up to design and carry out full scale trials.

In the feasibility/design stage, existing and new techniques will be examined, together with appropriate construction materials and methods, taking into account river hydraulics, bed and bank material. Geotechnical and topographical surveys, morphological studies, laboratory research on materials and possibly some modelling will be carried out. The performance of existing town protection works will be evaluated and due account will be taken of recent and on-going studies (eg. Jamuna Bridge Study, Brahmaputra River Training Study).

The next stage will involve the construction of full scale trial works. One pilot scheme will be to test different types of revetment and the other to test different types of groyne. These trials will

be located at priority sites and, because of the undoubtedly high cost, where they will have a long term benefit. The designs, construction aspects and performance of the protection works will be evaluated carefully to assess the real costs and effectiveness of alternative techniques.

E.8 River Training/AFPM Pilot Project (FAP No. 22)

The need for river training at this stage lies primarily in the prevention of bank (and embankment) erosion. The desire to constrain the river to stable and efficient channels coupled with the need to increase the land resource, will to an increasing extent determine river training efforts. Attention should therefore not be focussed solely on the bank stretches presently under attack. Shifting river channels in the active flood plains of Bangladesh's major rivers constantly threaten riverside towns and embankments. Bank protection works, the traditional solution are expensive to construct and maintain. A more cost effective approach is to divert currents away from threatened sections aiming to increase the hydraulic efficiency of the main channels and to reclaim land for agriculture.

Under the concept of Active Flood Plain Management (AFPM), pilot projects for river training will start in the northern reaches of the Brahmaputra. This is where the river is at its widest and shallowest and offers the best conditions for AFPM. Potential sites for trials will be selected in the active river channel between the Old Brahmaputra and Dhaleswari.

E.9 River Survey Programme (FAP No. 24)

The Action Plan envisages that the Brahmaputra and the Ganges may eventually be embanked on both sides, possibly followed by the Padma and Meghna rivers. Confining rivers between embankments will change their hydrological and hydraulic characteristics, which may induce adaptations in river geometry; increased scouring of the river banks and bed could follow. The planning and design of the proposed works require systematic monitoring of the present situation and subsequent changes so as to develop a basic understanding of the processes at work.

While the routine countrywide programmes continue, a special program for surveys and data collection, focused on the Brahmaputra, the Ganges, the Padma, the Meghna and the Lower Meghna is proposed to be set up as a key activity of the Action Plan with particular emphasis on the upgrading of the river gauging flow measurement and data collection systems generally.

Surveys and studies will continue for the duration of the Action Plan, after which they will be integrated with the routine programs.

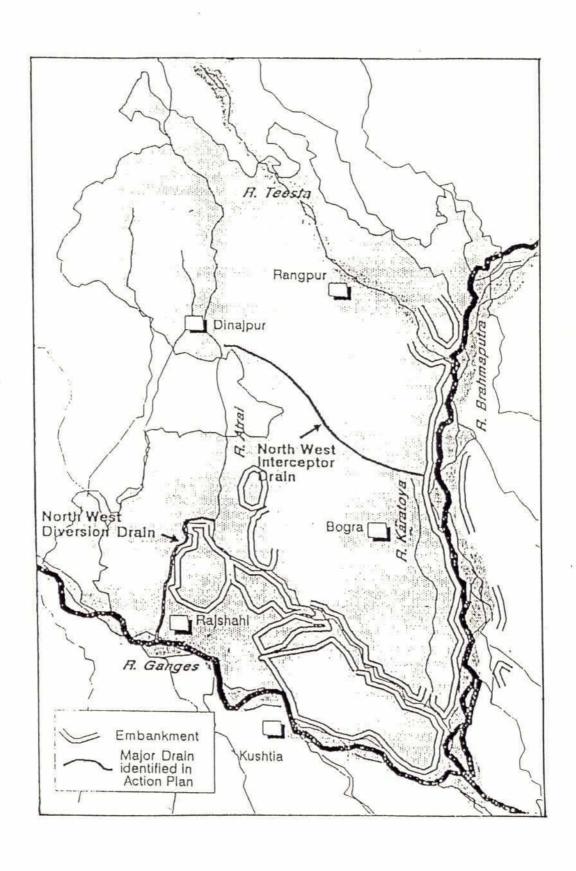
The location of the project is the whole of Bangladesh, with emphasis on the main river system as formed by the Brahmaputra (from the Indo - Bangladesh border to the confluence with the Ganges), the Ganges (from the Indo - Bangladesh border to Brahmaputra confluence), the Padma, the Meghna (downstream of Bhairab Bazar) and the Lower Meghna to about 20 km downstream of Chandpur. The coordination of activities

Not.

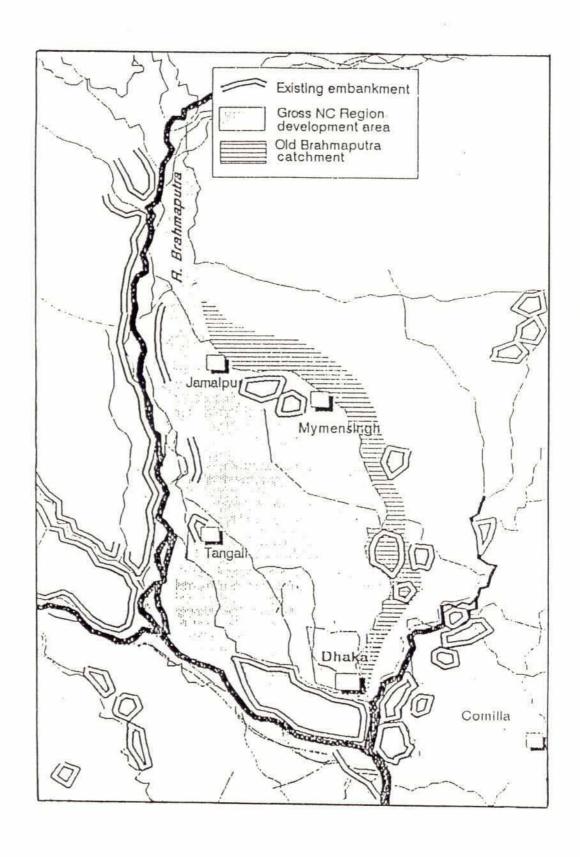
in the field and contact with other Project components and related agencies will be managed from a project office to be set up in Dhaka.

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BRAHMAPUTRA RIVER TRAINING STUDY AREA SHOWING NORTH WEST REGION



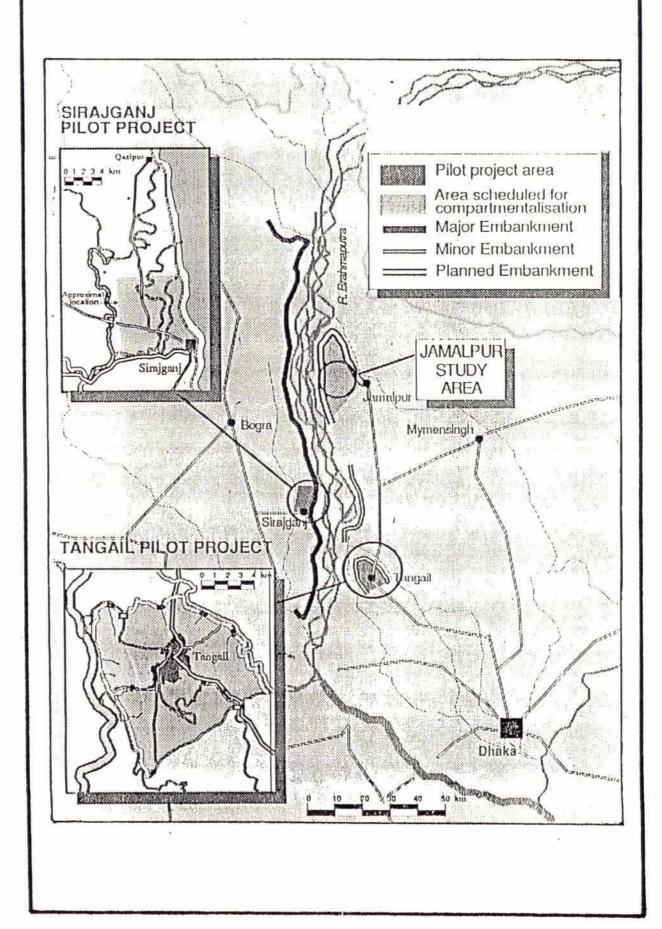
AREA SHOWING NORTH CENTRAL REGION



BRAHMAPUTRA RIVER TRAINING STUDY



COMPARTMENTALISATION PILOT PROJECT



INSTITUTES FAP-COMPONENTS: Comp. 1 BRE-Strengthening BIWTA Comp. 2 to 6 Regional Studies BWDB Comp. 8 and 9 Town Protection MPO Comp. 24 3+4 Comp. 10 River Survey SWMC Flood Forc. & Program (RSP) Early Warning RRI Comp. 18 Topographical SPARRSO Mapping SOB Comp. 19 GIS Comp. 21 and 22 Pilot Projects Comp. 25 BIWTA Bangladesh Inland Water Flood Modelling/ Transport Authority Management BWDB Bangladesh Water Development Board MPO Master Plan Organization SWMC Surface Water Modelling Centre 1 → surveys asked from RSP RRI River Research Institute 2 -→ data supply to RSP SPARRSO Bangladesh Space Research and 3 → data supply by RSP Remote Sensing Organization survey results) SOB Survey of Bangladesh 4 → feeding data to data base

Inter-relation between River Survey Project and other FAPcomponents/activities and with some insitutes in Bangladesh.

→ training

APPENDIX - F

Training

F. TRAINING

Training and technology transfer to local personnel will be carried out throughout the course of the BRTS programme.

The main forms of training will be through on-the-job skill transfer. This will benefit the local engineers on the project team, and will be extended to include four BWDB staff at Assistant Engineer level. They will be seconded to the project full-time, for periods that have to be agreed, as follows:

- One Assistant Engineer at the BRTS project office in Dhaka, attached to the Mathematical Modelling Team
- One Assistant Engineer attached to the Physical Modelling Team at RRI, Faridpur
- Two Assistant Engineers attached to the Field Data Collection/River Survey Team out in the field as well as at the BRTS office.

If feasible and where possible within the scope of the project programme, the on-the-job skills transfer will be supplemented by:

- Informal presentations to project staff by specialists on the team
- Participation in workshops and seminars on technical topics of relevance to the BRTS organised by external groups
- Guidance to project staff in the use of computer software packages used on the project.

Formal lectures will, from time to time, be given by the BUET Advisory Group on the BRTS team. These are intended to cover technical topics of a more specialist nature relevant to the BRTS such as: open channel flow; fluvial processes; sediment transport theories and river morphology.

The participation of the BUET Advisory Team and the secondment of staff from BWDB to project team will allow members of both these organisations to gain experience of the development and application of the data bases and mathematical models used on the project. Informal presentations on the capabilities of the models, and on practical aspects of their use in hydraulic analysis will be given by the Consultants' specialist staff to assist in the general transfer of computational modelling skills to both these organisations.

A key activity within the BRTS programme will be river surveying. Practical experience gained during the course of project duties will include demonstration of the modern equipment that can be used to make surveys of long reaches of the river and of bed forms with rapid processing of data. The capabilities of the equipment will be discussed and there will be an opportunity for obtaining some experience in handling the equipment itself.

APPENDIX - G

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