FLOOD PLAN
COORDINATION
ORGANIZATION
(FPCO)

KREDITANSTALT FÜR
WIEDERAUFBAU (KfW)

CAISSE CENTRALE DE
COOPERATION ECONOMIQUE (CCCE)

BANK PROTECTION AND RIVER TRAINING (AFPM) PILOT PROJECT FAP 21/22

INTERIM REPORT

Volume I

Main Report

JULY 1992

CONSULTING CONSORTIUM FAP 21/22

RHEIN-RUHR ING.-GES.MBH, DORTMUND/GERMANY
COMPAGNIE NATIONALE DU RHONE, LYON/FRANCE
PROF.DR. LACKNER&PARTNERS, BREMEN/GERMANY
DELFT HYDRAULICS, DELFT/NETHERLANDS

In association with:
BANGLADESH ENGINEERING &
TECHNOLOGICAL SERVICES LTD. (BETS)
DESH UPODESH LIMITED (DUL)

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MFN-2303
24-02

A-62

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BANK PROTECTION AND RIVER TRAINING (AFPM) PILOT PROJECT FAP 21/22

FLOOD PLAN CO-ORDINATION ORGANIZATION (FPCO)

Project Office :
Consulting Consortium FAP 21/22
House 4, Road 125, Gulshan-1
Dhaka-1212, Bangladesh
Tel : (880-2) 600751
Fax : (880-2) 883990

The Chief Engineer
Flood Plan Coordination Organization
7, Green Road
Dhaka.

Our Ref: CC/FPCO/L/92-551 July 16, 1992

Subj: **Interim Report**

Dear Sir,

We have pleasure in enclosing 50 copies of our Interim Report. It consists of the main report to which two volumes with annexes are attached.

We should like to take the opportunity to thank you and your staff for the excellent co-operation and are looking forward to receiving your comments.

Yours sincerely,

H. Brühl

Dr H Brühl
Project Director

Encl: As above

HB/Amal

RHEIN-RUHR INGENIEUR-GES. MBH, DORTMUND/GERMANY
COMPAGNIE NATIONALE DU RHONE, LYON/FRANCE
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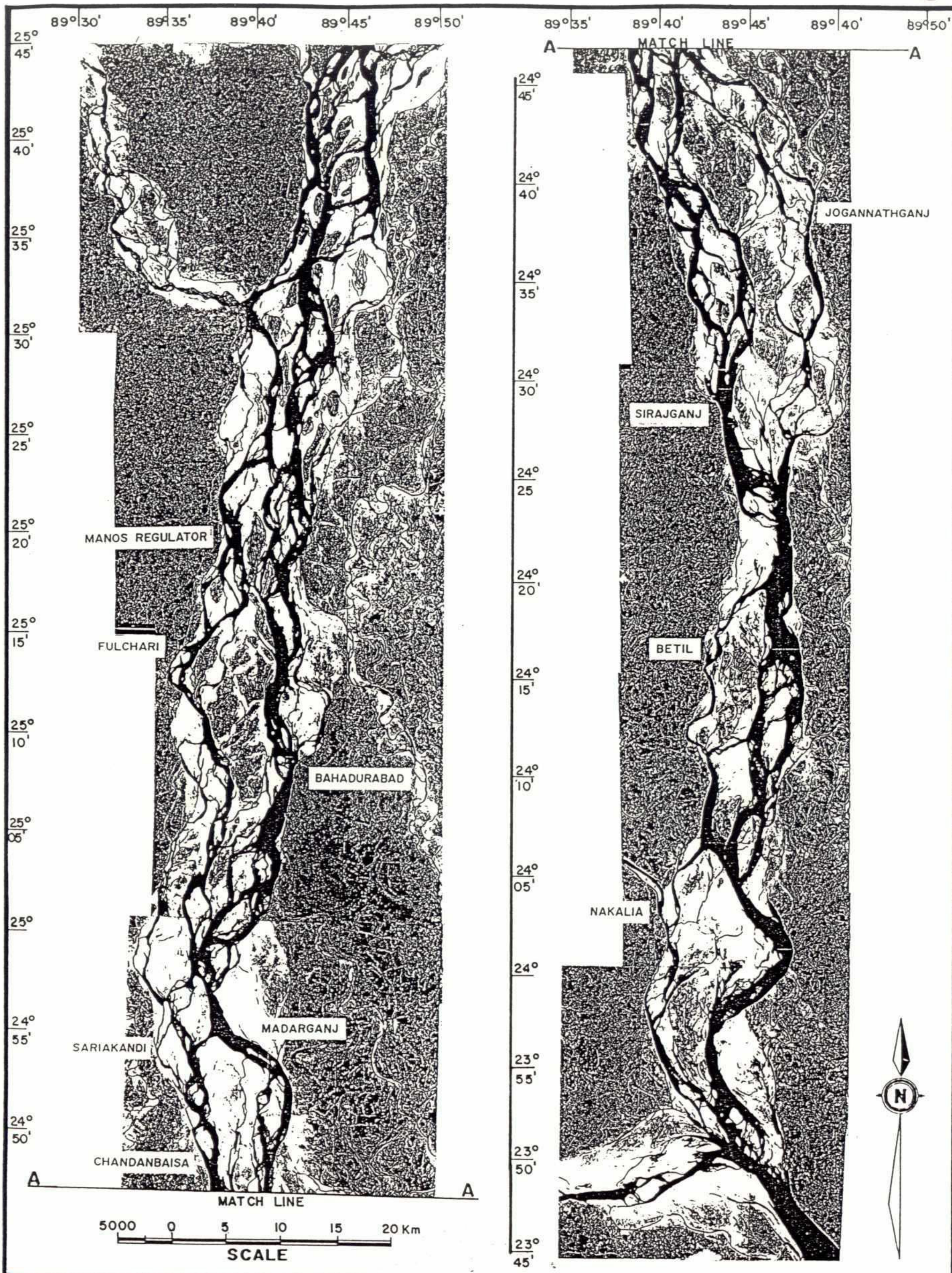

PROJECT AREA
JAMUNA RIVER
BASED ON SPOT IMAGE MAP, MARCH 1989

FAP - 21 /22
BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT

INTERIM REPORT	FIGURE - 1

GLOSSARY

AFPM	-	Active Flood Plain Management
ASTM	-	American Society for Testing and Materials
BBS	-	Bangladesh Bureau of Statistics
BM	-	Bench Mark
BRE	-	Brahmaputra Right Embankment
BRTS	-	Brahmaputra River Training Studies
BS	-	British Standards
BTM	-	Bangladesh Transverse Mercator (Projection)
BUET	-	Bangladesh University of Engineering and Technology
BWDB	-	Bangladesh Water Development Board
CC	-	Cement Concrete
CCCE	-	Caisse Centrale de Coopération Economique (French Funding Agency)
CPT	-	Cone Penetration (Penetrometer) Test
DHI	-	Danish Hydraulic Institute
DIN	-	German Standards
EDM	-	Electronic Distance Measurement
EIRR	-	Economic Internal Rate of Return
FAP	-	Flood Action Plan
Fig.	-	Figure
FPCO	-	Flood Plan Coordination Organization
GL	-	Ground Level
GIS	-	Geographic Information System
GM	-	General Model
GoB	-	Government of Bangladesh
HFL	-	High Flood Level (1:100 years return period)
HYMOS	-	Software for Analyzing Hydrologic Data
IWT	-	Inland Water Transport
KfW	-	Kreditanstalt für Wiederaufbau (Germany Funding Agency)
Landsat	-	Land (Remote Sensing) Satellite
LCD	-	Low Cost Dredging
LOTUS	-	Software Spreadsheet Programme
MIKE 11	-	1-dimensional mathematical model developed by DHI and used in SWMC
MIWRFC	-	Ministry of Irrigation Water Resources and Flood Control
MSS	-	Multi Spectral Scanner
NPV	-	Net Present Value
O & M	-	Operation and Maintenance
PWD	-	Public Works Department (datum level)
R & H	-	Roads and Highway

RRI	-	River Research Institute (Faridpur)
SHW(L)	-	Standard High Water Level
SLW(L)	-	Standard Low Water Level
SOB	-	Survey of Bangladesh
SPOT	-	Satellite : System Probatfore d'Observation de la Terre
SPT	-	Standard Penetration Test
SWMC	-	Surface Water Modelling Centre
TM	-	Transverse Mercator (Projection)
UNDP	-	United Nations Development Programme
UTM	-	Universal Transverse Mercator (Projection)
WB	-	World Bank

LOCAL EXPRESSIONS

CHAR	-	Sand bank, also floodable areas adjacent to the banks
CIRCLE	-	An BWDB office headed by a Superintending Engineer
CRORE	-	10,000,000
DISTRICT	-	Administrative Unit in the care of a Deputy Commissioner
DIVISION	-	An BWDB office headed by an Executive Engineer
KHOA	-	Brick chips (used as concrete aggregates and filter material)
LAKH	-	100,000
TK	-	Taka
UPAZILA	-	Administrative Unit, division of a District
UNION	-	Administrative Unit, division of an Upazila

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1 INTRODUCTION

1.1 BACKGROUND

The Project was awarded by the Flood Plan Coordination Organization (FPCO) represented by the Kreditanstalt für Wiederaufbau (KfW) to the Joint Venture Rhein-Ruhr Ingenieur-Gesellschaft.mbH as lead partner, Compagnie Nationale du Rhone, Prof.Dr. Lackner & Partners and Delft Hydraulics in association with Bangladesh Engineering and Technological Services Ltd. (BETS) and Desh Upodesh Ltd. (DUL).

The Consultancy Agreement was signed on October 14, 1991. The date of commencement was fixed on December 1, 1991.

The Agreement calls for a strictly limited period for undertaking the consultancy services for the Project with the intention to start the physical implementation of the first test structure immediately after the monsoon period 1993. To achieve that deadline the Draft Planning Study Report has to be submitted in January 1993.

Hence only 13 months are available to perform the Planning Study, including the mobilization period. That made it necessary to modify the contractual time schedule, mainly by reducing the period available for mobilization and preselection of test areas, in order to finalize the field surveys of the Planning Study before the beginning of the monsoon period 1992.

It is without doubt that already a short delay of say one to two months could result in postponing the implementation by one full year. The Consultant is fully aware of that time constraint.

As a consequence, in a special effort, the preselection and proposition of test areas (Task 7) was further anticipated and a special report on that issue was circulated for review and discussion on March 2, as a draft. The final version of that Technical Report No.1 was issued on March 14, 1992 for approval.

The Inception Report was issued on March 21, 1992 and hence also ahead of the original time schedule according to the Terms of Reference.

1.2 PURPOSE OF THE INTERIM REPORT

The report's main objectives are

- to inform of the activities undertaken and the progress achieved since submitting the Inception Report

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- to make the recommendations on the test sites
- to present the results so far gained in the studies
- to revise and, if found necessary, to reassess the scope of works and the Project's work programme.

Further, to allow GoB and the Funding Agencies to commence with their preliminary allocation of the funds for the Test and Implementation Phase, the present report also gives the Consultant's proposal for a tentative budgeting of the test works.
The Interim Report consists of 3 volumes:
- Volume I being the main report,
- Volume II being the Technical Report No.2 on River Training and Morphological Response (State-of-the-Art-Report) and
- Volume III containing the other annexes.

When preparing the report, the Consultant's intention was to present in Volume I all information required to give the reader a comprehensive conception on the activities undertaken and the results gained so far. More detailed information is given in the annexes included in Volume II and III, respectively.

The main components of the report are put at the front since they are required for further planning by GoB and the Funding Agencies. This refers to

Chapter 2 on the selection of the sites for bank protection test works,

Chapter 3 on a first tentative conclusion whether or not AFPM measures may be expected to be functionally viable and

Chapter 4 with a proposal for a tentative budgeting of test works including both bank protection and possible AFPM test works.

The following chapters give account on the activities undertaken and the outlook (Chapter 5 and 6, respectively).

As per the Consulting Agreement, the administrative and financial aspects are being informed of in a separate report, with a different distribution and including the second quarter of 1992 i.e. having June 1992 as a dead line. That Administrative and Financial Report No.2 also includes the staff employment, subcontracts awarded, financial prospect etc.

1.3 IMPORTANT DATES AND EVENTS

06.05.1991	Presentation of Proposal
14.10.1991	Signature of Consulting Agreement
01.11. to 09.11.1991	Premobilization mission by the Project Director
05.12. to 14.12.1991	Mobilization mission by the Project Director
13.01.1992	Start of expatriate staff deployment in Bangladesh
29.02.1992	Joint KfW/CCCE meeting with the Project staff
01.03. to 05.03.1992	2nd GOB-WB Conference on Flood Action Plan
02.03.1992	Circulation and discussion of the draft of the Technical Report No.1 on Pre-Selection of Test Areas
14.03.1992	Official handing over of the Technical Report No.1
19.03.1992	General Meeting in FPCO on the Preselection of Test Areas
21.03.1992	Submission of the Inception Report
21.03.1992	Approval of Test Areas
28.03.1992	Subcontract signed for subsoil investigations
02.04.1992, 08.04.1992	Subcontracts signed for topographic and hydrographic surveys
04.04. to 19.04.1992	Study Tour to Europe including attendance of 5th Symposium on River Sedimentation, Karlsruhe, Germany
21.05.1992	Submission of the Administrative and Financial Report No.1
22.05. to 09.06.1992	Braided Rivers Study Tour to the Yellow and Yangtze Kiang Rivers in China and the Mississippi River in U.S.A.

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2 SELECTION OF SITES FOR THE FAP 21 TEST WORKS

2.1 GENERAL APPROACH

In accordance with Task No.14 of the Consultant's Scope of Work definite locations of test sites have to be specified within the selected areas where alternative test measures shall be executed. In the following Section 2.2, test areas pre-selected as per Consultant's Technical Report No.1 (see Fig. 2.1-1) will first be reviewed in the light of recent morphological studies, considering satellite images from 1988 until March 1992.

After final selection of test areas the results of topographic and hydrographic surveys, the soil mechanics investigations (as far as available), and the preliminary results of environmental and socio-economic assessment will be taken into account for selection of test sites. Furthermore, the future morphological changes (retreat of bank lines due to erosion) will be predicted, still to be verified after the present monsoon season.

In preparation of Task No.16 - Selection of Alternative Test Measures - the Consultant is studying different protection methods and design alternatives. Furthermore, a first analysis of construction methods, materials and unit rates has been performed. As a preliminary result, type, location and alignment of possible test structures will tentatively be indicated at the selected sites and rough cost estimates prepared.

At present there seems to ~~exist~~ a exist a certain tendency to concentrate the test works on two sites viz. Kamarjani (North of the Manos regulator) and Bahadurabad. The main reasons are as follows:

1. The detailed reassessment of the morphological conditions came to the conclusion that prediction of safe attack over about 6 six seem to be more even difficult than anticipated. Whereas all test areas pre-selected are obtaining lower marks for the main criterian "certainty-of-attack" the two areas mentioned above are still scoring highest.
2. The restriction to two sites would save considerable funds from site installation and mobilization cost, as well as cost for appurtenant structures to secure the site, e.g. by connecting dams to the embankment to avoid outflanking of the test works. The saved funds would hence be used for the construction of the proper test works.
3. The restriction to two sites will result in an increase of alternative designs per site which would be tested under the same conditions, thus furnishing more comprehensive and more comparable results.

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Fig. 2.1-2 to 2.1-10 representing the Project area in 1989 and 1992 respectively give a good impression of the fast, and sometimes fundamental changes of the river's planform.

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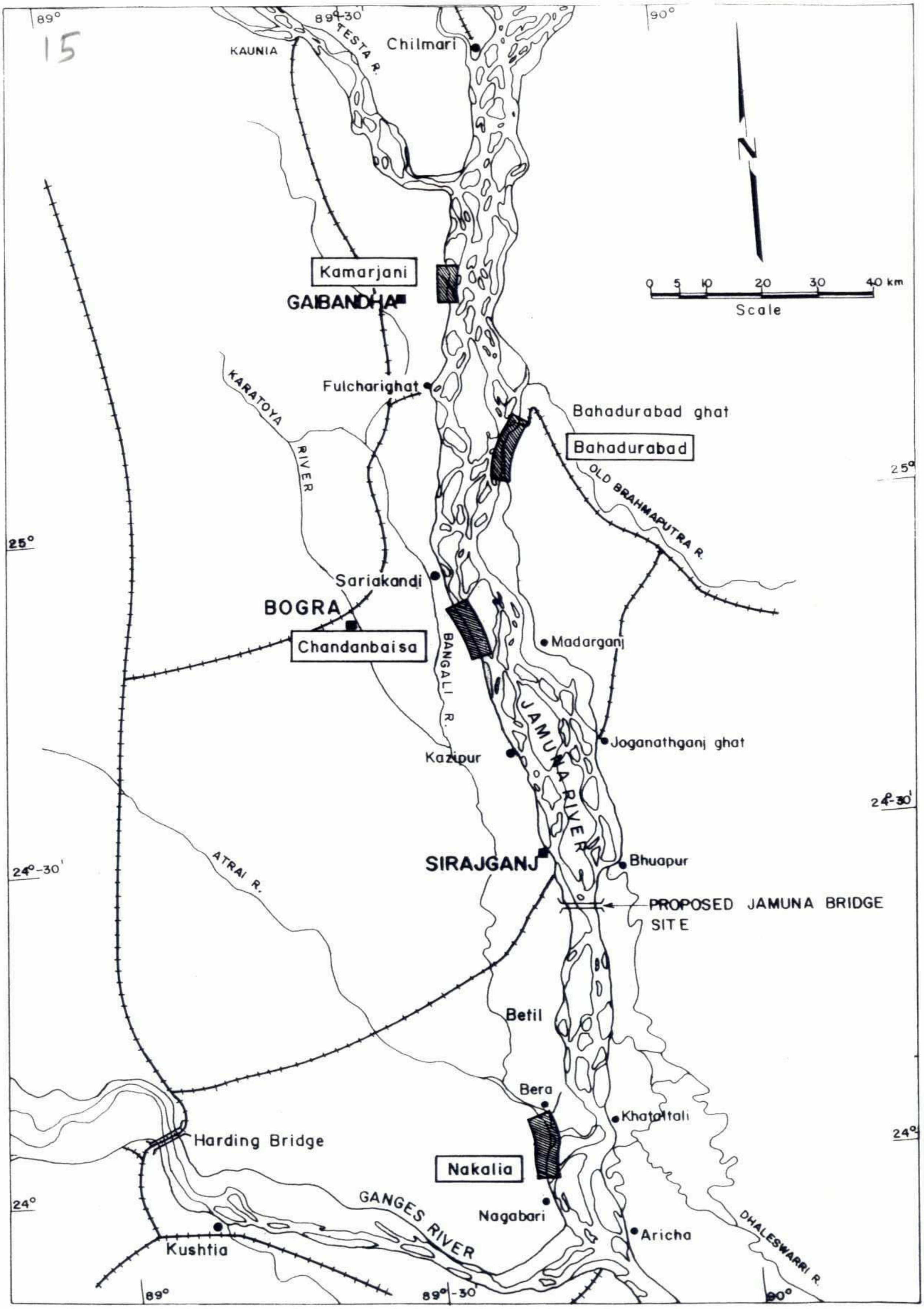

PRESELECTED TEST AREAS	FAP - 21/22 BANK PROTECTION AND RIVER TRAINING / (AFPM) PILOT PROJECT	
	INTERIM REPORT	FIG. 2.1-1

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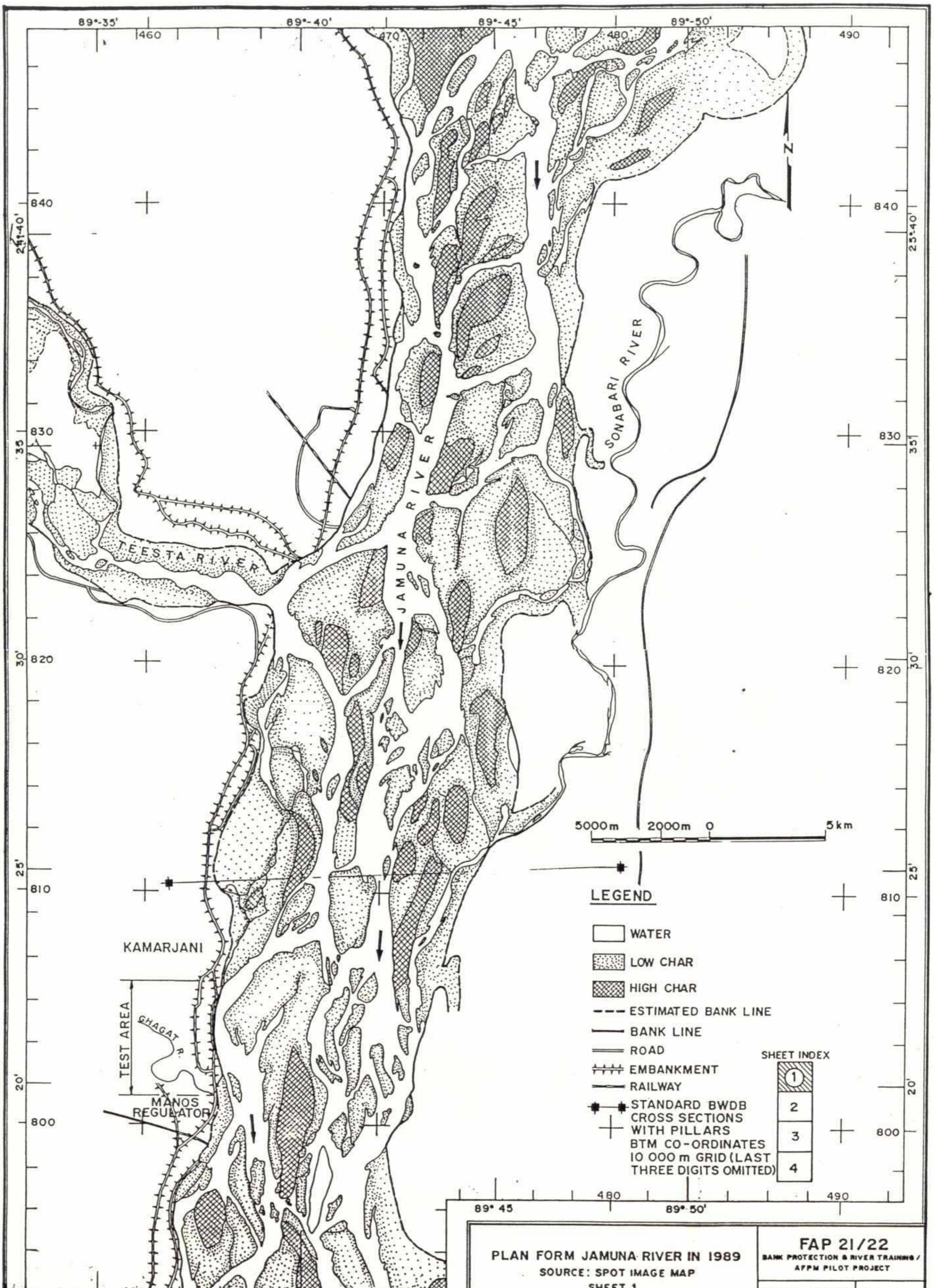
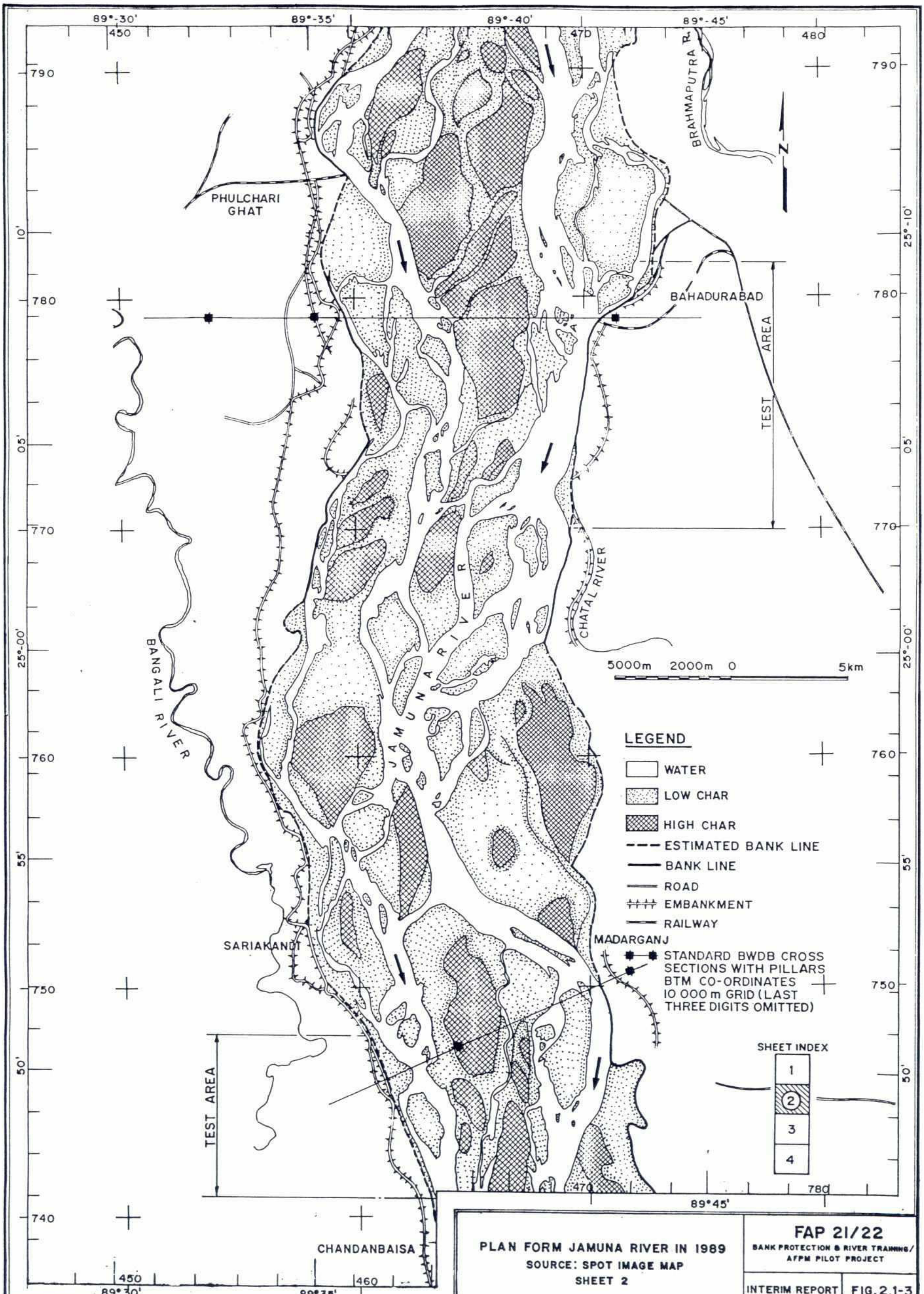


PLAN FORM JAMUNA RIVER IN 1989
SOURCE: SPOT IMAGE MAP
SHEET 1

FAP 21/22
BANK PROTECTION & RIVER TRAINING / AFPM PILOT PROJECT

INTERIM REPORT | FIG. 2.1-2



PLAN FORM JAMUNA RIVER IN 1989
SOURCE: SPOT IMAGE MAP
SHEET 2

FAP 21/22
BANK PROTECTION & RIVER TRAINING/ AFPM PILOT PROJECT

INTERIM REPORT | FIG. 2.1-3

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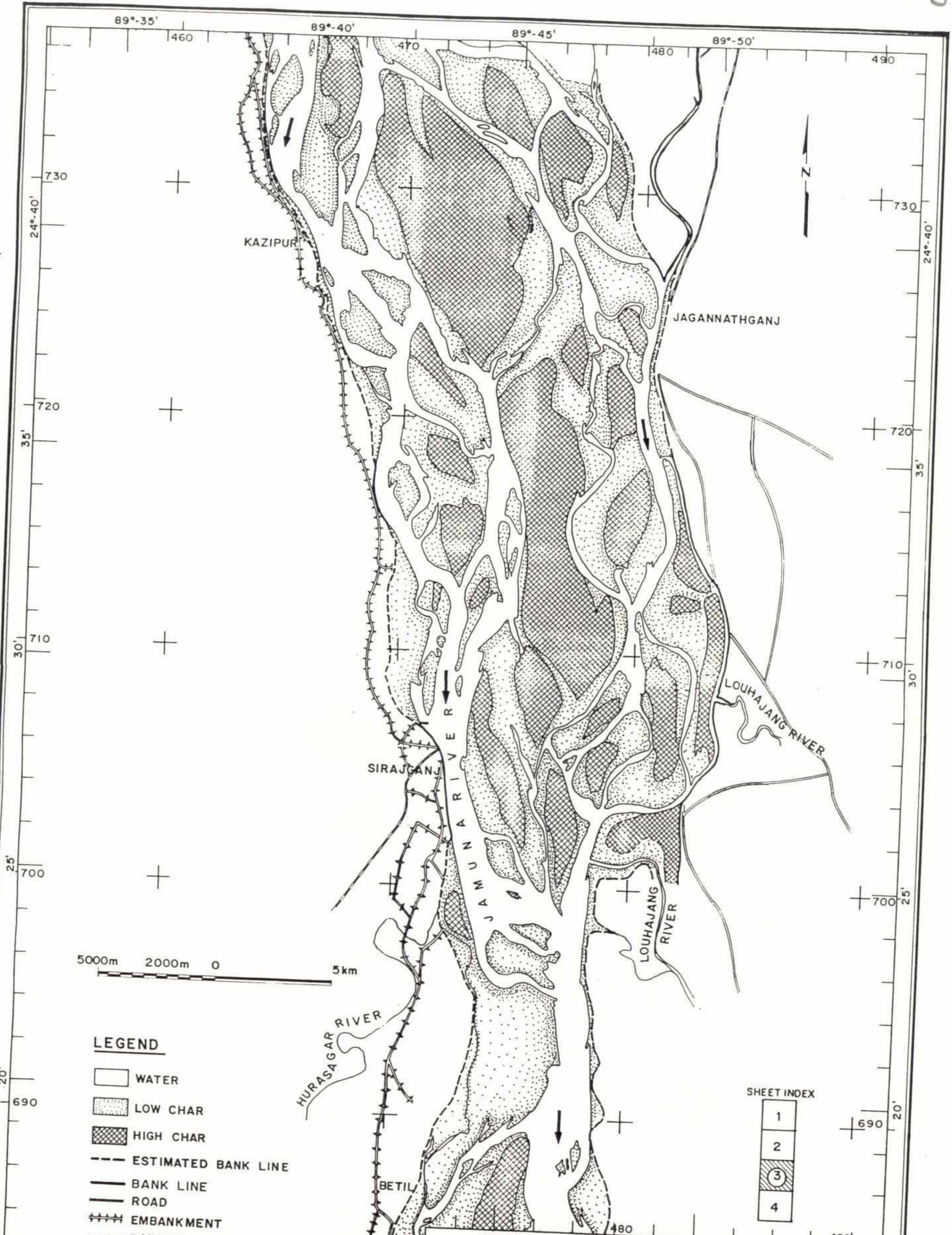

PLAN FORM JAMUNA RIVER IN 1989
SOURCE: SPOT IMAGE MAP
SHEET 3

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INTERIM REPORT

FIG.2.1-4

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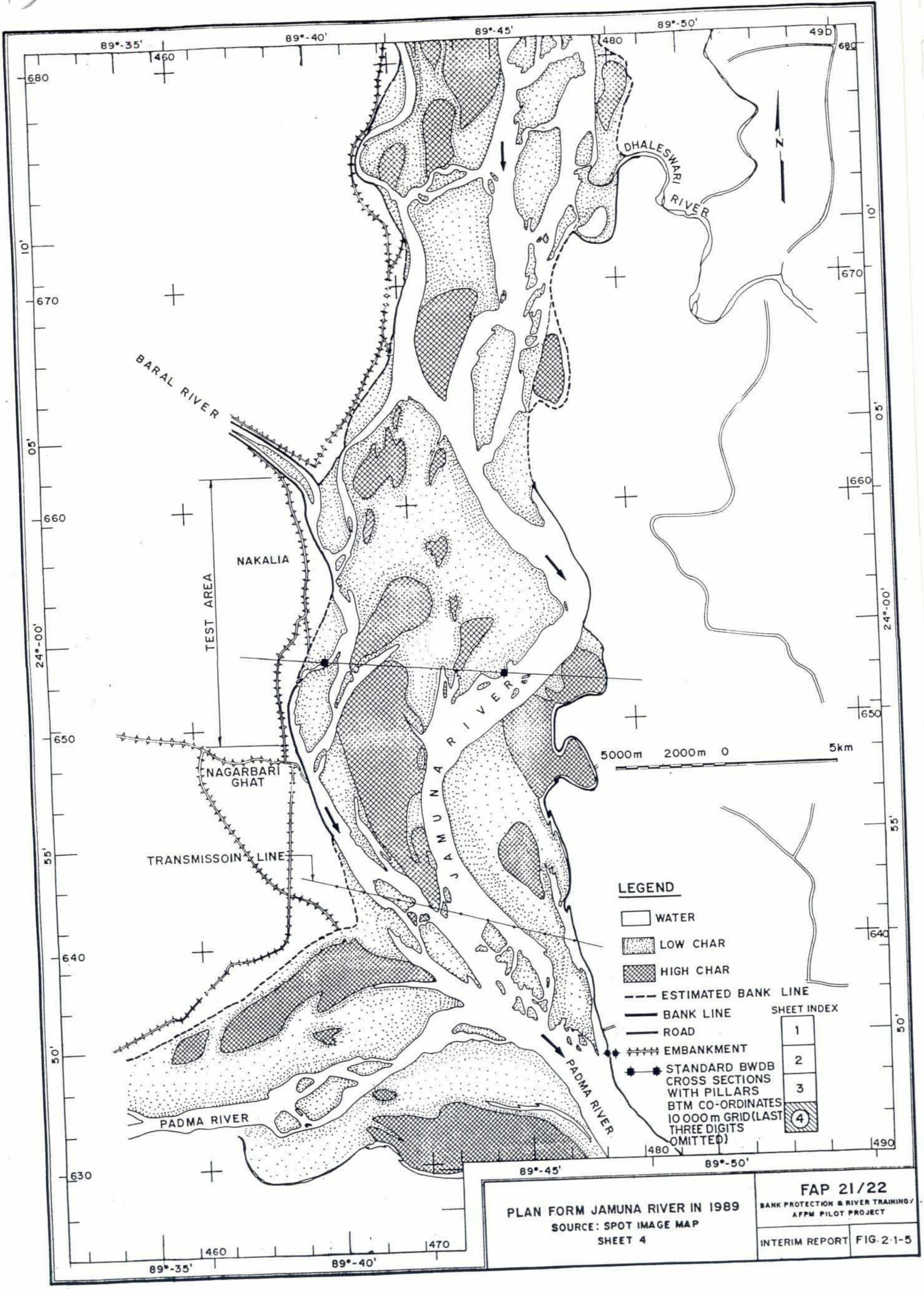
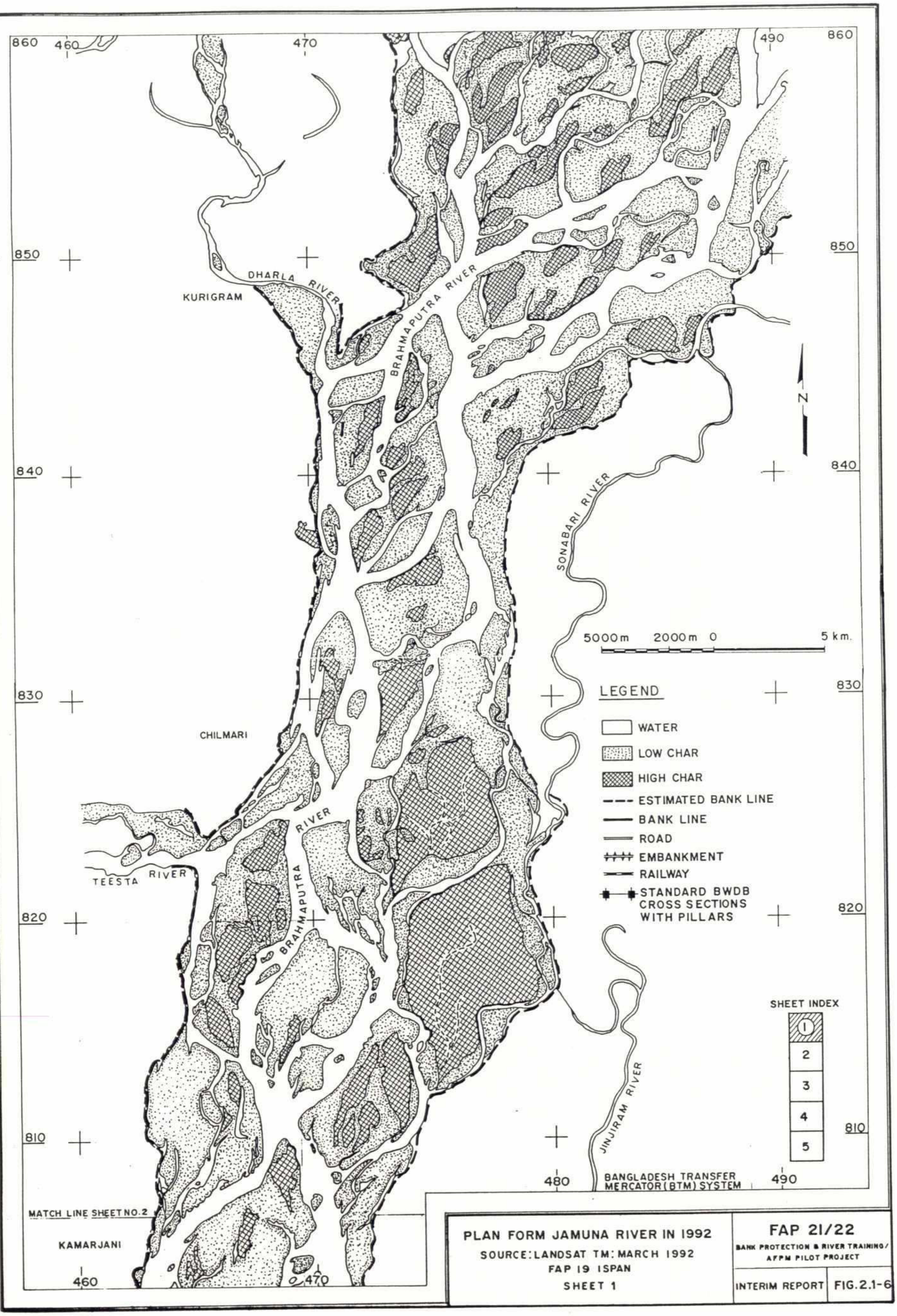


PLAN FORM JAMUNA RIVER IN 1989
SOURCE: SPOT IMAGE MAP
SHEET 4

FAP 21/22
BANK PROTECTION & RIVER TRAINING / AFPM PILOT PROJECT

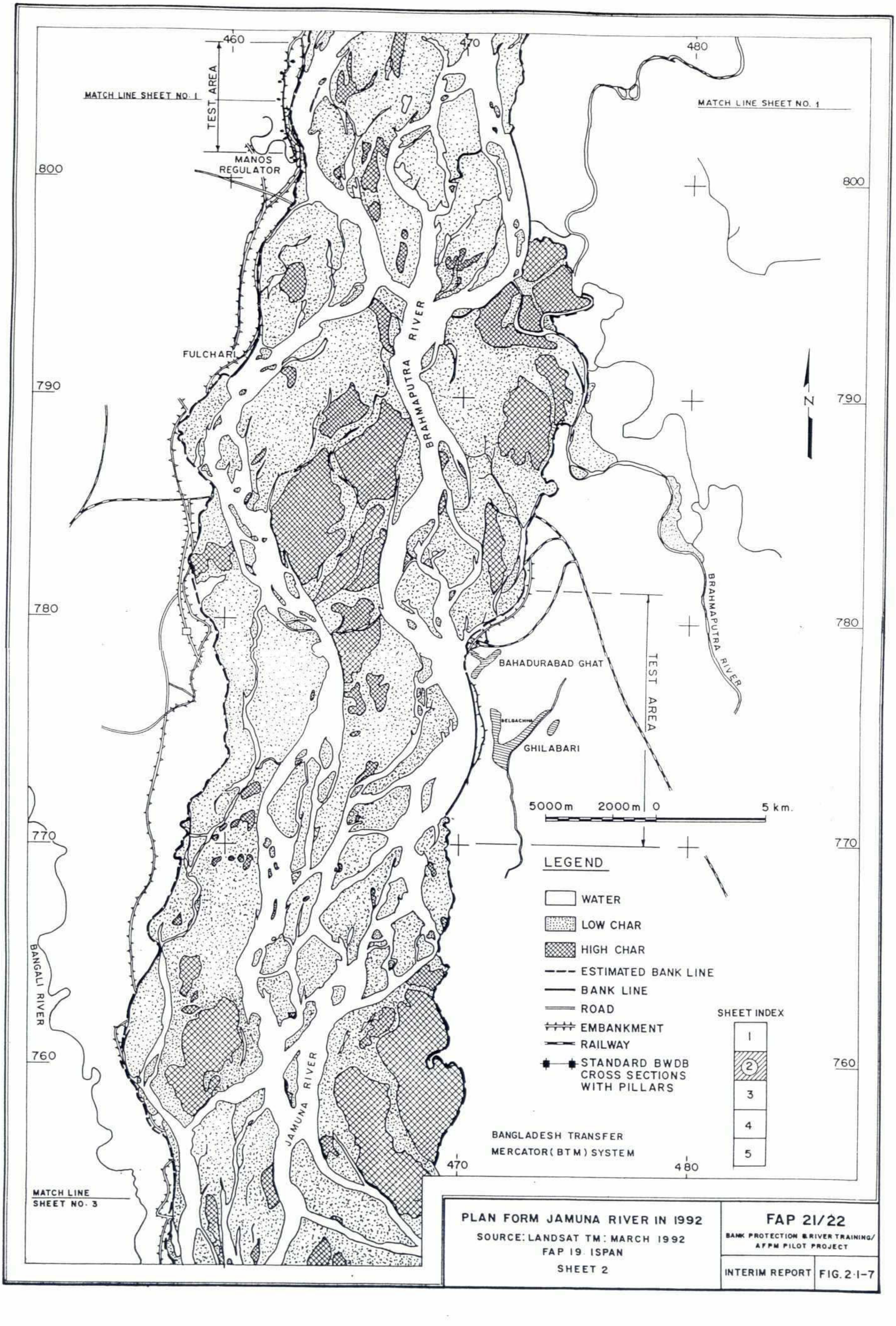
INTERIM REPORT | FIG. 2·1-5



PLAN FORM JAMUNA RIVER IN 1992
SOURCE: LANDSAT TM: MARCH 1992
FAP 19 ISPAN
SHEET 1

FAP 21/22
BANK PROTECTION & RIVER TRAINING / AFPM PILOT PROJECT

INTERIM REPORT | FIG. 2.1-6



PLAN FORM JAMUNA RIVER IN 1992
SOURCE: LANDSAT TM: MARCH 1992
FAP 19 ISPAN
SHEET 2

FAP 21/22
BANK PROTECTION & RIVER TRAINING/ AFPM PILOT PROJECT

INTERIM REPORT | FIG. 2·1-7

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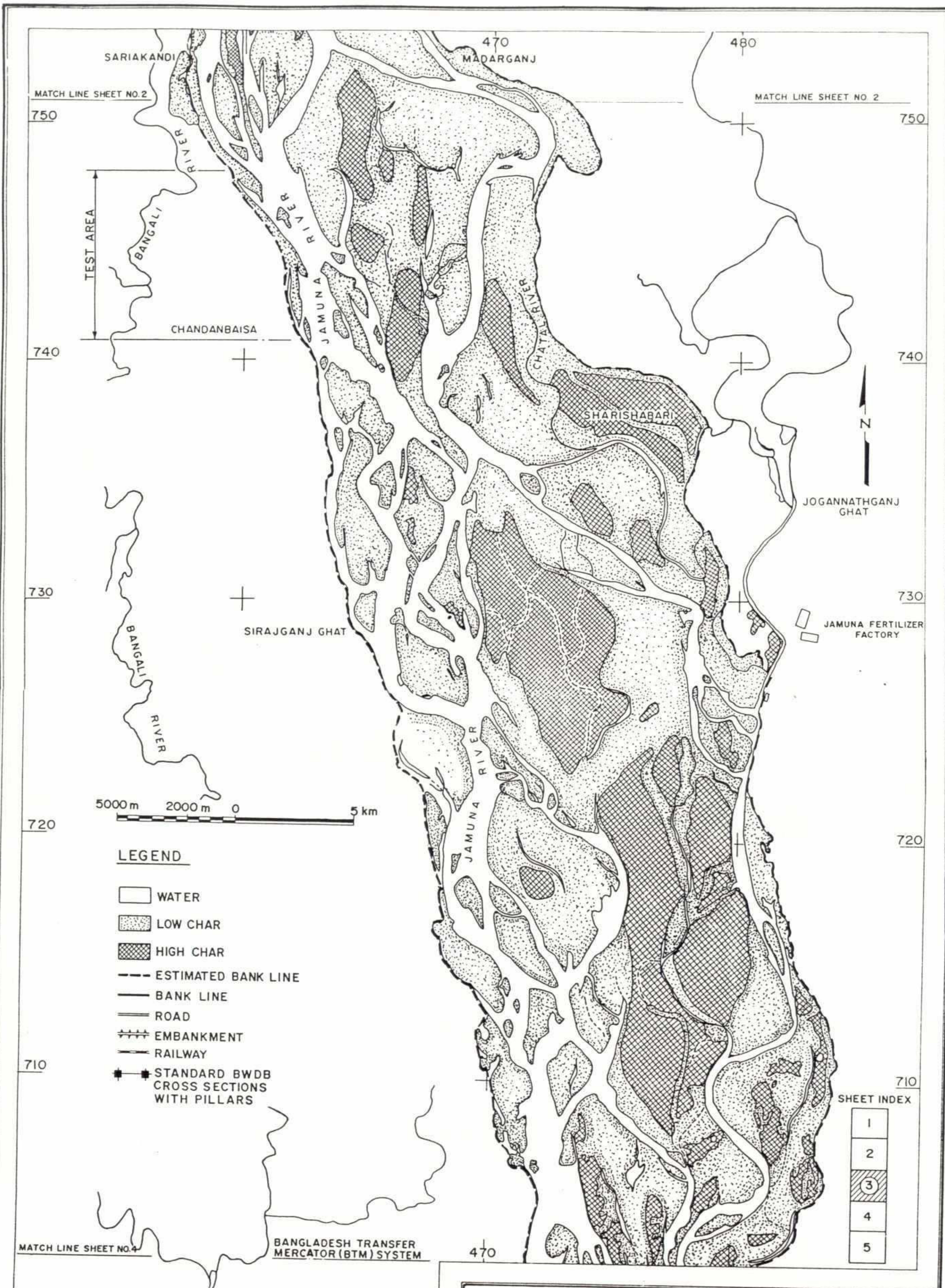
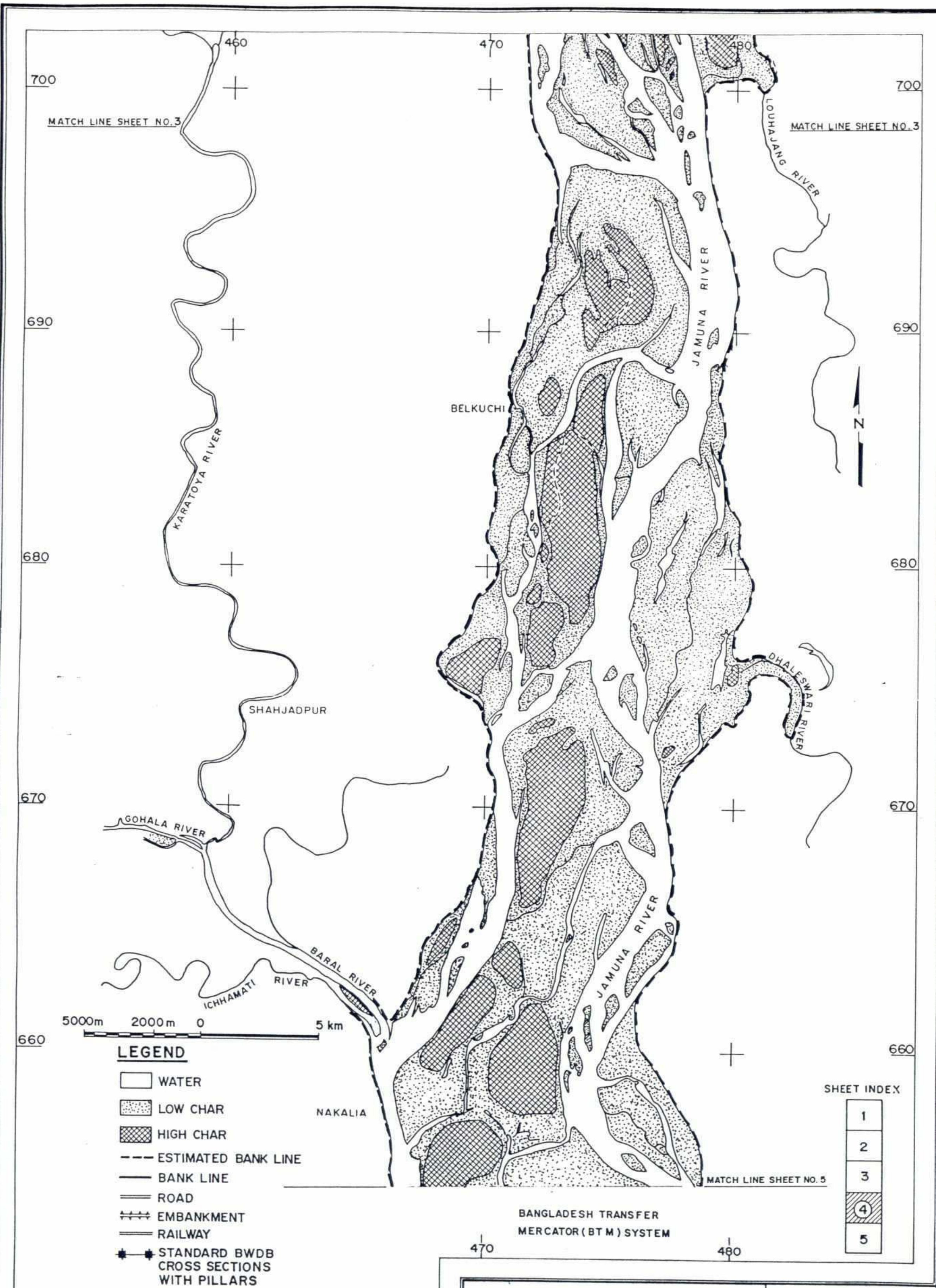


PLAN FORM JAMUNA RIVER IN 1992 SOURCE: LANDSAT TM: MARCH 1992 FAP 19 ISPAN SHEET 3	FAP 21/22 BANK PROTECTION & RIVER TRAINING / AFPM PILOT PROJECT	
	INTERIM REPORT	FIG. 2.1-8



PLAN FORM JAMUNA RIVER IN 1992
SOURCE: LANDSAT TM: MARCH 1992
FAP 19 ISPAN
SHEET 4

FAP 21/22
BANK PROTECTION & RIVER TRAINING/ AFPM PILOT PROJECT

INTERIM REPORT | FIG. 2.1-9

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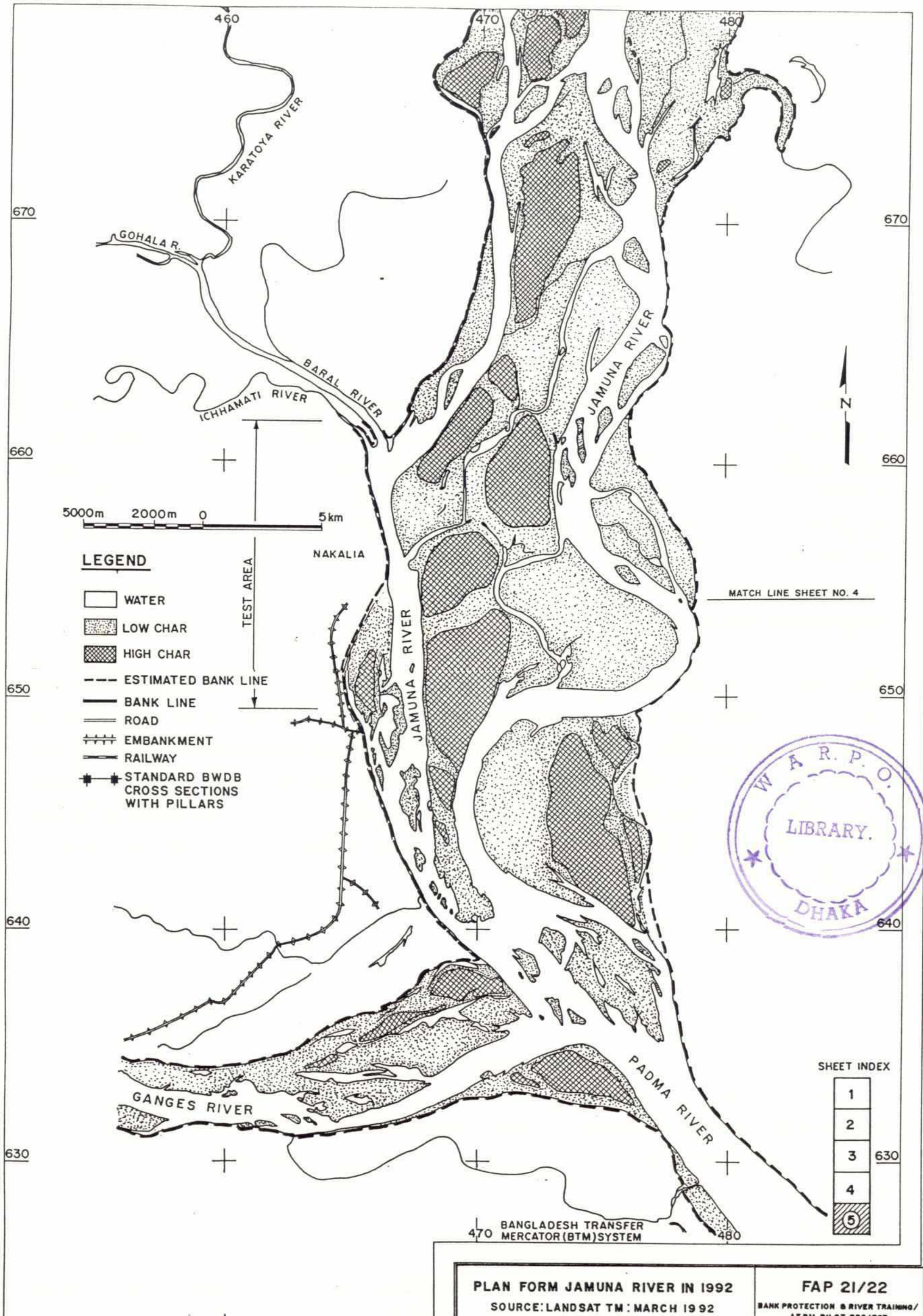

PLAN FORM JAMUNA RIVER IN 1992 SOURCE: LANDSAT TM: MARCH 1992 FAP 19 ISPAN SHEET 5	FAP 21/22 BANK PROTECTION & RIVER TRAINING/ AFPM PILOT PROJECT	
	INTERIM REPORT	FIG: 2.1-10

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2.2 RECONFIRMATION OF TEST AREAS

2.2.1 Morphological Studies for Pre-selected Areas

In the Technical Report No.1 (Consulting Consortium FAP 21/22, 1992) the following areas for test river training structures were pre-selected:

- Kamarjani
- Bahadurabad
- Chandanbaisa
- Nakalia.

The pre-selection was based on various criteria, one of them being the certainty-of-attack criterion. At the moment of pre-selection of the different areas only limited information was available on the recent developments in the river system. Since then more information on these recent developments became available over the last months as a result of the remote sensing study, described in more detail in Annex 2. Hence it is possible to evaluate the certainty-of-attack criterion in more detail based on information (in particular satellite images) on the recent behaviour of the river system near the proposed test areas.

The most recent planform data is the satellite image of 8 March 1992. Information on the most recent bank erosion rates are obtained from a comparison of this image with previous ones, notably 1991 for the areas downstream of Bahadurabad and 1989 for Kamarjani and Bahadurabad. In the Fig.s 2.2-1 through and including 2.2-4 this recent information is provided (see end of Section 2.2). On the right hand side of these figures the 1992 planform during low flow conditions is presented. Here the following colour code is sued:

- blue : water
- grey : bare land
- orange : sand
- green : vegetation

On the left hand side the results of a comparison of the planform with the previous years is made. The years over which this comparison extends is indicated below the figure. The colour code which is applicable to these images with temporal changes is explained in detail in Annex 2 (see Table 2.1-3 of that Annex). Here it suffices to indicate that erosion is indicated by pink, salmon rose and red colours. Light colours usually indicate sedimentation.

Older satellite images either were already available or were also obtained via purchase or otherwise. This resulted in an almost complete coverage of the Brahmaputra/Jamuna River in Bangladesh since 1973. Overviewing the images available (for more details see

Annex 2, Table 2.1-1), it can be stated that out of a period of 20 low-water seasons (1972/73 through 1991/92) 15 images became available, notably;

- 1972/73
- 1975/76 through 1979/80 (5 consecutive low-water seasons);
- 1982/83 through 1986/87 (5 consecutive low-water seasons);
- 1988/89 through 1991/92 (4 consecutive low-water seasons);

hence including three periods with fairly long records of 4 to 5 years. For two intervals no images were available (1973/74 through 1974/75 and 1980/81 through 1981/82), while the 1987/88 was finally not purchased to allow for the processing of the latest years. In fact the 1987/1988 image is the only image available but not obtained. For all other missing years simply no image is available for the low flow season.

Based on the above information, possible future developments at the four test areas were evaluated in more detail. This was done in two steps. First the historical developments were reviewed at each of the four areas. Next an estimate was made of the development to be expected over the coming years. This was done using the presently available understanding of the morphological processes in the Jamuna River. This understanding comprises in particular preliminary prediction methods regarding (1) bank erosion rates as function of the relative curvature of a bend, and (2) improved insight in the factors determining the occurrence of cutoffs. More information on these preliminary prediction methods is provided in Annex 2, Chapter 3.

Details on this evaluation of the morphological conditions at the four test areas are given in Annex 2, Chapter 4. The most interesting outcome of the analysis is a number of figures in which the possible future developments are indicated. These figures are included in Annex 2 as Fig.s 4.3-1 through 4.3-4. Fig.s 2.3.2-1 through 2.3.2-4 in the following section of this report show the results for the pre-selected areas in enlarged scale. In the following the possible developments and the probability that in some years from now there will still be bank erosion in the test areas is evaluated.

(1) Kamarjani

The conditions at Kamarjani were characterized by two channels eroding on both sides. The western channel has caused a lot of erosion over the last years, corresponding to an average bank erosion rate of about 250 m per year. Over the last years a mid-char channel has developed that appears to take over the conveying function of the eastern channel. In due time this may lead to a reduction of the importance of the western channel near Kamarjani. There is also a small risk of a cutoff. It is concluded that with a 75% probability the bank erosion near Kamarjani will continue at least until 1995. It is felt that the high bank erosion rate will hardly decelerate. As a consequence it may be expected that the Manos regulator will be eroded away before a test structure can be built.

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Developments after 1995 are increasingly difficult to predict, but it is estimated that the bank erosion will still continue, although probably at a slightly lesser rate. For more details reference is made to Subsection 4.3.2 of Annex 2.

(2) Bahadurabad

At Bahadurabad the erosion upstream of the ferry ghat has stopped. The channel that was responsible for this erosion is silting up now. This is due to a change in the upstream bifurcation. Downstream of Bahadurabad substantial erosion is going on, with rates up to about 500 m per year. Upstream of Bahadurabad two bends are present that have developed fair bends. The resulting bank erosion is supposed to continue over the coming years. This may lead to a cutoff, that may take place before or in the year 1995 with a high probability. It is not certain that this will result in a decrease of the bank erosion downstream of Bahadurabad, but considering observed planform characteristics in the past it seems that the possibility is there.

It is concluded that the probability of continuing bank erosion downstream of Bahadurabad is estimated at 75% until 1995 and at lesser rate until 1997. For more details reference is made to Subsection 4.3.3 of Annex 2.

(3) Chandanbaisa

Over the recent years there has been some erosion at Chandanbaisa. Due to a change in direction of the attack by the river, and the resulting coalescing of islands this bank erosion will probably not continue. A mid-bar channel upstream of Chandanbaisa seems to gain importance. Because it is directed towards the western bank this channel may induce bank erosion in the test area. The bend near Madarganj on the left hand side opposite of Chandanbaisa will probably be cut off in 1992 or 1993. The possibility exists (50%) that this will induce the flow to shift gradually from the western to the eastern bank.

The possibility of bank erosion at Chandanbaisa after the 1992/1993 floods, owing to the further development of the mid-bar channel and considering the possible shift to the eastern side, is estimated to be about 50%. For more details reference is made to Subsection 4.3.4 of Annex 2.

(4) Nakalia

Over the last years there has been significant erosion along the test area near Nakalia, and according to recent information this erosion is also continuing in 1992. There are, however, a number of developments ongoing and foreseen that may lead to a reduction and eventually even a stopping of the bank erosion near Nakalia. A major opposite bend will be short cutted soon and this may induce another short cut more upstream. This may lead to a reduction of the discharge and hence the erosive force of the western channel. Another upstream development may also lead to a reduction of the bank erosion.

Based on the above observations, it is expected that the bank erosion at Nakalia will continue to reduce and may stop (with a 50% probability) in 1994. For ore details reference is made to Subsection 4.3.5 of Annex 2.

In summary it can be stated that none of the pre-selected test areas completely fulfills the 100% certainty-of-attack criterion. This includes the possibility that for any test area there is some risk involved that the test structures will not be attacked during the testing period. This risk is lowest for Kamarjani and Bahadurabad, and larger for Chandanbaisa and Nakalia. In terms of the ranking of the test areas as done as part of Technical Report No.1, the marks given for the four test areas were looked upon again on the basis of the latest insight. The result is given in Table 2.2-1 below:

Test Area	Marking certainty-of-attack criterion		
	Maximum marking	Marking Technical Report No.1 (March'92)	Marking Interim Report (July 1992)
Kamarjani	9	7	6
Bahadurabad	9	8	5
Chandanbaisa	9	8	4
Nakalia	9	5	2

Table 2.2-1: Marking certainty-of-attack for pre-selected test areas

2.2.2 Other Possible Areas

As has become clear from the previous section, in none of the pre-selected test areas the certainty-of-attack criterion is completely fulfilled. It even appears that, based on the latest information on the planform development of the Jamuna River over the recent past, the probability that in due time erosion will occur at the various test areas is now rated less than during the preparation of Technical Report No.1. It is therefore a logical step to study the present planform of the Jamuna River and to try to identify areas where the certainty-of-attack criterion scores higher. Such a study was carried out by the Consultant and two of such areas were identified, notably Kazipur and Chauhali. These are discussed below.

(1) Kazipur

Already in Technical Report No.1 Kazipur was identified as one of the more promising test areas. It had been discarded, however, for non technical reasons. According to the recent satellite images (in fact the images of 1989, 1990, 1991 and 1992 were studied) it is clear that there is continuous erosion near Kazipur. It seems that the location of the erosion is slowly moving downstream with an estimated celerity of some 500 m per year.

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Near Kazipur the Jamuna river is divided in two reaches with a stable char in between. In the reach near Kazipur it seems possible to consider the river as a system of bars and channels that is moving in downstream direction. In terms of the discussion in Section 4.2 of Annex 2, it seems that here the bar approach can be applied fairly successfully which may help in selecting a test area. Also it may be an attractive site because the test structures can be built on char land and will later be exposed to the currents if the char has moved sufficiently in downstream direction. From point of view of the certainty-of-attack criterion Kazipur scores very highly and it is recommended to check if the non-technical reasons which led to excluding it as a test area still holds.

(2) Chauhali

The area is located on the left bank about 30 km upstream of Aricha, south of Chauhali. In this reach the river often forms large bends. It seems as if periods with a more braided pattern are interchanging with periods in which there is a tendency to meandering. The large bends that have been present in the reach downstream of Sirajganj during the more meandering phases, have been responsible for excessive bank erosion rates of up to one km a year. According to the Brahmaputra River Training Study, Interim Report No.2, Annex 4, the average life time of these bends is in the order of 5 years and as such they are one of the more permanent features of the river planform. If one of these bends would be identified in an early stage of development it would probably be a very good test site with a probability of more than 75% that bank erosion will occur in 1995 and later years.

It could well be that the reach near Chauhali is such an area. At present there is a quite developed bend slightly downstream and opposite of Nakalia but it may be expected that this bend will be cut off shortly. Upstream however, another bend seems to form and evaluating the future developments as is done in Subsection 4.3.5 of Annex 2 (see also Fig. 4.3-4), and it is expected that this bend will gradually increase in importance and will cause major erosion of the left bank. it is felt that this is potentially a good test area with possibly better prospects than all the other test areas considered now. The developments during the coming flood are important: if the formation of a bend is confirmed there is every reason to seriously consider this reach from the certainty-of-attack point of view. In terms of probability it is estimated that this reach has a probability of attack in 1995 and later years of also more than 75%. However, possibly the "something-to-defend" and the "accessibility" criteria may not be scoring high at that place. A further disadvantage of that area is its location downstream the planned Jamuna bridge site, a fact which may lead to additional uncertainties regarding the future morphological development.

Summarizing the following rating is proposed for these two areas as far as the certainty-of-attack criterion is concerned:

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Test Area	Marking certainty-of-attack criterion	
	Maximum marking	Marking Interim Report (July'92)
Kazipur	9	7
Chauhali	9	7

Table 2.2-2: Marking certainty-of-attack for alternative test areas

2.2.3 Present Ranking and Conclusions

In the previous sections marking of the test areas as far as the certainty-of-attack criterion is concerned were discussed based on (1) the most recent information on the planform of the Jamuna River and (2) the prediction of the future changes using preliminary results from the ongoing analysis of the satellite images. Considering the fact that the marking is substantially different for some of the areas, it seems appropriate to do a renewed ranking of the pre-selected test areas. This is done on the basis of the ranking of the shortlisted test areas as presented in Chapter 6 of Technical Report No.1. The results are given in Table 2.2-3.

Selection criterion	Maximum marks	Marking of pre-selected and alternative test areas					
		Pre-selected				Alternatives	
		Kamarjani	Bahadurabad	Chandanbaisa	Nakalia	Kazipur	Chauhali
Certainty-of-attack	9	6	5	4	2	7	7
Something to defend	6	3	4	4	3	3	?
Accesibility	3	2	3	2	3	2	1
Left bank	1	1	0	0	0	0	1
Availability of data	1	1	0	0	0	0	0
Total	20	13	12	10	8	12	9?

Table 2.2-3: Updated ranking of pre-selected test areas

The following remarks are made:

1. The something-to-defend criterion for Kamarjani has been kept as it is felt that the Manos regulator will not live until the test structures would be built.
2. The same criterion was reduced slightly for the Bahadurabad test area too, because the area to be protected is south of the railway terminal and not the terminal itself.

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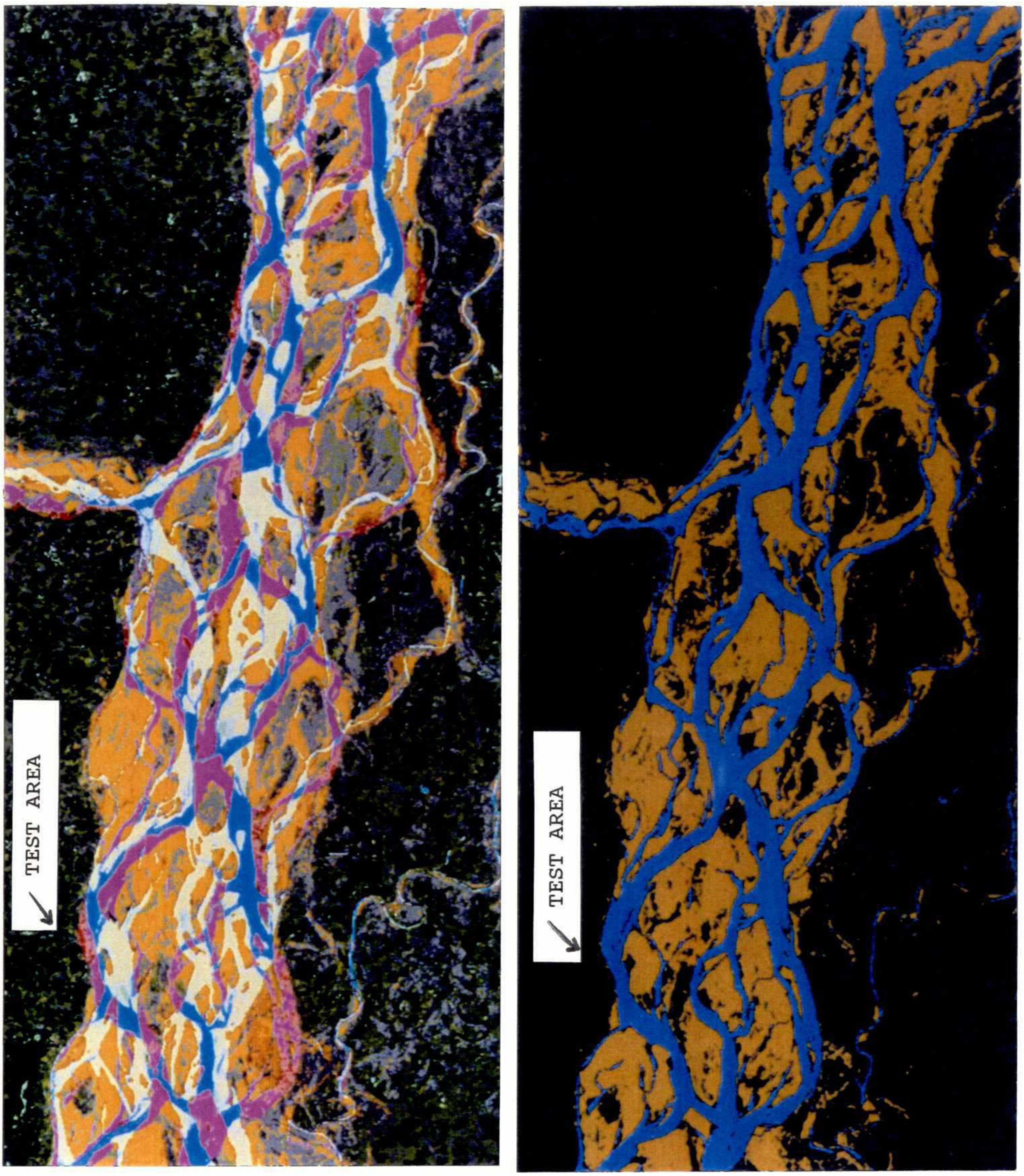
Furthermore the two alternative areas that were identified in the previous section as areas where the certainty-of-attack criterion scores very highly are also included in the above table. Some aspects cannot be evaluated at this very moment, but it appears that Kazipur ranks at least 3rd and Chauhali scores at least higher than Nakalia.

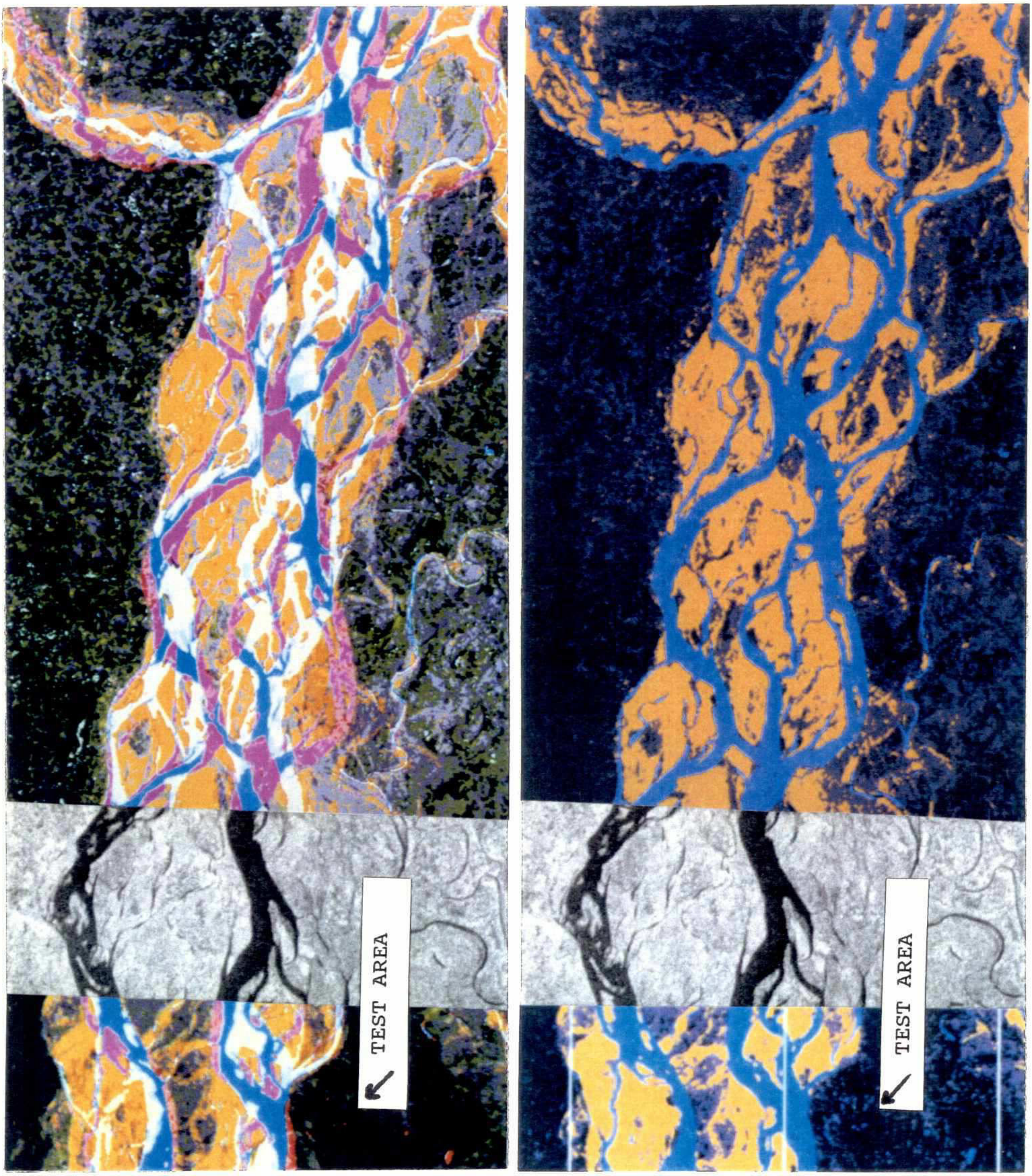
In conclusion the following can be stated as far as the re-confirmation of the pre-selected areas in concerned:

1. Based on the most recent information on the river's planform, generally speaking the certainty-of-attack criterion scores lower for all pre-selected areas than anticipated during the inception phase.
2. Still Bahadurabad and Kamarjani score fairly high, but the score for Chandanbaisa has reduced substantially.
3. The two other areas considered are worthwhile to be studied in more detail as far as their score for other criteria is concerned.
4. It is proposed and intended to check the predictions of future developments of the planform (as given in Annex 2) after the flood of 1992 to verify the prediction methods used and to reconfirm the selection of test areas in subsequent stages of the project (Test and Implementation Phase).



1989-1992 1992

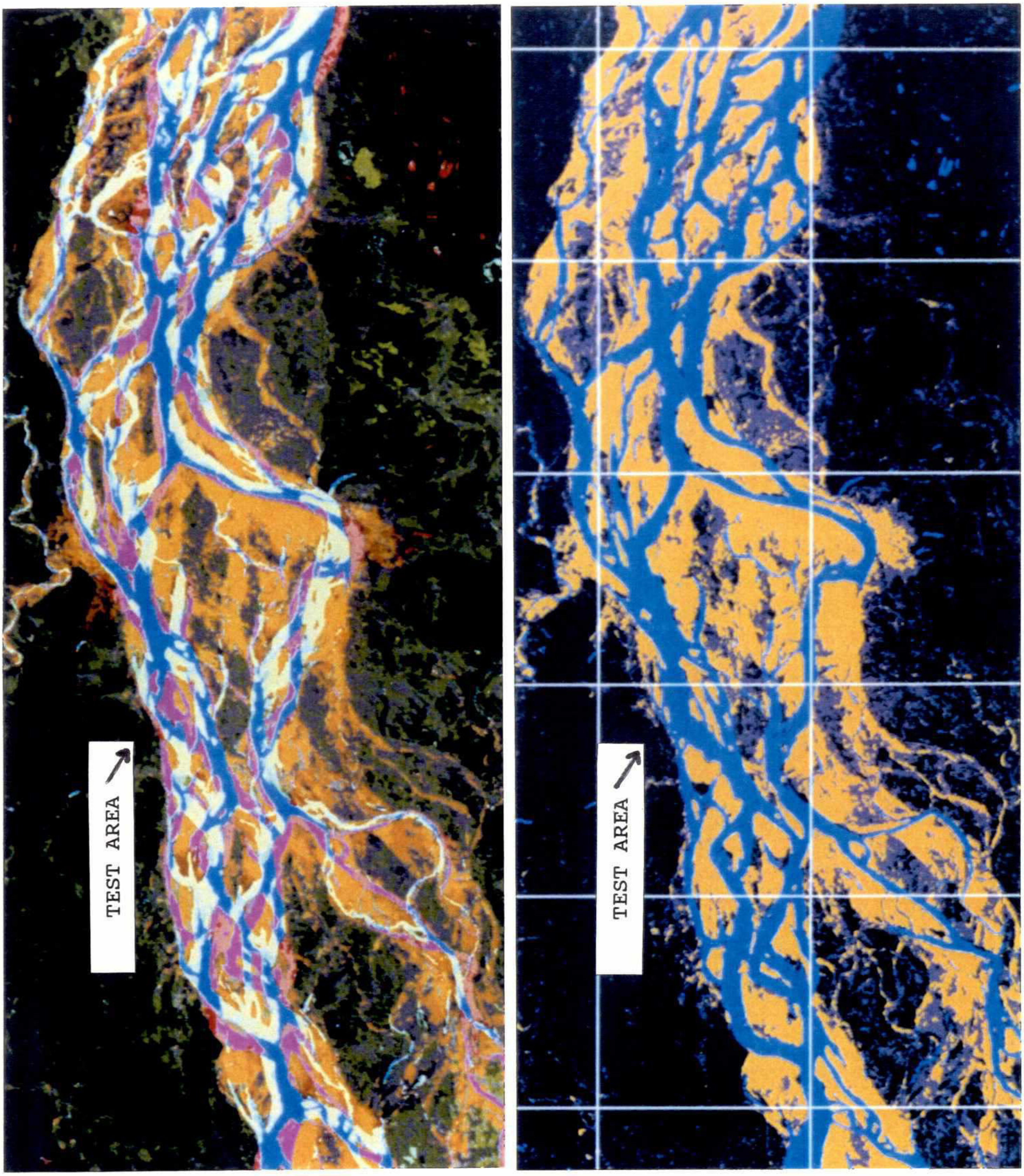
Fig. 2.2-1 Recent development and present planform at Kamarjani test area



1989-1992 (top)
1991-1992 (bottom)

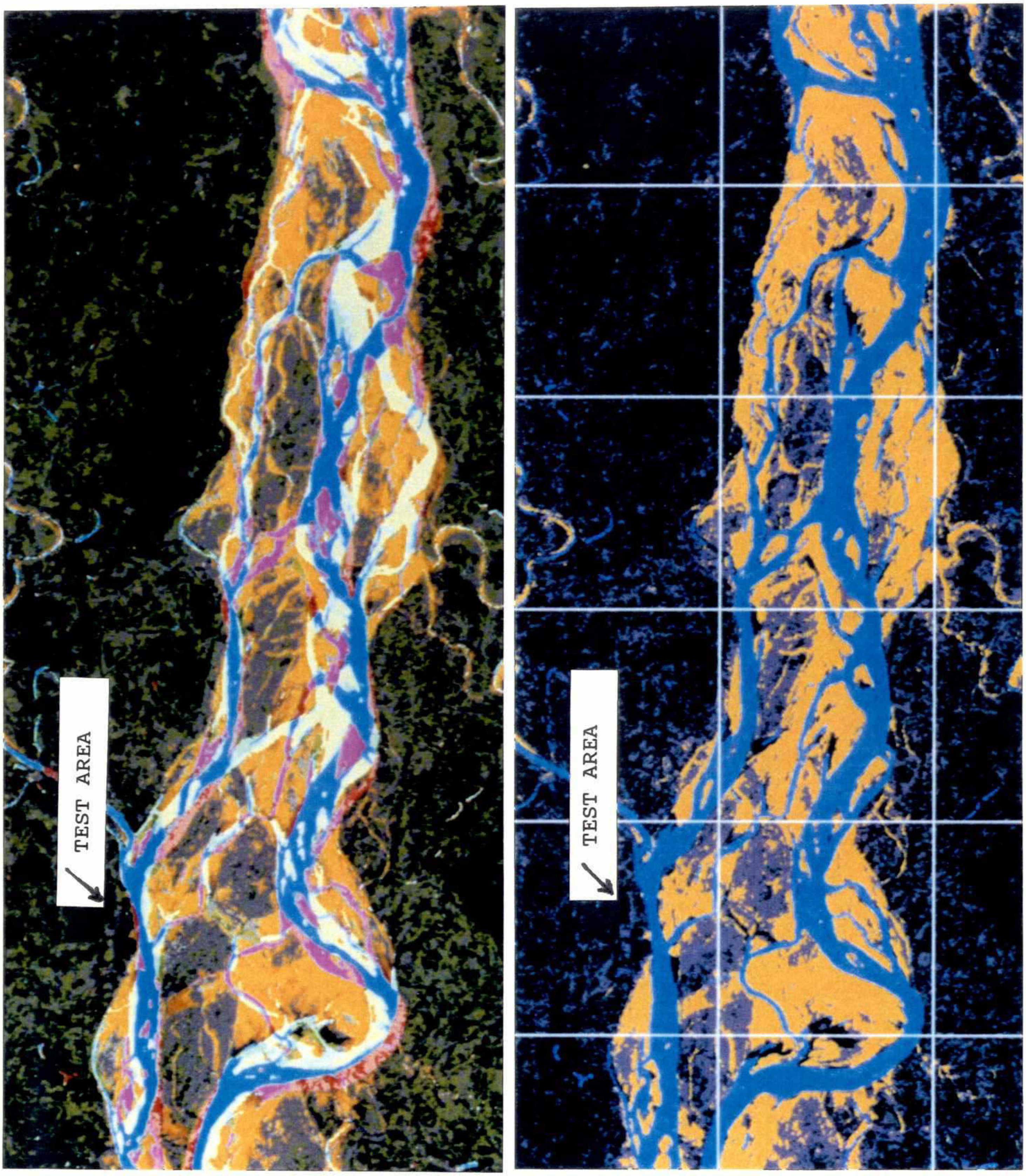
1992

Fig. 2.2-2 Recent development and present planform at Bahadurabad test area



1991-1992 1992

Fig. 2.2-3 Recent development and present planform at Chandanbaisa test area



1989-1992 1992

Fig. 2.2-4 Recent development and present planform at Nakalia test area

2.3 SELECTION OF TEST SITES

2.3.1 Criteria

The test sites are the locations where the test structures will be built. These test sites will be located within a test area, but the precise location still has to be fixed. Also for the selection of the test sites a number of criteria has to be used, conforming to what was done previously during the selection of the test areas. In principle some of these criteria are the same although applied now on a more local scale, but once the test areas are selected some other criteria lose their relevance. This holds for the following criteria (see Technical Report No.1, Chapter 3): (a) "left bank" criterion, (b) "availability of data" criterion, and (c) "no interference" criterion.

This leaves the following (re-numbered) criteria as relevant for the site selection:

1. "certainty-of-attack" criterion,
2. "something to defend" criterion,
3. "accessibility" criterion,
4. "constructional" criterion,
5. "helping the river" criterion.

In view of the anticipated problems at Kazipur (see Section 5.9 of Technical Report No.1) it is wise to include a further criterion, notably:

6. "acceptance" criterion.

In the following the criteria relevant for the selection of test sites are elaborated in some detail, using also essentials from the Technical Report No.1.

Re (1) "Certainty-of-attack" criterion:
Because the test structures should be subjected to flow attack in order to gain experience and check the design parameters under the prevailing circumstances, the probability that they will be attacked should be maximal. This implies that test areas should be selected which after construction will be subjected to erosion. This criterion can result in several optional suggestions for locations to be selected:

(a) locations that presently are being eroded,
(b) locations that are always eroding,
(c) locations that are presently not eroding but that according to predictions of the future morphological behaviour will erode after some years.

Regarding option (a) it can be stated that present bank erosion is definitely not guaranteeing future erosion. Reaches that are eroding very fast, notably eroding of outer banks (see Klaassen & Masselink, 1992) are very often subject to a cutoff after a few years, causing the bank erosion to stop suddenly. Hence presently eroding outer bends are not necessarily attractive locations for test structures.

Regarding option (b) the following is relevant. It appears that there are certain preferred locations where channels are present very regularly. If these channels are fairly straight usually a system of channels and chars develop. The bank erosion along these channels is characterized by alternating bank erosion and no bank erosion. The reason for the occurrence of such a system is the fact that the Jamuna River is "too wide". Such a straight channel with a system of chars and channels is probably one of planforms with the most predictable bank erosion phenomena in the Jamuna River.

Regarding option (c) the following remarks are made:

- Prediction of where in the future outer bends will occur, is extremely difficult (see Klaassen & Masselink, 1992)
- There appears to be some periodicity in the location where most of the conveyance of the river is concentrated. Because such a periodicity cannot be proven univocally, counting too much on it may be too risky.

Re (2) "Something-to-defend" criterion:
It has been stressed in the previous reports that the prime objective of the Project is the testing of alternative structural solutions for optimizing bank protection works, using most cost efficient design solutions. For assessing possible failure mechanisms which cannot be found if the structure is designed absolutely safe, certain damages will be desirable. It was for this reason that it was decided to have test structures not at places where essential objects have to be protected on top priority basis.

Nevertheless it is reasonable to choose sites where infrastructures existing or to come will benefit from the measures undertaken. The risk of total failure shall be minimized - if not excluded - because damages will have to be detected early during monitoring inspections and will be repaired immediately. Even unsuccessful structures can be converted to permanent protection with less effort and financial input than starting from scrap.

Re (3) "Accessibility" criterion:
Access to the test sites throughout the year is essential for the construction of test structures with reasonable cost and particularly also for proper monitoring during all flood and dry season conditions. If required, also repair and/or adaptation works have to be carried out at short notice.

The volume and desired quality of work to be organized and completed during one dry season requires movement of heavy equipment and continuous material supply, which can only be enabled through at least reasonably good road or railway access and good logistic arrangements. The same holds good for necessary repairs after the monsoon time. For certain structures (e.g. groynes) or with special precautions (e.g. for bank revetment works) it might be possible to carry out the works in two seasons, but this will not only increase the overall cost (double mobilization) but also reduce the period available for monitoring.

Monitoring of the behaviour of the test structures fulfills no purpose if done during fair season only. It is especially and above all required during periods of extreme discharge conditions and thus the test sites must be accessible even during worst conditions.

Re (4) "Constructional" criterion:
Construction of bank protection works, both for groynes and for revetments, can be done either in flowing water conditions or in stagnant water or in the dry.

Construction in dry conditions will only be possible (for technical and economic reasons) above water level.

Construction in flowing water has several definite disadvantages:

- Loss of building materials (e.g. sand spoil to be placed on slopes or for groyne cores), which can only be minimized by using gunny bags or other "hard" materials as protection, thus increasing costs considerably.
- Difficulties for placing filter layers under current and wave action, which require special and heavy equipment for laying and sinking of geotextiles as well as larger overlappings. Effective placing of granular filter layers is impossible.
- Difficulties for placing of protective layers accurately and uniformly. Hence a larger safety margin has to be accepted resulting in higher costs.
- Due to the increase in velocities also the safety of the vessels used during the construction may be endangered and need special precautions.

In view of this the Consultant has strong preference to construct the test structures in stagnant water, however, some portions may still be erected in flowing water in order to test also construction methods under such conditions and prepare guidance lines for future work.

Another aspect is whether the test structures should be built on the flood plain or partly on char land. Building on a char has an advantage as far as the certainty-of-attack criterion is concerned, but the up and downstream terminations against outflanking will become rather difficult and costly, as the river bed will have to be crossed for joining higher land structures. Erection completely on a char makes little sense considering Criteria (2) and (3). Thus this option will be excluded.

Subsoil conditions are normally a very important factor in selecting the site for a certain structure but here are less decisive, as they are more or less uniform over the areas chosen for other reasons.

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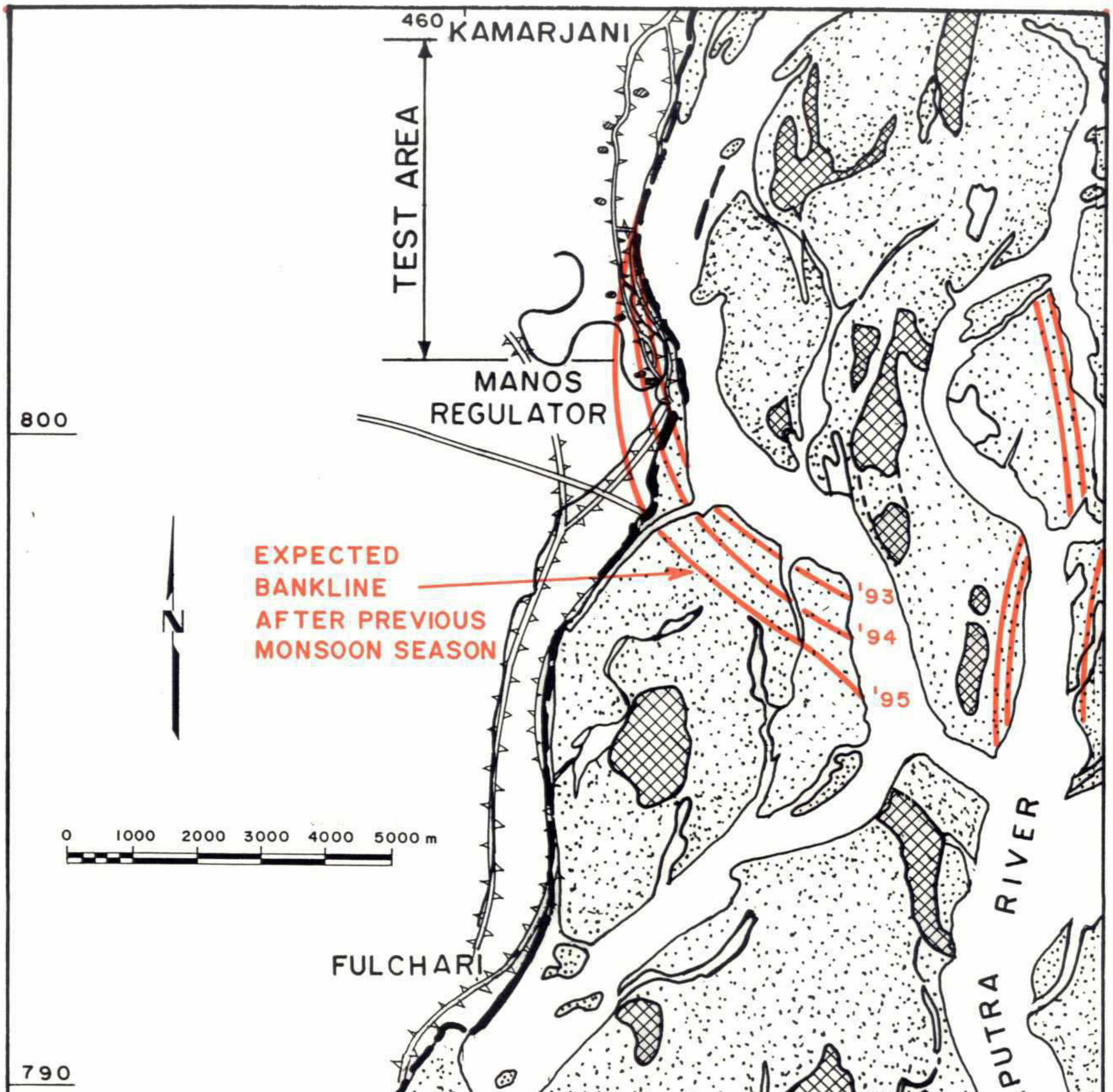
Re (5) "Helping the river" criterion:
Although the test areas are selected with utmost care and using the most up-to-date understanding of a braided river like the Jamuna River, nevertheless there remains still the (small) risk that the river will not attack the test structures because of unexpected changes in the local channel pattern. In some cases in may then be possible to "help" the river slightly. In this respect it may be useful to point out the option that a possible pilot project for FAP 22 could be used to induce a development in the river system favouring attack of the test structures. In this respect some reaches are more attractive if the need to "help" the river would arise than others. There is a certain preference for reaches where more (and hence smaller) channels are present, because this would reduce the costs of forcing the river into another channel pattern.

Re (6) "Acceptance" criterion:
This criterion, although dealt with last, will nevertheless be important as human feelings and needs cannot be neglected. In this connection Section 9.9 of the Technical Report No.1 regarding Kazipur is referred to, where ressentiments of the local population have been pointed out against structures which are not designed for stability under all conditions. Furthermore, existing buildings, settlements, land ownership and use etc. have to be regarded for already at this stage but will be further taken up by the Sociologist lateron.

2.3.2 Prediction of Future Morphological Changes

As explained in Subsection 2.2.1 possible future developments of the planform of the Jamuna River in the test areas were predicted, applying presently available knowledge on morphological processes in this river. Use was made of the preliminary results of the remote sensing study and earlier results obtained from studies carried out within the frame-work of the Jamuna Bridge Project (see RPT/NEDECO/BCL (1990) and Klaassen & Masselink (1982). Some background information on this prediction is provided in Annex 2.

The result of these predictions is a number of maps in which the future developments are indicated and where also the location of the expected bank erosion over the coming years is indicated. These maps are presented in Annex 2 as Fig.s 4.3-1 to 4.3-4. These maps are used as a guide line for site selection. Enlarged copies of these maps are presented as Fig.s 2.3.2-1 through 2.3.2-4 hereinafter on a scale 1:100,000.



KAMARJANI AREA
EXPECTED BANK EROSION
SCALE: 1:100000

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BANK PROTECTION AND RIVER TRAINING/
(AFPM) PILOT PROJECT

INTERIM REPORT | FIG. 2.3.2-1

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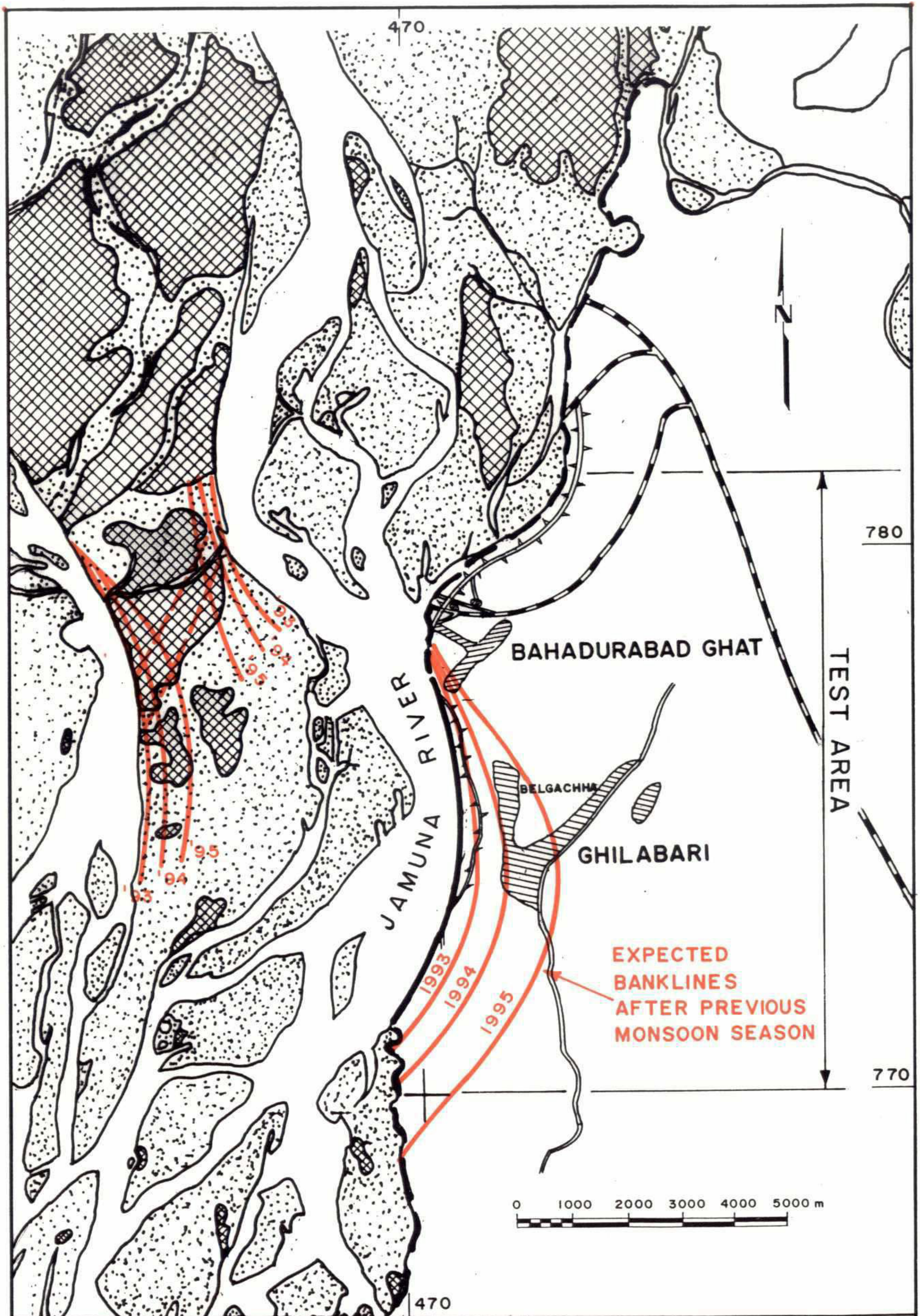


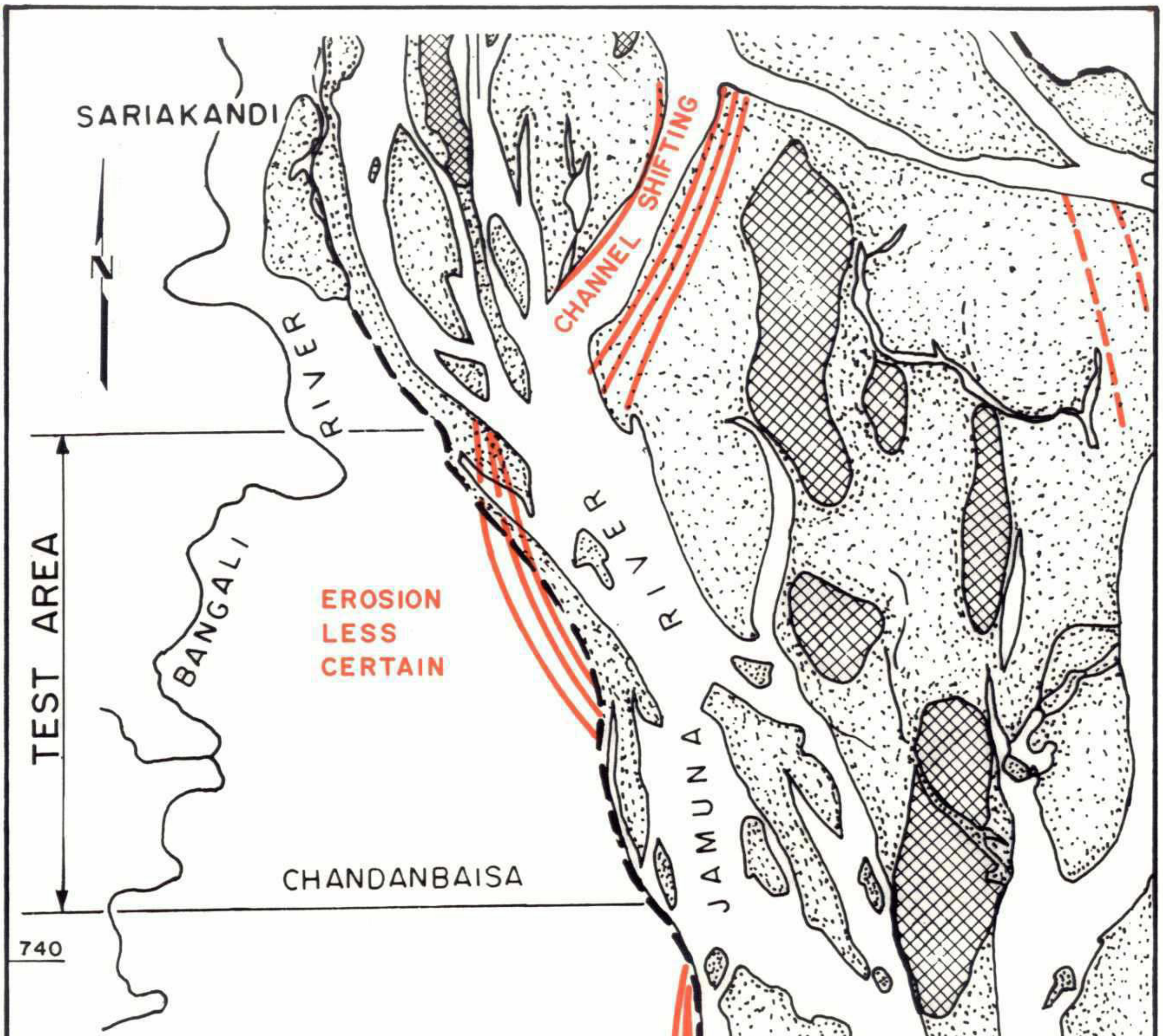
BAHADURABAD AREA
EXPECTED BANK EROSION

SCALE. 1 : 100000

FAP – 21/22

BANK PROTECTION AND RIVER TRAINING/
(AFPM) PILOT PROJECT

INTERIM REPORT | FIG. 2.3.2 – 2



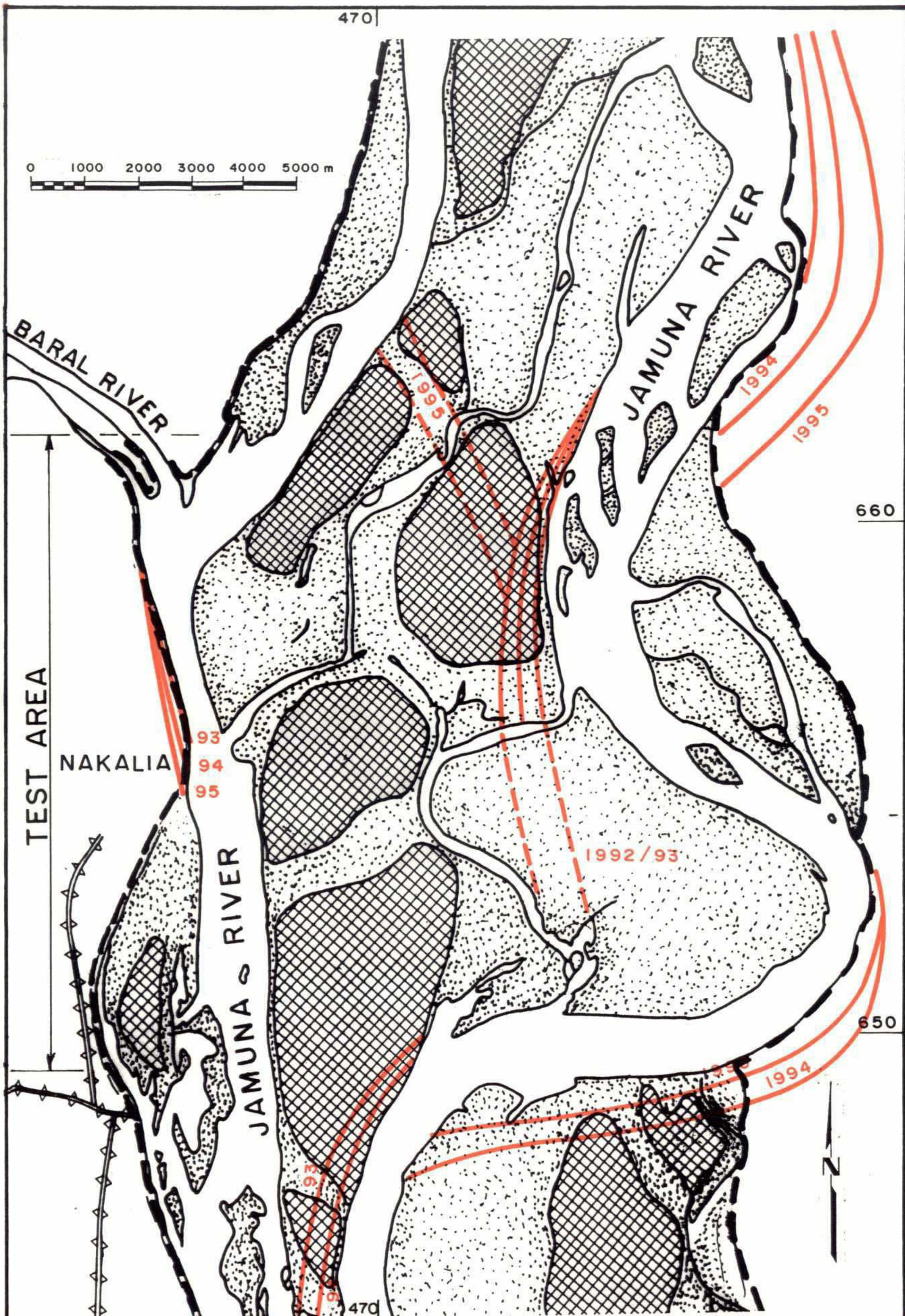
CHANDANBAISA AREA
EXPECTED BANK EROSION

SCALE: 1:100000

FAP - 21/22
BANK PROTECTION AND RIVER TRAINING/
(AFPM) PILOT PROJECT

INTERIM REPORT | FIG. 2.3.2 - 3

43



NAKALIA AREA EXPECTED BANK EROSION SCALE. 1 : 100000	FAP - 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	INTERIM REPORT	FIG. 2.3.2-4

It should be remarked that the predictions made are to be considered as tentative only. In a later stage of the project improved predictions will be made, because (1) by then the understanding of planform changes in the Jamuna River will have increased thanks to the remote sensing study, and (2) because more recent information on planform changes since March 1992 will be available, allowing for a better estimate of the future developments.

2.3.3 Aspects from Field Investigations

(1) Topographic and Hydrographic Surveys

Considerable erosion has been observed during the whole survey campaign at all four test areas, especially at Kamarjani/Manos and at Bahadurabad. Since the surveys cover limited river stretches at a certain moment only, and no other surveys on a similar scale are available for comparison, a judgement of the morphological occurrence cannot be derived from these unique surveys. They have to be understood as a more detailed representation of the most recent situation at the test sites on a larger scale for model testing and preliminary design of test structures.

In view of the final selection of the test sites, the following aspects were considered for the surveys:

- survey area large enough to permit planning flexibility
- inclusion of structures, buildings and other features influencing the site selection
- inclusion of the existing embankments and the actual shape of the river banks for planning purposes.

(2) Subsoil Investigations

Subsoil investigations were carried out at the 4 pre-selected test areas at about 2 km distance. The results have shown that the material becomes generally more coarse with increasing depth, whereas predominant silty and partly clayey material exists in the upper 3-5 m below surface. Standard Penetration Tests are low and hardly exceed 30 blows/ft up to a depth of 20 m, Chandanbaisa ranks slightly above the other areas in this respect. However, major differences within one area could not be found, which could justify preference to a particular site. Some results are given in Annex 8 for reference.

As laboratory tests have just been received or are not completed yet, no detailed analysis can be made in this report.

2.3.4 Types of Structures to be Tested

(1) Objectives

The objectives to be achieved are to develop and optimize design criteria as well as cost-effective and labour intensive construction and maintenance methods using locally available materials as far as feasible. Thus different types of protective works have to be designed, using different materials and design principles/methods and applying different geometries and safety levels for structures. Physical model testing will assist in this aim and make sure that the limited resources available will be used in the most effective way.

(2) Design Considerations

Some principles as applicable to the test structures can already be established already now, before having completed the study on design criteria:

a. The crest level of structures should be above high flood level (HFL, 1:100 years return period) so as to meet the Criterion (3) for accessibility even under worst conditions (see Subsection 2.3.1), although the structures are not intended to provide flood protection.

b. Use of imported geotextile filters will not totally be avoidable because of the most unfavourable soil conditions on the Jamuna and difficulties in proper placing granular filter under water. This has been proven be several failures of structures built in the past, partly attributed to this effect. However, all efforts will be undertaken to use local jute material wherever feasible. Moreover it is only logical that local industries with foreign help will be established soon which should be able to produce suitable geotextiles, considering the huge demand of this product in Bangladesh due to the country's natural conditions.

   The Consultant intends to have a workshop/seminar on the design and construction of filters for hydraulic engineering, with the participation of his specialist on this field. On this seminar, which is tentatively envisaged for the second week of September, the following main issues shall be discussed

   - design of granular and geotextile filters
   - demand on durability of filters
   - methods of placing granular and geotextile filters in stagnant and flowing water
   - utilization of geojute as alternative and or supplement to conventional geotextiles.

c. Use of heavy equipment will be restricted as far as possible and manual methods used instead. However, the necessity to complete the structures within one fair season puts certain limitations to this intention. Otherwise, large amount of investment may be lost if the flood attacks uncompleted structures or parts of it. Examples thereof are listed in Table 5.3-1. Moreover, the objectives of FAP 21 are then highly endangered.

d. Scour depths will be predicted using past experience and all available design tools, including latest scientific investigations (see Annex 3). In this connection also designs of other FAP-projects are being studied. Already now it becomes obvious that there exist different opinions and design approaches, resulting in different scour depth predictions (e.g. FAP 1/FAP 9B).

There is also another consideration to be made. On the right bank of the Jamuna River several priority works are proposed which may be considered as special design for important hard points. FAP 21 test structures are, however, intended for general bank protection and may not have the same safety level. It is intended to use the designed scour depths for BRE Priority Works of 29 m below HFL as the upper limit applicable for our test structures. The subject will be, however, further investigated and may have to be revised lateron.

e. It is common practice on the subcontinent and recognized standard to use a falling (or launching) apron as toe protection against scours developing as a result of the artificial hard structures in eroding soils. This method avoids costly excavations up to the expected scour depth and extending the slope revetment to such depth (leaving also no flexibility in case of predictions falling short). Therefore, falling aprons will also be used here. However, the design of such toe protection leaves several options and there actual behaviour can only be judged by tests. Hence different designs (width, heights, shape, material) will be incorporated in the test structures as well.

(3) Groynes

The inclusion of groynes (or spurs) in the test structures is a requirement of the Terms of Reference. There exists some preference for such structures in Bangladesh, although only single groynes have been built in the Jamuna River with varying success. With one exception (Saliabari T-head groyne) only straight (bellmouth shape) structures have been executed for cost reasons (vide also Table 5.3-1). However, their effectivity for bank protection becomes obvious only if constructed in series with minimum three numbers. Their benefit depends very much on a proper spacing, in relation to the width of the channel, the flow direction, whether in a straight, convex or concave planform curve, its length protruding from the embankment and other factors, with their influences not easily predictable.

On the other hand, cost effectiveness in comparison to a bank revetment parallel to the river flow depends on the spacing and length of the groynes, which are usually to be built into the river channel, involving great logistical efforts and management capabilities. Incomplete structures meeting unexpected floods can result in a complete failure. According to some investigations groynes are costlier than bank revetments in most cases, for the prevailing conditions.

Groynes can be of solid or permeable type, but both should be designed to withstand the flood action. For that reason permeable structures of pier type would require quite deep pile driving. Stone walls would need heavy unit weights and will silt up quickly. Thus permeable structures are at present not considered here but will most likely be suitable for recurrent measures only.

Direction of groynes should be with an angle towards the flow current (repelling groyne) to obtain best results for protection/siltation of the stretches in between. They must also be connected to an embankment and the upstream connection point needs special protection being exposed directly to the current.

Other considerations were discussed in para (2) above. Further design criteria will have to be investigated in the physical model tests.

Finally, reference should be made to the experiences on the Yangtze Kiang river where with some very few exceptions groynes are not utilized. For that exclusion the following reasons were given:

- groynes can be dangerous to navigation
- groynes are not suitable (since too expensive) at large water depths
- groynes are not suitable in rivers with fine sand as bed material due to the risks of failure by deep scours or too high cost for preventing that failure.

The Consultant will look in detail into these arguments particularly since the last two arguments would be true for the Jamuna as well. May be a probabilistic design approach could give further evidence whether or not groynes should be taken into consideration for construction.

(4) Bank Revetments

Revetments for sloped bank protection are the most common measure for this purpose, although not yet used at the jamuna River on a large scale. It is supposed to be also the most cost effective measure, vide para (3) above, but this point will have to be further elaborated by the Consultant.

T.P.

Several alternatives regarding filter and armour (top) layer as well as toe protection (falling apron) design shall be tested. This involves also different dredging depths for the placing of falling apron, i.e. at river bed level and deeper, facilitating different scour depths but limited by the capacity of dredgers available in Bangladesh.

Scour cannot be expected uniformly over the full length of the structure, but it will depend on the direction of the approaching flow (angle towards the bank line), the length of the structure and the possibility of shifting flow e.g. downstream.

The ends or termination points must be carefully secured in order to avoid outflanking of the structure; particularly the upstream termination structure will have to be protected as heavy as the main river bank. For cost reasons all test alternatives may be arranged in one line, thus avoiding double termination points.

There are several options for the position of the test structure in relation to the river channel, if constructed on the flood plain (see Criterion 4 in Subsection 2.3.1), as shown in Fig. 2.3.4-1.

— Jack - permanent groynes,

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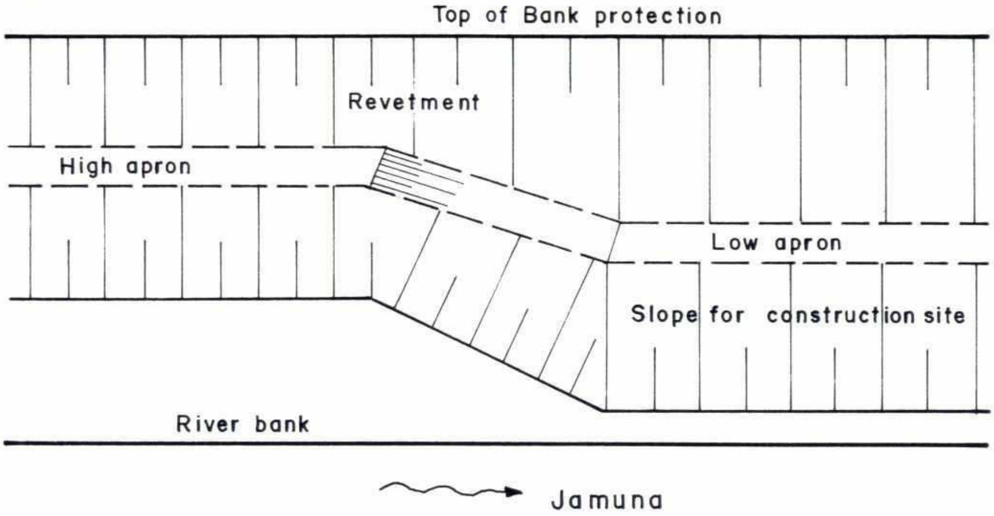
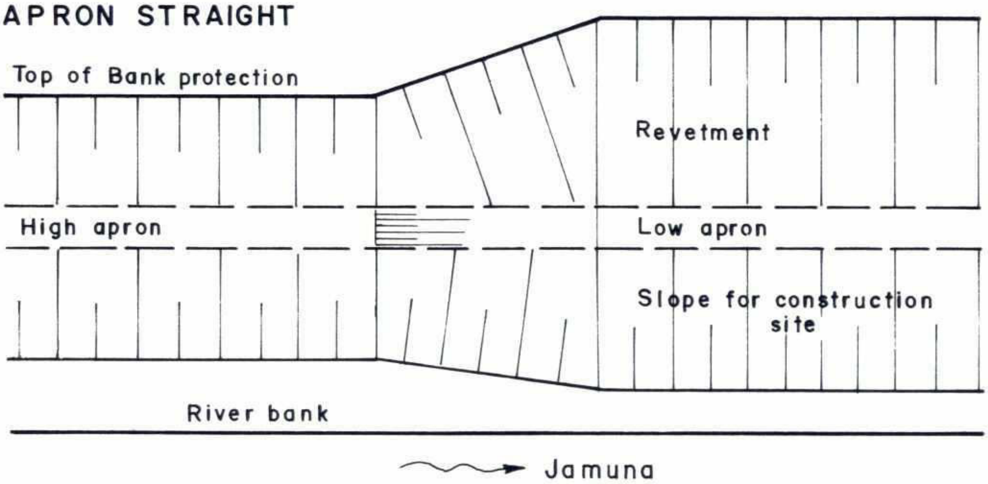
TOP STRAIGHT



Not clear

APRON STRAIGHT



PRINCIPLE DREDGING POSSIBILITIES FOR REVETMENT CONSTRUCTION ON FLOOD PLAIN	FAP-21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	INTERIM REPORT	FIG. 2.3.4-1

In both cases reverse flow direction could be possible, leading to 4 possibilities for execution. Advantages/disadvantages are still to be investigated and may also be examined in the physical model.

Special attention will also have to be given to the transition zones between the individual revetment types, ensuring that the change is smooth and gives no target for current attack.

2.3.5 Conclusions

1. As a first approach and following the Terms of Reference both groynes and bank revetments are foreseen to be tested and first rough cost estimates are made accordingly (see Chapter 4). This matter will, however, be further investigated in view of the doubts raised in para (3) of Subsection 2.3.4. Final proposal will be made in the Final Report, also including the results of the physical model tests.

2. Two test areas have been finally proposed, viz. Kamarjani and Bahadurabad (see Subsection 2.2.3). As can be seen from Fig.s 2.3.2-1 and -2, similar planform concave river bends are expected there with slightly different curvature. As concluded from Subsection 2.2.2, other areas threatened have similar geometry. Hence the selected locations are typical and the results obtained are expected to be applicable for general use.

different shape as per TOR

3. It is proposed to construct at Kamarjani a set of three groynes. The layout of groynes is somewhat more flexible for protecting the Manos regulator structure situated just south of the prospective test site. The same is applicable if this may have to be rebuilt, behind the present bank line. The morphological investigations and the tentative forecasts for Kamarjani show reasons to expect the loss of the Manos river regulator in the next 2 floods, see Subsection 4.3.2 of Annex 2.

   The location of the proposed test site may be seen from Fig. 2.3.5-1. It fulfills all the criteria set out in Subsection 2.3.1 as highlighted in the following:

Criteria		Kamarjani features
1- Certainty of attack	:	see Subsection 2.2.3
2- Something to defend	:	Manos regulator
3- Accessibility	:	Road up to regulator
4- Constructional	:	Both options, construction in stagnant and flowing water will be followed
5- Helping the river	:	Recurrent measures on opposite char possible
6- Acceptance	:	No resistance anticipated.

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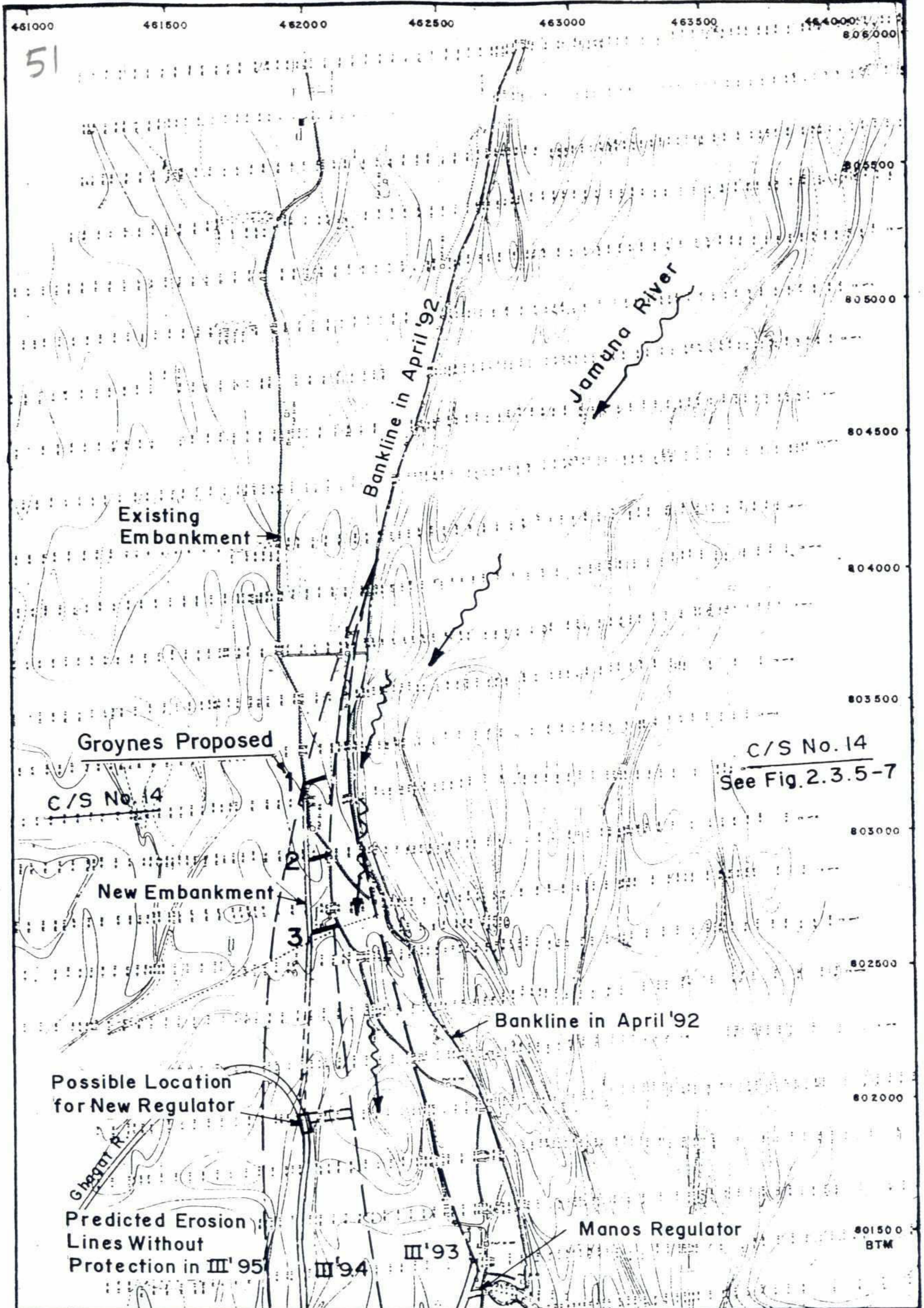


TEST SITE KAMARJANI 1: 20 000	FAP - 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	INTERIM REPORT	FIG. 2.3.5 - 1

A typical cross-section through flood plain and river channel is drawn on Fig. 2.3.5-7, showing the situation as in April 1992. As predicted in Subsection 2.3.2 (Fig. 2.3.2-1), the bank will have receded in this area by about 50 m after the monsoon season 1993 (see also Fig. 5.3.5-1). This will be the situation at the anticipated commencement of construction works in autumn 1993.

The approximate layout of groynes to protect further erosion is shown on Fig. 5.3.5-1, including the connection to and extension of existing embankments.

A typical longitudinal section through a groyne as used for preliminary cost estimates is shown in Fig. 2.3.5-2 below:

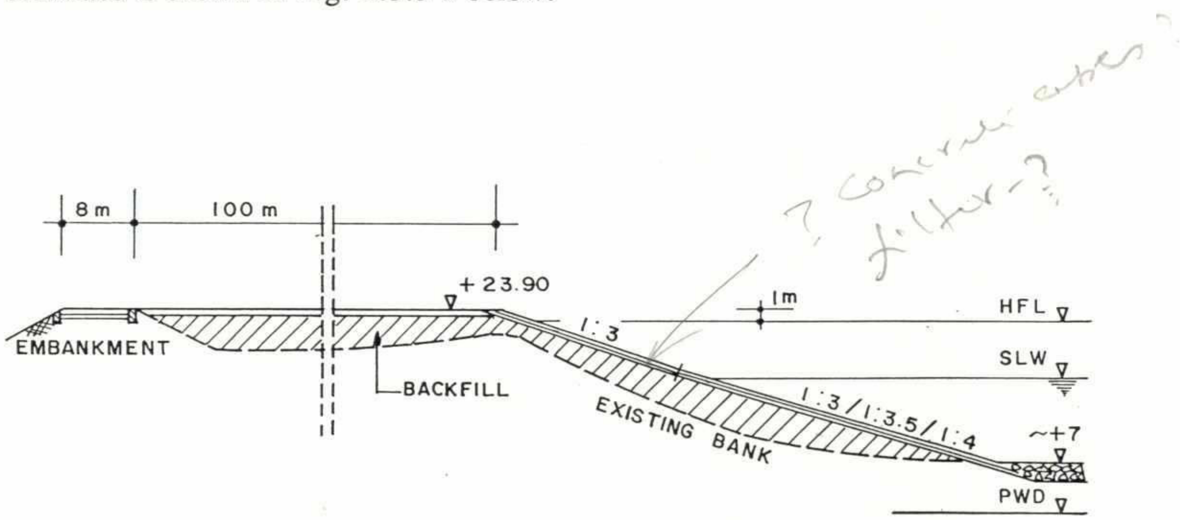
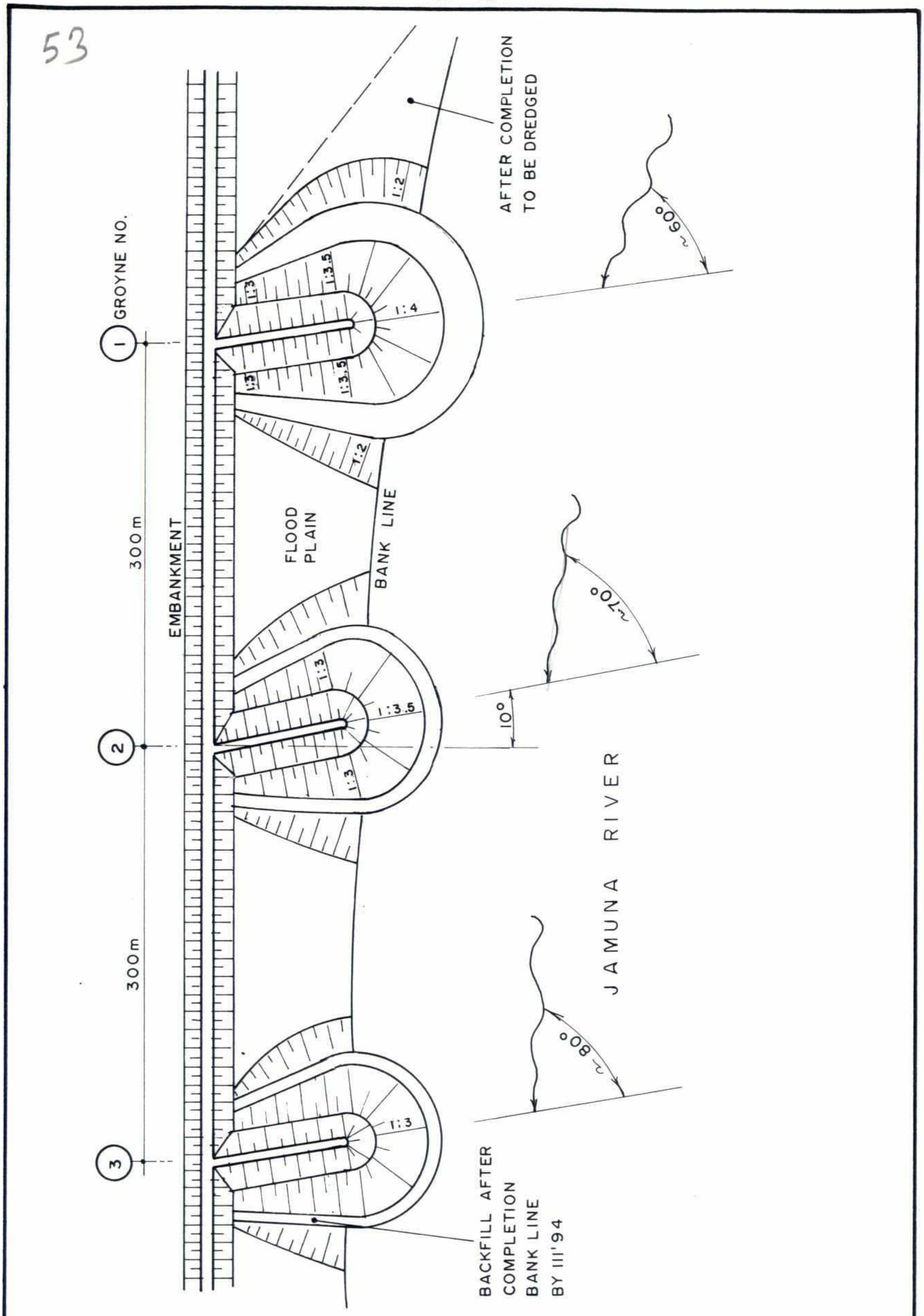


FIG. 2.3.5 – 2 : SKETCH FOR TYPICAL GROYNE SECTION

Slopes and falling apron shall be protected by concrete cubes with khoa aggregates, decreasing in size from Groyne No.1 (upstream) to Groyne No.3 (downstream). Similarly, the head slope will decrease from 1:4 to 1:3. The core will be achieved by dredging into the flood plain and desired slope graded with gunny bags. Any hydraulic fill will be secured by gunny bag walling. The principle arrangement for the groynes may be seen from Fig. 2.3.5-3.



PRINCIPLE ARRANGEMENT OF GROYNES AT KAMARJANI

FAP - 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
INTERIM REPORT	FIG. 2.3.5-3

The main design parameters will still have to be tested in the physical model, but for preliminary cost estimates the following has been assumed:

To be tested in model	Presently assumed as
- spacing of groynes	300 m
- slope head	1:4/1:3.5/1:3
sides	1:3.5 .....1:3
- design velocities	3.5 m/s
- scour depth	15 m
- form of upstream and downstream terminations/connection to embankments	as per Fig.2.3.5-1
- length of groynes	100 m
- direction of current approach	10°-30° to the embankment

Is it not too low? [illegible]?

(4) At Bahadurabad a bank revetment structure is proposed west of Belgachha as may be seen from Fig. 2.3.5-4. The alignment may be straight or in a curve protruding from the bank line, resulting from the model test outcome and as may fit the purpose to protect Belgachha village. The anticipated location is in the centre of the expected maximum current force but again will be judged by the model test results. The site fulfills the criteria of Subsection 2.3.1, although at somewhat lesser rate as the Kamarjani site, as pointed out in the following:

Criterion		Bahadurabad features
1- Certainty of attack	:	see Subsection 2.2.3
2- Something to defend	:	Villages Belgachha and Ghilabari
3- Accessibility	:	Railway Bahadurabad ghat, semi pucca road to Belgahha
4- Constructional	:	Both options, construction in stagnant and flowing water will be followed
5- Helping the river	:	Recurrent measures on opposite char may be possible
6- Acceptance	:	No resistance anticipated.

A typical cross-section through flood plain and river channel is drawn on Fig. 2.3.5-7, showing the situation as in May 1992. The section is located north of the proposed site as we assume, that this may present the situation in front of Belgachha after the 1993 monsoon with a steep slope.

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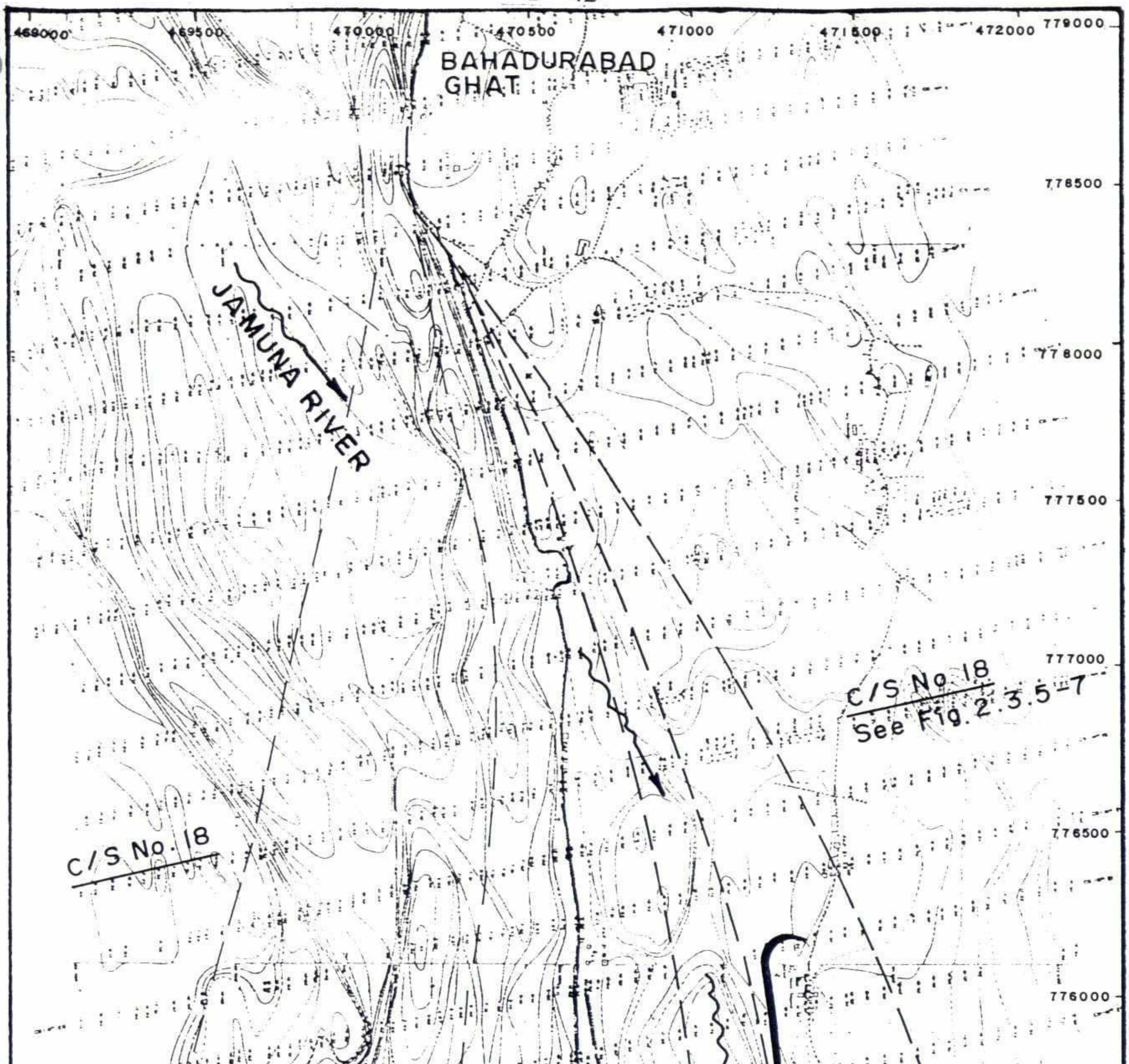

TEST SITE BAHADURABAD 1: 20 000	FAP – 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT
	INTERIM REPORT | FIG. 2.3.5 – 4

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As predicted in Subsection 2.3.2 (Fig. 2.3.2-2), the bank line will have receded in this area by about 300 m after the monsoon season 1993 (see also Fig. 5.3.5-4). This will be the situation at the anticipated commencement of construction work in autumn 1993.

A typical section through the bank revetment as used for preliminary cost estimate is shown on Fig. 5.3.5-5 below:

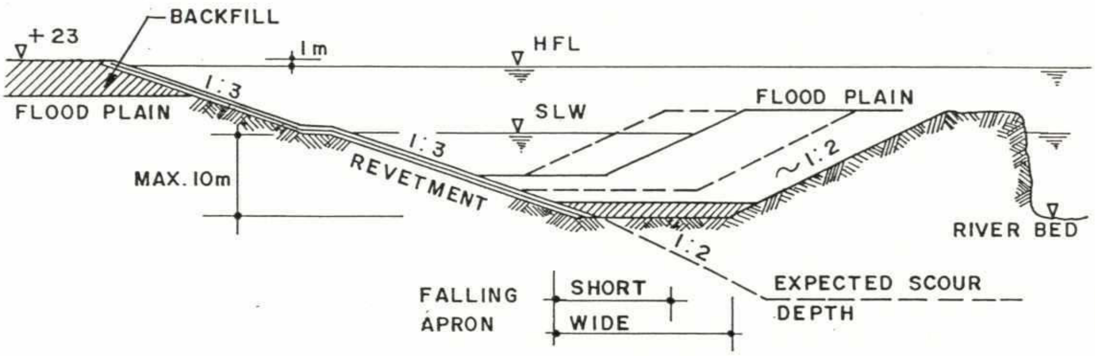
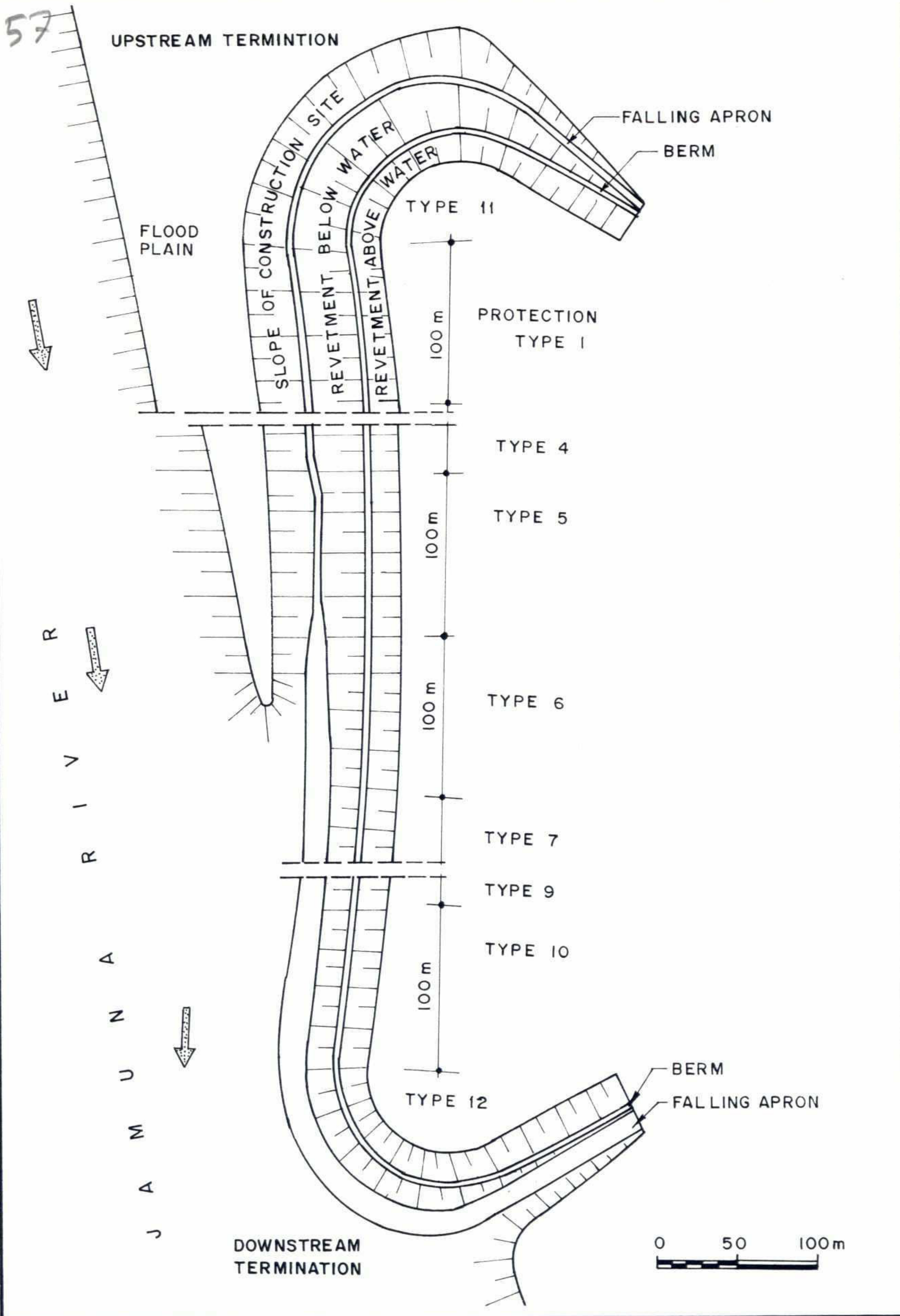


FIG. 2.3.5-5 PRINCIPLE CROSS SECTION OF BANK REVETMENT

The approximate layout of the bank revetment works is shown in Fig. 5.3.5-6.

The figure shows the upstream end of the section, where the site may possibly be protected by a dam against the current to enable construction in stagnant water to safe cost. At the end of the construction time, a channel will be dredged towards the river which will be expanded by the current shortly washing the remaining dam away. Thereafter will be exposed to full flow attack. However, at the downstream end construction will also performed in the full river flow.

The principle arrangement for the planned work may be seen from Fig. 2.3.5-6. According to a preliminary cost estimate about 10 different types of revetment combinations (filter, protection layer above and below SLW) and apron designs (short or wide with same volume of blocks etc.) can be tested. In addition, upstream and downstream terminations as per standard design will be provided against outflanking.



PRINCIPLE ARRANGEMENT OF BANK REVETMENT WORKS AT BAHADURABAD

FAP - 21/22

BANK PROTECTION AND RIVER TRAINING/ (A FPM) PILOT PROJECT

INTERIM REPORT | FIG. 2.3.5 - 6

The main design parameters will be tested in a physical model, but the following assumptions have been made for preliminary cost estimates:

To be tested in model	Presently assumed as
- slope indication above and below SLW (will also be checked by soils stability analysis)	1:3
- alignment (to ensure uniform scour conditions as far as possible)	bent outward
- scour depth	10-15 m low ?
- length of termination points	150 m each
- design velocities	3 m/s
- required length of each type of revetment, avoiding interference	100 m

5. As sequence of execution it is proposed to start with the construction of groynes in Kamarjani for the following reasons:
   - urgent need to defend old/new Manos regulator
   - development of scour may be best studied on such structure
   - the built-up of new filter and cover layer combinations for revetment works may first be tested in the filter rig.

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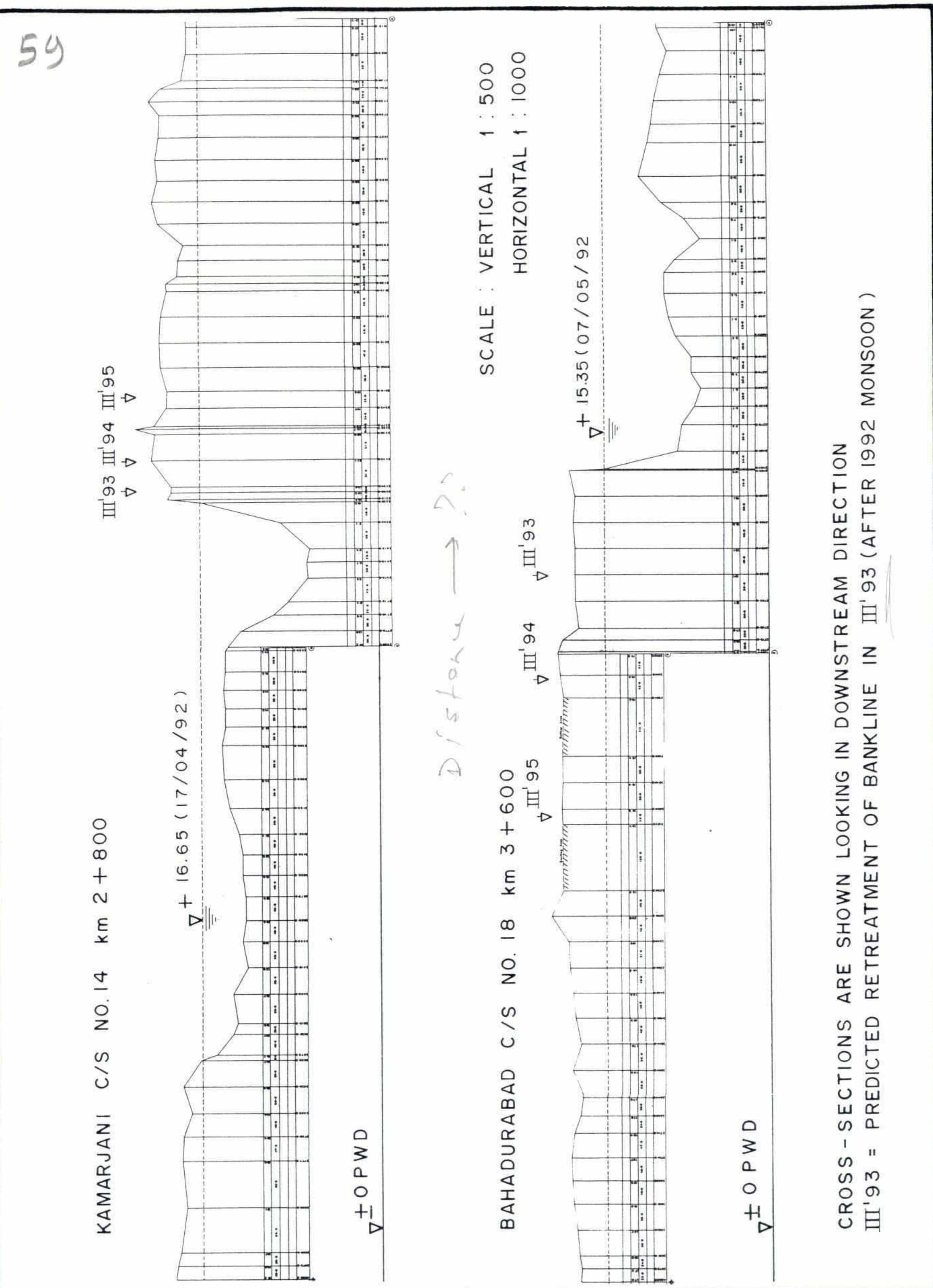

CROSS - SECTION AT KAMARJANI AND BAHADURABAD

FAP - 21/22

BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT

INTERIM REPORT | FIG. 2.3.5 -7

3. FIRST TENTATIVE CONCLUSIONS FOR AFPM

3.1 INTRODUCTION

Following the methodology as described in the Inception Report the scope and objectives of the River Training AFPM Pilot Project(FAP 22) have been focussed on an "active" approach trying to divert the river away from the threatened reaches and in due time, to change the characteristics of the river. Due to the highly unpredictable behaviour of the braiding Jamuna river (only 1 to 2 year predictions seem to be possible) the classical approach to narrow the river bed by applying "hard" measures for river training (e.g. groynes, bank protection) on a large scale has been excluded at present. The risk that such permanent structures may lay idle for quite some time (e.g. due to channel shifting) is considered too high. Therefore it is decided to consider the possible technical feasibility of a more flexible approach by applying "soft" recurrent measures.

As a first step to achieve a first order assessment of the practical use of such "soft" recurrent measures in the Jamuna River, these measures will be compared to the "hard" river training works which are commonly used in practice nowadays. This comparison should give insight in the technical and financial results of recurrent measures in order to indicate the possibility of applying such measures as an alternative to or in combination with "hard" permanent measures. The results of these first order assessments will be mainly related to the short term morphological response of the Jamuna River due to the very limited knowledge of the long term behaviour of such a mighty braided river. However, some introduction to strategies (consisting of a number of measures) aiming at a flexible approach of the floodplains of the Jamuna River will also be considered.

In order to achieve the objectives of the FAP 22 project a "State-of-the-Art" in River Training (see Annex I) has been made. Note, that the "State-of-the-Art" has to be considered as an inventory of river training measures emphasising the effectivity of measures rather than a design manual. For the preparation of the "State-of-the-Art" it was concluded that the river training measures should be considered within the scope of Active Flood Plain Management (AFPM) with emphasis on erosion control in outer channels in order to prevent outflanking or to promote closing. In this scope of AFPM four main methods of erosion control can be distinguished:

1. redistribution of sediment and/or water flow at bifurcations
2. redistribution of sediment and/or water flow in the cross section of an outflanking channel
3. protection works on outer banks
4. artificial cut-off to release the flow attack in an outflanking channel.

The results of the "State-of-the-Art" of River Training have resulted in a preliminary selection of promising recurrent measures which will be described in Section 3.2. As a result of both the activities performed for the set up of the "State-of-the-Art" and of internal brainstorm sessions the approach of the FAP 22 project has been based on a stepwise procedure as presented in Table 3.1-1. After each activity or combination of activities the decision of continuation has to be taken based on the results of activities so far. This might be clear regarding the following example, that deep going considerations on strategies only become useful at the moment that there is some (quantified !) insight in the effectivity of the individual measures. Without such first order assessment of the effectivity of individual measures, the considerations for strategies to achieve AFPM for the Jamuna River would be based on speculations only. Therefore a logical sequence of activities has been indicated in Table 3.1-1.

The present chapter of the Interim Report focusses mainly on the first results of activity 3 (Effectivity of recurrent measures) and activity 4 (Hydraulic and morphological changes through recurrent measures) as described in Sections 3.3 and 3.4 respectively. Although a final decision whether or not to proceed to the next steps of the stepwise approach as indicated in Table 3.1-1, the first impressions are sufficiently encouraging to make some initial steps forward. Therefore in Section 3.5 some options of possible AFPM strategies for the Jamuna river will be discussed briefly, while some short-term and long-term effects as a result of such strategies will be discussed in Section 3.6. A review of alternative constructions for surface bandals are given in Section 3.7. Finally, in Section 3.8 the prospects and continuation of the FAP 22 project will be highlighted.

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Table 3.1-1: Stepwise Sequence of FAP 22 Activities

No.	Activities	Continuation/Comments
1.	"State-of-the-Art" in river training and morphological response prediction	Carried out (see Sections 5.9 and 5.11 and Annex 1)
2.	Preliminary selection of recurrent measures (incl. most promising measure)	Carried out (see Section 3.2 and Annex 1)
3.	Quantification of effectivity of recurrent measure with respect to redistribution of sediment and/or water flow	Likely to be technically feasible? - yes, go to 4 - no, take another promising measure (upto 3 variants), otherwise stop project
4.	Quantification of short term hydraulic and morphological response to a measure	Likely to be technically feasible? - yes, go to 5 and following - no, stop project
5.	Formulation of strategies with respect to AFPM	Several options will be highlighted and commented.
6.	Cost estimates	Financial pre-feasibility of separate measures and or strategies ? - yes, go to 7 and following - no, stop project
7.	Estimates of environmental, socio-economical and land reclamation aspects	Some optional strategies related to the actual situation of the Jamuna River will be considered.
8.	Formulation of physical model tests and a possible Pilot Project	If the output of the preceeding steps is sufficient, rough outlines for the performance of model tests and/or a pilot project will be given.

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3.2 TENTATIVELY SELECTED RECURRENT MEASURES

The review of recurrent measures as presented in Annex 1, Part-A has mainly been focussed on their feature of erosion control as a tool for Active Flood Plain Management (AFPM). Emphasizing the erosion control in outer channels in order to prevent outflanking or to promote closing, four main methods of erosion control can be distinguished:

1. redistribution of sediment and/or water flow at bifurcations
2. redistribution of sediment and/or water flow in the cross section of an outflanking channel
3. protection works on outer banks
4. artificial cut-off to release the flow attack in an outflanking channel.

Note, that the fourth method can be compared to the preceding three methods. Actually, in the case of an artificial cut-off, a bifurcation has been formed by dredging a pilot channel. Therefore, as a first step a preliminary selection of the reviewed recurrent measures has been made, which might be considered as promising "low cost" solutions regarding the first three methods. At a later stage of the project, when there is more insight in the technical feasibility of the recurrent measures, the artificial cut-off method might be considered in more detail.

The preliminary selection of the reviewed recurrent measures is based upon a qualitative assessment of their individual effectivity with respect to erosion control. The most promising measure will subsequently be considered in more detail in order to assess quantitatively the effectivity of such a measure.

The most promising measures are summarized in the matrix as presented in Table 3.2-1.

Recurrent measure	At bifurcation	In outer channel	At outer bank
dredging	-	-	-
revetment	-	-	recurrent structures
dikes	permeable groyne	sill	permeable groyne
vanes	surface vanes	bottom vanes surface vanes	-
jacks	-	-	-
artif. cut-off	To be considered later		

Table 3.2-1: Preliminary selection of recurrent measures

This preliminary selection is based upon the following considerations:

- o Dredging is always possible but is not selected in first instance. The effects of low cost dredging (LCD) are limited. Only in a few cases reshaping of a channel entrance or a cross-section using LCD techniques can be considered. Other types of dredging (e.g. cutter suction) is costly especially in the main channels (volumes to be dredged against available dredge capacity). Instead of dredging vast volumes, other measures using the considerable natural transport of line sediments by the river are prefered.
- o Recurrent revetments at outer banks are possible; for instance with sand filled bags or tubes a mattress can be composed. Whether structural solutions can be found for the high banks of the main channels is questionable.
- o Permeable groyne types are preferable above impermeable ones, especially in view of scouring. For the same reason a needle groyne spanning the full width of the channel is preferable above a groyne of limited length (scouring at groyne head). Also short permeable groynes may be considered to protect the outer bank. Sills are possibly applicable to reduce bank erosion in outer channels. The position of such sills should be downstream of the eroding area. A recurrent sill can be made of bags, tubes or sand or a combination thereof (e.g. protected sand dike).
- o Solutions with bottom vanes spread over a consider able width of the river are not selected because of the fast changing bed shapes. Only a row of vanes along the bank is preliminarily selected.
- o Solutions with groynes and bottom vanes which are only effective in a careful lay out at the bifurcation are not selected, because a relative small change of the bed configuration may spoil the effects.
- o Surface vanes are probably effective because of the fine non-cohesive bed materials. This might be concluded from the application of bandals (surface vanes) for so many years in the Jamuna and such kind of rivers.
- o Jacks may be applied, especially in rows in the same way as the needle groynes. They are not selected but may be applied to replace needles for structural reasons.

As result of these qualitative considerations, it is decided that at this stage priority is given to those recurrent measures which aim at changing the flow conditions. The degree of these changes can be different. The measures may aim at either reducing the flow conditions (depth, velocities) towards more moderate values or reducing the flow upto zero (closing of the outer channel, eventually by repeating a couple of times the measures). The surface screens are recommended to be investigated in more detail in order to achieve a quantitative assessment of their effectivity (see Section 3.3)

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3.3 EFFECTIVITY OF RECURRENT MEASURES

3.3.1 Selection of Surface Screens

The principles of different recurrent measures have been explained in the previous sections, and the following measures seem to be the most promising ones: different types of surface screens, cut off channels and eventually closures of small channels. Of these measures first the surface screens (also called bandals or floating screens) were selected to develop a calculation method to assess the effectivity of this measure.

Some of the main assumptions in this calculation method are:

- The influence of the helicoidal flow on the effectivity of this measure can be neglected. The principle of one long row of surface screens is not based on deflecting the helicoidal flow, but on the passage of an underflow with a relatively high concentration of sediment and the deflection of an upperflow.
- Wind generated waves have a negligible influence on this effectivity during for example one year, mainly because waves are acting during relatively short periods only
- A row of screens is schematized in one long straight screen, which is connected with one of the banks, to create a relatively strong underflow.

The surface screens can be placed in principle at two different locations:

- The first location is a bifurcation, with only two outflowing channels. In the Jamuna river also more complicated bifurcations with more outflowing channels can be found, but these are not considered in this phase.
- A second location is in front of an eroding bank, normally an outer bend with a typical cross section in which the maximum depth occurs close to the outer bank. But in the calculation method a straight channel with a rectangular cross section is assumed (for the time being).

It is planned to elaborate also on the effectivity of other measures, as pile rows, cut off channels agitation dredgers and possibly closures during the next months.

3.3.2 Calculation Method

A simplified one dimensional calculation method starts with a schematization of the real channels and bifurcations in the Jamuna river. The cross sections of the channels are schematized into rectangular cross sections with an averaged depth and an averaged width. The bifurcations are simplified into one inflowing channel and two outflowing channels, all channels with rectangular cross sections, see Fig. 3.3.2-1. The hydraulic roughness, the sediment diameter is assumed to be constant, and the sediment transport equally distributed over the width.

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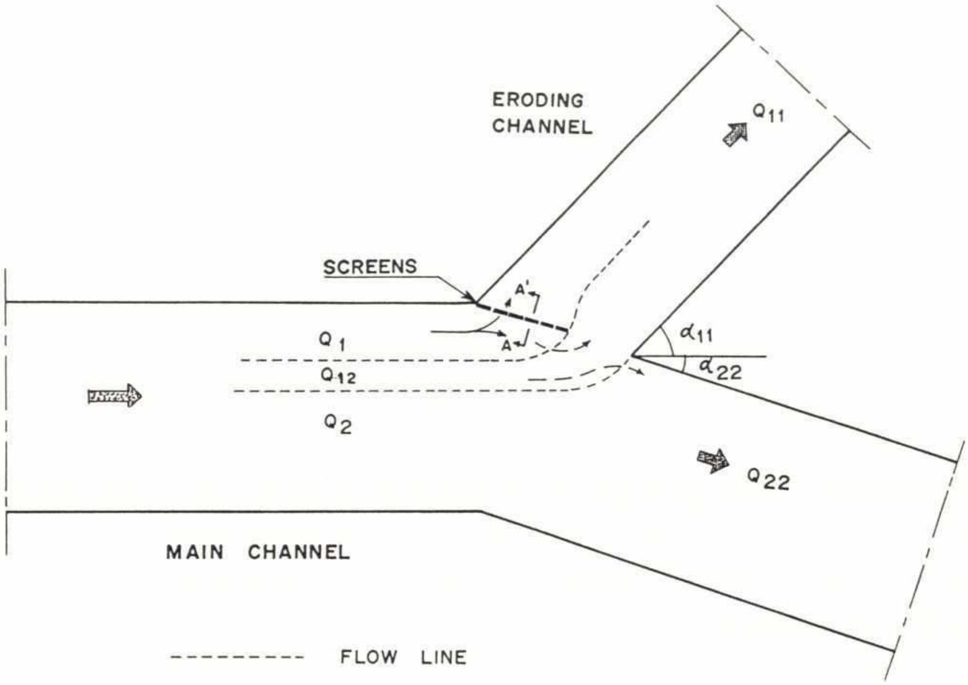

Fig. 3.3.2-1: Schematization of bifurcation

First the calculation of the flow and next the calculation of the sediment transport at a bifurcation are summarized.

$Q = C A I$?

The flow calculation

After the substitution of a known discharge, hydraulic roughness, and water level gradient in the Chézy equation the equilibrium water level is calculated. The flow in a cross section perpendicular to a screen, as indicated in Fig. 3.3.2-1, can be computed with the Bernoulli and continuity equations for an underflow gate, if a head difference upstream and downstream is known. The approach flow is separated in an underflow, which will pass under the screen and an upperflow, which will be deflected by the screen, see Fig. 3.3.2-2. Downstream of the screen a contraction of the underflow is expected and further downstream the flow will decelerate. This contraction is a function of the Froude number and the shape of the edge of the screen. The calculation method distinguishes sub-critical and super-critical flow with a drowned hydraulic jump downstream of the screen. The energy head loss, Δ E in Fig. 3.3.2-2, due to the deceleration of the flow is estimated with the formula of Carnot.

Vena Contracta

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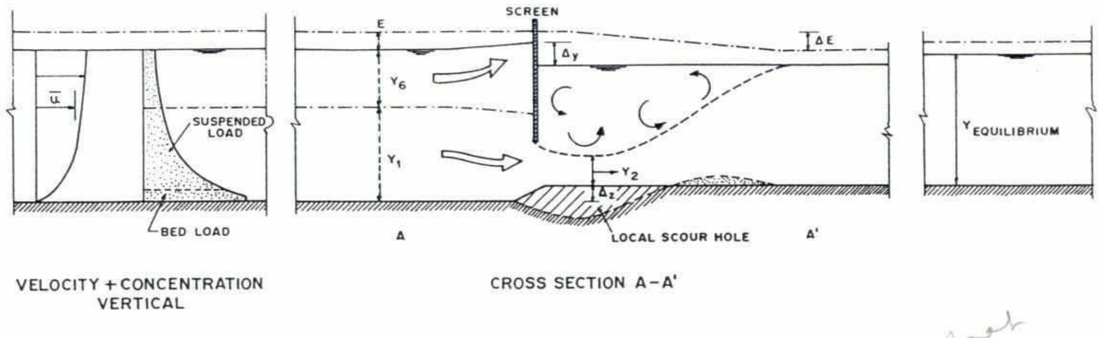

Fig. 3.3.2-2: Cross section A - A'

some what

At a **bifurcation** the rise in the water level upstream of the screen is divided in a small general rise at the whole bifurcation and a small rise just upstream of the row of screens. The bed level of the outflowing channels is some higher, Δ z in Fig. 3.3.2-2, than the bed level of the main channel.

The discharge of the deflected flow follows from the width of the discharge Q_1, the approach flow velocity and the calculated depth of the upperflow. The discharge passing through the gap is first estimated as the difference between equilibrium discharge in the eroding channel and the discharge passing the bandals. Next the water level difference upstream and downstream of the screens results in a small reduction of the water level slope in this eroding channel. And consequently the discharge through that channel is reduced and also the equilibrium water depth is adjusted. In this approximate calculation it is assumed that the hydraulic roughness of the channel bed does not change. The discharge through the remaining outflowing channel will increase slightly.

In the situation of several rows of surface screens in front of an **eroding bank** the rise of the water level is also splitted in two components: a rise over the whole width of the channel due to increased resistance by the surface screens, and a rise of the water level by the curved deflected flow (bend flow) just upstream of the screens. The flow pattern downstream of the screens determines the distance to the next screens. This will be elaborated in the next phase of the Project.

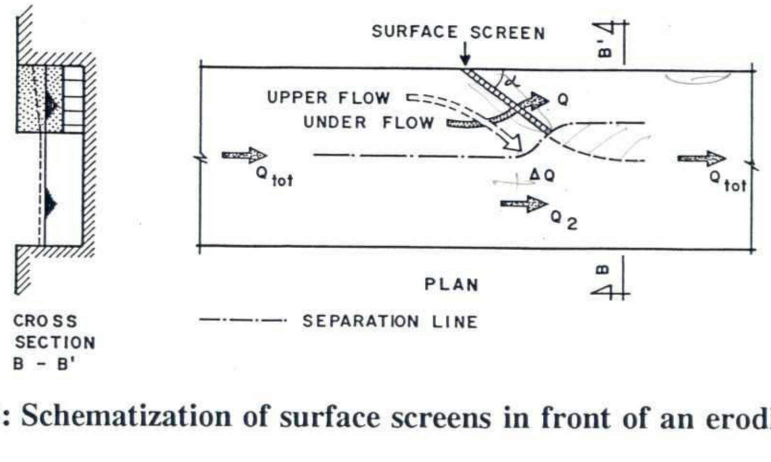

Fig. 3.3.2-3: Schematization of surface screens in front of an eroding bank

These calculation methods determine the flow field just after placement of the bandals. This situation will change because of the sedimentation in that channel. The morphological changes will be calculated in analogy with the approach as described in Section 3.4.

The sediment transport

The equilibrium sediment concentration vertical in the approach flow of the bandals is calculated with the method of van Rijn, 1984 (Van Rijn, L.C., 1984). The total sediment transport is the sum of the suspended sediment transport and the bed load transport. This total sediment transport according to van Rijn is compared with the total sediment transport calculated with the Engelund-Hansen formula (Englund, F. and Hansen, E., 1967) and often rather small differences can be observed. An aspect which has to be elaborated more in detail, is that the measured sediment transport in the Jamuna river is about 4 to 5 times the sediment transport, which is calculated with the formula of Engelund-Hansen.

In the approach flow the height of the separation line between the underflow passing the screens and the deflected upperflow has been calculated in the flow module and this separation line determines roughly which part of the equilibrium sediment concentration vertical is passing the screen and which part is deflected.
Through the remaining gap in a cross section with the screens in a vertical the equilibrium sediment transport of the eroding channel is assumed. The new sediment transport in the eroding channel is the sum of the sediment transport which passes the screens, and the sediment transport through this gap.

The contribution of the local scour hole under the screens on the morphology of the eroding channel is neglected. Most of the eroded material is deposited at a ridge just downstream of the local scour hole, see Fig. 3.3.2-2. A first estimate of the maximum scour depth has been made, because this depth is important for the foundation depth of the piles of a fixed structure.

3.3.3 Preliminary Results of Calculations with a Constant Discharge

The results of the described flow calculation with a spread sheet program have been compared with the results of a model of two parallel branches connected by a bifurcation and a confluence, which was made with a one dimensional hydrodynamic model. In the hydrodynamic module the row of screens has been represented by a structure for an underflow gate. In this model with a structure sediment transport phenomena cannot be calculated accurately. The results have been used to adjust the calibration parameters in the spread sheet program, especially the rise in the water level. And these results have shown that in practise downstream of the screens a drowned hydraulic jump will be probably an exceptional phenomenon. In most cases the flow will still be sub-critical in the contraction. The first results of this method of calibration are promising and this calibration will be further developed.

In the traditional bandals, the screens are spaced by regular openings between the short bandal screens in order to reduce the water level differences upstream and downstream of the screen and consequently also the forces on the screens are reduced, but on the other side the effectivity of this measure is reduced also.
Therefore the row of surface screens should preferably be continuous and strong enough to resist a water level head difference of about 0.1 m. To create such a head difference the screens should have a length of about 40 to 60 % of the channel width. If this length is increased, then the effectivity and the costs of the measure will increase.

needs proper analysis

In case of surface screens at a bifurcation this head difference will reduce the discharge through the eroding channel and increase the discharge through the other channels. A reduction of the discharge by 3 to 5 % seems to be possible, if the length of the screens is about 50 % of the channel width. This reduction is effective in reducing the total sediment carrying capacity of the discharge in the eroding channel.
This effectivity is based on a discharge below or around the bankfull discharge. If the discharge is higher than the bankfull discharge the flow over the chars can made the flow pattern much more complicated than the flow pattern represented in this schematized calculation method.

The screens are most effective if the depth of the screens is 40 to 70 % of the local water depth, depending on the gradients in the sediment concentration vertical. The row of screens can be a combination of screens with different depths and based on different structural designs, because the water depth will vary along this row.

In this case the sediment transport at the entrance of the eroding channel can increase initially with about 10 to 25 %.
In the remaining gap a local scour hole can develop also, which benefits the sedimentation in the eroding channel. Note, that possible uncontrolled bank erosion at the bifurcation can probably be prevented by placing the screens on both sides of the entrance of the eroding channel.

The following activities in order of priority are envisaged for the next phase:

- The improvement of the spreadsheet program for the surface screens placed in front of an eroding bank. Especially the determination of the flow pattern downstream of a row of surface screens determines the distance to the next screen.
- Assessment of the effectivity of surface screens during varying discharge conditions (hydrograph).
- As an option the spread sheet program might be extended for pile rows.

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- Assessment of the effectivity in case of using an agitation dredger in order to increase the sediment concentration for achieveig downstream siltation.
- Some additional activities might be the assessment of effects considering (i) spacing between adjacent screens and (ii) helicoidal flow conditions.

3.4 HYDRAULIC AND MORPHOLOGICAL CHANGES THROUGH RECURRENT MEASURES

3.4.1 Introduction

Referring to the "State-of-the-Art" in River Training (see Annex 1) it was found, that no actual knowledge for quantifying the hydraulic and morphological response to recurrent measures is present. Therefore some preliminary considerations for quantifying such a response has been presented as Part C of Annex 1. One of the options for quantifying the short term hydraulic and morphological response is the development of a "tailor made" simplified mathematical model. Such a model should give a good insight in the sensitivity of a number of parameters (such as: Chézy's roughness co-efficient, grain size D_{50}, water level slope i, sediment transport, etcetera) on the prediction of water and bed levels as a function of time. The alternative to such an approach is the use of a numerical model as the one dimensional MIKE-11 model. The analysis should then be based on a great number of calculations, covering the spectrum of all possible channel dimensions as present in the Jamuna River. The output of such an approach would also be numerous, while the interpretation of this output also has to lead to graphs from which sensitivity analysis has to be carried out. Besides this there is another number of disadvantages with respect to the use of MIKE-11 in this specific case of sensitivity analysis such as:

- inaccuracy of the morphological computation scheme in nodes resulting in time dependent bottom level disturbances affecting the final sedimentation results due to a simulated recurrent measure,
- generation of bed level disturbances due to the upstream sediment boundary condition, which also may affect sedimentation results,
- no easy access to the Engelund/Hansen transport formula to increase the prediction values upto Jamuna conditions.

Referring to Section 3.2, the decision was made to investigate as a first step the hydraulic and morphological response of an outflanking channel due to a recurrent measure at the bifurcation (see Fig. 3.4.1-1). To avoid the disadvantages (and consequently time consuming analysis) as described before, it has been decided to develop a simplified mathematical model for the prediction of water level and bed level changes due to overloading in one single river. This overloading has to be considered as a constant sediment supply (q_s) per unit river width at a certain location of the river (see Fig. 3.4.1-2) due to a recurrent measure.

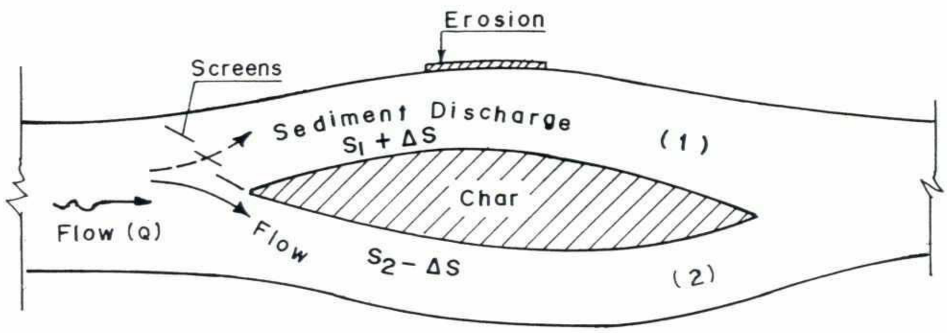

Fig. 3.4.1-1: Typical problem spot

This first step in developing a simplified model should be done in order to get basic understanding of the morphological process due to overloading. Results of MIKE-11 computations are envisaged to be used for calibration and verification due to the reliability of MIKE-11 for such a single channel. Moreover, this approach could give insight in the consequences of the upstream sediment boundary condition, as used in MIKE-11, for the predicted bed levels. Once having such a simplified model, it is expected to be possible to apply this simplified model for an outflanking channel making use of the boundary condition that the water level at the bifurcation hardly changes due to the redistribution of flow. This approach has the advantage, that no disturbances will be generated as this happens to be at nodes using the MIKE-11 model. For a detailed report on the development of the simplified model reference is made to Annex 5.

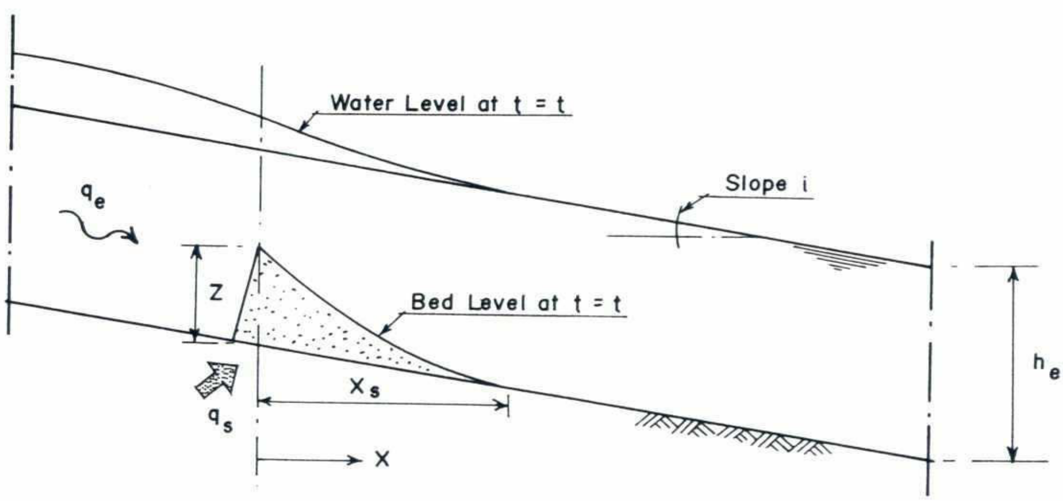

Fig. 3.4.1-2: Schematization of morphological process in a single channel

In Section 3.4.2 a summary of the simplified model will be given with specific attention to the results of the hydraulic and morphological response in outflanking channels after bifurcations. Conclusions and outlook to further developments will be presented in Section 3.4.3.

3.4.2 Simplified Mathematical Model

As described in the Introduction (Section 3.4.1) the set up of the simplified model has been started for a situation in one single channel subjected to a time constant overloading. The aggradation process and water level changes due to this overloading has been described on the basis of quasi-steady flow conditions and the use of the Engelund/Hansen transport formula (as this can be done for this specific case, see e.g. Jansen, P.Ph. et al., 1979 and Ribberink, J.S. and Van Der Sande, J.T.M., 1984). Besides to this special considerations have been made for the sediment balance description. For specific details reference is made to Annex 5. The results of this initial set up have mainly been focused on the prediction of the bottom level elevation z and the length of the aggradation x_s (see Fig.3.4-2) due to the constant overloading q_s. MIKE-11 runs have been used for calibration of the simplified model. Verification to a number of flume experiments by Soni et al. (see Engelund, F. and Hansen, E., 1967) showed a good agreement between predictions and measurements. From this it has been concluded that the simplified model will serve as a basic tool to describe the aggradation process in an outflanking channel under the condition of redistribution of flow at the bifurcation. This approach is justified due to the "tailor made" output for a fast analysis to estimate the technical feasibility of using recurrent measures at bifurcations. The technical feasibility will be based on predicted time scales necessary for either stopping the bank erosion in the outflanking channel or siltation of the outflanking channel. From the experience in the first step of the simplified model (see Annex 5) it is envisaged, that graphs can be produced giving dimensionless relation as:

$$\frac{z}{h_e} = f\left(\frac{t}{T_e}, n\right) \tag{3.4-1}$$

$$\frac{x_s}{h_e} = f\left(\frac{t}{T_e}, n\right) \tag{3.4-2}$$

in which $n(= q_s/s_e)$ is the ratio between the additional sediment transport (q_s) due to a recurrent measure and the initial equilibrium sand transport (s_e) in the outflanking channel. Fig.3.4.2-1 gives a schematic impression of the hydraulic and morphological process in the outflanking channel as result of a constant overloading q_s at the bifurcation.

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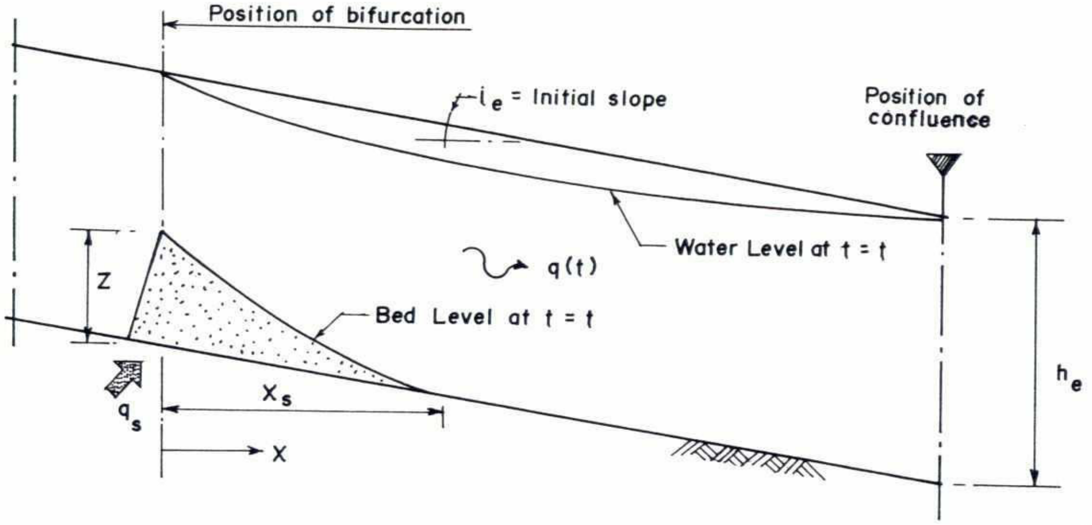

Fig. 3.4.2-1: Schematization of morphological process in an outflanking channel

The remaining symbols in the Equations (3.4-1, 2) are as follows (see also Annex 5):

z = aggradation height at $x = 0$
x_s = length of aggradation
t = time
T_e = a morphologic time computed from known input parameters (see Annex 5)

Once again it is emphasized, that the results as described according to the Equations (3.4-1 and 2) are comparable to results of MIKE-11 for similar situations. However, the main advantages of the "tailor made" simplified method with respect to the MIKE-11 model are:

- a streamlined output focused on the wide spectrum of situations as occurring in the Jamuna flood plain,
- avoiding of disturbances as they can occur in the solutions of the MIKE-11 model due to the upstream sediment boundary condition and relatively inaccurate morphological scheme in nodal points (such as: bifurcations),
- an easy access to the applied sediment transport formula according to Engelund and Hansen (Engelund, F. and Hansen, E., 1967) in order to consider situations agreeing to the sediment transport conditions as observed for the Jamuna River (e.g. R.P.T., NEDECO, Bangl. Cons. Ltd., 1987)
- no problems with respect to the correct initial sediment distribution on the bifurcation. With a one dimentional model as MIKE-11 this is always a problem which also is a source of possible negative disturbances.

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The objective of the simplified model is the development of relatively simple formulas describing the aggradation height and length as a function of time and sediment over-loading induced by a recurrent measure at the bifurcation. The simplified method should also enable the user to assess the water level changes in the outflanking channel. The approach for achieving the mentioned objectives will be described briefly on the basis of the results as described in Annex 5.

With specific reference to Chapter 5 of Annex 5 the following results can be summarized:

1. The water level on x = 0 (= bifurcation, see also Fig. 3.4.2-1) remains constant as a result of the flow redistribution due to the sedimentation in the outflanking channel.
2. The initial phase of the aggradation in the outflanking channel can be characterized by an acceleration process. The flow velocity on x = 0 will increase to a maximum in order to carry the increased transport. The time span of this process is characterized by T_a.
3. In the initial phase ($t \leq T_a$) the aggradation in the outflanking channel can be predicted with the simplified model for one single channel (see Fig. 3.4.1-2 and Annex 5).
4. The redistribution of flow is represented by a constant discharge gradient as assumed on the basis of some MIKE-11 computations. This discharge gradient is linearly related to the bottom level gradient $\dot{z}_a$ on x = 0 and at t = T_a.

These considerations have resulted in a set of formula's for a first order assessment of the aggradation process in an outflanking channel due to a constant sediment overloading. The results, as presented below, have to be considered as preliminary due to the restricted time for a more extensive verification so far. The results are:

INPUT:

$q = c\sqrt{h^3 i}$

$$q_e = C\, h_e^{\frac{3}{2}}\, i_e^{\frac{1}{2}} \qquad (m^2/s) \qquad (3.4\text{-}3)$$

$$s_e = \frac{0.05}{\Delta^2 \sqrt{g}\; C^3 D_{50}} \left(\frac{q_e}{h_e} \right)^5 \qquad (m^2/s) \qquad (3.4\text{-}4)$$

according to Engelund, F. and Hansen, E., 1967

$$n = \frac{q_s}{s_e} \qquad (-) \qquad (3.4\text{-}5)$$

= Addl. Sed. Transport / Initial eq. Sand Transport) ratio

OUTPUT:

?

Initial depth of water

$$T_e = \frac{n\,(1-\varepsilon)}{5.25\,(2n+1)} \cdot \frac{h_e^2}{s_e\, i_e} \qquad (s) \qquad (3.4\text{-}6)$$

Initial slope

75 Time span

$$T_a = \{ \frac{5}{n} (1 - \frac{1}{(n + 1)^{0.2}}) \}^{2 + \frac{1}{n}} T_e \qquad (s) \qquad (3.4\text{-}7)$$

$$\frac{z}{h_e} = \frac{n}{5} (\frac{t}{T_e})^{\frac{n}{2n+1}} \qquad \text{for} \quad t \leq T_a \qquad (-) \qquad (3.4\text{-}8)$$

$$z_a = \frac{n}{5} (\frac{T_a}{T_e})^{\frac{n}{2n+1}} . h_e \qquad (m) \qquad (3.4\text{-}9)$$

$$\dot{z}_a = \frac{n^2}{5 (2n + 1)} (\frac{T_a}{T_e})^{- \frac{n+1}{2n+1}} . \frac{h_e}{T_e} \qquad (m / s) \qquad (3.4\text{-}10)$$

$$\frac{z}{h_e} = \frac{z_a}{h_e} + \frac{\dot{z}_a}{h_e} (t - T_a) \qquad (-) \qquad (3.4\text{-}11)$$

$$\frac{x_s}{h_e} = \frac{0.6 (1 + 0.1n)}{1.75 (1 - \varepsilon) i_e} (\frac{t}{T_e})^{\frac{n+1}{2n+1}} \qquad \text{for} \quad t \leq T_a \qquad (-) \qquad (3.4\text{-}12)$$

$$\frac{x_s}{h_e} = \frac{0.6 (1 + 0.1n)}{1.75 (1 - \varepsilon) i_e} (\frac{T_a}{T_e})^{\frac{n+1}{2n+1}} \qquad \text{for} \quad t \geq T_a \qquad (-) \qquad (3.4\text{-}13)$$

$$q = q_e - \frac{q_e}{h_e} (n + 1)^{0.2} . \dot{z}_a . t \qquad (m^2 / s) \qquad (3.4\text{-}14)$$

The symbols as used in Equations (3.4-3) to (3.4-14) are explained in the list of symbols at the end of Section 3.4, while on the other hand an impression of these symbols also can be subtracted from Fig. 3.4.2-1.

In the Fig. 3.4.2-2 and -3 the results of z/h_e and x_s/h_e have been presented graphically for several values of n in the range of the effectivity of a recurrent measure (see Section 3.3). From these figures it can be observed that the aggradation length x_s increases rapidly during the initial acceleration phase. However, due to the redistribution of flow this length remains constant after the initial phase ($t > T_a$).

Note, that the graphs in Fig. 3.4.2-2 and -3 are dimensionless and consequently covering a wide field of applications. On the other hand the impact of the water depth h_e and the morphological time T_e cannot be observed easily. Therefore, an example will indicate the use of the simplified model to assess the impact of several parameters on the aggradation process in an outflanking channel.

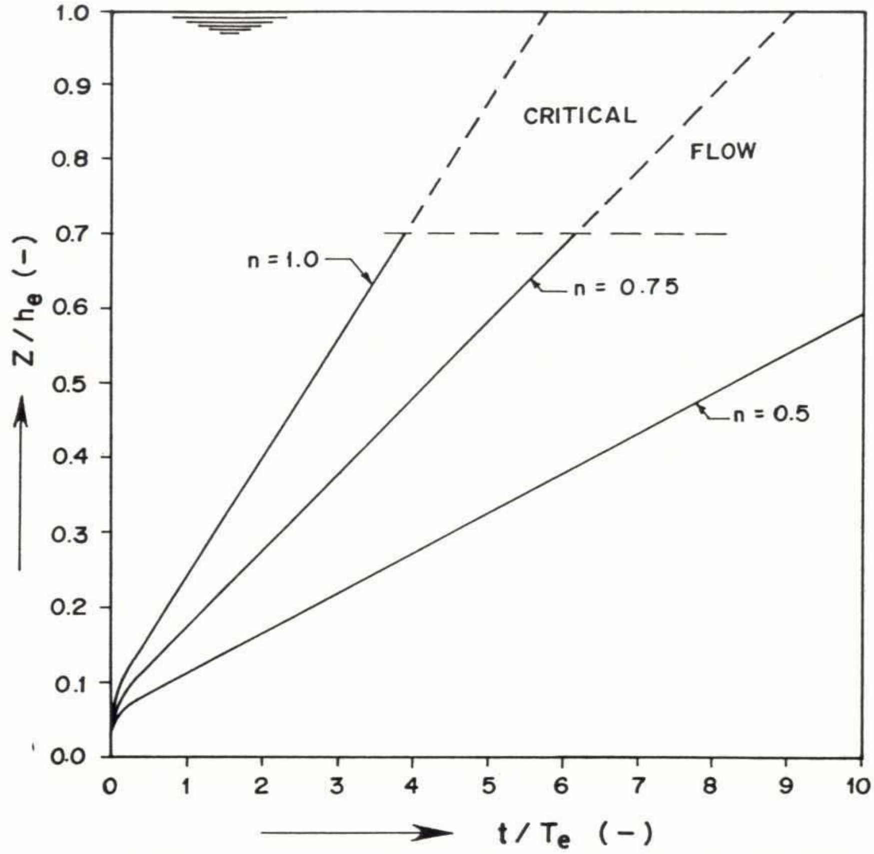

Fig. 3.4.2-2: z/h_e versus t/T_e

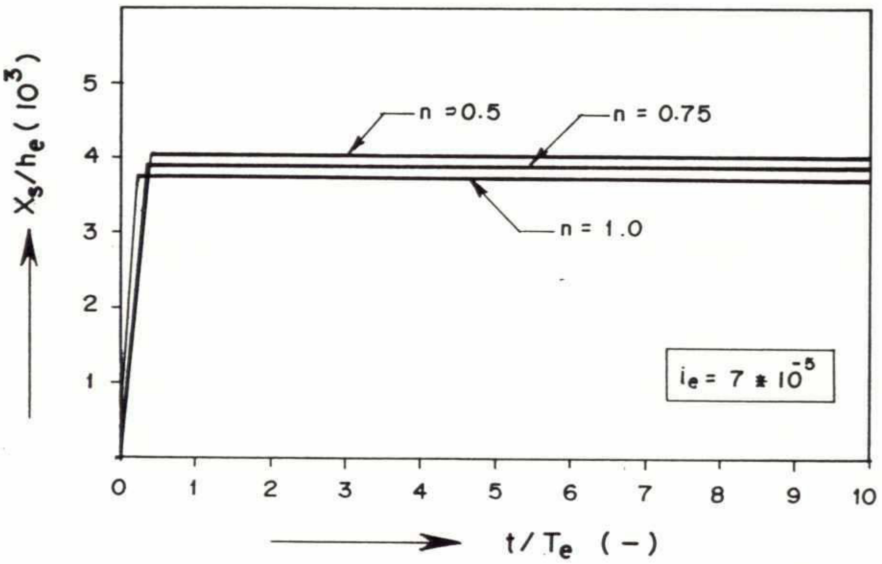

Fig. 3.4.2-3: x_s/h_e versus t/T_e

Example

A situation is selected on the basis of a satellite image of the Jamuna. This situation is schematically presented in Fig. 3.4.2-4, while a discharge of the Jamuna around bankfull discharge is considered.

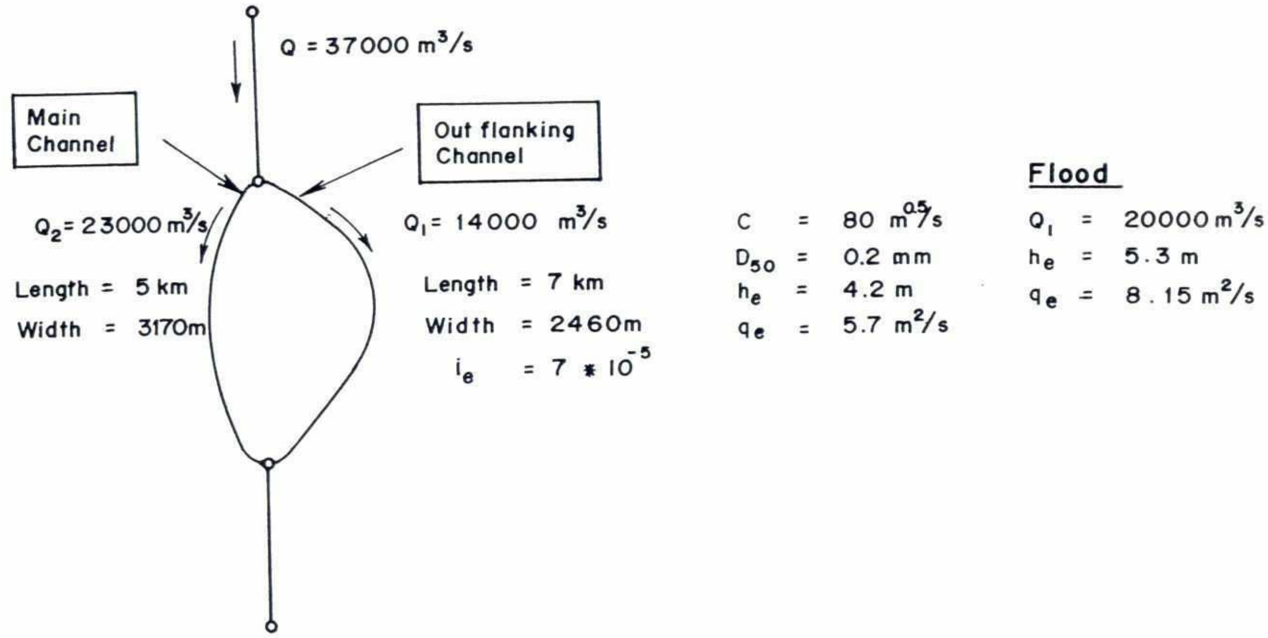

Fig. 3.4.2-4: Schematized problem situation along the Jamuna

The question is whether the use of a recurrent measure (e.g. surface screens) at the bifurcation should be a solution to prevent further erosion in the outflanking channel or even to achieve a closure. To answer this question the data as presented in Fig. 3.4.2-4 for the outflanking channel are sufficient to make a first order assessment with the simplified model. Note, that the slope of the outflanking channel is less than that of the main channel due to the longer length.

The morphological time T_e (see Eq.3.4-6) depends on the sediment transport capacity s_e of the outflanking channel. For Jamuna conditions this means that the sum of the bed load and a part of the suspended load (to be considered as that part that contributes to the bottom level changes) is representative for the actual value of s_e. Referring to the Jamuna Bridge Appraisal Study (R.P.T., NEDECO, Bangl. Cons. Ltd., 1987) it has been noticed that the Jamuna sediment transport s_e exceed the sediment transport as predicted according to Engelund and Hansen (see Eq. 3.4-4) upto 5 times or even more for the higher discharges. For the present situation, with a discharge condition just below bankfull discharge, the sediment transport s_e is therefore supposed to be 5 times higher than that according to Engelund and Hansen. Using Equation (3.4-6) the morphological time T_e can be computed as a function of the effectivity n of the recurrent measure. In order to indicate the sensitivity of T_e for the effectivity n some representative results have been summarized in Table 3.4.2-1.

	bankfull discharge			flood condition		
n (-)	0.5	0.75	1.0	0.5	0.75	1.0
T_e (month)	2.1	2.5	2.8	1.8	2.1	2.4

Table 3.4.2-1: Morphological time T_e

As indicated in Fig. 3.4.2-4 the water depth in the outflanking channel h_e = 4.2 m. On the basis of the known T_e and h_e the results for the aggradation height z and length x_s can be derived from the Fig. 3.4.2-2 and -3 respectively. For a direct interpretation of the results reference is made to Fig. 3.4.2-5, in which z has been plotted as a function of the time t and the effectivity n. Assuming that bankfull stages or higher last for 4 to 5 month per year on the average, it might be concluded that the aggradation height at least has reached a height of 50% or more (due to flood conditions) of the water depth during bankfull discharge. During lower discharges (dry season) this might lead to a complete closure of the outflanking channel, which enables possible additional measures (e.g. sand suppletion with dredgers!) to a complete silting up (land reclamation) of the outflanking channel. The impact of a flood condition on the aggradation process has been indicated in Fig. 3.4.2-5 with the dotted line, assuming an effectivity of the recurrent measure of n = 1 and a discharge in the outflanking channel (without recurrent measures !) of Q = 20.000 m³/s.

From Fig. 3.4.2-3 it might be concluded that the aggradation length grows rapidly (within 2 to 3 months) to a maximum length of about $x_s \approx$ 16 to 17 km. This means that the aggradation length exceeds the length of the outflanking channel (length = 7 km). Some initial computations with MIKE-11 have shown, that this exceedance has no significant impact on the aggradation process in the outflanking channel. A reason for this might be, that the redistribution of flow starts immediately from the beginning resulting in a relatively fast decreasing discharge in the outflanking channel. Fig. 3.4.2-6 gives an impression of this decreasing discharge for bankfull conditions.The decrease of the discharge might be upto 30% (also including the effect of a flood situation) in one season (ca.4 to 5 months). This consequently leads to a fast decrease of the carrying capacity of the outflanking channel. Therefore, it is assumed that the aggradation on the bifurcation and in the outflanking channel is not really affected by the confluence. However, this aspect will be further investigated in the next phase of the project. ?

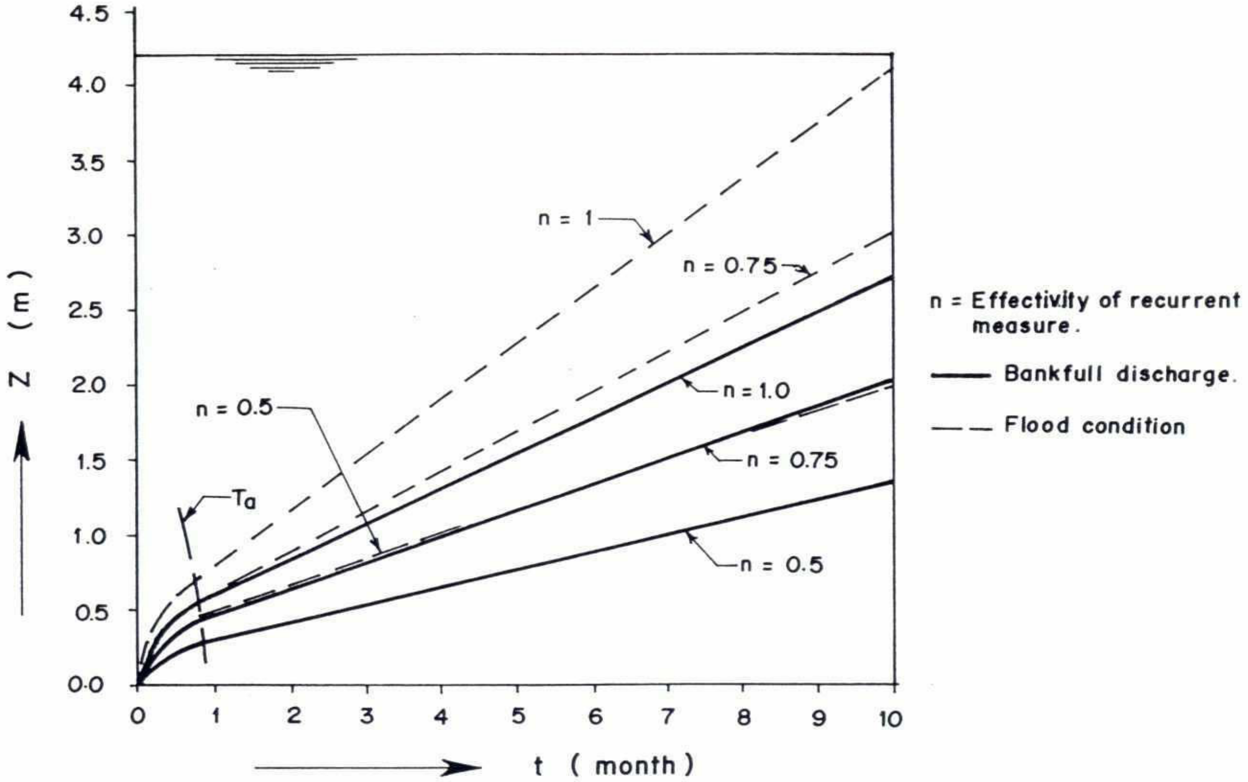

Fig. 3.4.2-5: Aggradation height as a function of time and effectivity

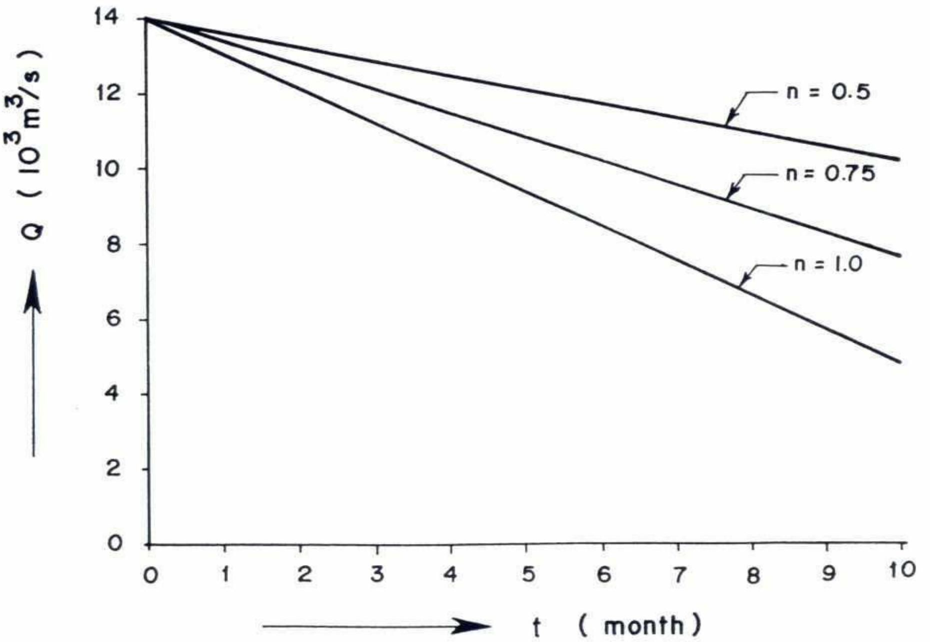

Fig. 3.4.2-6: Decrease of discharge in outflanking channel

On the basis of the preliminary results with respect to the effectivity of surface screens on a bifurcation (see Section 3.3.4), the following assessment of n can be made. Considering the situation that the screens have a span of half the channel width a reduction of the discharge (ΔQ) in the outflanking channel upto 5% may occur, while an initial sediment overloading (ΔS) of about 20% might be expected. Assuming an accumulative effect of both features on the effectivity n and taking a fifth power influence of the discharge reduction due to the sediment transport relation, the following result for n has been obtained:

$$n = \left(\frac{Q}{Q - \Delta Q}\right)^5 - 1 + \frac{\Delta S}{S} \qquad (3.4\text{-}15)$$

Change in Sediment Load

leading to:

$$n \approx \left(\frac{1}{0.95}\right)^5 - 1 + 0.2 = 0.5$$

Note, that this assessment is based on very preliminary considerations. The impression exists that the effectivity might be higher, especially due to the initial flow diversion as caused by the screens. In the next phase of the project this will be further elaborated.

Considering the Jamuna example as discussed before (see also Fig. 3.4.2-5 and -6), the preliminarily assessed effectivity leads already to very reasonable results with respect to the reduction of shear stresses in the (aggressive) outflanking channel. Although a complete closure seems not to be achieved within two seasons considering bankfull conditions, the outflanking channel has been silted up in the dry period. Besides that, the discharge for bankfull conditions has been reduced by ca. 30 to 35% leading to a reduction of shear stresses of about 50 to 60%, which is significant in the light of bank erosion.

As an indication to show the output of the simplified model under varying discharge conditions due to the existing hydrograph reference is made to the Fig. 3.4.2-7 and -8. The varying discharge has been simplified to a block diagram of discharges considering the Jamuna example (see Fig. 3.4.2-4). The computed bottom elevations with an effectivity n = 0.75 show clearly the aggradation height at 50% of the original water depth during bankfull stages after two years. During low flow conditions the closure becomes complete within the time span of two years. In the next phase of the project the influence of varying discharges will be further pointed out.

As a general conclusion at this stage of the project, the recurrent measure of surface screens seem to be promising. The effectivity can still be increased by using the screens over the total width of the (aggressive) outflanking channel. The results as presented have to be considered as preliminary due to the limited number of verifications of the simplified model for outflanking channels as presented in this Section.

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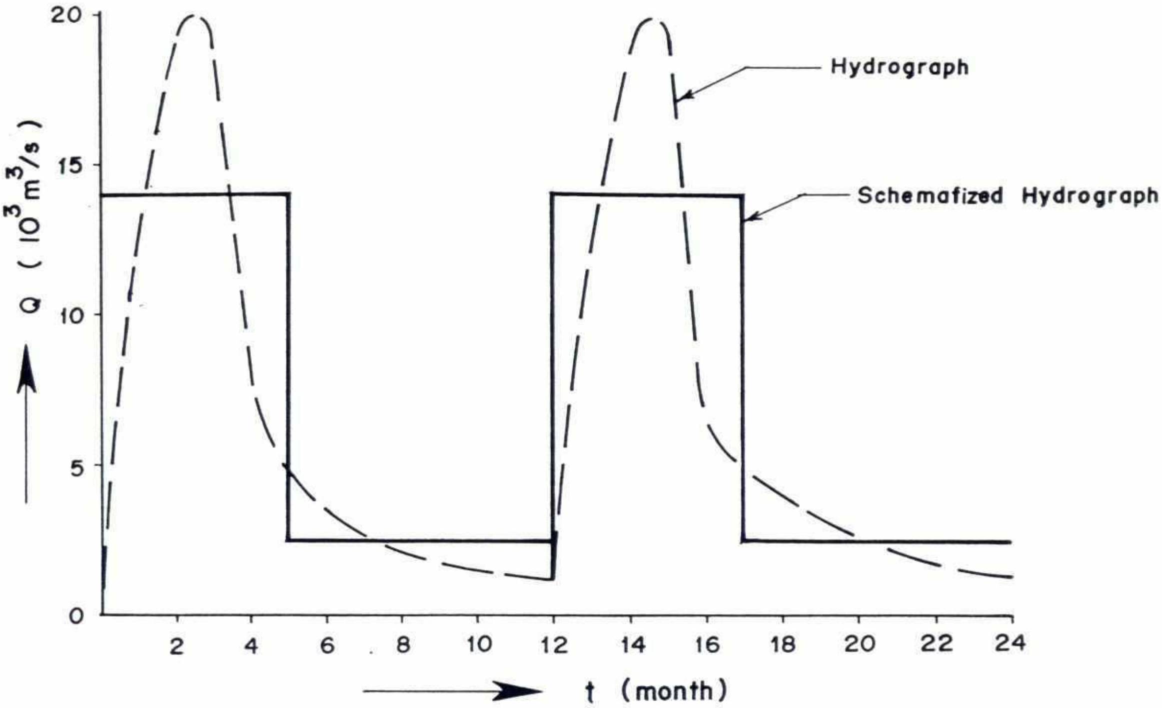

Fig. 3.4.2-7: Schematized hydrograph

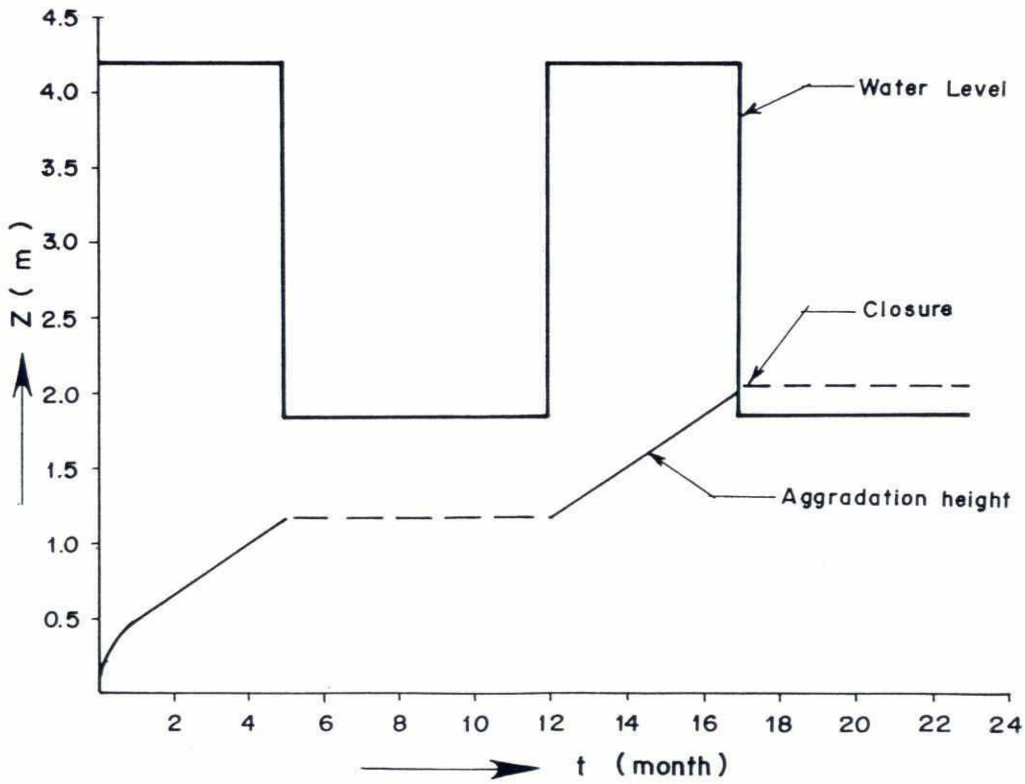

Fig. 3.4.2-8: Aggradation process

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3.4.3 Conclusions and Further Development

The main conclusion is that the described simplified model promise to provides an easy tool to predict first order morphological and hydraulic consequences in an outflanking channel as result of recurring measures on the bifurcation.

As a preliminary result with respect to surface screens it might be concluded that this type of recurrent measure seems technically feasible in the light of a strategy, that focusses on bank erosion reduction of "important" stretches along the Jamuna River. Some preliminary details on strategies are presented in Section 3.5, while some tentative cost estimates for several types of (possible) surface screens are indicated in Section 4.2.

In the next phase of the project the following developments are foreseen:

- A further verification of the simplified model, especially focussing on the diversion of flow as initiated by surface screens.
- A more thorough investigation in the effects due to the aggradation length, when this becomes longer then the channel length.
- Consideration of a situation, in which the caused aggradation will be prevented to run out of the channel by applying a bottom sill in the downstream section of the channel.
- A further elaboration of the hydraulic effects in the outflanking channel in order to indicate the reduction of bank erosion which really should occur as a result of the surface screens on the bifurcation.
- The impact of varying flow conditions (hydrographs) will be investigated more thoroughly.
- Quantification of morphological and hydraulic response in outer channels due to other recurrent measures. In this respect the use of agitation dredgers for increasing the sediment concentration at the mouth of the outflanking channel is mentioned. Probably this method can be a good alternative to achieve a faster overloading (and thus siltation) of the outflanking channel.
- Assessment of the hydraulic and morphological response (bank erosion, water level elevations) in the adjacent (main) channel due to the increased discharge.

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LIST OF SYMBOLS

C	=	Chézy's roughness parameter	($m^{1/2}/s$)
D_{50}	=	specific grain size of bottom material	(m)
g	=	acceleration due to gravity (= 9.81)	(m^2/s)
h_e	=	initial equilibrium channel depth	(m)
i_e	=	initial equilibrium channel slope	(-)
n	=	ratio q_s/s_e	(-)
q	=	water discharge per unit channel width	(m^2/s)
q_e	=	initial equilibrium water discharge per unit channel width	(m^2/s)
q_s	=	sediment overloading per unit channel width	(m^2/s)
s_e	=	initial equilibrium sediment transport per unit channel width	(m^2/s)
t	=	time	(s)
T_e	=	characteristic morphological time	(s)
T_a	=	initial acceleration period	(s)
x_s	=	aggradation length	(m)
z	=	aggradation height	(m)
z_a	=	aggradation height at $t = T_a$	(m)
$\dot{z}_a$	=	aggradation gradient at $t = T_a$	(m/s)
Δ	=	specific weight of bottom material (= 1.65 for sand)	(-)
ε	=	porosity (= 0.4 for sand)	(-)

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3.5 POSSIBLE STRATEGIES AND TECHNICAL FEASIBILITY

3.5.1 General

At this stage of the project it has been concluded that the results with respect to the surface screens are sufficiently promising as a tool for Active Flood Plain Management. It has been indicated quantitatively in Sections 3.3 and 3.4, that their effectivity and the induced morphological channel response may at least enable strategies (i.e. combinations of measures) aiming at erosion control in outer channels to prevent further outflanking. This already can be considered as a first indication, that strategies based on the use of surface screens are technically feasible. A step forward in the activity scheme (see Table 3.1-1) is therefore justified. Reference is made to Section 3.6, in which some possible options of AFPM strategies are discussed. This Section is restricted to a more detailed description of a single strategy aiming at prevention of bank erosion with the use of surface screen. This Section is especially meant to indicate and discuss the aspects to achieve a well balanced scenario for the performance of a strategy. These aspects are:

1. determination of the main objectives
2. selection of the channel to be prevented from further erosion
3. timing
4. location of the screens at a bifurcation
5. further criteria for bifurcation and eroding bank.

Each aspect will be discussed in the following subsection.

3.5.2 Aspects of a Strategy

The main objective of a strategy:
The objective of a defensive strategy for one location with surface screens is mainly the prevention of bank erosion, which should be expected if the channel can develop free. In future this short term objective can become part of a long term strategy in which it is guaranteed that the not eroded area will be protected against erosion in future. With this guarantee new investments can be expected in the development of such an area as part of Active Flood Plain Management.

This short term objective can be extended in some cases with a closure of the channel within 2 years. At this moment there is some doubt that a complete closure is not possible for bankfull discharge conditions, using only a row of surface screens at a bifurcation. If the channel has been silted up to a depth of about 1 m to 2 m an ordinary closure of the remaining small channel is probably most effective. In a more offensive strategy the objectives may be adverse and even aim to keep open an existing channel, for example to enforce an artificial cut-off channel.

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The mentioned objectives are realised with a combination of floating screens of different types and fixed structures like bandals. The fixed structures in the shallow section of a cross section are attractive if they can be constructed on a dry bed during the low flow season (winter time). Besides that the location should be in such a way that the row of screens will not shift during a season.

or immediately before construction

Selection of a channel

The possible and promising locations for a row of surface screens have to be identified from an analysis of satellite images of recent years. A rough classification of the channels distinguishes small, medium and main channels. The siltation of the medium channels seems to be most interesting, because the main channels should be kept open, and the induced strong erosion of the smaller channels, which are parallel to the main channel, is probably not acceptable. The smaller channels are not interesting because their life time is only about 1 to 3 years and this is too short for planning, installing the screens and to have some benefit during a period of at least a few years with reduced bank erosion. These life times of the smaller channels can be compared with the life time of a medium channel, which ranges roughly from 3 to 5 year. This life time is considered to be sufficiently long to obtain some profit of this measure.

The medium channels are often outflanking channels, which cause most often bank erosion of the left bank, see for example Fig. 3.5.2-1 (such a figure can be derived from satellite images as presented in Section 2.2) The length of the medium channels should be measured from the bifurcation to the confluence and this length should be more than a certain minimum value, suppose about 3 km, because in short channels also the length of the eroding bank is relatively short.

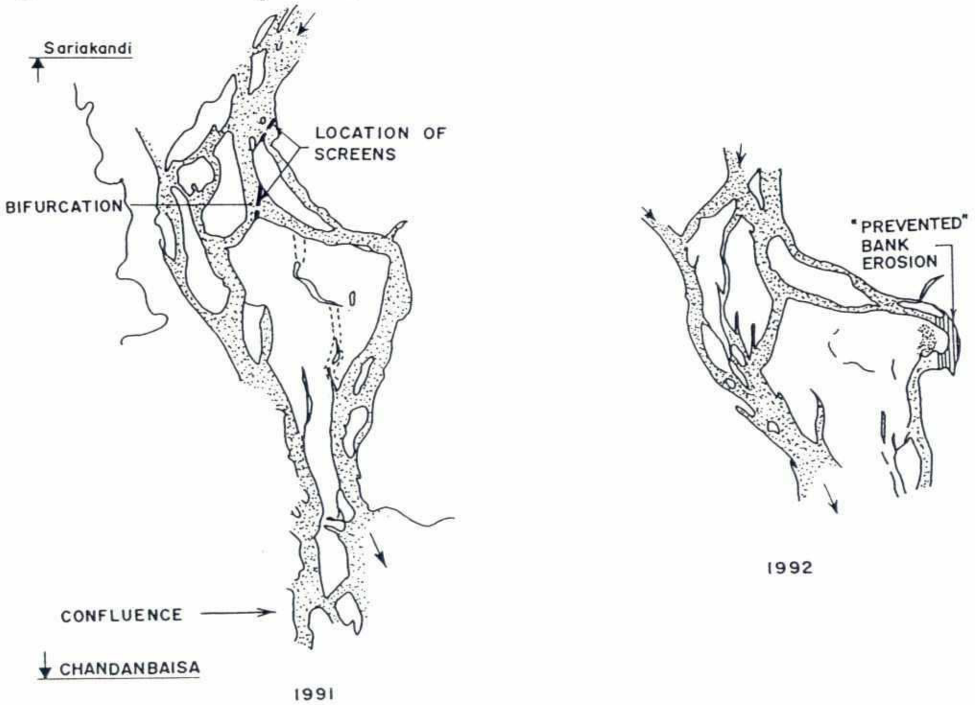

Fig. 3.5.2-1 : Outflanking channel at left bank of Jamuna River

As a consequence of the siltation of a channel the discharge in the other outflowing channels of the bifurcation has to increase and the rise of increased bank erosion in those channels has also to be estimated. If this adverse effect is not acceptable, an alternative is the placement of some rows of surface screens just in front of the bank, which is expected to be eroded. Probably a local shift of such an outflowing channel will also be prevented by this measure.

Timing

As soon as after the monsoon the changes in the channel pattern are identified, the possible locations for measures with surface screens should be determined. From the satellite images of the Jamuna river we expect that each year 1 to 4 possible locations of medium channels can be determined. After studying all recent data related to these locations a decision where to place a row of screens (including the size and the length) can be taken. The row of screens can become effective in the new location just before the start of the rising limb of the hydrograph.

A part of the strategy is the determination of the moment at which the row of screens should be placed and when this row should be removed, as a function of the hydrograph. The measure is supposed to be most effective during the flood in the monsoon period, because the sediment transport capacity is high during this period. However, during this period the anchor forces are maximum which can limit the application of floating screens.

Criteria for the bifurcation

In a strategy also the criteria for the selection of the location of the row of screens is formulated. Some of these criteria are for surface screens at a bifurcation:

- The height of the banks: The flow pattern in the channel can change during flooding of the chars, which might affect the sediment transport in the channel. A high char on both sides along the selected channel is considered as favourable. The rise of unforeseen bank erosion near the beginning and the end of the row of screens is relatively small with high banks.
- The width and the depth of the cross section at the bifurcation: A cross section with small gradients in the bed will be favourable. A cross section with for example a relatively narrow deep channel is probably prone to sedimentation, which requires regular adjustment of the depth of the screens.
- The stability of the bifurcation: In a stable bifurcation fixed structures can be applied. In an unstable bifurcation floating screens are most appropriate.
- The number of outflowing channels at the bifurcation: The prediction of the effectivity of the measure will be less accurate if the number of outflowing channels at the bifurcation increases.
- The fetch length for the wave forces on the screens: A short fetch length is favourable, but inevitable during flood conditions

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- The inland navigation: If the inland navigation uses the selected channel, then alternative routes have to be indicated.

The same type of criteria as above can be established for locations in front of an eroding bank:

- The height of the banks: A bank with a low height above the water level will erode faster than a bank with a high height.
  If the opposite bank is relatively low, then a rather quick shift of the channel, caused by bank erosion of the opposite bank, becomes possible.
- The cross section and the flow pattern.
- The length of the eroding bank: A sharp bend with a short length of the eroding bank is probably more favourable.
- The use of the bank by fishermen, country boats and ferries.
- The soil conditions are less important because the variation in these conditions is rather small. Also the influence of the groundwater flow is probably less important than the other criteria.

As a final conclusion it is stated that only "learning by doing" as result of practical experience will be the concept to define the criteria more explicitly.

3.6 SHORT TERM AND LONG TERM EFFECTS

3.6.1 General

One of the important aspects when considering the application of AFPM for the Jamuna River is the estimation of the response of the river system. This response can be divided into:

(i) response at short notice, and

(ii) the long term consequences for the river characteristics.

In this respect also a differentiation in space can be made. Responses at short notice usually are limited in distance at which their effect is noticeable, while long term consequences will in due time become apparent over the whole length of the river.

Regarding the **response at short notice** again a difference can be made, notably the effect that is actually the purpose of the actual measure, and non-intended side effects. Regarding the former one the effect of e.g. the placing of bandals is of course noticeable in the branch which has to be closed: gradually sedimentation will occur, the discharge in the channel will be reduced and also the bank erosion will gradually reduce in time. Non-intended side-effects can be noticeable in the other branches, that are subject to less sediment: degradation and widening will occur, the discharge in the channels will increase and gradually also the bank erosion along curved reaches will increase. Understanding of this response is important for avoiding not-acceptable backlashes.

The **long term response** of the river to AFPM may be that the river characteristics may change. How serious this will be depends fully on the extent of the AFPM measures. If only one or two channels are closed yearly, the overall impact will be very small. If, however, the strategy of the AFPM measures is to reduce the total width of the river to say 10 km and to tackle all channels that are tending to cross an imaginary line 5 km on both sides of the centerline of the river, then the measures to be taken are much more . In that case it may be expected that also the response of the river to this strategy will be much more serious. This may lead to a reduction of the braiding index (the number of channels per cross-section) and this in time may lead to larger channels, with deeper scour holes and even larger bank erosion rates. The identification and assessing the extent of these responses are very important as these responses determine to a large extent socio-economic benefits and damages due to AFPM.

Hereafter both short-term and long-term effects of AFPM strategies are discussed. It should be stressed that especially the assessment of the long-term effect can only be discussed in a qualitative way, as prediction methods are only being selected at present. In a later stage of the project more quantitative results will become available.

3.6.2 Short Term Effects

The short-term effects have to be considered as the direct (near field) hydraulic and morphological response to individual measures. According to the procedure as described extensively in Chapter 6 of Annex 1 the following approach is followed:

1. quantitave assessment of the hydraulic and morphological response of an outflanking channel due to measures at bifurcations,
2. quantitave assessment of the hydraulic and morphological response (including bank erosion) of the branches adjacent to the bifurcation and suffering from increased water discharges due to the measures,
3. quantitave assessment of the hydraulic and morphological response of an outflanking channel due to individual measures in this channel and at the outer bank to prevent further bank erosion.

As an initial result of this approach reference is made to Section 3.4 aiming at the first step in this approach. At a later stage of the project the following steps will be high-lighted.

3.6.3 Long Term Effects

In a braided river like the Jamuna River the number of freedoms is fairly large, and relationships are missing to establish all river parameters univocally in a theoretical way. Hence empirical relations have to be used to assess the long-term effects of AFPM strategies.

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AFPM strategies can have a variety of objectives. Some possible options are the following:

Option 1 Close only very aggressive eroding channels, probably some 2 or 3 per year.

Option 2 Try to reduce the total width of the braided belt by consequently closing the most outward channels, and by forcing artificial cutoffs.

Option 3 Construct gradually more bank protection works at vulnerable places, which will lead to a narrower channel system (conform what has been the case downstream of Sirajganj over the last decades).

Option 4 Try to create a transition of the braided river with multiple channels to a meandering river with one channel.

Option 5 As option 4 but in combination with river training works to stabilize the alignment of the river

In principle all these options should be studied under FAP 22, but for the time being the latter two options are not considered here: they are too extreme, major investments are required and the effects of these options may be very serious in the sense of changes in water levels.

Some preliminary estimates on the three remaining options are given below.

Re Option 1 Close only very aggressive eroding channels, probably some 2 or 3 per year. It is estimated that the long term effect of this strategy is negligible. This can be demonstrated by comparing the total length of the river in Bangladesh (some 150 km), with on the average 2 to 3 channels, so in total some 400 km, corresponding to some 10 km. Hence only 2.5% of the total reach of the river will be affected. The effect seems indeed negligible and not noticeable against the background of the highly variable conditions in the Jamuna River.

Re Option 2 Try to reduce the total width of the braided belt by consequently closing the most outward channels, and by forcing artificial cutoffs. Reducing the total width of the river will have effects on the number of parallel braids and the width and depth of the individual channels in the braiding belt. A tentative idea about the effect can be derived from:

(1) an empirical relation between the number of channels in the Jamuna River and total width of the river system, as given in Fig. 3.6-1, whereby the mode of oscillation is approximately double the number of channels;

(2) regime relations for the Jamuna River as derived by Klaassen & Vermeer, 1988, which for bankfull conditions read as (see also Fig. 3.6-2):

$$h_b = 0.23Q^{0.32} \qquad (3.6\text{-}1)$$

$$B_b = 16.1Q^{0.53} \qquad (3.6\text{-}2)$$

where B_b = bankfull width (m), h_b = bankfull depth (m) and Q = bankfull discharge (m^3/s).

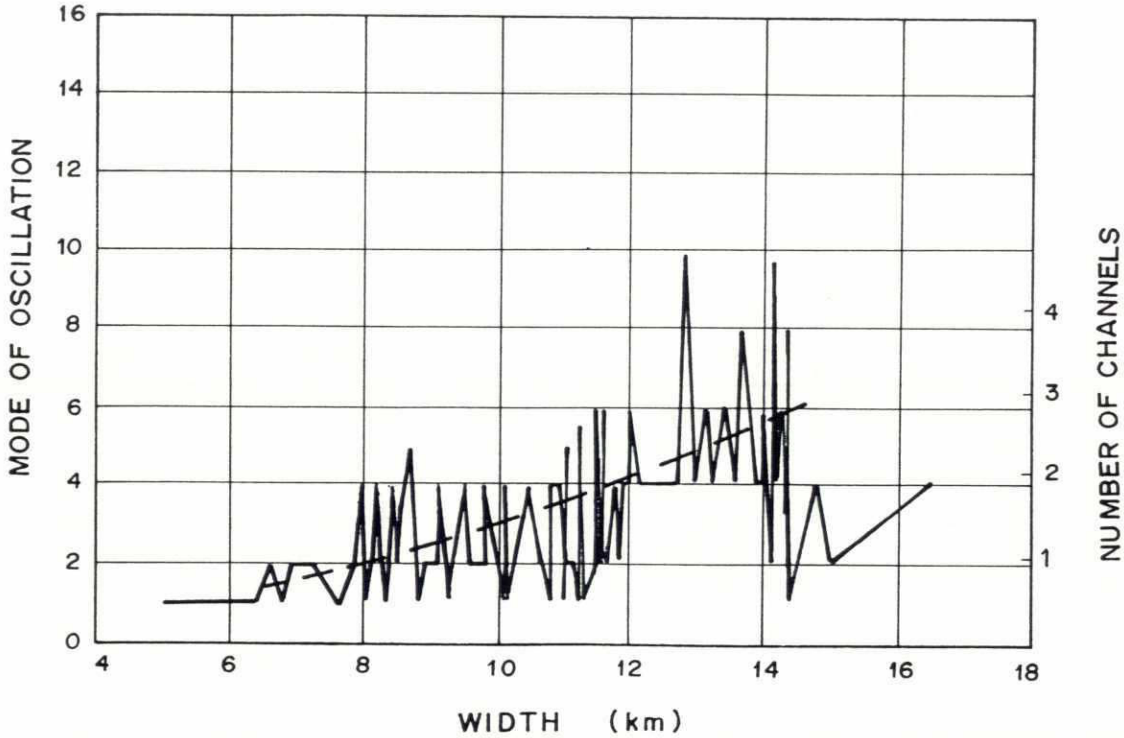
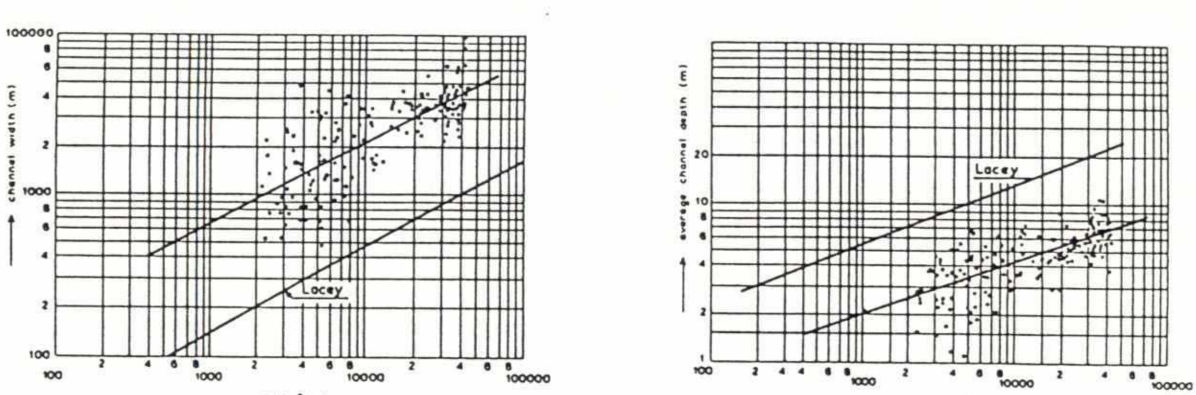


Fig. 3.6-1: Empirical relation between number of channels and total width of Jamuna River



(a) width versus discharge **(b) average depth versus discharge**

Fig. 3.6-2: Regime relations for the Jamuna River channels (Source: Klaassen & Vermeer, 1988)

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It has been shown (Klaassen & Vermeer, 1988) that bankfull conditions in the Jamuna River correspond to a discharge of about 44,000 m^3/s, and this discharge of course has to be divided over the number of channels present. Application of the above empirical relations leads to the tentative assessment of the long term effects as indicated in Table3.6-1.

Total width (km)	Number of channels n (-)	Bankfull discharge per channel (m^3/s)	Average bankfull depth (m)	Average bankfull width B_b (km)	Total width channels $n*B_b$ (km)
14	3	15,000	5.0	2.63	7.9
12	2	22,000	5.6	3.22	6.4
8	1	44,000	7.0	4.65	4.6

Table 3.6-1: Tentative assessment of long-term effect

In addition changes in slope can be expected: reducing the number of channels will result in a smaller slope. First estimates are that the slope of the river will be reduced in the order of 5 to 15%. This will probably be compensated by a slightly increased sinuosity of the individual channels.

An aspect that has to be considered furthermore is the possible increase in bank erosion rates. As a first estimate the rate of bank erosion increases linearly with the average discharge of the channels, hence a decrease of the total width of the river will increase the bank erosion rates with a factor 1.5. The socio-economic benefits of the river occupying less area (as the factor $n*B_b$ becomes less) has to be weighted against the socio-economic losses due to this increased bank erosion rates. It should be realized however that this erosion can be controlled by the AFPM measures themselves and may therefore be even less harmfull than under the present conditions.

Re Option 3 Construct gradually more bank protection works at vulnerable places, which will lead to a narrower channel system.
For the time being this option is considered to be comparable to option 2. The main difference is that because the creation of hard points is explicitly part of the strategy, there could be less problems with increased bank erosion rates. This comes at a price of course, because at more locations bank protection works have to be constructed in a shorter period.

Overviewing the preliminary results presented above for the options 1 to 3, it can be stated that a relative minor change of the total width of the river results in a reduction of the number of channels, an increase in the average depth of the channels and a reduced "wet width" allowing for increased land use along the river.

3.7 REVIEW OF ALTERNATIVE CONSTRUCTIONS FOR SURFACE BANDALS

Considering the first tentative conclusion for AFPM as described in the previous sections the impression exists that surface screens can serve as a technically feasible tool for the development of the Jamuna floodplains. Whereas up to now the recurrent measures have been discussed in terms of their general systems effectivity (Sections 3.3 and 3.4) and the experiences gained in other projects (Annex 1), this section intends to discuss some first (sketchy) designs which may serve in a possible FAP 22 pilot project on the Jamuna River.

The following options for possible surface bandals have been considered (see Fig. 3.7-1):

1. Bamboo bandals (water depth to 4 m)
2. Bamboo structures (water depth 4 to 8 m)
3. Light floating structures (water depth 5 to 10 m)
4. Anchored barges (water depth 5 to 6 m)
5. Barges with movable screen (water depth 5 to 10 m)
6. Floating screen structures with iron pipes (water depth 5 to 10 m)
7. Geo-membrane floating structures.

Re 1. Bamboo bandals: This type of construction is being traditionally used in the Jamuna River during low flow for increasing navigation depth. The experience at present in Bangladesh with the bandals has learned that this type of construction is only applicable in water depth upto 3 to 4 m. This type of construction is the cheapest option available. The costs amount to about Tk. 500 / m.

Re 2. Bamboo structures: As there is no experience for this type of structures due to problems associated with local scour and water pressure (static and dynamic) in bigger water depth (4 to 8 m), a preliminary design has been made on the basis of hydraulic load assessments and bamboo strength factors, such as:

i)	fibre stress at elastic limit	65 N/mm^2
ii)	modulus of rupture	117 to 122 N/mm^2
iii)	modulus of elasticity	12 to 16 N/mm^2
iv)	crushing strength	56 to 58 N/mm^2

(Source: The use of bamboo and reeds in building construction, United Nations, Page 90)

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The costs of this type of structure has roughly been estimated to amount to Tk.3,500 / m.

Re 3. Light floating structure: This type of structure can be considered as a modification of the bamboo structure in order to achieve a flexible solution by using a pontoon made of empty barrels. Here the screens are connected to the pontoon and are not movable but have fixed heights. Although this structure is more flexible than the bamboo structures (Re 2.), in practice this solution would meet problems due to the varying water levels. This problem can be overcome supplementing of these structures with different screen heights. Such an additional supply leads consequently to higher costs. Cost estimates from manufacturers come roughly to Tk. 35,000 / m (including roughly estimated costs for anchoring).

Re 4. Anchored barge: This type of solution has also been considered due to the high reliability and mobility, which is an important factor regarding the requirement of an Active Flood Plain Management. Although it was known from the outset that this type of structure would be a costly option, some cost indications from manufacturers have been collected due to the interesting features of these structures. The costs including anchoring costs vary from about Tk. 60,000 / m for old barges (dimensions: 60 m * 8.5 m * 3.5 m) to Tk. 175,000 / m for new barges (dimension: 15 m * 5 m * 3 m).

Re 5. Barge with movable screen: This option is very attractive considering reliability and high flexibility. Especially the last aspect is very attractive due to the easy mobility and movable screen for varying water levels. Anyhow, there will be additional costs in comparison with the anchored barge solution (Re 4.). A rough estimate comes to around Tk. 75,000 / m for old barges and Tk. 190,000 / m for new barges.

Re 6. Floating screen structure with iron pipes: This option can be considered as an alternative for the floating screen structure from a floating barrel pontoon (Re 4.). However the flexibility with respect to the varying water levels has been increased by providing different drafts through partially filling the pipes. Although there are no cost estimates from manufacturers at present, it is assumed that the costs involved are comparable to the "old barge with movable screen" (Re 5.), say Tk. 75,000 / m.

Re 7. Geo-membrane floating structure: This option seems to be a durable and easily adjustable structure. However, at present no cost estimates can be presented due to a lack of experience with such structures.

In Table 3.7-1 the most important aspects as discussed for the 7 optional screen types have been summarized.

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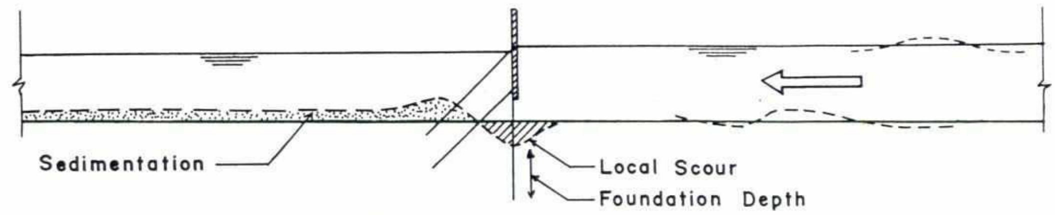
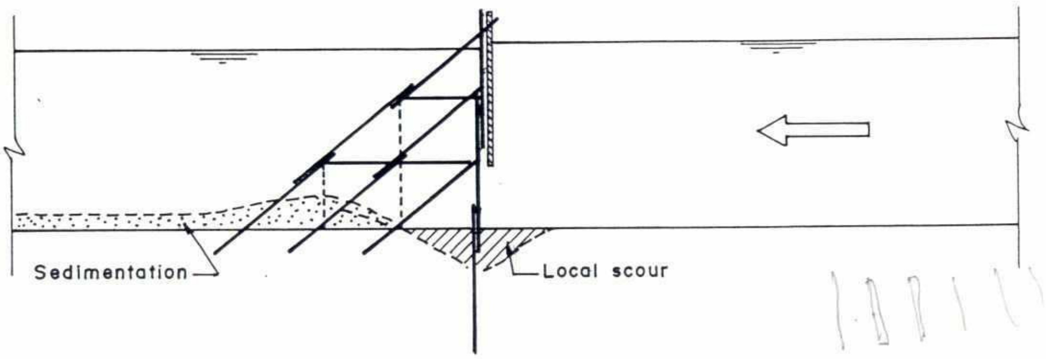
No	Option	Suitable water depth	Durability	Flexibility	Initial costs Tk. / meter
1	Bamboo bandal	3 to 4 m	+	⊕	500
2	Bamboo structure	4 to 8 m	+	⊕	3,500
3	Light floating structure	5 to 10 m	+	+	35,000
4	Barge	5 to 6 m	++	+	60,000 *) 175,000 **)
5	Barge with screen	5 to 10 m	++	++	75,000 *) 190,000 **)
6	Iron pipe structure	5 to 10 m	+	++	75,000
7	Geo-membrane structure	?	++	++	?

++	highly advantageous	*)	old barges
+	moderately advantageous	**)	new barges
⊕	poor		

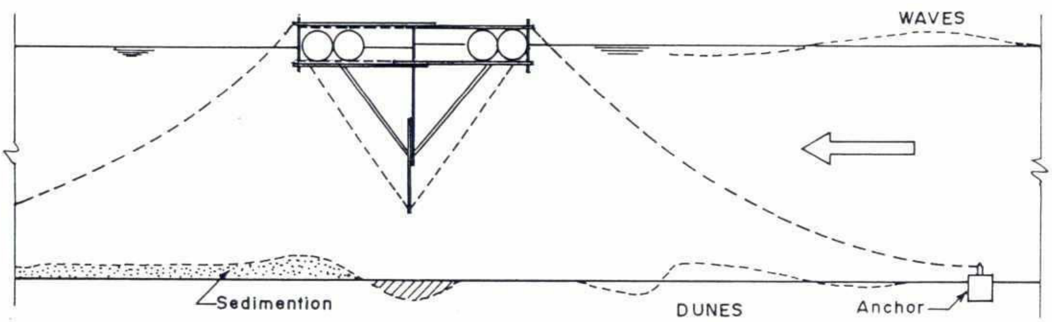
Table 3.7-1: Comparative review of alternative constructions



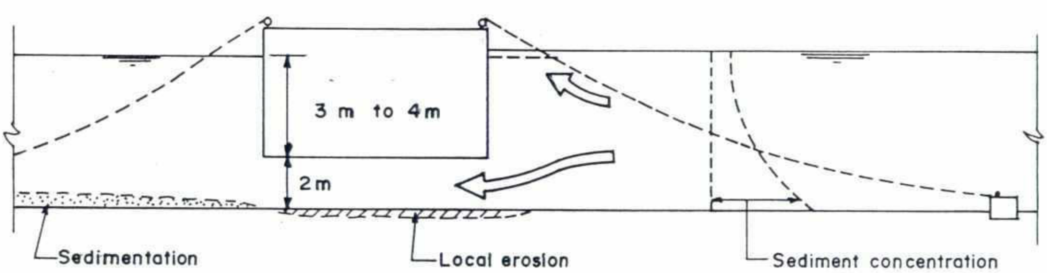
1. Bamboo bandals (water depth 3 to 4 m)



2. Bamboo structure (water depth 4 to 8 m)



3. Light floating structure (water depth 5 to 10 m)



4. Anchored barge (water depth 5 to 6 m)

Fig. 3.7-1: Alternative constructions

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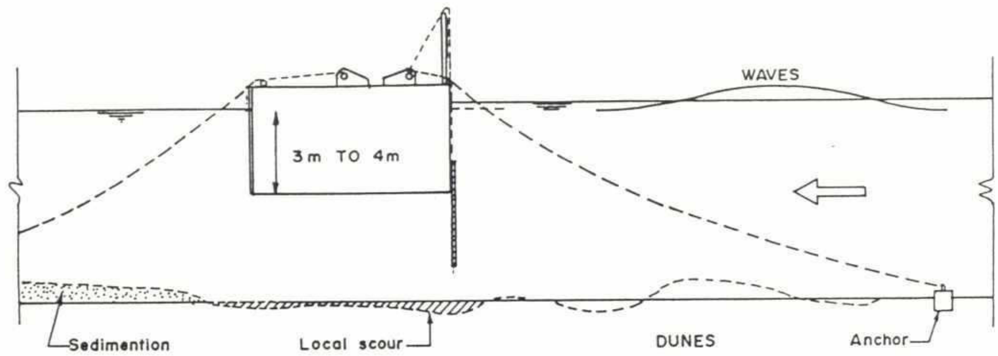
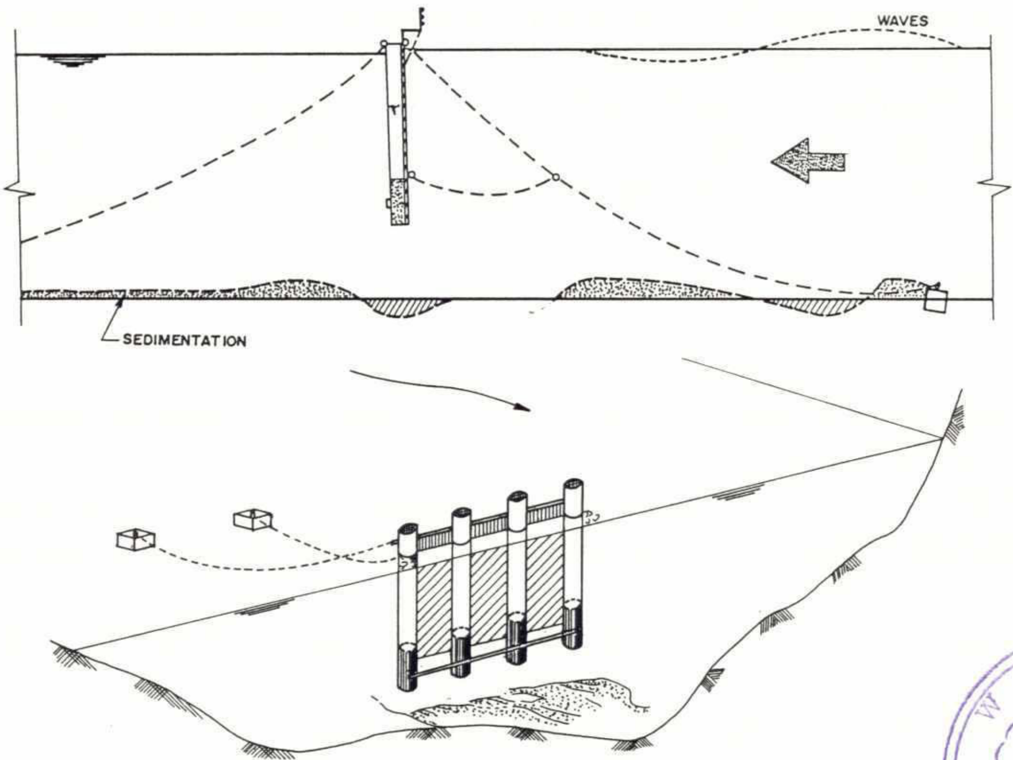
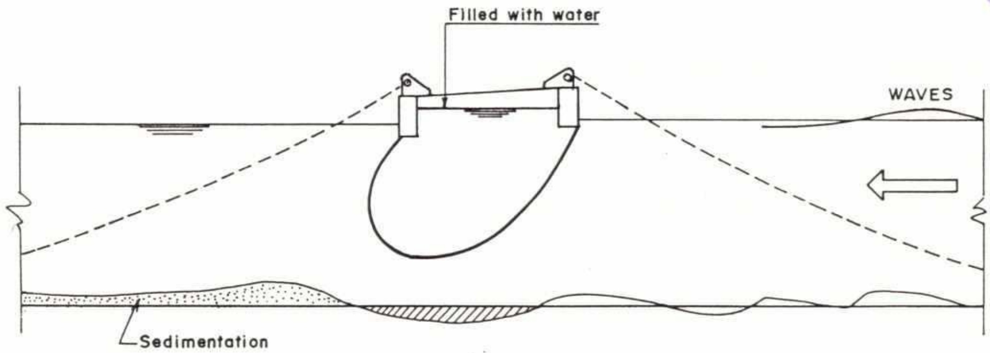


5. Barge with movable screen (water depth 5 to 10 m)



6. Iron pipe structure (water depth 5 to 10 m)



7. Geo-membrane structure

Fig. 3.7-1: Continuation

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3.8 PROSPECTS AND CONTINUATION

Prospects for an AFPM approach still depend very much on the results of the ongoing studies concerning the effectivity of the measures as well as the hydraulic and morphological response of the river. As discussed in Section 3.1 the activities to be performed within the framework of the FAP 22 project are being done according to a stepwise approach (see Table 3.1-1). From the results upto the Interim Report it has been concluded that recurrent measures as surface screens can make a valuable contribution to river training and AFPM. From this conclusion it seems to be justified to consider a combination of recurrent measures and heavy permanent structures as a prerequisite for the future development of the Jamuna floodplains. From this point of view some preliminary cost estimates for surface screens are presented in Section 4.2. The variety of constructions has indicated that the degree of flexibility of a construction affects the final costs (the more flexible, the higher the costs). However, a combination of some constructions might offer a "low cost" recurrent measure to be implemented as a tool for the development of the Jamuna floodplains. Without these relatively "low cost" recurrent measures it seems obvious that training of the Jamuna River will most probably be limited to the protection of isolated points of importance, like towns, ferry ghats and bridge crossings.

On the basis of the present results of the FAP 22 project the following activities are envisaged for the next phase:

1. Further developments into the effectivity quantification of some other promising recurrent measures, such as: sills, pile rows, agitation dredgers (see Section 3.3.3).
2. Further elaboration of the simplified methods to quantify the short term hydraulic and morphological response to a measure (see Section 3.4.3).
3. Further analysis of the Jamuna River behaviour in order to assess more accurately than upto now the long term response of the river to AFPM.
4. Formulation of some strategies (to be considered as combinations of measures) with respect to the development of the floodplains.
5. Further cost estimates of optional recurrent measures.
6. Estimates of environmental, socio-economical and land reclamation aspects (benefits) on the basis of some strategies, selected as possible technically feasible options.
7. If the output of the preceding activities is sufficient, rough outlines for the performance of model tests and/or a pilot project will be given.

As indicated for the activities 4 and 6 it is envisaged that a number of problem situations will be selected on the basis of a thorough analysis of satellite images of the Jamuna River. After that, some strategies will be formulated as possible examples of AFPM. The aspects to be considered should focus on the direct benefits of a combined river training

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and flood plain development, such as:

- prevention of erosion of agricultural land, villages, etc.,
- reduction of damage to embankments and levees resulting in less breaches and consequently in less maintenance costs,
- improvement of the navigability of the river.

The estimates as per activity 6 will be made from the point of view that the reduction of erosion risk would allow a more efficient use of the floodplain. A more planned development and more investments in agriculture will then result in a higher production of the land and increased security of the people.

Last but not least it is noticed that AFPM requires a qualified organization having explicit authority to take immediate decisions as well as having the right means to implement the required measures without any delay. The organization should closely monitor the river development in order to take measures in an early stage when the recurrent measures have their highest effectivity. The set-up and the tasks for such an organization will be formulated in a later stage as part of a possible pilot project.

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4 TENTATIVE BUDGETING OF TEST WORKS

4.1 FAP 21 WORKS

4.1.1 Basis of Tentative Cost Estimates

To derive at tentative but reasonable cost estimates for proposed test works the Consultant has performed a unit rate analysis including labour, equipment and material costs. This analysis so far is based on all available BWDB Schedule of Rates (particularly for Bogra and Mymensingh O&M Circle), FAP project reports (particularly FAP 1, 3.1 and 9B), System Rehabilitation Project (SRP) Schedule of Rates, recent tenders received (e.g. Teesta Barrage Project) and present market rates from other sources. Jamuna Multipurpose Bridge (JMB) cost estimates were used for comparison.

The rates evaluated as before were taken for the estimation of construction cost for structures tentatively selected as per Subsection 2.3.5. They have still to be verified by a more detailed analysis of construction materials and methods (Tasks 17 and 18 of the Consultant's Scope of Work), which will include discussions with local contractors, inspection of their equipment fleet and their performances, quality and suitability of material resources, etc.

In this connection also improvements to traditional construction and new methods under local conditions will be discussed. Thereafter, including also the outcome of the design method study regarding alternative revetment types etc., the cost estimates will have to be refined. Thereby, also latest tenders and contracts will be considered.

The estimate includes:

1. Three groynes to be constructed at Kamarjani test site each 100 m long, having different slopes, slope protection and falling apron designs. The crest level shall be horizontal 1 m above HFL. The works shall be carried out by cutting into the flood plain but the structures will partly protrude into the open river too, thus saving costs but testing construction methods under flowing water conditions at the same time.

2. About 1000 m of bank revetment works at Bahadurabad test site with additional upstream and downstream terminations each 150 m long to prevent outflanking. Within this structure 10 different types of revetment can be tested, varying in filter layer build-up, materials for cover layer and falling apron design, placed at different levels (above and at same level as river bed). The slopes shall have uniform inclinations, both above and below SLW, with a berm in between. The works shall be carried out in a construction site excavated from flood plain level and dredging a trench into it, thus partly protected against the current by a dam. The downstream end will, however, be executed in flowing water conditions.

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The tentative execution cost for the different types of the structure varies between about 11,000 DM and 17,000 DM per running meter length, including all earth work with dredging, toe protection etc. but excluding installation, overheads and contingencies.

Based on 1993 price level, the tentative overall construction costs have been estimated as follows:

Groynes at Kamarjani site	13,700,000 DM
Bank revetment at Bahadurabad site	12,300,000 DM

	26,000,000 DM
Site installation and demobilization at 7%	1,820,000 DM
Contractors overheads at 20%	5,560,000 DM
Contingencies at 10%	3,320,000 DM

Tentative total costs	36,700,000 DM
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4.2 FAP 22 PILOT PROJECT

4.2.1 General Considerations

A pilot project for FAP 22 component would include the testing of some recurrent measures aiming at modifying the river's planform either by silting up a or by increasing the flow in a certain branch. It would possibly be preceded by a specific (model) study to define the eventual location where to implement such measure as well as its dimensions.

At present no pilot project has been finally defined yet, this is due for the end of the study. However, in order to allow for preliminary allocation of funds a tentative budgeting has been tried to be made on some general and basic thoughts on possible AFPM.

The main question to be answered would be:
Is there a rational chance that recurrent (low cost) AFPM measures may work in a river like the Jamuna? The Consultant has concentrated on that question, the various components for coming to an answer being presented in Chapter 3, and has come to the conclusion: Yes, there seems to be a fair chance for that, e.g. by installing surface screens.

The next thought refers to the questions where and at which size to implement such a measure, and the outcome is as follows: To test the effectiveness of such a measure in prototype scale it has to be done in an area which would allow for a comparison - with and without measure. In the highly variable Jamuna this means that the measures cannot reasonably be tested on a smaller channel of say 500 m width since experience gained in

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recent morphological investigations in this Project (mainly the remote sensing study) showed that such small channels have only a very restricted life time in the tune of may be not more than 2 to 3 years. For a first tentative cost estimation it will be assumed that the measure will be implemented on a 1000 m wide branch. The investigations on the tailor-made mathematical model showed that closing of a channel with a surface bandal appears possible under the condition that the entrance of it is at least half closed. Hence, the tentative cost estimate will assume a closure on 700 m length.

The third and last basic thought refers to the time and period of the year when the pilot measure should be implemented. At the end, and in order to achieve larger river bed modifications, it will be necessary to have the measure operating during the flood season, up to say bankful discharge. However, for testing, this will probably too risky so that it is anticipated that the first measure would be tested during low flow. It might even be that the effectiveness of a measure could better be assessed during the lower discharge season with less sediment transport. The low flow test could in this light be conceived as an about 1 in 5 scale test of the operation at bankfull discharge conditions.

pre-monsoon / post monsoon

4.2.2 Basis of Tentative Cost Estimates

Alternative structural solutions for surface bandels, with their respective pros and cons are presented and discussed in Section 3.7. That review of alternatives also includes tentative costs, expressed as unit costs per metre. The prices are based on inquiries of contractors, shipyards, workshops, BIWTA etc. and the Consultant has cross-checked them whenever possible. However it should be kept in mind that the prices are still very much subject to possible modifications since (1) the price informations were not binding and (2) the design basis is not yet clearly defined.

For calculating the cost of a pilot project some additional cost have to be added viz:

- preceding model tests
- preparation of site
- working boat (it should be capable to do some low cost dredging to increase the sediment load in the bottom layer)
- local operation & maintenance staff.

The implementation schedule in estimated as follows:

1993	- additional study (not quoted for in this chapter)
	- model investigations
1994	- purchase of equipment and installation of screens in Oct/Nov. 1994
1995	- dismantling screen in May 1995
	- reinstallation of screen in Oct/Nov.1995
1996	- dismantling screen
	- final evaluation of efficiency, definition of further procedure etc.

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As a first approach the screen of 700 m is supposed to be composed of the following structures, the mix being chosen partly for technical reasons (water depth, resistance to flow velocity) and partly for testing purposes:

Basic costs

100 m of bamboo bandals (Re1)		
100 m of bamboo structures (Re2)		DM 20,000
200 m of light floating structures (Re3)		DM 280,000
300 m of barges with movable screen (Re5)		DM 900,000
100 m of floating screen with iron pipes (Re6)		DM 300,000

	Subtotal 1	DM 1,500,000

Additional costs

Model tests		DM 200,000
Preparation of site		DM 200,000
Working boat (second hand)		DM 500,000
Operation and maintenance staff for 2 seasons		DM 100,000

	Subtotal 2	DM 1,000,000

Contingencies		DM 500,000
		5%

	Tentative Total cost	DM 3,000,000
		=======

4.3 TENTATIVE BUDGETING OF THE TEST WORK CONSTRUCTION AND ADAPTATION

The following table presents a tentative disbursement schedule for construction and adaptation of the tentative test works. The construction costs on 1993/1994 price basis are escalated by 10% for the costs for works constructed in the second dry season (1994/1995). The Consultancy costs are not included.

Table 4-1 Tentative disbursement schedule

Cost in 1000 DM						
FAP 21	1993	1994	1995	1996	1997	Total
Groynes Kamarjani	6,000	13,350				19,350
Revetm. Bahadurabad		5,000	12,400			17,400
Escalation			1,250			1,250
Subtotal Construction	6,000	18,350	13,650			38,000
Adaptation		1,000	2,000	3,000	2,000	8,000
Total FAP 21	6,000	19,350	15,650	3,000	2,000	46,000
FAP 22						
Model Test	200					200
Structures, Const.O&M		2,600	200			2,800
Total FAP 22	200	2,600	200	-	-	3,000
GRAND TOTAL	6,200	21,950	15,850	3,000	2,000	49,000

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5 HIGHLIGHTS OF ACTIVITIES UNDERTAKEN, ONGOING AND PLANNED

5.1 INTRODUCTION

The periods since the presentation of the Inception Report in March was packed with a number of rather different activities, some of them quite time consuming, and nearly all of them being cornerstones of the Project.

To start with, there has to be mentioned the **morphological studies** for the reconfirmation of the test areas which had been pre-selected at an early stage of the Project, based on quite preliminary data. Now, these data were substantially completed and updated to allow for a high quality remote sensing study on the planform modification of the Jamuna during the past 4 years and to produce the basis of a sound forecast. The activities related to and the results of that study were described in Section 2.2 and more details are found in Annex 2.

Parallely, to the reconfirmation of the test areas the **field investigations** were carried out at these four determined areas along the Jamuna River viz: Kamarjani, Bahadurabad, Chandanbaisa and Nakalia. Quite intensive surveys, both topographic and hydrographic, as well as subsoil investigations took place, always under the pressure of the approaching monsoon season which, for that Project, was fortunately late in this year. The field investigations are described in Section 5.2 and in the Annexes 7 and 8.

The development of new standards for cost efficient bank protection techniques requires a profound knowledge of currently and previously applied techniques on that field. As a result of intensive travel and discussions an **inventory of existing and planned bank protection works** has been compiled. The technical and economic activities in that context are summarized in Section 5.3 and 5.8 respectively as well as in Annex 9.

Whereas the previously mentioned inventory was related to the FAP 21 component the elaborations on the **state of the art of river training** is related to FAP 22. In fact, the Consultant has increased the scope of that task by including some elaboration on the morphological response to recurrent river training measures. The details on the respective activities are reported in Chapter 3 and in Annex 1.

Model investigations, both physical and mathematical, are important tools to reach the objectives of the Project. Whereas the mathematical model investigations on the MIKE 11 package and on own tailor-made models are already in full swing, the physical model investigations are starting during the days this report is written. Information on the model tests run by the Project is given in the Sections 3.4, 5.5, 5.6, 5.7, 5.9 as well as in the Annexes 3, 5, 6 and 10.

Last but not least mention should be made on two **study tours** which were jointly done by representatives of GoB and the Consultant. The first study tour in April went to Europe concentrating on attending the 5th International Symposium on River Sedimentation in Karlsruhe, Germany, followed by a visit to several European rivers. The destination of the second study tour in May/June were the large braided river systems of the Yellow and the Yangtze Kiang Rivers in China and the Mississippi River in U.S.A. The experiences of these tours are reflected in many aspects of this study, particularly in relation to the training and active flood plain management component (FAP 22).

5.2 FIELD INVESTIGATIONS

5.2.1 Geotechnical Investigations

5.2.1.1. Purpose of Investigations

Subsoil investigations have already been executed in the past along the left and right river banks of the Jamuna in connection with other projects, e.g. Brahmaputra Right Embankment Project (FAP 1), Jamuna Multipurpose Bridge Project, Jamalpur Priority Project (FAP 3.1) etc. They provide detailed information on the particular locations and general information on the entire river stretch.

In accordance with Task No. 10 of the Project's Scope of Works, further soil exploratory works have been carried out to obtain a basic knowledge of the subsoil conditions in the selected areas, as well as basic soil mechanics parameters for preparation of alternative preliminary designs of the planned bank protection measures.

More detailed subsoil investigations shall be executed immediately on commencement of the Implementation Phase, at the exact locations of structures finally proposed and approved.

This preliminary report on geotechnical first phase investigations contains a description of the field works and of the in-situ and laboratory test results as far as completed till now.

5.2.1.2 Scope of Works

Four areas along the Jamuna River have been tentatively selected for implementation of the test structures (see "Technical Report No.1" of March 01, 1992 as well as Fig. 2.1 - 1) i.e.

- Kamarjani (North of Manos Regulator)
- Bahadurabad ghat
- Chandanbaisa
- Nakalia.

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In order to obtain a general information of the prevailing soil strata within the test areas, varying between 5 and 13 km in length, the boring and sounding locations were spread as far as practicable in regular distances along the river banks, vide Fig. 5.2.1 - 1 and 2.

The geotechnical investigations include:

- Execution of boreholes, depth 20-40 m.
- Extraction of disturbed and undisturbed soil samples from boreholes/ adjacent test pits.
- Execution of Standard Penetration Tests (SPT) at 1.5 m interval.
- Execution of Cone Penetrometer Tests (CPT).
- Installation of stand pipe piezometers for in-situ soil permeability tests and observation of ground water levels.
- Laboratory testing of disturbed and undisturbed samples.
- Compilation of field and laboratory test results including comprehensive final report.

5.2.1.3 Field Work Execution

(a) Time Schedule

Four bids for the soil exploratory works were submitted by local contractors specialized in this field of works. After their evaluation the contract was awarded to Foundation Consultants Ltd. Dhaka, with the obligation to start the field works on 1st of April and to complete them by 15th of May 1992. Due to delay in the mobilization of equipment and the Eid-holidays in early April the actual commencement date was 11th April, 1992.

The following chart describes the field tests executed and the execution period at each test area.

Test Area	Type and Volume of Works	Work Period	
		From	To
Kamarjani (North of Manos Regulator	4 Nos.borings (1x40 m, 2x25 m, 1x20 m deep) inclusive of Standard Penetration Tests	30/04/92	05/05/92
	2 Nos.Cone Penetration Tests	29/04/92	17/05/92
	1 No. Piezometer		
Bahadurabad Ghat	4 Nos.borings (1x40 m, 1x25 m, 2x20 m deep) inclusive of Standard Penetration Tests	08/05/92	16/05/92
	3 Nos.Cone Penetration Tests	20/05/92	22/05/92
	1 No. Piezometer	08/05/92	
Chandanbaisa	4 Nos.borings (1x40 m, 2x25 m, 1x20 m deep) inclusive of Standard	11/04/92	24/04/92
	Penetration Tests	16/04/92	20/04/92
	2 Nos. Piezometer	17/04/92	
Nakalia	4 Nos.borings (1x40 m, 2x25 m, 1x20 m deep) inclusive of Standard Penetration Tests	24/05/92	30/05/92
	3 Nos.Cone Penetration Tests	26/05/92	01/06/92
	1 No. Piezometer	24/05/92	

The field works were finally completed on 03.06.92. Work on soil mechanics laboratory tests commenced on 18.05.92 and were completed end of June, except triaxial sheets tests, completion for which is now scheduled for early August.

The subsoil Expert-1 left on 16.06.92, after the majority of tests were completed and as it became obvious that execution of triaxial shear tests were delayed further due to breakdown of the subcontractor's equipment. The remaining tests will be supervised by Subsoil Expert-2. It is the intention to have the evaluation of test results (including soil stability investigations etc.) done by another expatriate who is specialized in soils mechanics and hydraulic engineering, as soon as all test results are available. The remaining 0.5 man-month from Subsoil Expert's-1 assignment can be used therefor.

(b) Equipment

The tender document for the exploratory works left it to the bidders as to which method they will apply for sinking the boreholes, either light cable percussion or wash boring. All bidders preferred the latter one, since this method is more common in Bangladesh.

However, as no continuous accurate sampling can be expected by the water or mud circulating method, representative soil samples could only be obtained from the SPT split spoon sampler.

The contractor engaged two drilling machines for the field work:

1. Koken heavy duty drilling machine RK-2 (weight about 3.0 tons)
2. Tone boring rig THS/IC (weight about 1.5 tons)

Both machines were used simultaneously at different locations for sinking of holes and execution of Standard Penetration Tests. In addition the hydraulic gear of the Koken drilling machine was suitable for the performance of the Cone Penetration Tests. The main equipment was supplemented by two engine operated high pressure mud pumps.

(c) Description of Work Operations

Mobilization and Site Situation

All 4 test areas were inspected by the Consultant and his subcontractor in advance of the actual field works, in order to study the access conditions from the land and river side and to mark the test locations.

Generally, the accessibility from land side was found to be rather difficult, because of the existing infrastructure and in addition it often required to pass through cultivated lands.

The distance between test locations and the next accessible road (normally unpaved surface) in each test area ranged between :

1.	Kamarjani:	200-300 m
2.	Bahadurabad ghat:	200-2000 m with few cross bars
3.	Chandanbaisa:	2-14 km including crossing of the Bengali River
4.	Nakalia :	300-600 m

Under these conditions it was agreed upon with the subcontractor to mobilize and approach each test location with the whole equipment from the river side. A 12m long steel boat was used for transporting and shifting of the equipment from one test location to the other.

Sloped ramps were prepared at the river banks to load and unload the drilling equipment to and from the boat, respectively.

During soil exploratory field work, the water levels showed a rising tendency. The river level rose during the working period by about one meter. It resulted in bank heights above river water level at different landing places as follows :

Kamarjani	:	2.0 - 3.0 m
Bahadurabad ghat	:	2.5 - 4.0 m
Chandanbaisa :		1.0 - 1.8 m
Nakalia	:	1.0 - 5.0 m

Drilling of Boreholes for SPT

As already mentioned under Subsection 5.2.1.3 wash boring method was adopted to sink the boreholes. The soil at the bottom of the hole was loosened by a 95mm dia bit and carried to the surface by water recirculating under high pressure. To avoid collapsing of the hole, a 125 mm diameter casing was driven, generally 8 to 10 m deep. Below this depth drilling mud was used for hole stabilization. For determination of the character and consistency of the soil strata, Standard Penetration Tests were carried out at 1.5 m intervals and disturbed soil samples collected from the split spoon sampler.

Undisturbed soil samples from cohesive layers could be obtained by means of open tube samplers of 75 mm diameter, but hardly below water level.

It must be noted that the situation could have been improved by introducing a thin walled sampler or a piston sampler which, however, were not available in Bangladesh.

The dimensions of the split barrel sampler which was used for soil sampling and Standard Penetration Tests procedure corresponds to the specifications of ASTM D 1586.

Fig. A8-3 through A8-A18 of Annex 8 present the respective data comprising depth below ground level, 'n'-value (No. of blows) and soil sampling for Standard Penetration Tests as well as main laboratory test results (to be completed).

Penetrometer Tests

Ten Penetrometer Tests were performed in the test areas by using mechanical cone penetrometers. Two types of penetrometer cones were used:

Type 1: mantle cone and

Type 2: friction jacket cone.

Both have been manufactured in Bangladesh according to the specifications laid down in ASTM D 3441. Fig. 5.2.1-3 shows dimensions of the cone penetrometers used. While Type 1 could be used for measuring the cone resistance only, Type 2 was suitable for measuring cone resistance as well as local skin friction.

The procedure of measuring the forces on the cone and friction sleeve was repeated at regular intervals of depths, normally at 20 cm.

At some test locations the test had to be discontinued due to jamming of the cone mechanism caused by soil particles which penetrated between sliding surfaces. The reason for this effect was most probably the presence of very fine grained soils in the test area. However, after extracting and cleaning the cone penetrometer the test could be resumed.

Fig. A8-19 through-28 of Annex 8 present illustrative diagrams of measured cone resistance and skin friction at different test locations.

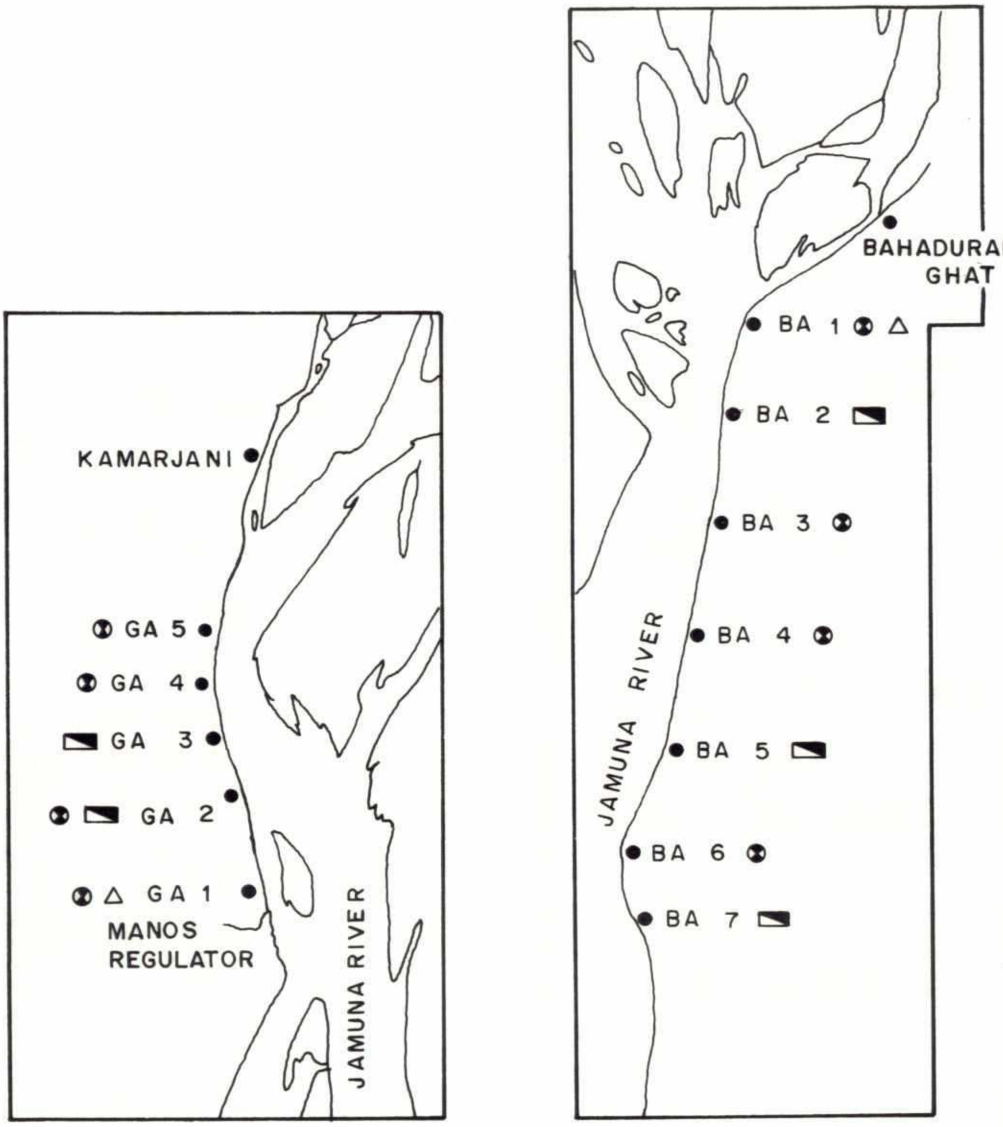
Permeability Test

For determination of the in-situ permeability of the subsoil, at least one piezometer has been installed at each test area. Fig. 5.2.1-4 shows the details of piezometers installed.

The depth of the piezometers ranges between 6 and 8 m below ground surface.

For installation of piezometers the boreholes were drilled by wash boring method. The annular space between strainer and hole was filled with coarse sand beyond the upper level of the strainer and bentonite balls and cement bentonite grout was used as sealing material above that level.

The in-situ permeability test was conducted as a "Constant Head Test" in accordance with the recommendations laid down in BS 5930: 1981. To perform the test, the piezometer was filled with clean water up to the top of piezometer stand pipe which was approx. 1.0 m above the ground level. This water level was kept by adding additional water until a steady rate of flow could be observed. Prior to the test, the static ground water level was checked in the piezometer.



KAMARJANI
(NORTH OF MANOS REGULATOR)

BAHADURABAD

LEGEND

BA 1 – Bahadurabad Location 1
GA 1 – Kamarjani Location 1 (Gaibanda area)
– Standard Penetration test
– Cone Penetrometer test
△ – Piezometer installation

LOCATION MAP OF SOIL EXPLORATORY WORK (BASED ON SPOT IMAGE OF 1989)	**FAP – 21 /22** BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
	INTERIM REPORT	FIG. 5.2.1–1

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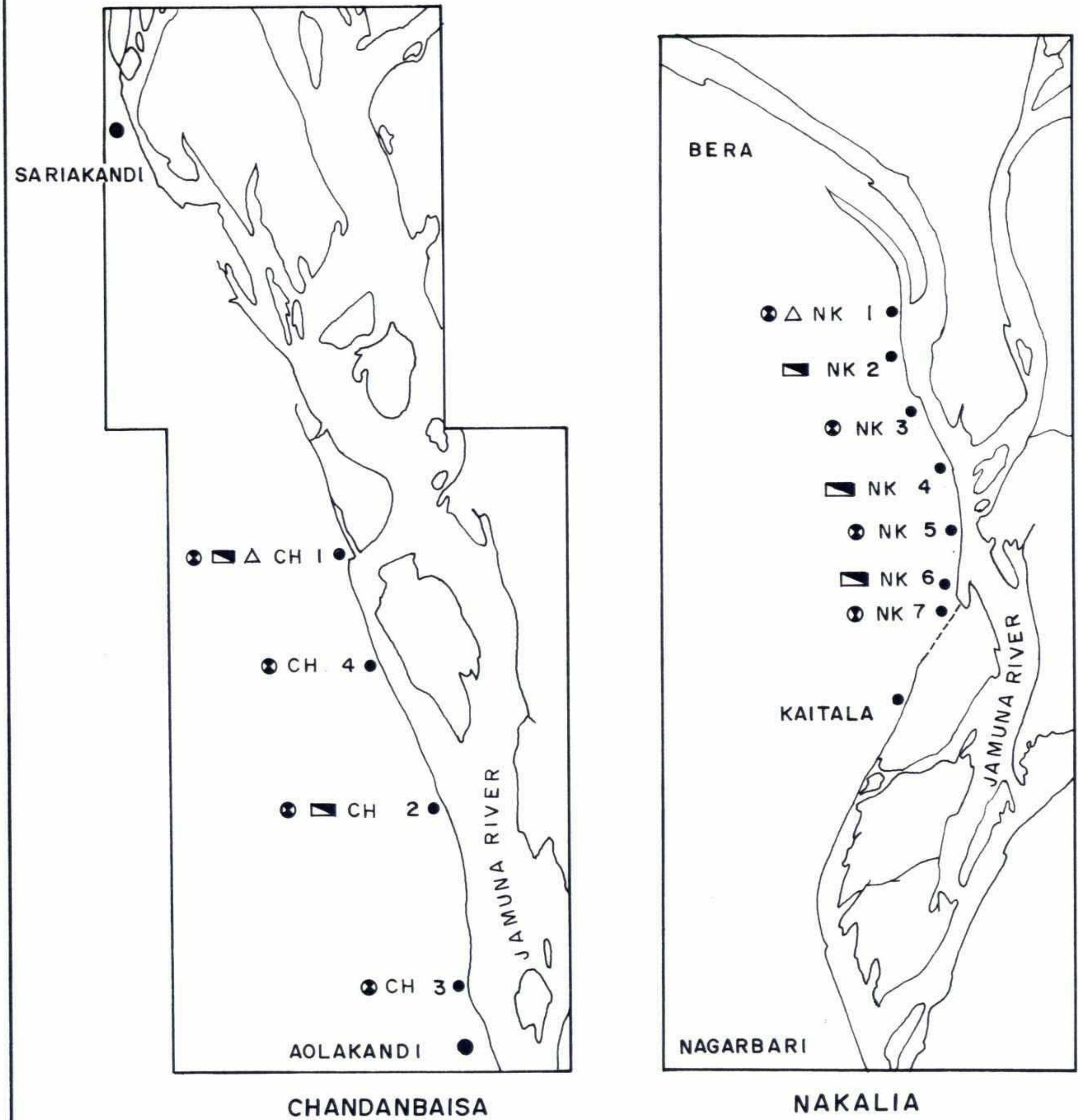

LEGEND

CH 1 – **Chandanbaisa Location 1**

⊗ – Standard Penetration test

◨ – Cone Penetrometer test

△ – Piezometer installation

LOCATION MAP OF SOIL EXPLORATORY WORK (BASED ON SPOT IMAGE OF 1989)	**FAP - 21/22** BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT
	INTERIM REPORT | FIG. 5.2.1 - 2

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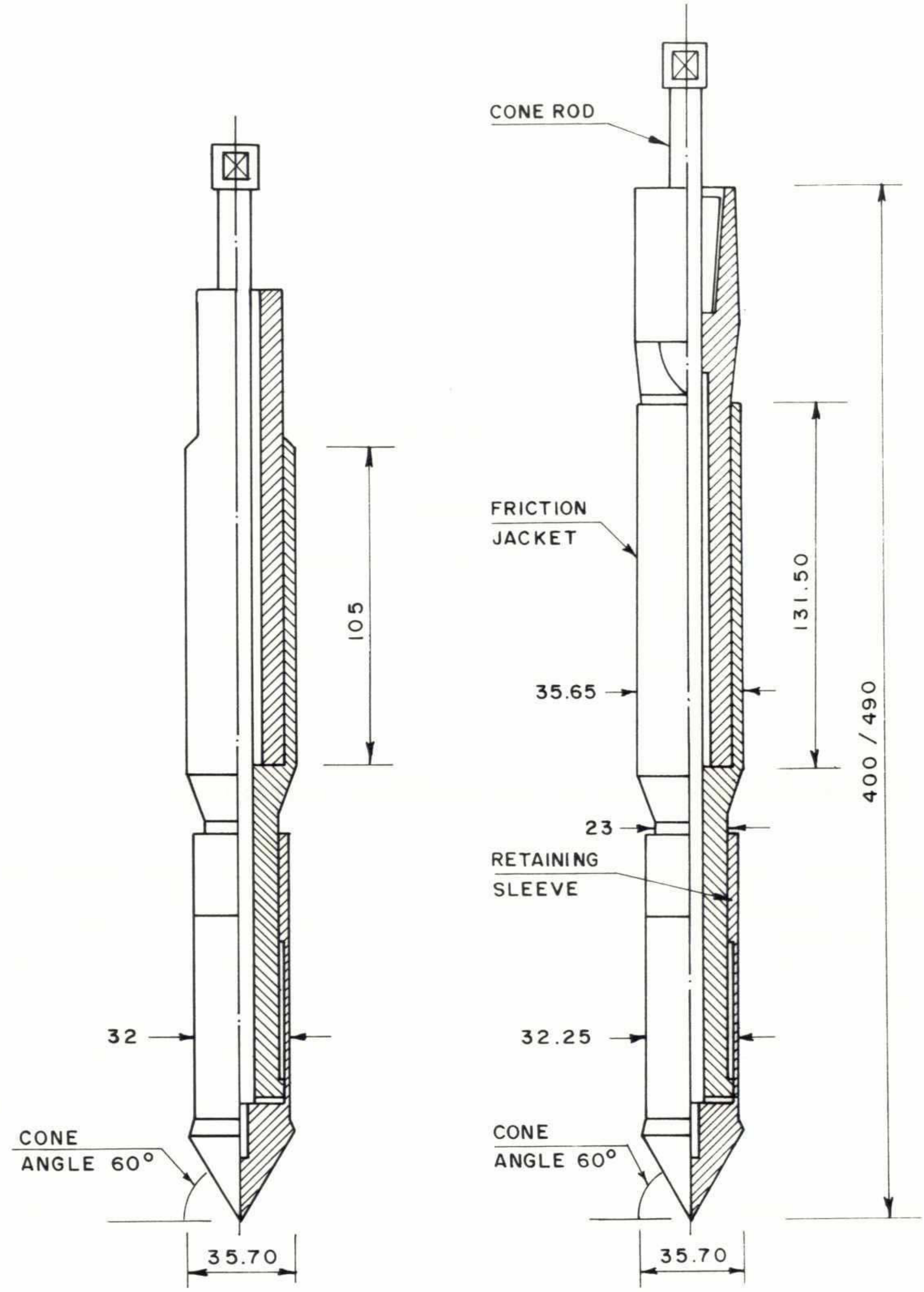

MANTLE CONE

FRICTION JACKET CONE

ALL DIMENSIONS ARE IN MILLIMETER

WORKS EXECUTED BY FOUNDATION CONSULTANTS LTD.

SKETCHES OF CONES USED IN CONE PENETROMETER TEST	**FAP-21/22** BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT
	INTERIM REPORT | FIG. 5.2.1-3

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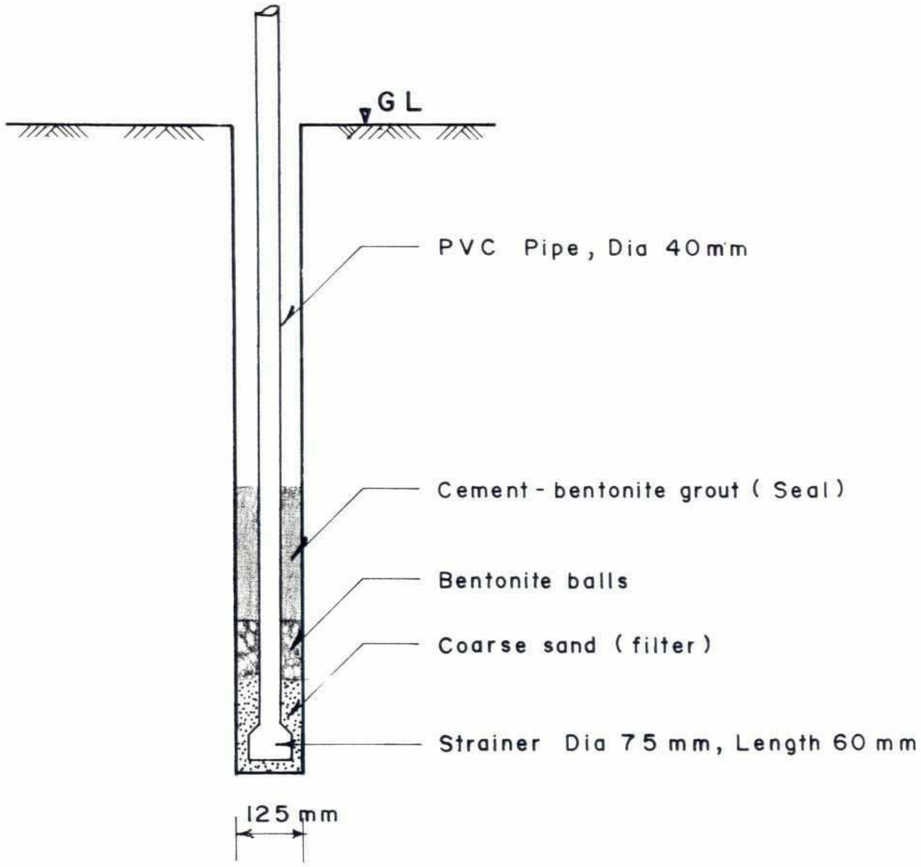

SCHEMATIC DIAGRAM OF PIEZOMETER INSTALLED

Particulars of piezometer installed	GA – I	BA – I	NK – I
Date of installation	29 – 4 – 92	8 – 5 – 92	24 – 5 – 92
Date of test	1 – 5 – 92	11 – 5 – 92	28 – 5 – 92
Boring depth below G.L	6.07 m	7.50 m	7.77 m
Length of PVC pipe	7.00 m	8.34 m	8.71 m
GWT from G.L on test date	2.90 m	3.60 m	3.00 m
Length of PVC above G.L	0.95 m	0.88 m	1.05 m
Length of filter materiel (as measured)	0.18 m	0.17 m	0.21 m
Soil at filter level	Fine sand with little silt	Fine to med sand, little silt	Fine sand, little silt
Time for steady flow of 3 litres	4m 33secs	2m 42 secs	2m 25 secs

IN-SITU PERMEABILITY BY CONSTANT HEAD METHOD

FAP - 21/22

BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT

INTERIM REPORT | FIG. 5.2.1–4

5.2.1.4 Laboratory Testing

A number of laboratory tests were or are still being performed on undisturbed and selected disturbed soil samples to establish the soil properties. All laboratory tests other than triaxial shear tests were performed at the soils laboratory of the subcontractor. The triaxial shear tests are being delayed do to breakdown of the subcontractor's equipment.

The tests were carried out in accordance with ASTM specifications unless otherwise mentioned. A compilation of the number of tests performed in the laboratories is presented in Table A8-1 of Annex 8.

A summary of test results obtained in the laboratory is included in Fig. A8-3 through -18, with the exception of triaxial shear tests which have not been done yet. Grain size distribution curves of samples taken are depicted in Fig. A8-29 through-72, all contained in Annex 8.

An evaluation of soil data obtained has been started but could not be completed due to the fact that results of tests are partly still pending or were received only few days before preparing this report.

5.2.2 Topographic and Hydrographic Surveys

This chapter deals with the description of topographic and hydrographic surveys, which were subcontracted to local surveying companies and carried out under the supervision of the Consultant, and with other hydrometric surveys, carried out by the Consultant's own personnel and equipment.

5.2.2.1 Purpose of Investigations

Topographic and hydrographic survey plans at an appropriate scale form an important prerequisite for the tasks of FAP 21/22, e.g. for:

- final selection of the test sites within the preselected areas
- preparation of the physical models and
- preparation of alternative preliminary designs of the planned test structures.

Hydrometric measurements are aimed to provide additional hydrological data for physical modelling.

The existing topographic maps and images of the Jamuna (c.f. also Section 3.4 of the Inception Report) and the surveys executed in the past in connection with other FAP activities do not provide sufficient detailed and up-to-date information on the particular test areas of FAP 21.

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In order to provide such data and information, extensive surveys have been planned and carried out at four locations in accordance with Task 8 of the Scope of Works of the Consulting Agreement after the selection of possible test areas had taken place.

The surveys were aimed at producing the documentation of the most recent condition at the test areas on a larger scale, as basis for the above mentioned tasks, even though the bank configuration and the river bed morphology are subject to steady significant changes, and the survey can hence represent a unique condition of the time of the measurements only. Repetition soundings of some representative cross-sections in areas of particular interest are planned at the beginning of the next dry season in order to record morphological changes.

More detailed topographic surveys shall also be executed at a later date for the final design during the Test and Implementation Phase once the locations of the structures are finally decided upon. Further hydrometric investigations are also planned at the end of the monsoon period under high water conditions.

This report on topographic and hydrographic first phase investigations mainly deals with a description of the field works executed by the subcontractors, and the survey results and documents so far completed. Since the hydrometric surveys as still going on, they will be described in brief only. The results of these investigations will be subject to later reporting.

5.2.2.2 Scope of Work

Based on the results given in the "Technical Report No.1 - Preselection of Test Areas" - of March 1, 1992 four areas along the Jamuna have been selected for the implementation of test structures (see Fig.2.1-1):

- Kamarjani (North of Manos Regulator)
- Downstream of Bahadurabad ghat
- Chandanbaisa
- Nakalia.

The scope of works for the topographic and hydrographic surveys had to fulfil the following conditions:

- sufficient coverage in order to give enough flexibility and information for an optimum site selection
- scale of mapping, arrangement and density of survey adequate for physical modelling
- construction of survey pillars including horizontal and vertical control survey for re-establishing/discovering particular survey areas at a later date.

The following basic parameters had been fixed for that:

- cross-section survey at approx. 200 m intervals
- length of cross-sections approx. 3 km, 1.5 km on the landside and 1.5 km on the waterside

- extension of survey along the Jamuna: Kamarjani 5 km, Bahadurabad 12 km, Chandanbaisa 10 km and Nakalia 12 km
- layout plans in the scale of 1:5,000 with contour line equidistances of 0.25 m
- cross-sections in the scale of 1:2,000/100.

The scope of the hydrometric surveys included flow measurements, bed load sampling and sounding of particular river profiles.

A detailed description of the Scope of Works is given in Chapter 4.2.3 of the Inception Report of March 1992.

5.2.2.3 Execution of Works by Subcontractors

(a) Schedule of Surveys/Subcontracts

Some constraints were imposed on the schedule of the surveys due to the dependence on other activities and conditions:
On the one hand the field works had to be finalized before the monsoon rains and therefore - due to the quite extensive volume of works - to be started as early as possible. On the other hand subcontracts could not be awarded and the surveys not be started before the test areas were identified by the Consultant and agreed upon by FPCO. But all preparation were made to permit the immediate beginning of the field works after approval of the test areas by FPCO. Fortunately the field works could be concluded without being too much hampered due to bad weather conditions at the end of May 1992. Due to the fact that a further area near Nakalia had to be investigated upon request of FPCO, the Consultant decided to split the works into two packages and to employ two different surveying companies. Six bids were submitted by local surveying companies. After evaluation of these offers contracts were awarded to:

(1) Hydroland Survey Ltd., Kalabagan, Dhaka-1205
(2) The Surveyors & The Realtors, Dhaka-1000.

After signing the contract on 02.04.1992, Hydroland started the field work on 11.04.1992 at three sites, at Kamarjani, Bahadurabad and Chandanbaisa actually.

The Surveyors & The Realtors signed the contract with the Consultant on 08.04.1992 and started on 12.04.1992 at Nakalia.

Both survey subcontractors completed the field works by the end of May, 1992 in accordance with the contractual time schedule. The deadline for the submission of drawings for the individual test areas was fixed in the contracts as follows:
Kamarjani: June 7; Bahadurabad: June 14; Chandanbaisa: June 14; Nakalia: June 14.

Unfortunately all drawing works have been behind time schedule, and some documents had still not been handed over to the Consultant at the time of issue of the present report.

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The following table describes the course of activities and the periods of execution for each test area.

Test Area	Type and Volume of Works	Work Period	
		From	To
Kamarjani (North of Manos Regulator)	Survey:		
	- Erection of pillars (10 Nos.)	11.04.92	21.04.92
	- Height connection of Kamarjani BM to Manos regulator BM	03.05.92	08.05.92
	- Height connection of pillars	13.04.92	21.04.92
	- Erection of temporary gauges	13.04.92	21.04.92
	- Traverse survey	02.05.92	06.05.92
	- Cross-section survey, water	13.04.92	21.04.92
	- Cross-section survey, land	15.04.92	09.05.92
	Drawings:		
	- Layout plans (date of completion)	-	11.07.92
	- Cross-sections (date of completion)	-	07.07.92
Bahadurabad	Survey:		
	- Erection of pillars (20 Nos.)	15.04.92	30.04.92
	- Height connection of BM	21.04.92	30.04.92
	- Height connection of pillars	21.04.92	07.05.92
	- Erection of temporary gauges	21.04.92	30.04.92
	- Traverse survey	14.05.92	20.05.92
	- Cross-section survey, water	21.04.92	21.05.92
	- Cross-section survey, land	21.04.92	21.05.92
	Drawings:		
	- Layout plans (date of completion)	-	17.07.92
	- Cross-sections (date of completion)	-	11.07.92
Chandanbaisa	Survey:		
	- Erection of pillars (20 Nos.)	12.04.92	21.04.92
	- Height connection of BM	13.04.92	21.04.92
	- Height connection of pillars	13.04.92	30.04.92
	- Erection of temporary gauges	13.04.92	30.04.92
	- Traverse survey	08.05.92	14.05.92
	- Cross-section survey, water	13.04.92	30.04.92
	- Cross-section survey, land	13.04.92	14.05.92
	Drawings:		
	- Layout plans (date of completion)	-	-
	- Cross-sections (date of completion)	-	11.07.92
Nakalia	Survey:		
	- Erection of pillars (20 Nos.)	12.04.92	16.04.92
	- Height connection of BM	18.04.92	29.04.92
	- Height connection of pillars	23.04.92	09.05.92
	- Erection of temporary gauges		
	- Traverse survey	16.04.92	14.05.92
	- Cross-section survey, water	09.05.92	17.05.92
	- Cross-section survey, land	10.05.92	12.05.92
	Drawings:		
	- Layout plans (date of completion)	-	13.07.92
	- Cross-sections (date of completion)	-	13.07.92

Table 5.2.2-1: Performance of Topographic and Hydrographic Surveys

(b) Mobilization and Site Situation

All 4 test areas were inspected by the Consultant and the survey contractors prior to the actual field works in order to fix the limits of the survey areas in the field, to mark the locations for the pillars, and to discuss the work programme. The contractors proved to be very familiar with the condition at site which could be realized from their logistic approach.

Especially at Bahadurabad and Chandanbaisa the accessibility from the landside is rather difficult, but to a certain extent also at Kamarjani test area. Furthermore, the landside movement is handicapped by a poorly developed transport infrastructure and the lack of accommodation.

Hydroland Survey Ltd. therefore mobilized and operated from the waterside. Two hired passenger ships of about 25 m length served for mobilization and travelling from Dhaka to the sites, for accommodation, as drafting office and for storage of equipment at the various places. A number of smaller country boats was used in addition for transportation of the survey crews in the field, and - equipped with an echo sounder and navigational instruments - for the bathymetric surveys, too.

The Nakalia test area showed a much better accessibility from the landside and far better conditions in view of mobility, supply, accommodation etc. than the other test areas. The Surveyors & The Realtors mobilized from the landside but travelled in the field by hired country boats, which were also used for the echo soundings. A rented house of corrugated iron at Nagarbari ghat served the survey crews as accommodation and office.

The crews suffered sometimes very much in the heat and in sandstorms during periods of extremely bad weather conditions. But the late start of the rainy reason of this year offered a good chance to complete the field works as planned.

(c) Performance of Surveys

At the beginning of the field works the Consultant and the contractors identified the limits of the survey areas and fixed the location of the control stations. Furthermore the Consultant provided initial Bench Mark data and co-ordinate figures for the connection of the surveys to the generic system. During the whole period of the field works the Consultant made extensive field visits in order to guide the works, to discuss and solve problems which arose during the surveys, and to check the works at random, using own equipment. The professional and supporting personnel of both survey companies was in general adequately staffed to permit a simultaneous working in all required disciplines, like bathymetry, topography, traversing, levelling etc.

Hydroland Survey Ltd. was working in general in two test areas simultaneously. They started at Chandanbaisa and Kamarjani first and concentrated their staff and activities on Bahadurabad after finishing the first two places.

The Surveyors & The Realtors worked with a lower number of employees, since they had to survey one test area only.

The following survey works have been carried out in total:

- Construction of survey fix points (pillars) - 70 numbers
- Traversing/horizontal control survey - 67 km
- Connecting/control levelling - 97 km

- Topographic cross-section survey - 336 km
- Hydrographic cross-section survey - 290 km

The fixed points/control stations consist of T-shaped reinforced concrete pillars of the dimensions of 15 x 15 x 90 cm, placed in sheltered locations as far as possible. The traversing has been done by means of EDM (electronic distance measurement) at all sites. Control levelling has been made by double levelling at Kamarjani, Bahadurabad and Chandanbaisa. At Nakalia the levelling connected several stations along the line for checking, and has finally been closed on two stations.

The cross-sections on the landside areas have been surveyed using conventional techniques (chaining and levelling), whereas the bathymetric cross-section have been recorded by means of echo-sounders installed on small country boat. The survey boat was tracked along prefixed parallel lines (transacts) at about 200 m intervals. The lines were arranged perpendicularly to transit lines, which were arranged almost parallelly to the river banks.

The position of the survey boat was fixed in regular intervals by the resection (Hydroland) using sextants on the boat and by the intersection method (The Surveyors & The Realtors) using theodolites on land.

During the bathymetric surveys the rivers water level has been recorded for proper connection of the soundings to PDW datum by means of provisional river gauges.

For the survey of topographical features of importance (like buildings, embankments, roads etc.) plane table surveying was applied in addition in some areas.

(d) Equipment

The equipment used for the surveys complied fully with the requirements to such tasks. Part of the available electronic equipment formed the electronic distance measuring equipment and the echo-sounders. A problem for the operation of electronic equipment in the field, especially in remote areas, is the power supply for charging of batteries. Hydroland Survey Ltd. operated a generator for this purpose.

The other survey equipment represented standard instrument like theodolites, automatic levels, sextants, station pointer, plane table equipment, survey chains, tripods, staffs etc.

The more sophisticated equipment of the Consultant was employed for checking and supporting the contractors' work as well as for own additional surveys.

(e) Evaluation and Drawings

The followings documents and drawings had to be prepared by the survey companies and to be delivered to the Consultant:

- Contour and sounding maps 1:5000
- Cross-sections 1:2000/100
- Lists of co-ordinates and elevations of Control Stations
- Location sketches of Control Stations
- Lists of gauge readings
- Survey report.

Furthermore, all original field records including calculation notes had to be handed over to the Consultant. The latter were already received in parts during the work progress.

The final survey documents as mentioned before have partly been handed over to the Consultant and were partly still outstanding at the time this report was written (early July).

5.2.2.4 Hydrometric Surveys Carried out by the Consultant

(a) Schedule of Surveys

According to the description in Task 8 of the Scope of Works of the Consulting Agreement the hydrometric surveys have to be understood as complementary works, to be carried out if and when required. Thus, they were performed without following an fixed schedule. The individual works were done at random, mostly in connection with the supervision and the control of the subcontracted surveys.

(b) Performance of Works and Equipment

The following works have been carried out by the Consultant:

- measurement of longitudinal and transverse river profiles by echo sounding
- fix point current measurements by means of an electronic current meter at selected points
- taking of bottom samples.

The equipment used consists of hydrographic and topographic instruments as follows:

- working boat (inflatable rubber boat with rigid GRP hull) and 50 HP outboard motor
- electronic current meter with sensors for current speed, depth (pressure) and direction (fluxgate compass), data terminal
- portable winch
- water sampler
- bottom sampler (grab)
- digital echo sounder
- electronic range - range position fixing system (Trisponder)
- electronic tachometer
- levelling equipment
- handhold GPS receiver.

In order to carry the boat to the sites a boat trailer has been built by a Bangladeshi workshop according to a design prepared by the Consultant, and fixing devices have been constructed to carry the instruments on the boat (e.g. winch, echo sounder, transducer, master station of Trisponder etc.).

A very important tool for position fixing in connection with all investigations was the Trisponder navigation system, since it permits a precise and continuous survey of the boat position on the river. This equipment will also be used for the re-survey of selected cross sections after the monsoon period for comparison.

The result of the investigation will serve as input for other activities of the project with the aim of further evaluation.

5.2.2.5 Co-ordinate System

Various co-ordinate systems are in use in Bangladesh resulting from the different projections which are applied by the several institutions for its mapping. These different systems are causing imminent problems when comparisons have to be made or survey works to be carried out.

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The situation can be summarized as follows:

- Official maps of Bangladesh prepared under the responsibility of SOB are based on a "Lambert Conformal Conic Projection". Since it has a number of disadvantages, it is intended to utilize another system in the future. However, no decision has been taken so far.
- The Universal Transverse Mercator (UTM) projection is commonly used throughout the world, but also for some mapping in Bangladesh.
- Many information from other sources are based on geographical co-ordinates of latitude and longitude only, which are normally not useful for plane surveying and large scale mapping.
- Standard handhold GPS-receivers are normally based on geographical co-ordinates too, or alternatively on UTM co-ordinates which require conversion, when using a small GPS-receiver for position fixing in the field.
- SPOT image maps bear geographical co-ordinates and in addition a plane cartesian co-ordinate system which is also a transverse Mercator Projection but is using other parameters than UTM (e.g. ellipsoid, scale factor, central meridian).
- Finnmap recommends a system called BTM (Bangladesh Transverse Mercator) which is also based on a Transverse Mercator Projection similar to the SPOT TM system but with some alteration. Landsat images used by FAP 19 for digital mapping are related to the BTM system, too.

A comparison of different Transverse Mercator Projections used in Bangladesh are given in the following table:

PARAMETERS	UNIVERSAL TRANSVERSE MERCATOR PROJECTION (UTM)	BANGLADESH TRANSVERSE MERCATOR PROJECTION (BTM)	SPOT TRANSVERSE MERCATOR PROJECTION (SPOT TM)
Projection	Transv.Mercator	Transv.Mercator	Transv.Mercator
Ellipsoid	WGS 1984	Everest 1830	Everest spheroid
Scale Factor	0.9996	0.9996	0.9998
Central Meridian	87°/93°	90° E	90° E
Latitude of Origin	0°(equator)	0°(equator)	0°(equator)
False Easting	500000 m	500000 m	500000 m
False Northing	0 m	- 2000000 m	0 m
UTM Zone	45/46	-	-

Table 5.2.2-2: Comparison of Different Transverse Mercator Projections

The previous explanations clearly show the necessity to introduce a uniform projection/co-ordinate system for use by FAP activities as suggested by FAP 19 (c.f. Technical Notes Series No.1 of FAP 19 of 24 May, 1992).

Following the proposal of FAP 19 the FAP 21/22 project has decided to set up their maps and plans utilizing the tentative BTM system because most of the recent information at FAP 21/22 (Landsat images) are based on that system.

FAP 21/22 acknowledges the valuable assistance given by FAP 19 in converting co-ordinates to/from different projections.

5.2.2.6 Conclusion

The topographic and hydrographic surveys have been concluded at four test areas. The results have been evaluated and the drawings been finalized by about 80% at the time of issue of this report.

Hydrometric surveys have been carried at random. The results have to be evaluated further.

Resurvey of some selected river sections together with additional hydrometric investigations is scheduled for a later project phase at the end of the monsoon period.

Detailed surveys at the finally selected and approved test sites on a large scale will have to be carried out at the time of the final design of the test structures.

The Transverse Mercator Projection has been adopted by FAP 21/22 for all its mapping.

Selected preliminary results of the surveys are compiled in Annex 7 for information. The documents include layout plans of Bahadurabad and Kamarjani as well as some selected cross-sections.

5.3 INVENTORY OF EXISTING AND PLANNED BANK PROTECTION WORKS

A survey has been made by the Consultant on existing structures and measures taken to protect river banks in Bangladesh.

It was the intention of the Consultant to determine on the basis of design data of structures built in the past and on information of their behaviour whether experiences made in the past have led to changes in subsequent designs or whether special measures and designs have proven to show better results than others.

Data and information collected from various field and design offices have been compiled in Tables 5.3-1 and 5.3-2 as attached hereinafter. Locations of structures are shown on Fig. 5.3-1. An evaluation of these data shows however, that basic differences or changes could be found neither in design or construction methods nor in the use of materials.

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The only exception is the introduction of geotextile materials in the form of filter mats or bags during recent years, which however still requires foreign exchange for the import of such materials and therefore has been used only at few locations. Further details were given in the Inception Report, Section 3.4.5.

A discussion on experiences in bank protection works raises a lot of questions. As a matter of fact many groynes, spurs and cross bars constructed on various rivers in Bangladesh were washed away by the floods (Chandpur, Maizbari/Kazipur, Tambulpur, Belka) others were heavily damaged, whereas some have sustained the loadings or require only minor repairs or have never been exposed to river attack due to morphological changes.

Therefore, when assessing experience it would be necessary to know the exact cause of each damage but hardly any information is available for the past failures. As it is most difficult to determine the initial cause and subsequent damage development of a structure which failed totally during high floods, various assumptions are generally the result of subsequent investigations as expressed in the damage reports. In case of severe damages, planar or similar failures can afterwards be observed and surveyed, but also in such cases different interpretations of cause and location of damage (e.g. design assumptions, loads and geometrical conditions which actually prevailed, construction mistakes etc.) are possible. As the damages start at invisible locations and surveys are not carried out during periods of severe conditions it is generally extremely difficult of indicate the cause of failure and as a result of it to propose improvements in design or execution.

The fact that total failures and totally undamaged structures could be observed after a flood phase - although all structures had been equally designed and constructed in a close river stretch - can only be explained with different loadings, scour depths etc. or construction mistakes. Other structures were erected in areas where accretion occurred soon after completion (Sailabari, Fulchari).

Groynes are mostly built with bell shape heads due to construction problems in flowing water. Except at Rajshahi all groynes are single structures.

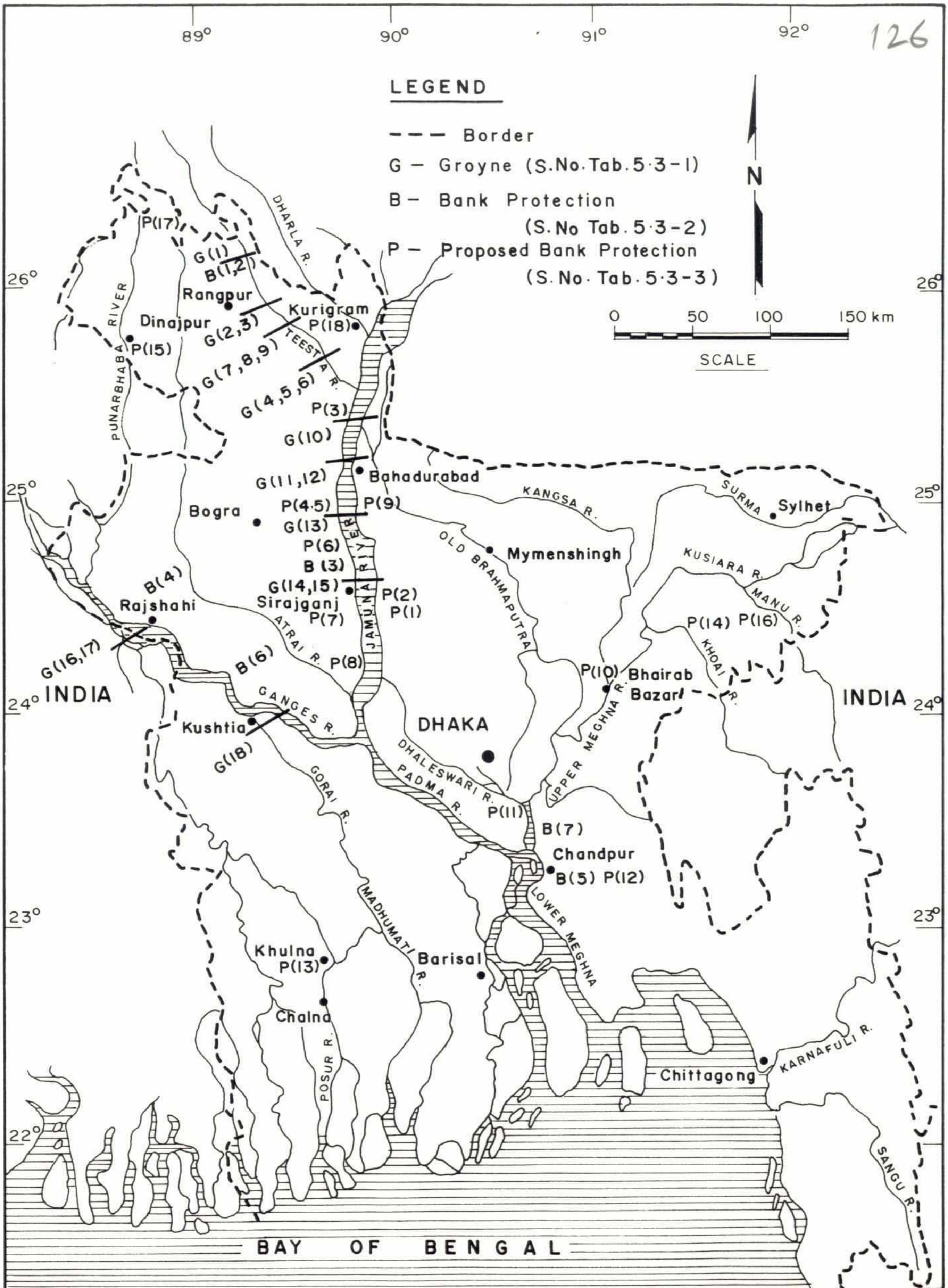
In view of the fact that only manual construction methods have been applied in the past and that revetments could only be constructed above low water levels accurately, the design and construction of the "falling aprons" supposed to protect the underwater slopes of a bank or groyne are of utmost importance when assessing the stability of such structures. Upto what extent design assumptions and actual as-built conditions of aprons differ or comply after launching of the apron can only be determined through proper surveys, but such surveys are hardly made as learnt from the discussions at site. As a matter of fact no proper and regular records of underwater slopes of structures are available which could assist in damage assessment.

As a result it can generally be stated that experiences which may lead to changes and improvement in design or execution are rather poor or not available.

This situation can only be improved if:

1. obvious or most probable causes of failures are excluded, i.e. proper mechanized compaction of core material, installation of filter materials etc.,
2. a reliable permanent and proper supervision of all construction works is guaranteed by which sound workmanship in accordance with strict specifications can be ensured,
3. proper monitoring of completed structures is carried out so that design assumptions and actually prevailing conditions (flow velocity, scour depth, slopes etc.) can be compared, design adjustments/improvements be determined and reinforcements be executed, if and to the extent necessary,
4. regular annual surveys are ensured in order to detect any changes in bed topography, slopes etc. and
5. adequate funds are made available as required for proper maintenance of the structures.

A similar survey as for existing structures, erected as per BWDB design, has been made for structures planned for the near future and its result is summarized in Table 5.3-3. Location of these works proposed in different reports has likewise been indicated in Fig. 5.3-1. It is obvious that all designs provide geotextile filter mats, except above low water level in minor flood protection embankments on secondary rivers.



LOCATION MAP OF EXISTING/PROPOSED BANK PROTECTION/ RIVER TRAINING STRUCTURES IN BANGLADESH.

FAP – 21/22 BANK PROTECTION AND RIVER TRAINING/ (AFPM) PILOT PROJECT	
INTERIM REPORT	FIG. 5·3 – 1

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Table 5.3-1

BANK PROTECTION and RIVER TRAINING WORKS IN BANGLADESH
Details of Groynes and Cross Bars on Major Rivers

Sl. No.	Location	Year of Construction	Type of Structure	Levels Crest/ HW/LW	Structural Features of Groynes/Cross Bars: Shape	Length (m)	Height From	Height To	Crest Width	Core Material	Slopes U/S	Slopes D/S	Slopes Groyne	Filter layer	Armour layer Thickness	Armour layer Material	Falling Apron Width	Falling Apron Thickness	Falling Apron Material	Experience
	TEESTA RIVER																			
1.	Kaliganj	1978-79	Groyne	Crest+63, 45 HWL LWL+60,70	T-Head	Shank = 635m (865m) T=800 m	2.1 - 2.5		9.15	Sandy material	Shank 1:3	1:3 T-bar		0.15m khoa	0.15	Brick mattressing	-	-	-	No Major damage reported
											Waterside =		1:3	0.15m khoa	0.61	Brick blocks/ Crates	15.25	0.61 - 0.61 +0.30 - 0.30	Brick blocks/Crates boulders crates	
											heads =		1:3	0.15m khoa	0.61	Boulders	15.25	0.92 - 0.92	Boulders	
											Landside =		1:2	0.15m khoa	0.15	Brick mattressing	-	-	-	
2.	Painalghat (15,3 km d/s Kaunia	1987-88	Cross-bar	Crest+27.45 HWL LWL+20.45	Bell	436		-8.80	6.10	Sandy material	Shank 1:2	1:2	2	0.15m khoa		Brick mattressing	-	-	-	Groyne head and part of shank (73.0m) washed away in 1988)
	-do-, temporary repair	1988-89			Bell	363									Tip of x-bar protected by brick crates					
	-do-, new X-bar head	1989-90			Hockey	412							1:2.5 (1:3)	0.30m khoa	0.53 +0.53	Brick gabions c.c. blocks	15.25	0.53 +1.10-1.90	Brick gabions c.c. blocks	Some damage at head in 1991 River channel located away from Cross-Bar
3.	Tambulpur (18,5 km d/s Kaunia)	1985-86	Cross bar	Crest+27.97 HWL LWL+20.13	Bell	1373		-6.70	6.10	Sandy Material	1:2.5 (1:2) close to bank	1:2.5 (1:2)	1:3	0,15m khoa	Shank 0.15 x-bar head	Brick mattressing Brick crates				1987-88 a length of 610m washed away
	-do- Rapair works (new x-bar head)	1989-90			Bell	533 new head = 119m		-4.30	6.10	"	1:2.5	1:2.5	1:3	0.30m khoa	0.53 +0.53	Brick crates c.c. blocks	15.25	2.0 - 3.20 2.75	c.c. blocks (at tip of bell head) c.c. blocks over brick gabions (at sides of bell head)	Cross bar washed away during 1990 flood
4.	Belka No.I (33.8 km d/s Kaunia)	1988-89	Cross bar	Crest + 25.90 HWL+25.0 LWL	Bell	253		-4.00	6.10	Sandy Material	1:3	1:3	1:3	0,15m khoa	Shank 0.15m x-bar head 0.60m	Brick mattressing 2 layer brick crates (0.63x0.63x0.30)	13.75	1.07-1.53	Brick crates	Cross bar washed away during 1991 flood
5.	Belka No.II (35.4 km d/s Kaunia)		Cross bar		Bell	274	} Design Feature similar to Cross-Bar Belka No.I													No damages reported
6.	Belka No.III (32.2 km d/s Kaunia)		Cross bar		Bell	183	}													Cross bar washed away in 1989
7.	Tarapur No. I (24.1 km d/s Kaunia)		Cross bar		Bell	320	} Design Feature similar to Cross-Bar Tarapur No.III													Cross bar washed away in 1989
8.	Tarapur No.II (25.8 km d/s Kaunia)		Cross bar		Bell	440	}													No damages reported
9.	Tarapur No.III (27.4 km d/s Kaunia)	1988-89	Cross bar		Bell	769					1:2	1:2	1:2		Otherwise same as Belka cross bars					251 m of cross bar protected with hard material washed away in 1991
	JAMUNA RIVER																			
10.	Fulchari-Gazaria at 81.56 km	1988-89		Crest+27.97		827														Jamuna channal changed its course, therefore Cross-Bars undamaged and erosion further downstream
	- Fulchari I at 88.99 km	1988-89		HWL+21.50		813	4.5		4.30	Sandy soil	1:3	1:3	1:3	0.15m khoa	0.15m	Brick mattressing	9.15	0.15m	Brick Mattressing	
	- Fulchari II at 82.35 km	1988-89	Cross bar	LWL+13.82	Bell	979														
	Munshihat	1986-87				365														

Table 5.3-1

BANK PROTECTION and RIVER TRAINING WORKS IN BANGLADESH
Details of Groynes and Cross Bars on Major Rivers

Sl. No.	Location	Year of Construction	Type of Structure	Levels Crest/ HW/LW	Shape	Length (m)	Height From - To	Crest Width	Core Material	Slopes U/S	Slopes D/S	Slopes Groyne	Filter layer	Armour layer Thickness	Armour layer Material	Falling Apron Width	Falling Apron Thickness	Falling Apron Material	Experience
11.	Pakulla at 107.87 km d/s of Kaunia	1988-89	Cross bar	Crest+20.43	Bell	150	8.0	4.30	Sandy soil	1:3	1:3	1:3	0.15m khoa	2 layers	Brick mattressing Brick crates at head				only minor damage at head so far, effective in diverting flow
12.	Antapara at 118.17 km d/s of Kaunia	1988-89	Cross bar	Crest+19.22 HWL LWL	Bell	122	4.50	6.10	Sandy soil	1:2	1:2	1:2	0.15m khoa	2 layers	Brick mattressing Brick crates at head				Minor damage of brick crates
13.	Kalitola/Sariakandi at 121.78 km d/s of Kaunia	1987-89	Groyne	Crest+19.83 HWL+18.90(?) LWL+7.93	Bell	366	14.30	6.10	Sandy soil	1:3	1:3	1:3	0.15m khoa	0.15	Brick mattressing (d/s of shank)	13.75/ 15.25	1.53-2.45	c.c. blocks	Same damage in 1988 Apron reinforced in 1989. Thereafter minor slides. Addl.blocks placed in 1991-92 Investment costs=4 crores Tk.
14.	Sailabari at 160.71 km d/s of Kaunia	1977-78	Groyne	Crest 15.86 HWL+14.34 LWL+6.71	T-head	Shank = 952m T-bar= 70m	5.20 - 9.15	8.55	Sandy soil	Shank 1:3	1:3	T-bar 1:2 (waterside/heads) 1:3 (landside)		0.15 1.22	Brick mattressing 2 layers of c.c. blocks (0.61m)	40.0	1.22-2.44	c.c. blocks (0.61 m)	Area of groyne silted up soon after its completion
15.	Ranigram/Sirajganj at 164.70 km d/s of Kaunia	1985-86	Groyne	Crest+16.17 HWL+14.64 LWL+6.71	Bell	808	6.10 - 13.75	7.95	Silty soil	Shank 1:3	1:3	Head 1:3		0.20 1.22	Brick mattressing c.c. blocks (0.30 to 0.61m)	35.0	1.22-1.83	c.c.blocks c.c.blocks (old railway waggons at tip of groyne)	In 1987 and 1988 the groyne was severly damaged and large slides occured both on u/s and d/s side After completion of repair works damages continued, but minor scale. Presently it appears that attack is reduced due to diversion of main channel
	GANGES RIVER																		
16.	Rajshahi-groyne no.1	1970-72	Groyne	Crest+21.0 HWL+20.0 LWL+8.96	T-head	189 (shank) 107(T-bar)	3.0 - 13.70	6.10	Sandy material	1:3	1:3	1:2		0.15 0.15 0.61-1.22	Brick mattressing (shank) Brick mattressing cement-sand blocks (placed)	15 30.5	0.15 1.20-6.10	Brick mattressing (shank) Stone boulders	No damages observed above LWL after passage of 1991 flood
16(a)	Repair of groyne no.1	1990-91	---------------- as above ----------------							1:3	1:3		Geotextile mat Geotextile bags Geotextile mat Geotextile bags (fill up of holes)	0.15 0.30 0.68 0.30 0.68-0.83	Brick mattressing c.c.blocks (placed) above LWL c.c.blocks below LWL 0.38x0.38x0.30 c.c.blocks above LWL Assorted c.c.blocks 0.38 to 0.53m below LWL	Shank T-bar			
17.	Rajshahi-spur 2B		Spur of brick crates	Crest+20.0/18.24 HWL+20.0 LWL+8.96	Straight	60.0	3.0 - 16.50	0.91	Brick crates	1:1	1:1	1:1		0.60	Brick gabions 0.90x0.90x0.60				
17(a)	Shengthening spur 2B	1990-91	---------------- as above ----------------							1:1	1:1	1:1			Assorted c.c.blocks base and slope protection				
	GORAI RIVER																		
18.	Groynes on Rt. Bank of Gorai at Kustia	1985-86	Groyne	Crest+15.24 HWL+13.71 LWL+4.57	T-head	152	3 - 14	4.57	Sandy soil	1:2	1:2	1:2	Shank 0.15 khoa 0.15 sand T-head 0.15 khoa 0.15 sand	0.15 0.75	Brick mattressing c.c./s.c. blocks	20	1.2	c.c./s.c. blocks	Performance good No damage occoured
	MEGHNA RIVER																		
19.	Ekhlaspur protection	1992	Groyne (Training wall)	Crest+6.0 LWL+0.60	T-head	Shank -183m T-head -625m	3.3 - 5.5	3.0	Silty soil	1:2	1:2	1:2	0.15 khoa	0.90	c.c. blocks	14	2.0	c.c. blocks	The work completed in 1992. The groyne is constructed for protecting the embankment of Meghna Dhonagoda project.

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Table 5.3-1 (contd.)

Table 5.3-2

BANK PROTECTION and RIVER TRAINING WORKS IN BANGLADESH

Major Bank Revetment Works

Sl.	Location (Length of Revetment)	Year of Constr.	Structural Features of Revetments												Experience/Comments
			Levels	Av. Water	Bank	Type of bank	Type of filter layer		Armour Layer on slope		Toe	Falling Apron			
1.	Mahipur (Teesta) (1000 m)	1986	Crest+36.12 HWL+35.05 LWL+32.50	2.55	1:25	fine sands	8cm coarse sand 8cm khoa	-	0.92	S.C. blocks 0.46m (2 layers)	-	10.70	1.05/1.40	S.C. blocks	Materials quantity=30 m3/lin,m Revetment cost =Tk.40,000-/m Bank erosion/sliding during past years. Urgent repair works in 1992
2.	Godownerhat (Teesta) (400m)	1990	Crest+40.0 HWL+39.0 LWL+35.15	1.5	1:2	fine sands	8cm coarse sand 8cm khoa	(propex 6064 for extension in 1992)	0.30 0.60	S.C. blocks placed above+37.0 S.C.blocks 0.30 to 0.38m at random below +37.0	-	10.60	1.25/2.12	S.C.blocks 0.3 to 0.38m	Material quantity =30m3/lin.m Revetment cost=Tk.40,000-/m No visible damage so far
3.	Sirajganj Town (Jamuna)	1964-69					-	-		Brick mattressing/ dumping	-				Brick mattressing placed in 1964 and 1969 washed away after 4 and 1 year respectively contrigent on seriousness of attack
	Section (1) = 1770m Section (2) = 830m	1971-74	Crest+16.15 HWL+14.60 LWL+6.70	24.0	1:3	fine/medium sands	-	-		S.C.blocks (size 0.15 to 0.60m)					By annual dumping of S.C./C.C. blocks the revetment could be maintained till 1985. In 1985 serious sliding and damages occoured at various places over a length of 1160m
	Repair and strengthening works	1986 and after words			Natural		-	-	1.21	C.C. blocks and railway waggons	-	14 to 30m	1.52+03	C.C. blocks	Repair costs 1988-89 2.7 crores Tk.
4.	Rajshahi Town Protection work (Ganges)	1960	Crest+20.50 HWL+19.20 LWL+8.53	-	1:2	Silty soil	0.075m khoa 0.15m sand	-	0.15	Brick Mattressing with wire mesh and wooden pegs	0.30x0.30x0.45 C.C. block with Balli and Bamboo pins	-	-	-	Damage occoured at many places
	Rajshahi Town Protection work	1988-92	Crest+20.50 HWL+19.20 LWL+8.53	-	1:2	Silty soil	-	Geotextile 2308/m² (Polyfelt, Australia)	0.15	Brick Mattressing with wire mesh and wooden pegs	0.30x0.30x0.45 C.C. block with Balli and Bamboo pins	-	-	C.C. blocks	After 1989 Geotextile are being used as filter below brick mattressing
5.	Chandpur Town (2562m), Meghna	1972 onward	HWL+5.35 LWL+0.19	46	Natural	Silty soil	-	-	Various	Boulder dumping to bring the slope 2:11	Dumped boulder	-	-	-	Protection by wild dumping of boulders did not work and the township 15 threatened to be eroded
	Chandpur Town (200m), -Do-	1989-90	-Do-		Natural	Silty soil	0.3m khoa above LWL	2 layer geotextile bags dumped below LWL	0.90	C.C. Block, Boulder	-	18	3 layer geotextile bags	Geotextile bags filled with sand	Work at two places at Puran Bazar and Nutun Bazar executed as per recommendation of National Committee
	Chandpur Town (443m), -Do-	1991	-Do-		Natural	Silty soil	-Do-	-	0.9x0.9x0.45 wire crates filled with boulders	Boulders in crates to the damaged area	Dumped wire crates	-	-	-	The boulder crates have been dumped on emergency basis to stop the erosion during end of 1991
6.	Hardinge Bridge (Ganges)	1932 1965	-	-	Natural	Silty soil	Nill	Nill	Various	Boulders dumped at random on the slope	Not known	N.K	N.K	N.K	Working well for a long time. Railway Dept. occassionally dump boulders to the damaged areas.
7.	Bhairab Bazar (Upper Meghna)	86-87 & 89-90	G.L.+6.70 LWL + 1.80	13	1:2	Silty soil	0.22 khoa over 0.15 sand	-	0.70	Boulders	Falling apron	13	1.25	Boulders	Severe erosion occoured upstream of Railway bridge during 1988. Work under-taken by Railway Dept. for protecting the bank by boulders Pitching.

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Table 5.3-3

MAJOR PLANNED/PROPOSED BANK PROTECTION STRUCTURES IN BANGLADESH

RIVER	SL. NO.	PLACE	STRUCTURE	GENERAL DESIGN FEATURES OF SLOPE PROTECTION						TOE PROTECTION	SOURCE
				ABOVE SLW			BELOW SLW				
				SLOPE	COVER LAYER	FILTER LAYER	SLOPE	COVER LAYER	FILTER LAYER		
JAMUNA	1	JM Bridge	East+West Guide bunds	1:3.5 1:5	Open stone asphalt 0.15m rip-rap 10-60 kg, 0.50m bitumen grouted	Composite geotextile	1:3.5 1:5	rip-rap 10-60 kg t = 0.50m	Fascine mattress with geotextile	rip-rap 0-100 kg max h = 2.90m	JMB Phase II Study Feasibility Study, Vol.VII Annex D+J, Nov.'87/May'90
	2	Bhuapur	Slope Protection	1:3.5 1:5	Open stone asphalt 0.15m rip-rap 10-60 kg, 0.50m	Composite geotextile	On Orig. river bed	Cellular geot. mattress filled with sand-asphalt	none	Same as cover layer	Do, and Tender Drg., Apr.'90
	3	Fulcharighat	Bank Protection	1:3	2-layer hand placed CC-blocks 0.7x0.7x0.7 m with gaps, t=1.40m	geotextile	1:3.5	2-layer dumped CC blocks 0.7x0.7x0.7 m, t = 1.40 m	Fascine mattress with composite geotextile	dumped cc blocks 0.7x0.7x0.7 m max. h=3.50m	Brahmaputra River Training Studies (BRTS) Short Term Documents, Oct.'91 (FAP 1)
	4	Sariakandi	-Do-	-Do-	-Do-, but 0.55x0.55x0.55m t = 1.10m	-Do-	-Do-	-Do-, but 0.55x0.55x0.55m t = 1.10m	-Do-	-Do-, but 0.55x0.55x0.55m max h = 2.75m	-Do-
	5	Mathurapara	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-
	6	Kazipur	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-
	7	Sirajganj	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-
	8	Betil	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-	-Do-
	9	From Bahadurabad to Jogannath-ganj ghat (left banks)	Embankments	1:3	Interlocking cc blocks 0.30x0.30x0.15 m, 1 layer t = 0.15m	geotextile 400g/m²	to be constructed on flood plain			trench fill with surrounding geotextile (h=H/2)	Jamalpur Priority Project Study, Interim Feasibility Study, June'92 (FAP 3.1)
UPPER MEGHNA	10	Bhairab Bazar	Protection existing bank (Altern.1) Bank protection (Altern.2)	~1:3.6 1:3.5	CC blocks 0.3x0.3x0.3 m t=0.50m Open stone asphalt 0.15m	geotextile geotextile	1:3.5 1:3.5	rip-rap 10-60 kg, t=0.50m boulders of d50=0.15 m, t = 0.30 m	geotextile fascine mattress with geotextile	rip-rap 1-100kg max. h=3.30m boulders d50=0.15m max. h=3.00m	Meghna River Bank Protection, Short Term Study, Final Report, Feb.'92 (FAP 9b)
DHALES-WARI	11	Munshiganj	Protection exist. embankment (Altern.1) Bank protection (Altern.2)	~1:6 1:3.5	Open stone asphalst t= 0.15m -Do-	geotextile -Do-	~1:5 1:3.5	boulders d50 = 0.15m t = 0.30m -Do-	fascine mattress -Do-	--- boulders d50=0.15m max h=2.90m	-Do-
LOWER MEGHNA	12	Chandpur	Bank protection	1:3.5	Open stone asphalt t = 0.20m	geotextile	1:35	rock d50 = 0.35m t = 0.70m	fascine mattress with composite geotextile	rock d50 = 0.35m max h = 3.00m	-Do-
PUSUR KHOAI PUNAR-BHABA MANU KARATOYA DHARALA	13 14 15 16 17 18	Khulna Habiganj Dinajpur Moulvibazar Panchagarh Kurigram	Bank protection	1:2	2-layer brick mattressing (steel wire meshing) or boulders/cc blocks	Khoa+sand (0.23m) geotextile between SLW and SHW	1:2	boulders/cc blocks	---	boulders/cc blocks max h=2.76t	Secondary Town Integrated Flood Protection, Final Report, Apr.'92 (FAP 9A)

Explanations : SHW = Standard High Water
SLW = Standard Low Water

t = Thickness of Cover Layer
h = Thickness of falling apron
H = Height of Embankment

5.4 HYDROLOGY STUDY

5.4.1 Introduction

The Both Project components (FAP 21 and FAP 22) require hydrologic data for the design of the bank protection measures at the test sites and for the estimation of the effectiveness of river training measures. These hydrologic data are collected and analysed in an hydrologic study which has been carried out from mid February to the beginning of April 1992. In this period a first selection of the location of possible test areas has been made on basis of the available morphologic data. It is mentioned that the hydrologic study does not include the results of the field surveys near the selected test areas.

The objectives of the hydrology study is to provide hydrological boundary conditions in conjunction with FAP 25 for the selected sites along the Jamuna river. These objectives include the analysis of a kind of construction window during low water periods and the analysis of quick rises and falls in the water level as a boundary for the study of groundwater flow near the test sites.

5.4.2 Data Collection

A satisfactory network of hydrological stations in the Jamuna river catchment in Bangladesh has been established by the Bangladesh Water Development Board, (BWDB), which is the main source of hydrological data for this Project. The hydrological data of interest for the hydrological study were collected from several sources and stored in a computer database in the Consultant's office. The emphasis was placed on available computerized data, but some additional data was also stored manually.

Also the rainfall data have been stored in a data base and these data can be used as input for the rainfall-runoff module of the 1-dimensional model (NAM module) to run together with the general model or with one of the regional models.

An extensive network of water level gauging stations along the Jamuna river and its distributaries has been established also by the BWDB. The data of these stations and of some secondary stations have been collected. The accurate location of these gauging stations, the reliability of the zero datum and the quality of the data has been checked with all available information.

Discharge data of the station in Bahadurabad is the most important ganging and discharge station on the Jamuna because it is the only one where discharges are regular by measured. A new set of improved rating curves with consistent extrapolation characteristics will be used by the Project.

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For calculating the water levels of the Jamuna between the ganging stations and for calculating the levels for defined return periods the general model (GM) including all major rivers in Bangladesh is used. Based on the hydrodynamic module of Mike 11 Software, the FAP 25/GM model is a reduced version of the GM with runs for a long period from 1965 to 1989 with a fixed bed. At this moment the so called run 6 of FAP 25/GM is considered as the final run for the existing situation with a recalibrated model.

Although the systematic errors between measured and calculated time series at a station will be assessed in detail by FAP 25 in their final report, some quick checks have already been done in this hydrology study.

The collected hydrologic data have been stored logically into several databases: Lotus files, General Model data base, and HYMOS database.

At the beginning of this hydrologic study it was decided to use the calculated hydrologic data from the FAP 25/GM model for an hydrologic analysis for each test area. But because of the results of run 6 were not finalized at the beginning of the study and a BWDB station is located in the vicinity of each test area, an analysis of the most suitable data has been done site by site, keeping in mind that for the modelling activities, to be consistent, the results of the FAP 25/GM model will **always** be used as boundaries conditions for the determination of the decisive data in design conditions.

5.4.3 Flood Frequency Analysis

With a frequency analysis of the available data the design water levels and the design discharges have been established. The recommendations which were made by FAP 25 for the selection of probability distributions, have been used as guideline for this hydrology study. The design water levels and the design discharges for selected return periods of 2, 5, 10, 25, 50 and 100 year are determined for representative cross sections at the test areas.

The design water levels should include a recommended safety margin. These safety margins have to be **added** to the free board of the bank protections, accounting for wind set-up, wave run-up and others possible safety factors.

Only one parameter, as the maximum discharge, is not necessarily sufficient to characterize the flood discharge and the morphologic consequences of a flood discharge. As an alternative parameter the mean discharge during the months July, August and September has been chosen.

From the analysis it can be seen that in 1988 the maximum discharge had a return period of 100 year, but the maximum water level was not so extreme: a return period of only 60 years. The selection of a return period of one parameter in one location is not sufficient to characterize a hydrologic event as a typical design event. It is a reason why long-term simulation with the regional models for the period 1965-1989 is advocated by FAP 25.

5.5.4 Water Level Analysis

A construction window has been defined by the number of days during which the water level is below a certain level with a certain probability.
From the duration curve, the level not surpassed during periods of 60, 90, 120 and 180 days can be extracted for the selected frequencies.
The small variations in the water level during the receding limb of the hydrograph in the dry season are remarkable. As soon as the monsoon period starts the variation in the water level at a certain date of each year increases.

Relatively short rises and falls in the water level can be observed in all water level stations along the Jamuna river during the rising limb of the hydrograph, that is during the start of the monsoon period. These rises and falls have been analysed:
From November to February the water level is changing very slowly with a few centimeter per day without exception. And from April to October the water level can rise or fall suddenly with a few decimeters per day.

5.5 PHYSICAL MODEL INVESTIGATIONS

The approach of the physical modelling for the pilot project with bank protection structures, FAP 21, is summarized as follows:

- The determination of the hydraulic design conditions for the test structures, especially flow velocities and local scour depths near these test structures
- The determination of the combination of bend scour and local scour near groynes in a separate physical model investigation, which is described in the next section
- In an applied research project the stability of different types of toplayers and underlying filterlayers will be studied at a scale 1 in 1 in a filter test rig, with the objective to refine the existing rules for the specific conditions in Bangladesh. This is described in Section 5.7.

The physical model investigations to determine the hydraulic design conditions for the test structures are planned in the River Research Institute in Faridpur.

The main objectives of these model investigations are:

- The selection of an optimum alignment of the test structures
- The determination of the distribution of the hydraulic load (shear stresses) on the top layer of the test structure as a function of the measured flow velocities, but probably also of the direction of the main flow

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- An optimization of the shape and the layout of the head of groynes as a function of the reduction of the local scour depth and the volume of materials for a falling apron
- An optimization of the number and the locations of the measuring instruments during the monitoring phases of the test structure.

The preparation of these physical model investigations had been continued with the preliminary negotiations on the basis of the submitted draft Terms of Reference for these model investigations. In these draft Terms of Reference some additional data is given as characteristic discharges and water levels, the average slope of the river, the D_{50} of the sediment and the bed material, and a length of 3.5 to 4 km of the channel should be modelled. The bed geometry will be based on a schematization of the representative cross-sections which were measured during the recent field surveys which cover four test areas.

The Consultant prefers a length scale 1 in 100 to guarantee turbulent flow at all important locations of the model, in some tests the scale factor of the flow velocity will be according the Froude condition, in other test this scale factor will be smaller. The scale factor of the model sand will be around 1.

The size of the model area is about 50 m long and 25 m width and a part of this area will be covered by a temporary shed. The model sand should be cleaned and sieved for the section with a movable bed. The available pump capacity is less than the 1 in 100 year discharge with a 25 % additional capacity. The design of the model had to be adjusted to the available pump capacity. Since in RRI a separated water circulation of 600 l/s for each model is not possible, therefore a combined water circulation had to be accepted.

As mentioned in the Inception Report the Consultant had requested the reservation of space in the first permanent hall for physical models in RRI. However, according to RRI no space is available in this hall before the beginning of September, due to some delay in the work of the contractor. As an alternative an open air model, which is covered by a temporary shed, had to be accepted as the only possibility. Open air models are regarded as less attractive because the results of a test in an open air model is less accurate than the results of a similar test in a permanent hall.

All planned measurements can be carried out with exception of the vertical photographs of the flow field and the local scour holes after finishing a test. The photographs will not be vertical but oblique.

The discussions with RRI which could be finalized just before presenting this report resulted in a certain modification of the originally intended scope for the model investigations, due to restraints in funds, time, staff and equipment. Two models of about 50 m by 20 m will be constructed representing some schematized test sites. The reasons for choosing schematized rather than exactly reproduced models are on the one hand that, due to the fast morphological changes, also a model constructed exactly according to a survey at a certain time would only reproduce the prototype at that time and not necessarily be representative for the site on the average. On the other hand, a certain schematization has the advantage that model result can easier be correlated to other sites. Hence, in these rather large models a schematized channel geometry will be tested and therefore the results of these investigations are not site specific, but representative for different locations with eroding bends along the Jamuna river. These in depth investigations are sufficient for the present preliminary design phase.

On each model 10 extended test series are planned, and all processed and checked data from measurements in these test series should be submitted to the Consultant before December 1, 1992.

The planned test structures to be investigated include both groynes and revetments as the main types of bank protection structures.

As indicated in the Inception Report the Consultant has considered possible scale effects in the local scour tests with long revetments. At this moment the Consultant elaborates a proposal to improve the model testing technique to reduce possible scale effects in the local scour depths to an acceptable level. These planned improvements consist of careful removal of excess sedimentation downstream of the scour hole.

During the implementation phase the bank erosion upstream and downstream of the revetment will probably continue at a lower rate as without the test structure, and these changes in bank line will also induce changes in the main direction of the flow which attacks the revetment. This will be tested in the physical model, in which also the geometric details of the revetment will be varied.

5.6 SCOUR INVESTIGATIONS

5.6.1 Introduction

A commonly used method for preventing bank erosion along outer bends of rivers is the construction of groynes. An important parameter for the design of these groynes is the maximum scour depth. In an outer bend the water depths are usually relatively deep due to the spiral flow and the induced complex flow and sediment motion. Around structures like groynes always local scour occurs due to the complex 3-dimensional flow pattern around them. The topic of this present study is how to combine these two types of scour to arrive at design criteria.

In the past some research has been carried out which has led to design rules that are still in use. These design rules, however, do not explicitly take into account the specific conditions in a particular bend. To generate better scour predictions, use can be made of the increased understanding of the flow and sediment transport in bends due to research over the last decade.

Within the frame-work of the present study also an exploring study was done into prediction of combined scour for groynes in outer bends. The study was carried out by the Consultant in a small experimental facility in the De Voorst research station of DELFT HYDRAULICS in the period February-June 1992. Here only a summary of the study and some results obtained are presented, whereas some more details can be found in Annex 3. A more detailed Technical Report is due in October 1992, giving a full account of the study including the conclusions and recommendations.

5.6.2 Experiments

Following a literature survey, an experimental facility was designed and built. The approximate dimensions of this facility are 9m x 6m. In this facility a movable bed channel could be shaped. The sediment that was transported in the channel was collected downstream in a sand trap, and from there it was recirculated to the upstream end of the flume. Also the water was recirculated. Fig. 5.6.2-1 provides an overview of the experimental facility and the sediment and water circuit.

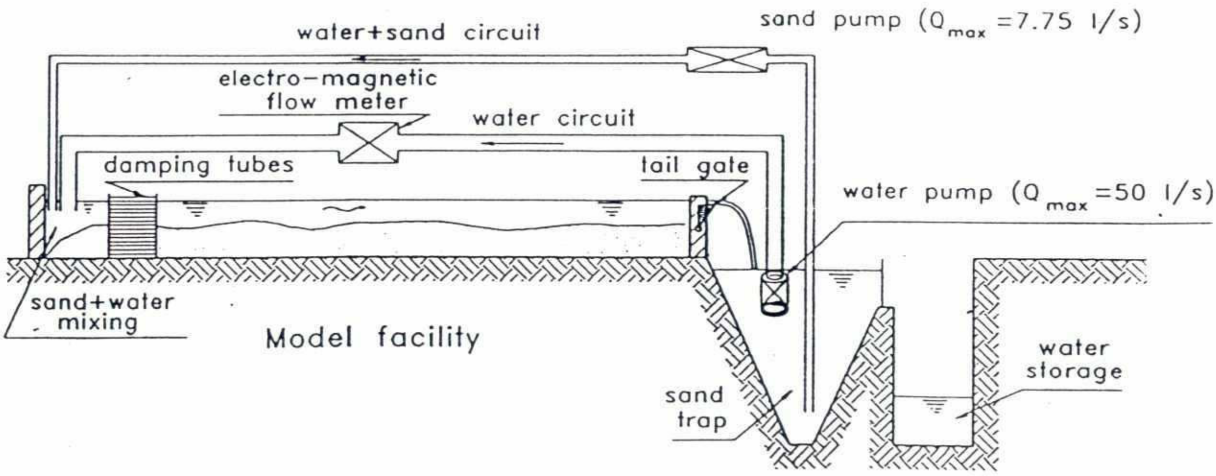

Fig. 5.6.2-1 Experimental facility, water and sand circuit

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The bed material used during the investigation was fairly uniform sand with a mean diameter of about 0.2 mm, that means a sand like the one found in the Jamuna.

In total three series of experiments were carried out, each series with approximately the same slope. One series consisted of four experiments: (1) a straight channel without groynes (SCWG), (2) a straight channel with groynes (SCIG), (3) a curved channel without groynes (CCWG), (4) a curved channel with groynes (CCIG). For two series an additional experiment (CCWIG) was done with slightly retired groynes to study the effect of bank erosion on the transverse slope in bends and the effect on the ultimate combined scour. During the experiments the main interest was in the depth of the outer bend scour and the local scour near all groynes. They were measured once equilibrium had established. In addition the other basic parameters of the experiments (like slope, water depth, flow velocity, sediment transport, etc.) were measured during equilibrium.

5.6.3 Analysis of Results

During the analysis of the results of the experiments the combined scour measured near all groynes in the experiments with a curved channel with groynes were compared with the experiments with local scour and bend scour alone. Furthermore, comparisons were made with existing prediction methods. Improved guidelines for scour prediction for groynes along a curved channel were developed. Furthermore the role of bank erosion in reducing the initial depth along the out bend was elucidated, and the importance of including this into the prediction methods was demonstrated.

5.6.4 Preliminary Conclusions

From the above analysis of the results it was concluded that the approach followed (with series of four comparable test in straight and curved channels and with and without groynes) has been quite successful and allows for the preparation of recommendations for the design of groynes along outer bends.

The following simple design rule is tentatively recommended:

$$h_{bl} - h_o + \Delta h_b + \Delta h_l$$

where h_{bl} = scour depth near groynes in outer bends, h_o = average water depth for straight channel, Δh_b = additional scour of channel with average depth h_o due to bend scour, and Δh_l = additional scour due to local scour in a straight channel due to groynes.

Furthermore it was demonstrated that in rivers with severe bank erosion like in the Jamuna River, the measured bend profiles should be corrected for the influence of the bank erosion products, before the local scour groynes in bends is computed according to the above design rule. Finally it is concluded that additional studies both in laboratory channels under controlled conditions and in the field are required to verify the recommendations given on the basis of this exploring investigation.

More detailed conclusions and recommendations are due in the forthcoming Technical Report with a detailed account of the present study.

5.7 FILTER TEST RIG

Within the framework of the project FAP 21/22 the planned applied research in a filter test rig is considered in principle as suitable for a co-operation with a research institute or an university, as mentioned in the Inception Report, since the Project expects benefits of such a cooperation for both parties. After a first contact with the Bangladesh University of Engineering and Technology a promising cooperation between BUET and FAP 21/22 seemed possible and it was decided to continue the preparation of this cooperation with the Water Resources Department and the Civil Engineering Department. A preliminary location of the filter test rig was selected in the hydraulic laboratory of the Water Resources Department.

The main characteristics of the preliminary functional design of the filter test rig has been described in the Inception Report. A functional design, see Annex 6, could be elaborated after this preselection of a possible location of the filter test rig. On the basis of this functional design a cost estimate has been prepared by BUET for the workshop drawings, a mock-up model and the construction of the filter test rig. These preparations have taken quite some time and it is foreseen that only with a high priority for this applied research project from all parties involved, this applied research project can be completed before the end of the planning study phase of FAP 21/22.

As an alternative for the complete construction of the filter test rig in Bangladesh the Project explores the possibility to import an existing filter test rig and additional small construction work for the connecting pipes and the pump. A serious disadvantage of this option is the long time which will probably be needed for transport and the clearance by the Customs. Without this disadvantage the Consultant would consider this option as a very attractive alternative.

5.8 ECONOMIC STUDY

The Project aims at evolving appropriate bank protection techniques and cost-effective methods for works in the Active Flood Plains. As such it is not anticipated to include a full economic analysis of costs and benefits but to provide useful technical and economical data for the preparation of alternative bank protection designs and possible AFPM strategies with a particular attention given to the cost-effectiveness of the recommended measures and construction methods.

Economic aspects are therefore to cover the following subjects:

i. Analysis of past budgets for bank protection and river training in Bangladesh with due consideration given to their effectiveness;

ii. Contribution to unit rate and cost analysis for future works possibly involving new construction methods and the use of materials that are not yet familiar to the executing agencies and to local contractors;

iii. Preliminary inventory of potential benefits to be expected from bank protection and river training works with a rough estimate of their possible order of magnitude and of their economic impact.

In agreement with the Terms of Reference, the study concentrates mainly on Brahmaputra-Jamuna River although the applicability of the tested works to other rivers in Bangladesh will be also examined.

The economic study for FAP 21/22 will consist of 2 short-term assignments of the Project Economists 1 and 2. The first assignment was primarily aimed at gaining more information of cost related to the bank protection component (FAP 21) rather than on the river training/AFPM component (FAP 22).

Main objectives were

- to gather more information on investment cost and operation & maintenance (O&M) cost of bank protection works, the latter being eventually repair costs
- to obtain insight to the methods used by BWDB to develop their Schedules of Rates and to unit price calculation by contractors.

Both are considered to be important factors for assessing the economic efficiency of existing construction methods and of construction methods to be developed in the course of this Project. Information on the investment and maintenance cost, particularly the latter one, is not easy to gather because the BWDB do not keep regular records of cost broken down for specific projects.

In the second phase of the economic study of the Project the main stress would be laid on macro-economic aspects related to possible benefits and dis-benefits of river training and AFPM measures.

It is expected that the results of that investigation would contribute in finding some quantitative and monetary criteria which would help GoB to decide on possible long term strategies. Some general information in this context has already been gathered and is also compiled in Annex 9.

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5.9 1-DIMENSIONAL MODELLING

5.9.1 Introduction

In the study of the effectivity of recurrent measures for active flood plain management 1-dimensional hydrodynamic computations and 1-dimensional morphologic computations have been used for comparison and for calibration purposes. These mathematical models have been made with the MIKE 11 package. Two modules of the MIKE 11 package have been used in this study so far: the hydrodynamic(HD) module which is capable of simulating unsteady flows in a network of open channels and the non-cohesive sediment transport (NST) module of which the morphological mode has been used.

Some local models of a few branches, which represent the channels in the braided Jamuna river, have been developed and in these models the hydrodynamic and morphological effects of some river training measures have been simulated. Some relevant steps in the development of these models are summarized in this section, more detailed information can be found in Annex 10.

Following measures have been simulated:

- dredging,
- surface vanes.

Up to now most attention has been paid to develop accurate and reliable models with the mentioned software package. The approach to simulate a river training measure is first to establish a morphologic equilibrium, this means that during a period of about 2 years with constant boundary conditions and a constant discharge no substantial erosion or sedimentation is calculated in the cross-sections of the model. In a restart computation the effect of the river training measure is superimposed on this equilibrium situation. Although an equilibrium cannot be observed in the prototype because the discharge is changing according to the hydrograph, a main advantage of this approach is that the results of different computations can be compared on the same basis.

It has to be mentioned that in some cases it took quite some effort to establish this equilibrium in a model, sketched in Fig. 5.10-4, especially if the roughness coefficient varies during the simulation time. Therefore it is preferred to make the computations with a fixed roughness coefficient.

5.9.2 Development of Local Models

The study with the local models with one or a few branches has increased the Consultant's experience with the software package and some of the relevant steps in the development of these models are summarized below, more details and background information can be found

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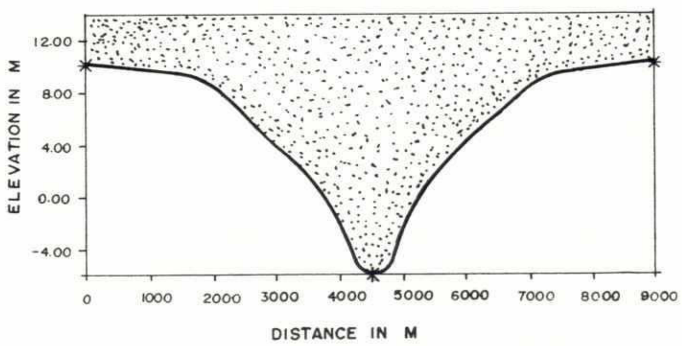
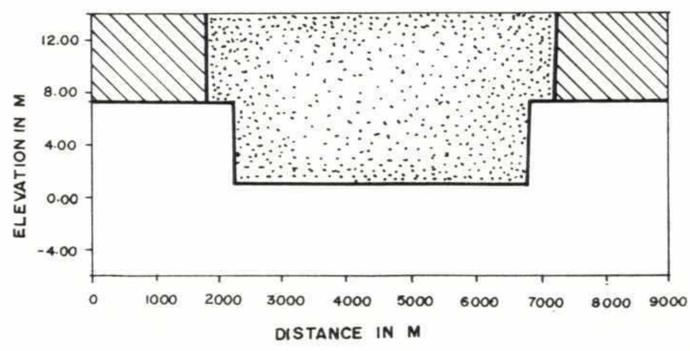
in Annex 10. The final results concerning the effectivity of the simulated river training measures are not discussed.

Schematization of a cross-section:
The measured cross-sections of the channels differ widely in shape. Therefore in the mathematical models schematized cross-sections should be preferred. A first schematization of a cross-section was based on a type of regime equations for the averaged width and depth of the cross-section. In a second schematization the cross-section was reduced to a rectangular cross-section for the main channel and a rectangular flood plain, see sketch in Fig. 5.9-1. If the total width of the flood plain is reduced to 20%, as is recommended in other studies, a rather good similarity with the first schematization is obtained. If the water level is at the bankfull stage then the extreme transition in the width of the main channel to the full width including the complete flood plain can cause instabilities in the calculation. In that case a more gradual transition is recommended. The conclusion is that in this study schematized rectangular cross-sections can be used in computations with hydrographs without introducing serious deviations in the computed water levels.



SYNTHETIC CROSS SECTION



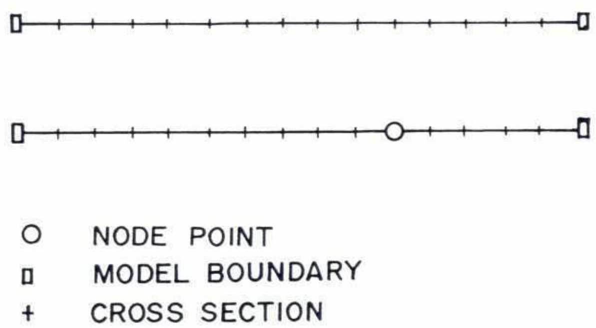
RECTANGULAR CROSS SECTION

Fig. 5.9-1

The influence of nodal points:

The influence of a nodal point on the main morphologic parameters as bed level and sediment transport has been investigated by comparing these parameters in a single branch model with a similar model with two branches, which are connected by a nodal point, see the sketch in Fig. 5.9-2. In case of equal spaced cross-sections this comparison showed small differences of about 0.5% to 2.5 % in the sediment transport and as a consequence also small differences in the bed levels, about a centimeter after a few months. These computations have been made with version 2.10 of the software package, but with the new version 3 also slightly smaller differences will be found.

Some improvement can be obtained to reduce the distance between the cross- sections adjacent to the nodal point by inserting more cross-sections. As a consequence also the time step in the full hydrodynamic approach should be reduced. From these comparisons it is concluded that a long simulation time of several years (and many time steps) with a model of a network of several branches connected by nodal points the accuracy of the computed bed levels, and sediment transport in the whole model can be considerably less than expected.



SCHEMATIZATION SINGLE CHANNEL MODEL

Fig. 5.9-2

Simulation of dredging:

Dredging can be simulated by a lateral discharge of water and sediment in the cross-sections, which are placed in the stretch to be dredged. This schematization is compared with a stepwise computation in which after each three months the bed level is lowered, according to the dredged volume in this period, see the sketch in Fig. 5.9-3. It should be realized that the full width of the bed level in a rectangular cross-section is lowered. This schematization is time consuming and the results are the same as with the other, very simple, schematization method, if the lateral sediment outflow is multiplied by (1 - porosity) to calculate the dredged volume. In general the porosity of sand is about 0.4.

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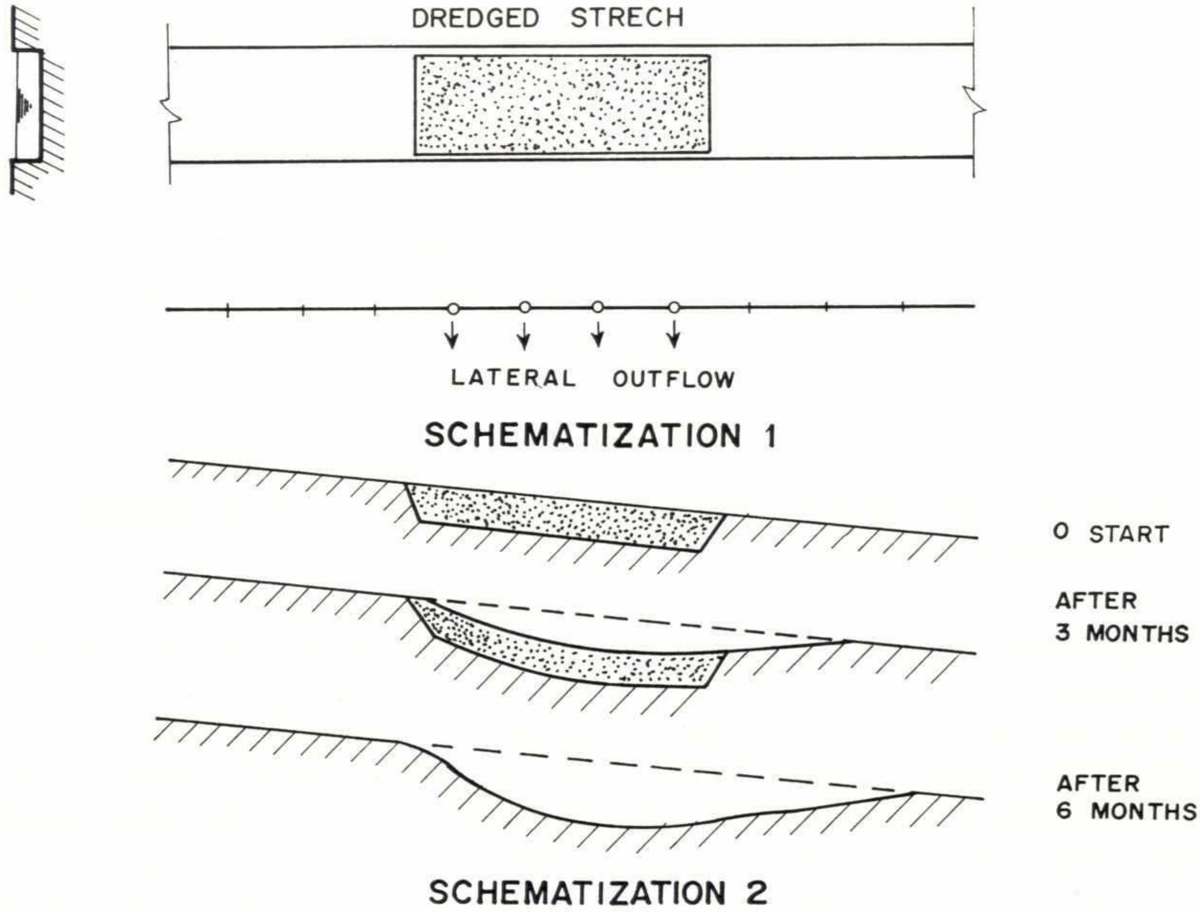

Fig. 5.9-3

Simulation of surface of vanes:
Up to now the schematization of surface vanes in a bifurcation with two channels and in one of these a structure did not result in a satisfying reproduction of the water levels and discharges with the hydrodynamic module. However with Consultant's own software a more realistic schematization of these surface vanes is possible and these results were used for a preliminary calibration of the developed spread sheet program, as described in section 3.3.

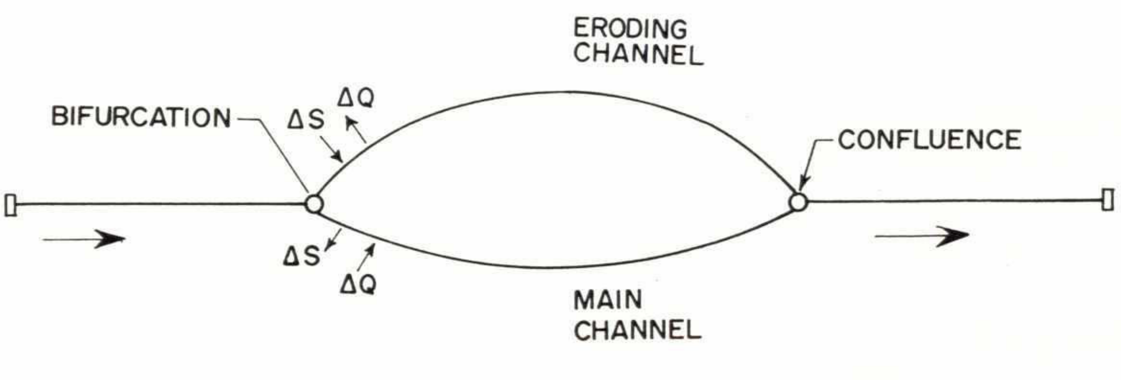

Fig. 5.9-4

The model consists of two parallel channels connected by a bifurcation and a confluence, see sketch in Fig. 5.9-4.

The morphological effects of surface vanes can be simulated by a lateral inflow of sediment in the eroding channel and a lateral outflow of sediment in the main channel, which is parallel to the eroding channel. And also a change in the discharges is simulated by a lateral outflow, located at the eroding channel, and a lateral inflow in the main channel. All these lateral in- and outflows are located close to the bifurcation, as indicated in Fig.5.9-4. The results of this schematization of the effect of surface vanes are analysed in the continuation of this study.

5.10 RECONNAISSANCE OF THE JAMUNA AND OTHER MAJOR RIVERS IN BANGLADESH

During inception phase of the Project the Consultant concentrated all efforts, visits and field inspections on both banks of the Jamuna River from its confluence with the Teesta up to the Ganges, as required for the urgent selection of test areas and further investigations (subsoil, surveys etc). Thereafter, a number of other rivers have been visited with the aim to compare river characteristics and to obtain first hand information on the spot on structures executed earlier regarding type, experience during construction and maintenance, suitability of materials used, expenditures etc. Discussions were held with the local BWDB authorities in this respect, and also with BWDB head office officers, Bangladesh Railway and others.

The following rivers and places other than on the Jamuna were visited so far :

1. During end of March 1992 field trip to Rajshahi and Hardinge Bridge on Ganges River and to Kushtia on Gorai River.
2. In early April, 1992 field trip to Dalia, Godownerhat, Mahipur, Kaunia and Painalghat on Teesta River.
3. On 19.06.92 field trip to Eklashpur and Chandpur on the Lower Meghna

The data obtained are summarized in Tables 5.3-1 and 5.3-2 of Section 5.3. A list of officers met in this connection is given hereunder.

FPCO, Dhaka

- Nurul Haque, Chief Engineer
- S.M.A. Salam, Superintending Engineer
- Akhtar Alam, Executive Engineer

BWDB, Dhaka

- A.C. Sarker, Chief Engineer, Design-I
- Md. Afazuddin, Chief Engineer, Design-II

- Md. Liaquat Hossain, Chief Engineer, Planning
- T.K. Ganguly, Superintending Engineer, Design Circle-I
- Sadhan Chandra Das, Superintending Engineer, Design Circle-II
- Mofizuddin Ahmed,Superintending Engineer, Design Circle,Northern Zone
- Wahedul Hoque, Executive Engineer, Design Circle-I

Metrological Department, Dhaka
- Ft. Lt. Mahtab Uddin Ahmed, Deputy Director

BWDB, Gaibandha
- Aminul Haque, Executive Engineer
- A. Samad Mondal, Sub Divisional Engineer

BWDB, Serajganj
- Bishnupada Halder, Executive Engineer
- Fazlul Karim, Sub Divisional Engineer

BWDB, Rangpur
- Md. Asadduzzaman, Superintending Engineer
- A.K.M. Anisur Rahman, Superintending Engineer
- Habibur Rahman, Executive Engineer

BWDB, Bogra
- Md. Fazlul Qader, Superintending Engineer
- Md. Giasuddin, Executive Engineer

BWDB, Rajshahi
- Mazharul Islam, Chief Engineer
- Shafiuddin Ahmed, Superintending Engineer
- Aminul Islam, Executive Engineer

BWDB, Tangail
- Abdus Satter, Executive Engineer

BWDB, Mymensingh
- A.H.M. Kawser, Executive Engineer

BWDB, Pabna
- Tazul Islam, Executive Engineer

Bangladesh Railway, Paksey
- Md. Golam Kibria, Bridge Engineer

The above list is not complete but covers the most important discussions.

It is intended to continue the reconnaissance trips to visit other places like Brahmaputra right bank from Chilmari up to the Indian border, Bhairab Bazar and others, as well as to repeat visits to previous inspected sites as soon as any new developments may have taken place. (e.g. completion of closure dam at Rajshahi). Due to transport strike and hartal a site visit planned for 24th to 27th June to Kurigram and the upper Jamuna (Brahmaputra) area had to be postponed for after the Interim Report.

5.11 REMOTE SENSING STUDIES

5.11.1 General

As an additional component of the present study an extensive analysis of satellite imagery of the Brahmaputra/Jamuna River is being carried out. A detailed description of this study component is given in Annex 2. Here a summary of the study is given and the most important applications of the study results are discussed. The study can be considered as a continuation of the study carried out under the Jamuna Bridge project.

5.11.2 Selection and Processing

For the analysis mostly LANDSAT-images were selected. Partly these images are (older) MSS images (with resolution of 80 m x 80 m) and partly the more recent TM images (with a resolution of 30 m x 30 m). In addition some MOS images were purchased. Criteria for the selection of the images were: (1) (almost) cloud free, (2) low flow season, (3) water level in Sirajganj approximately the same.

The origin of the data is diverse: part had already been acquired under the Jamuna Bridge Project, some processed tapes were provided by FINNMAP, other processed data were obtained from FAP 19 and finally a number of tapes with the digital material was bought from either EOSAT in the USA or the National Remote Sensing Center in Thailand. The MOS images were acquired from Japan. In total 35 images became available (including the ones already processed under the Jamuna Bridge Project). The images relate to both the lower reach of the Jamuna River (148(138)/43. downstream of Bahadurabad) and the more upstream reach (148(138)/42.

Overviewing the images available it can be stated that out of a period of 20 low-water seasons (1972/73 through 1991/92) 15 years became available, notably:

- 1972/73
- 1975/76 through 1979/80 (5 consecutive low-water seasons)
- 1982/83 through 1986/87 (5 consecutive low-water seasons)
- 1988/89 through 1991/92 (4 consecutive low-water seasons)

hence including three periods with fairly long records of 4 to 5 years. For two intervals no images were available (1973/74 through 1974/75 and 1980/81 through 1981/82), while the 1987/88 was finally not purchased to allow for the processing of the latest years.

The processing of the tapes included:
- geocorrection and
- classification.

As in the Jamuna Bridge project, for the present study four classes were distinguished, i.e. water, bare land, sand and vegetation. The classification was done on the basis of band 5 and band 7. In doing this a distinction was made between water (blue on the processed images), bare land (grey), sand (yellow) and vegetation (green). Changes over the years in water and land distributions are obtained by comparing the classification for different years. In total 16 possibilities are present, based on the four identified classes.

Compared to the Jamuna Bridge study a slightly different code was used to indicate changes. For more details see Annex 2.

Primary results of the present remote sensing study are geometrically corrected, classified images of the Jamuna River for particular years. In total 30 of these images have been produced or are still in the process of being produced, 15 for the Southern and the Northern reach respectively. From these images "difference-images" can be prepared according to the method described in the preceding section. It is foreseen that in total 22 of these multi-temporal images will be prepared. About half of them have been produced as per 1 July 1992. In addition some special products were prepared, notably (1) an image where all channels were plotted over the period 1973-1987, giving all channels different colours and (2) an image where the probability of occurrence of a major channel in the period 1973-1987 is indicated.

5.11.3 <u>Analysis</u>

The processed single year images and the "difference-images" are being analysed at present. The use of these products for five different purposes is foreseen, notably:
(1) selection of test sites and areas,
(2) determination of the characteristics of the Jamuna River,
(3) study of morphological processes in the Jamuna River,
(4) verification of future morphological model of planform changes of a braided sand bed river,
(5) development of AFPM strategies under FAP 22.

Some details on these studies are given hereafter.

Re(1) Selection of test sites and areas
The most recent satellite images, in particular the years 1989, 1990, 1991 and 1992 were used to study the present planform of the Jamuna River and the recent changes. Based on this the pre-selected test areas were re-confirmed and test sites were selected. More details are given in Chapter 2 and in Annex 2.

Re(2) Determination of the characteristics of the Jamuna River
To select prediction methods for the response of the river system to AFPM measures under FAP 22, prediction methods that have been proposed in the literature have to be verified. This verification has to be done on the basis of the present river characteristics of the Jamuna River. Hence these river characteristics have to be established. Presently this is being done for the more recent years. Some results are presented in Annex 1, and more will become available. For the determination of especially the planform characteristics the satellite images are extremely useful, even more than the SPOT image maps of scale 1:50,000, because the 1:250,000 LANDSAT/MOS allows a much better overview.

Re(3) Study of morphological processes in the Jamuna River
At present the possibilities to predict future planform change in the Jamuna River are fairly limited. Only predictions for one or two years ahead can be given with acceptable accuracy, any prediction beyond that period is subject to increasing inaccuracies. Hence in the selection of the test sites no sites could be identified where bank erosion can be 100% guaranteed over the coming 5 years. There is a need for improving the predictions for Jamuna type of rivers beyond what is presently known. Within the framework of the present study some elements of the morphological behaviour of the Jamuna River are being studied, notably bank erosion rates and the probability of occurrence of cut-offs. For more details see Chapter 3 of Annex 2. In due time more elements have to be studied.

Re(4) Verification of future morphological model of planform changes of a braided sand bed river
Further on the study of the different morphological processes in the Jamuna River, it will be attempted to integrate these phenomena into a morphological model of planform changes of the Jamuna River. It is proposed to develop under an additional component of one-and-a-half manmonths a conceptual model for the prediction of planform changes. This conceptual model would be applied to the
selected test areas to provide improved predictions of the morphological behaviour near these sites and to indicate the consequences for the test structures in terms of where and how to be built and what type of attack to be expected. Such a conceptual model has to be verified. In due time this can be done using images of 1993 and later years. For the time being series of old satellite images will be used for this purpose. This verification will probably lead to improved model concepts. It is of interest to indicate here that it will be investigated whether a cooperation between FAP 21/22 and FAP 19 with respect to the model development is possible, especially as far as input and output of the (future) morphological model is concerned.

Re(5) Development of AFPM strategies under FAP 22
The satellite images can be extremely helpful in developing AFPM strategies. At present they are used to study the actual conditions in certain years and to decide upon inspection of the particular planform where AFPM are formulated and next by consulting the satellite images per year the number and extent of AFPM measures are identified. This leads to insight in the consequences of certain targets and it provides information on how, when and where measures have to be taken. This can be used in assessing the technical feasibility of certain AFPM strategies.

In summary it can be stated that the remote sensing study provides indispensible information on the river behaviour and is extremely helpful in selection of the test sites and in formulating AFPM strategies.

5.12 STATE-OF-THE-ART IN PREDICTION OF RESPONSE

5.12.1 General

As part of the studies for FAP 22 a state-of-the-art in predicting the response of the river to any FAP 22 activities was prepared. The results of this review is included in Annex 1 as Chapter 8. Here the main conclusions from this review and some preliminary results of studies to verify the prediction methods identified are presented.

5.12.2 Present State of Prediction Methods

In Chapter 8 of Annex 1 a review is given of what is known as far as prediction methods for channel characteristics of braided river systems with fine sand as bed and bank material is concerned. In particular the prediction of the width of the channels, the sinuosity, the number of braids and the total width of the river system are dealt with. Summarizing it can be stated that for these four dependent parameters no undisputed theoretical predictors are available. The theoretical predictors that have been proposed either are based on questionable assumptions like extremal hypotheses or are applicable only for very small disturbances and hence their application to real rivers is doubtful. Some empirical predictors are available, either developed especially for the Jamuna River or potentially applicable. From these methods a selection has to be made to identify the methods that are most suitable for use within the present Project for the prediction of the response of the river to FAP 22 measures.

5.12.3 Verification

Considering the above, an important step in the selection procedure is the verification of the applicability of the various proposed methods against data on the Jamuna River. The river characteristics of the Jamuna River have been determined on the basis of satellite images. Some results of this analysis are presented in the Fig. 5.12-1 (notably the total width of the river and the width of the channels as a function of the chainage) and 5.12-2 (providing a relation between the number of channels and the total width of the river).

In a further step the different prediction methods are being compared with these river data. During this comparison both theoretical and empirical predictors are being verified. The preference is of course for theoretical predictors, but in the experience of the Consultant even theoretical predictors often have to be calibrated using field data. If no theoretical predictors are applicable, it will be necessary to use empirical relationships. If necessary, even empirical methods have to be developed especially for the Jamuna River.

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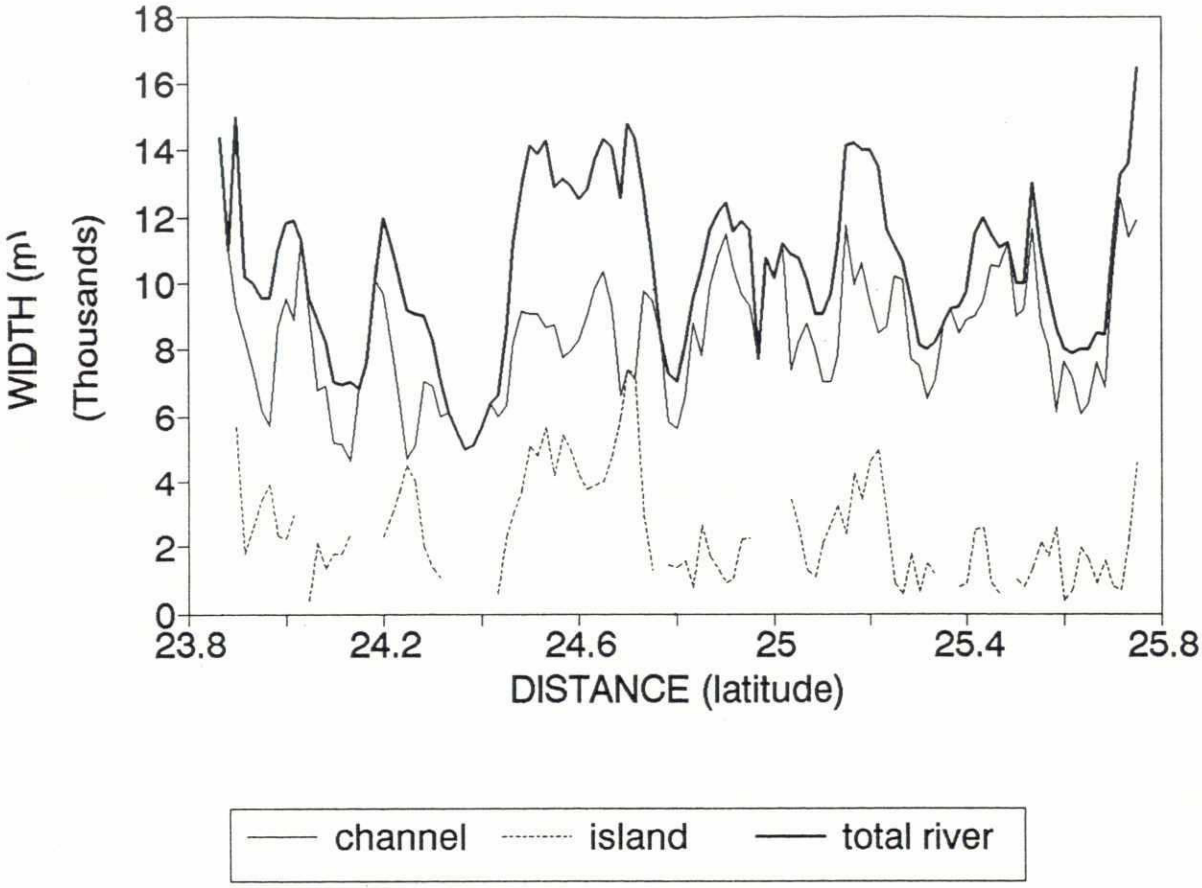

Fig. 5.12-1 Total width and combined width of all channels versus chainage of the Jamuna River

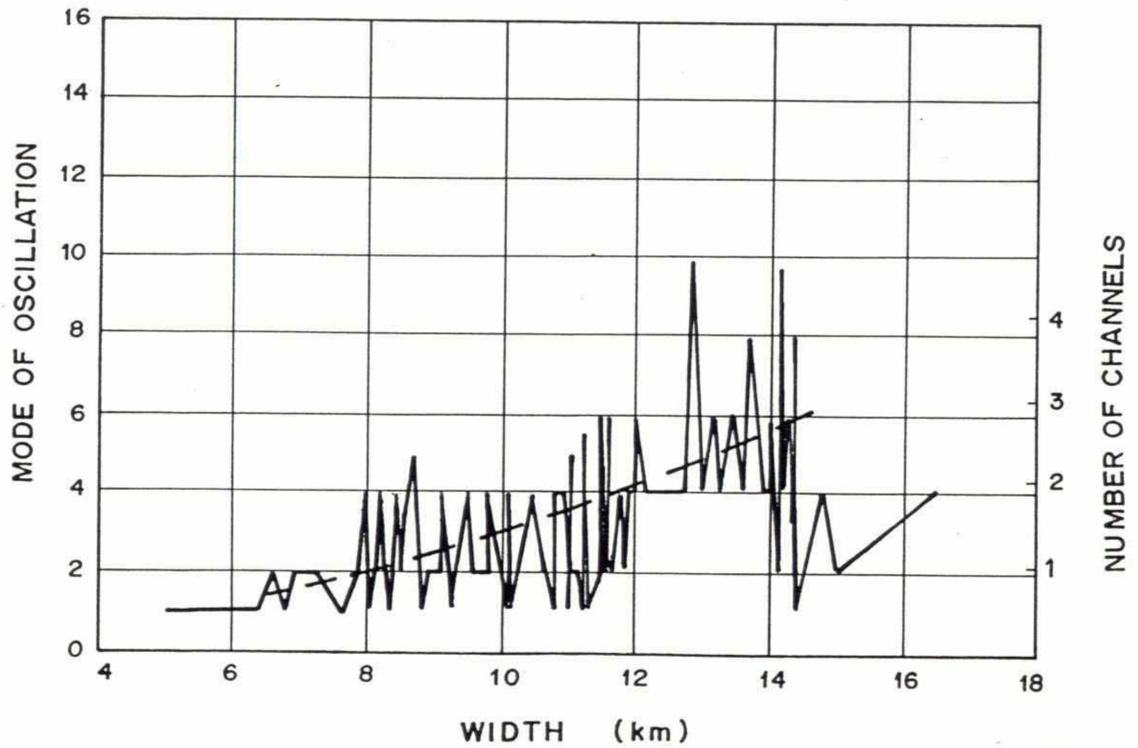

Fig. 5.12-2 Number of channels versus the total width of the Jamuna River

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5.12.4 Some Preliminary Conclusions

For the time being the verification has concentrated on the extremal hypotheses, according to Bettess and White the only methods (apart from empirical regime equations) to provide fair predictions for the channel width. The approach of Chang is being followed: the independent variables are (1) discharge, (2) sediment transport, (3) size of bed material and the number of channels is assumed to be 1. The method of Chang is based on the identification of a minimum slope. It was found here that for the assumption of very wide channels (an acceptable assumption as far as the flow is concerned because the hydraulic radius R virtually corresponds to the water depth h; for B in the order of 1 km and h in the order of 7 m), that no minimum is found. Only via introducing the hydraulic radius a minimum is obtained but as is shown in Fig. 5.12-3 the location of this minimum depends very much on the schematization of the banks. In view of the very wide channels in the Jamuna River these results appear to be very doubtful. Fig. 5.12-3 is based on the combination of the Ackers & White sediment transport formula and the White et al. roughness predictor but a similar result is obtained based on the Engelund & Hansen sediment transport equation and roughness predictor. It is therefore doubtful whether the extremal hypotheses yield acceptable results for Jamuna type of rivers.

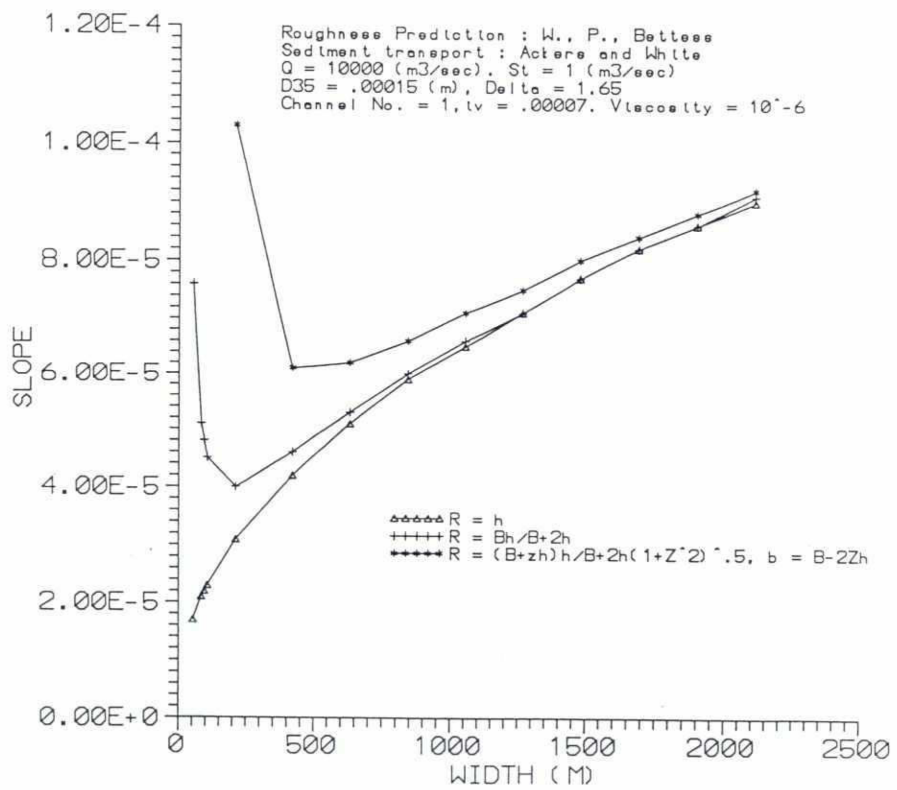

Fig. 5.12-3 Application of extremal hypotheses to predict channel width based on Ackers & White sediment transport equation and the White et al roughness predictor

6 OUTLOOK

6.1 UPDATED WORK PLAN

As reported in the previous chapters the Project activities have developed by and large in accordance with the work flow chart as given in the Inception Report.

The updated work plan as per figure 6.1-1 shows the activities as they were actually undertaken until the submission of the Interim Report as well as the forecast of future activities.

6.2 UPDATED STAFFING SCHEDULE

The schedule on Fig.6.2-1 shows the staff assignment as agreed after the Inception Report and updated according to the actual assignment of the staff until the Interim Report.

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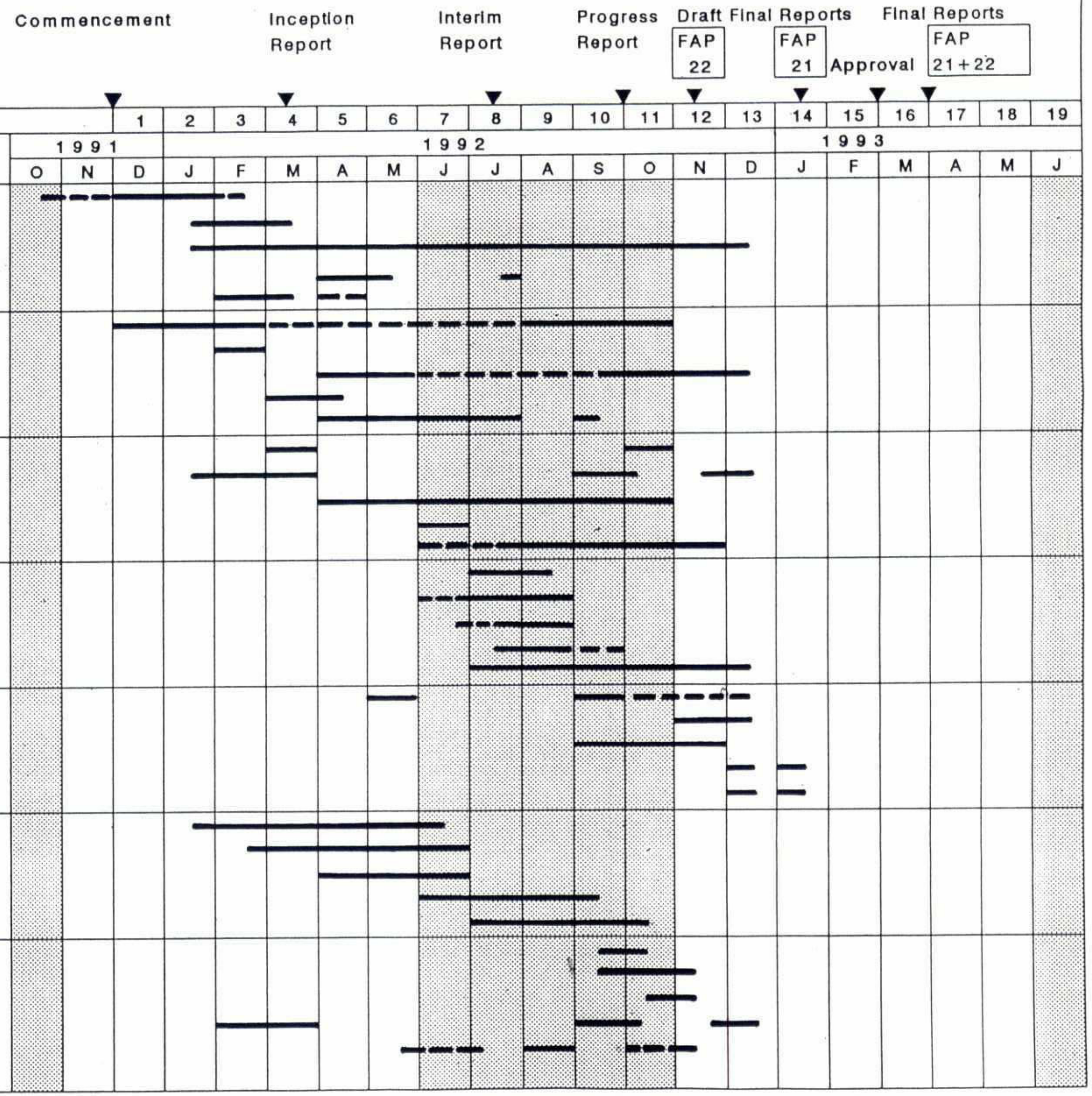
FIG. 6.1-1

FAP 21 / 22 WORK FLOW CHART - PLANNING STUDY

15 JULY 1992



No.	Task	FAP
1	Mobilization and Project Preparation	21,22
2	Review of Existing Data	21,22
3	Installation of 1-D Mathematical Model (Mike 11)	21,22
4	Reconnaissance of Major Rivers in Bangladesh	21,22
5	Field Inspection of Jamuna River	21,22
6	Morphological Analysis	21,22
7	Preselection of Test Areas	21
8	Topographic and Hydrometric Surveys	21(22)
9	Specification of the Hydrological Design Events	21
10	Subsoil Investigation in Test Areas	21
11	Environmental Assessment	22
12	Socio-Economic Assessment	22(21)
13	2-D Mathematical Flow Modelling	21(22)
14	Selection of Test Sites	21
15	Physical Modelling	21,22
16	Selection of Alternative Test Measures	21
17	Analysis of Construction Materials	21
18	Analysis of Construction Methods	21
19	Assessment of Local Contractors' Capabilities	21
20	Preparation of Alternative Designs	21
21	Rate Analysis and Cost Estimation	21(22)
22	Selection of Design and Contruction Methods	21
23	Inspection of Locally Available Construction Equipment	21
24	Staffing and Scheduling of the Test and Impl. Phase	21
25	Budgeting of the Test and Implementation Phase	21
26	Review of Possible River Training Methods and Concepts	22(21)
27	Prediction Methods for Morphological Behaviour	22(21)
28	Formulation of River Training/AFPM Concept	22(21)
29	Formulation of Altern. Strategies of River Training/AFPM	22(21)
30	Sel. of Recommended River Training/AFPM Strategies	22(21)
31	Approach for Development of Medium-Term Plan	22
32	Design of River Training/AFPM Pilot Project	22
33	Preparation of Implementation of Pilot Project	22
34	Proposal of Institutional Arrangements	21,22
34 A	Navigation Study	22

Monsoon

TABLE 6.2-1

FAP 21/22 STAFFING SCHEDULE-PLANNING STUDY
REVISION NO 2, AGREED AFTER INCEPTION REPORT

15 JULY 1992

MILESTONES: COMMENCEMENT OF SERVICES — PREMOBILIZATION — MOBILIZATION — INCEPTION REPORT — INTERIM REPORT — PROGRESS REPORT — DRAFT FINAL REPORT FAP 22 — FINAL REPORT FAP 21 — APPROVAL — FINAL REPORT FAP 21 + FAP 22

Months: 1991: O, N (1), D; 1992: J (2), F (3), M (4), A (5), M (6), J (7), J (8), A (9), S (10), O (11), N (12), D (13); 1993: J (14), F (15), M (16), A (17), M (18), J (19)

C.F. LINE 1/4.1 CHIEF RESIDENT ENGINEER

No.	FUNCTION (ASSIGNED STAFF)	PERSON		Man-Months Expatriates BD	Man-Months Expatriates EUR	Man-Months Local	Flights
	PROJECT DIRECTORATE						
1	PROJECT DIRECTORATE	Dr H Brühl					
2	ADVISORY BOARD PROJECT ACTIVITIES	5 Experts		5.0	1.0	2.0	10
3	TECHNICAL HOME OFFICE SUPPORT				7.0	6.0	
	PROJECT MANAGEMENT		SUM P D	5.0	8.0	8.0	10
1/4.1	CHIEF RES. ENG. (PROJ. MANAGER)	Dr H Brühl		11.0	3.5		11
4.2	DEPUTY PROJECT MANAGER	S M Mansur				15.5	
	FAP 21		SUM PM	11.0	3.5	15.5	11
5.1	CHIEF HYDR. DES. ENG. + TEAM LEADER	H Schwenk		10.5	-		4
5.2	HYDRAULIC DESIGN ENG. 2	A Q M Ali				14.5	
6.1	MODELLING EXPERT 1	M v d Wal		4.5	-		1
6.2	MODELING EXPERT 2	J Islam				4.5	
7.1	PHYS. MODELLING EXP. 1	E Doutriaux		5.0	-		1
7.2	PHYS. MODELLING EXP. 2	Q Saifuddin				6.5	
8.1	HYDROLOGIST 1	G Fleury		1.0	-		1
8.2	HYDROLOGIST 2	Z H Khan				3.0	
9.1	MORPHOLOGIST 1	G J Klaassen		1.0	-		1
9.2	MORPHOLOGIST 2	M Salahuddin				3.0	
10.1	SURVEYOR 1	J Heise		9.0	1.0		2
10.2	SURVEYOR 2	H Kamal				9.5	
11.1	SUBSOIL EXPERT 1	W Schönung		4.0	-		2
11.2	SUBSOIL EXPERT 2	M M Haque				7.0	
12.1	CONSTRUCTION MANAGEM. EXPERT 1	C Netzeband		6.0	-		1
12.2	CONSTRUCTION MANAGEM. EXPERT 2	A N Chowdhury				3.0	
13.1	SOCIO ECONOMIST 1 / INSTITUTIONAL SPEC.	C Potin		1.5	-		1
13.2	SOCIO ECONOMIST 2	K Nizamuddin				2.0	
13.3	LAND ACQUISITION SPECIALIST	M A Jabbar				2.0	
15.1	MECHANICAL ENGINEER 1	J L Ormières		3.0	-		1
15.2	MECHANICAL ENGINEER 2	M Rahman				4.0	
16.1	ECONOMIST 1	F de Cock		1.0	-		1
16.2	ECONOMIST 2	K Hussain				1.0	
20.1	AGRICULTURAL DEVELOPMENT SPECIALIST 1			1.0			1
20.2	AGRICULTURAL DEVELOPMENT SPECIALIST 2					1.0	
	FAP 22		SUM FAP 21	47.5	1.0	61.0	17
17.1	CHIEF RIVER TRAINING ENGINEER + TEAM LEADER	F v d Knaap		10.0	1.0		3
17.2	LOW COST - RIVER TRAINING SPECIALIST	P v Groen		2.0	-		2
17.3	RIVER TRAINING ENGINEER 2	S I Chowdhury				11.0	
8.1	HYDROLOGIST 1	G Fleury		0.5	-		-
8.2	HYDROLOGIST 2	Z H Khan				1.5	
9.1	MORPHOLOGIST 1	G J Klaassen		2.0	-		2
9.2	MORPHOLOGIST 2	M Badiuzzaman				2.5	
6.1	MODELLING EXPERT 1	M v d Wal		5.5	-		2
6.2	MODELLING EXPERT 2	J Islam				6.5	
18.1	LAND RECLAMATION EXPERT 1	E Elizechea		2.0	-		2
18.2	LAND RECLAMATION EXPERT 2	A Mia				4.5	
13.1	SOCIO ECONOMIST 1 / INSTITUTIONAL SPEC.	C Potin		1.5	-		1
13.2	SOCIO ECONOMIST 2	K Nizamuddin				2.5	
13.3	LAND ACQUISITION SPECIALIST	M A Jabbar				2.0	
14.1	ENVIRONMENTAL EXPERT 1	C Bertrand		2.0	-		2
14.2	ENVIRONMENTAL EXPERT 2	A H Huq Bhuiya				3.0	
16.1	ECONOMIST 1	F de Cock		1.0	-		1
16.2	ECONOMIST 2	K Hussain				1.0	
19	LEGAL ADVISOR	H I Bhuiyan				1.0	
20.1	AGRICULTURAL DEVELOPMENT SPECIALIST 1			1.0	-		1
20.2	AGRICULTURAL DEVELOPMENT SPECIALIST 2					1.0	
21.1	INLAND WATER TRANSPORT ECONOMIST 1			1.0	-		1
21.2	INLAND WATER TRANSPORT ECONOMIST 2					2.0	
			SUM FAP 22	28.5	1.0	38.5	18
			TOTAL	92.0	13.5	123.0	56

Legend: MONSOON — IN EUROPE — IN BANGLADESH — STUDY TOUR