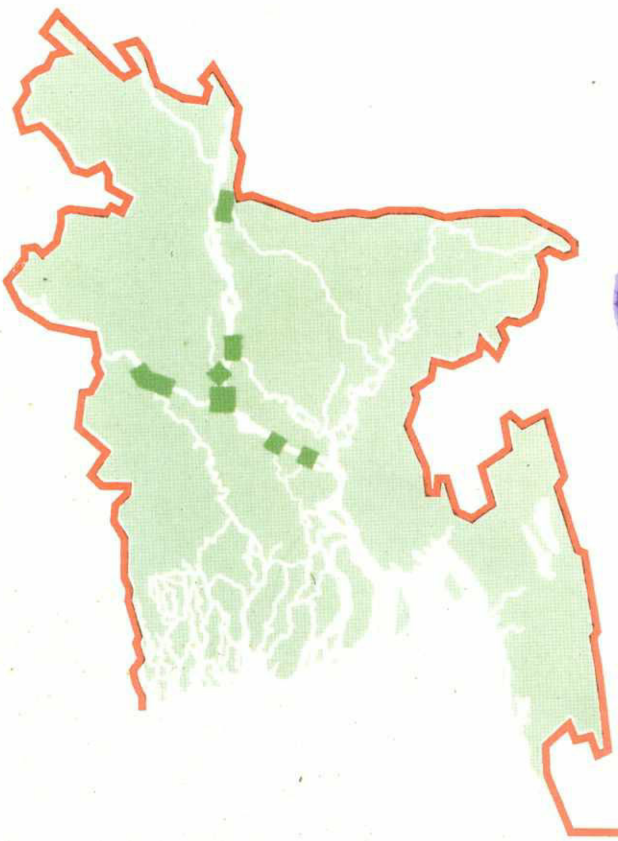
GOVERNMENT OF BANGLADESH
FLOOD PLAN COORDINATION ORGANIZATION

FAP 24 RIVER SURVEY PROJECT

1° Interim Report
Volume III
Annexures on studies, etc.



DELFT HYDRAULICS
DANISH HYDRAULIC INSTITUTE
OSIRIS
HYDROLAND
APPROTECH

Project ALA/90/04 — Commission of the European Communities

2

1° Interim Report

Volume III

Annexures on studies, etc.

CONTENTS OF THE INTERIM REPORT

INTERIM REPORT
(Volume III)
Annexures on studies, etc.

Contents Volume III

Annexure 5

Previous documents, reports, comments, etc.

5. 1 Project brief

5.1.1 Components and objectives

The River Survey Project is one of the supporting activities of the Flood Action Plan. The main components of the project are :

- **Surveys**
- **Studies**
- **Training**

o Surveys

The objective of the survey is to collect reliable all season hydrological and morphological data at key locations of the country's main river systems. This type of surveys are routinely done so far by Bangladeshi organizations applying traditional methods and equipments which have shown their limitations in the high flow ranges. However, the hydro-morphological data of these ranges are crucial for the design of flood control works as embankments, river training, and bank protection. Therefore the River Survey Project will emphasize the data collection during the monsoon season, introducing improved or new technology where possible and appropriate.

o Studies

Special studies will be undertaken aiming at a further understanding of the behaviour of the main river system in Bangladesh. Starting points for these studies are obviously the existing studies done and the data already collected, especially within the FAP context. Besides that, use will be made of the fresh data collected by the River Survey Project (sometimes purposely measured during supplementary surveys for a study component).

o Training

On the job training will be provided to among others BWDB staff both in the fields of surveys and studies. The objective of the training is to upgrade the capability so that after the River Survey Project the relevant staff can continue the data collection and the study programme.

5.1.2 Timing and scope

The River Survey Project started in June 1992 and will cover a period of about four years. This period is divided into Phase 1, covering the first year, a transition phase during the monsoon period of 1993 and Phase 2 covering the subsequent three years. In Phase 1 the survey techniques and the study - and training programmes will be selected tentatively. Selection will be finalized in the transition phase and implemented in Phase 2.

Phase 1

The survey work in Phase 1 is concentrated on the Jamuna River near Bahadurabad. The measurements of water - and sediment characteristics have been divided into :

- o Test measurements
- o Routine measurements
- o Special surveys

The test measurements aim at comparing the improved or new survey technology with the traditional methods. Techniques and instruments considered are for instance :

-	positioning	:	sextants, DGPS, vessel control, anchoring
-	flow	:	propeller current meter, floats, electromagnetic types, acoustic doppler type, moving boat
-	suspended sediments	:	water sampling, pump-bottle, optical, acoustic type.
-	bed load	:	direct method with trap-type, bed form tracking, side scan sonar.

October 1992 the first test measurements have been executed on the Jamuna river near Bahadurabad in mid flow conditions. December 1992 additional testing has been done in the Lower Meghna in tidal conditions. And in the monsoon of 1993 final testing is planned on the Jamuna in high flow conditions.

From November 1992 to June 1993 the LW routine measurements are done at regular intervals. In this period the appropriate equipment will be selected tentatively.

A special survey was done in September 1992 using BWDB's survey vessel Anwesha in order to realize a timely start of the survey work. A second special campaign is done in January 1993 together with a survey team of BWDB to execute simultaneous measurements facilitating a detailed comparison of instruments and methods.

The studies will be limited in this phase to initial studies aiming at collecting and reviewing the available hydrological and morphological study material and selecting the study topics for Phase 2.

The training activities will comprise limited initial on-the-job training in survey - and data processing techniques. A training programme for the second phase will be elaborated.

Transition phase.
The survey work in the transition phase consists of three main campaigns

- o Bathymetry near Bahadurabad
- o HW routine measurements
- o Final test gauging

The bathymetric work is also aiming at finding the optimum way of executing the survey work finding an appropriate blend of bathymetric, topographic and other survey techniques (water line contour measurements, remote sensing techniques).

The HW routine gaugings will include all selected locations (see Figure 5.1) applying a moderate visiting frequency (of about once per month for the main stations).

The final test gauging will lead to a final selection of survey techniques to be applied in phase 2.

At the end of the transition phase the study programme will be discussed and completed in an international workshop.

Phase 2
The routine measurements of the flow of water and sediments will continue applying the techniques established in the transition phase. For the location of the measurements see Figure 5.1

At seven locations routine bathymetric surveys will be done before and after the floods.

Additional survey work is envisaged both to support own study components and at request from other (FAP) projects.

The study - and training programme as outlined in the previous phase will be implemented.

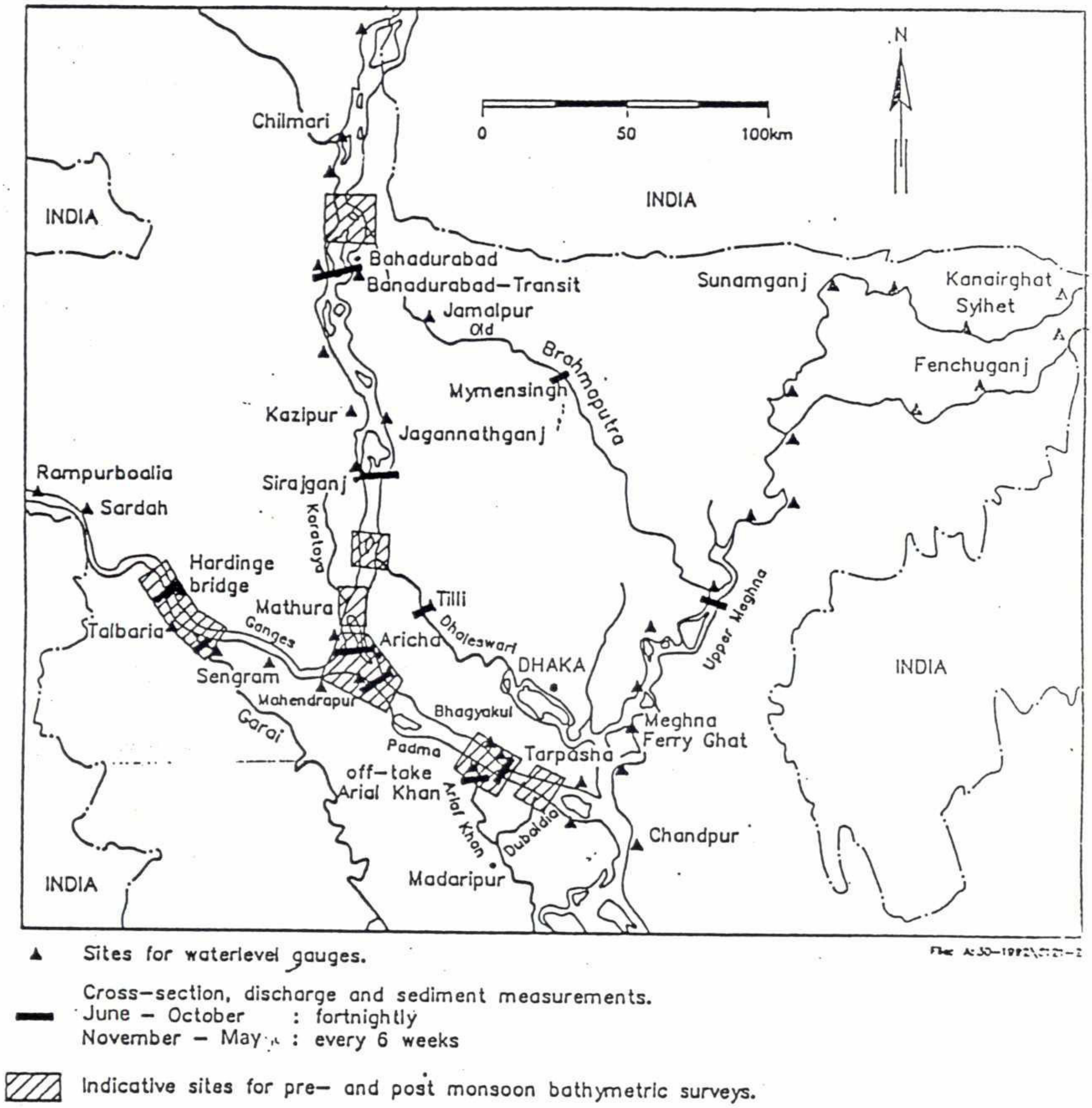


Figure 5.1 Field survey activities

5.2 Questions from the TS

Part of the tender documents of 1991 for the River Survey Project consisted of the Technical Specifications (TS). The TS give a detailed description of the required activities. In quite a number of cases the consultant is asked to give his comment on a certain technical aspect. These comments are given gradually. First in the proposal, later in the inception report and now in the interim report. For some of the questions it holds that the final answers will be given in the final report at the end of the River Survey Project.

Nevertheless, it is thought useful to summarize the questions from the TS and give the best possible answers.

Question No.	Main questions	re. TS (sub)section no.
1	Optimum survey techniques?	3.1 & 3.3
2	Type of AWLR?	3.1.2.b
3	Methods of flow gauging?	3.1.3
4	Methods of sediment gauging?	3.1.4
5	Bathymetric and topographic techniques?	3.2.3. & 3.2.4
6	Reduction method?	3.2.6 & 3.4.4
7	Positioning method?	3.2.2
8	Rating curve method?	3.4.3b
9	Morphology and surveying?	3.2.7 & 3.2.8
10	Training activities?	3.5

Table 5.1 Questions from the TS

Hereafter the main questions were elaborated and consultants comments are given.

Q1 : Optimum survey techniques ?

This is the most general question which can be split into questions like:

- o What are the specific survey problems per site and per season?
- o What is the optimum equipment (vessels, winches, instruments) there and

then?
- o What are the optimum methods to be applied (measuring, data-processing)?
- o What is the optimum survey programme in view of the various possible objectives?
- o What does this mean inside and outside the River Survey Project?

C1 : The answers can only be given gradually. The specific survey problems per site are still subject of the on-going reconnaissance survey activities. The specific monsoon problems will be encountered in the coming HW season 1993. The optimum equipment will be assessed thereafter. First answers are given tentatively in Chapter 4, Volume I of this report. See also the comments C2 to C7 hereafter.

Q2 : Type of AWLR ?

Detailed questions connected herewith are
- o Criteria to select type ?
- o Choice?
- o Details of installation?
- o Aspects of operation and maintenance?

C2 One of the main aspects for selecting the type of AWLR is the hydro-morphological characteristics of the site. Prime parameters are water-level range, flow velocity, sediment concentrations and river bed stability. Reconnaissance work is on-going to collect this information in the lean season. Additional work has to be done in monsoon conditions. Critical in the set-up of a water-level station are the stability of the platform and the possible sedimentation near the transducer. Therefore the consultant considered different types of AWLR such as float-well, bubble-type, pressure cell type and acoustic type. The latter having the advantage of being completely installed above the water-level, thus avoiding the sedimentation problem. Where bridges exist the acoustic recorder may be installed underneath avoiding also the instability problem.

Steps are taken to install one AWLR at Bahadurabad to be tested during the monsoon of 1993. At easy locations (where bridges exist) acoustic recorders will also be installed in phase 1.

Testing of acoustic recorders is on going at the moment of reporting. The gauge at Bahadurabad station will continue to operate for both phase 1 and 2. Installation of the recording gauge includes construction of a steel structure with triangular form or a steel pipe with a small platform on top to be installed at the selected location. The pressure cell will be mounted inside a perforated iron pipe of about 25 cm in diameter. The pipe will be vertically fitted at the middle of the platform structure. The recording instrument will be mounted in a small house on top of the platform. Servicing recorders will take place on a monthly basis. The data are to be collected on a paper recorder and/or on an electronic data logger (solid state or magnetic support) with an autonomy (functioning without maintenance) of at least one month and a sampling frequency of at last-four per day for stations not affected by tidal influence twelve per hour for stations affected by tidal confluence.

Q3 : Methods of flow gauging
More detailed questions related with flow gauging are
- o Methods for overland flow?
- o Possible improvement of the location of the gauging section?
- o Relation between average velocity and surface velocity?
- o Alternative methods (other than the velocity area method)?

C3 : For the measurements of discharge including overland flow a first reconnaissance will be done to distinguish sections with longitudinal and làteral overland flow and deeper channel sections. For the sections with overland flow smaller survey boats for instance shallow draft inflatables will be applied. For current measurements the electromagnetic flow meters will be applied, where possible in the moving boat mode.

The location of an appropriate gauging section may deteriorate rapidly due to morphological changes. Therefore a regular check of the site is required. If for instance the crest of a sand dune is just passing the section during the measurements the section should either be shifted or the measurements should be postponed. Within the River Survey Project these checks can easily be executed with the aid of the side scan sonar. However, it is noted that flexibility of location also asks for flexibility in positioning.

For the optimization of flow gauging procedures, the relation between (near) surface flow and flow averaged over the water depth will be established. Thereafter the measurements can be simplified by using for instance only an EMF in the moving boat mode. See also comments in Annexure 5.4.

Two alternative methods applied :

- o Moving boat using EMF and
- o Moving boat using EMF and ADCP in combination.

For details reference is made to Volume II

Q4 : Methods of sediment gauging?
Detailed questions related with the measurements of sediment gauging are:

- o Approach in view of the objectives?
- o Which type of sampler(s)?
- o Assessment of accuracy?
- o Depth integrating versus point integrating?
- o Distribution of verticals?
- o Direct or indirect method?
- o How to position the bed load sampler on the river bed?
- o Alternative methods applied?

And some questions about the procedures of sediment analysis:

- o New techniques or laboratory instruments?
- o Laboratory procedures?
- o Justification of selected procedures?

C4 : Some objectives for sediment gauging are indicated in the TS, such as:

- o Making sediment balances
- o Morphological studies.

In fact the background of the measuring programme is unknown. From the project's morphological studies a better definition of required morphological data will emerge, see also Annexure 7.4.

For suspended load measurements four type of instruments are applied:

- o Pump-bottle sampler
- o Optical turbidity meter
- o ADCP
- o Depth integrating sampler

For bed load measurements

- o Bed form tracking with dual frequency echo-sounder supported by side scan sonar
- o Helley - Smith sampler

For details of samplers see Volume II

Assessment of the accuracy of sediment gauging is a subject of the morphological study, see further Annexure 7.

For the comparison between depth integrating and point integrating see Volume II. Important point with depth integrating method is to assess (or control) the intake velocity of the sampler.

Present practice is to use each alternate velocity vertical for sediment gauging.

First much data need to be collected on the variability of the sediment transport before the density of verticals or in general spatial and temporal density can be optimized.

Direct methods aim at measuring sediment transport, while the indirect methods aim at measuring the sediment transport indirectly for instance via concentrations or bed form tracking. The only direct method used so far in the River Survey Project is the method using the Helley - Smith sampler.

The feasibility of using a sampler on the river bed is questionable in the mid flow ranges and need further testing. In low flow it is applied. During peak flow it seems impossible. Further trials are envisaged in May/June 1993.

Suspended sediment gaugings

The testing of the various sediment gauging methodologies will be carried out simultaneously with the standard flow test gauging. Suspended sediment sampling will be carried out as point sampling. The number of samples for depths larger than 3m should be six: close to surface, o.2D, o.4D, o.6D, o.8D and as close to bottom as possible. In each vertical a depth integrated sample is also taken. Per point also turbidity measurements are done. The point sampling will be concluded with an ADCP crossing recording the relative variation of suspended sediment concentration in the channel.

Bed load transport measurements

Trials with bed load transport measurements will be carried out by monitoring of sand dune movements during an intensive bathymetric survey campaign. A suitable area will be located by side scan sonar survey showing details of the general river bed configuration including sand dune lengths and indicative directions. A bathymetric survey grid will be defined which will cover an area 500m - 1000m x 500m to 1000m depending on the actual size of the dunes. Distance between survey lines will be 50m longitudinal and 100m between cross-lines. The entire grid will be covered a few times during a few days survey campaign. Bed load transport quantities will be established during post processing of data by calculation of volume differences as function of time.

The results will be compared with the Helley - Smith trap type sampling

Laboratory analysis of sediments

The following analysis will be carried out in the laboratory.

- o Suspended sediment concentration by Millipore micro filtering.

- o Grain size distribution of suspended sediments, by Andersen settling tube test
- o Grain size distribution of coarse river bed sediments by wet sieving
- o Grain size distribution of fine river bed sediments by hydrometer testing,
- o Organic contents of sediment solids by ignition loss and
- o Density of inorganic sediments by pycno-meter tests.

Results of analysis comprise suspended solids concentration and grain size tables. Grain size distribution curves will be prepared from the tables by a small computer programme. For examples of laboratory analysis see Volume II.

Various procedures applied are still subject of study. Especially the problem of separation of fine and coarse sediments is under study at the moment.

Q5 : Bathymetric and topographic techniques?
Some sub-questions are:

- o What is the purpose of these surveys?
- o Characteristics of selected sounding equipment and procedures?
- o Accuracy in various field conditions?
- o Transverse or longitudinal profiles?
- o Data-processing method?
- o How to organize and optimize a comprehensive bathymetric and topographic survey?

The main purpose of the hydrographic surveys is for morphologic river studies. The programme for this survey indicate seven locations in phase 2 and will be carried out before and after each flood. If considered necessary, bathymetric surveys will also be required during the floods. The survey equipment set up includes a computer controlled and integrated system of positioning and echo-sounding which also provides navigation data for operation and execute data-logging and recording. The positioning system is discussed in C 7. The echo-sounders will be hull-mounted dual and single frequency units respectively. The echo-sounder is interfaced to the navigation computer and data are recorded on line on paper chart and digitally displayed as well as logged and stored on 3.5" disks for post processing later on .

During surveying the predefined survey lines and the real time position of the survey vessel will be visualized on a track plotter and a left right indicator helps the helmsman to follow the track as precisely as possible. Surveys will be carried out in a predefined net of transverse profiles with a survey line distance of 200 m for 1:20,000 charting. For other scales other inter-spacing will be applied. Also a few longitudinal profiles will be taken to support the analysis of data for detection of various river bed configurations. This will also be supported by side scan sonar mapping in selected areas. The performance of the integrated bathymetric survey system was verified during selection of a suitable testing area at Bahadurabad, see further Volume II.

Calibration of echo-sounder will be carried out in two stages : (a) A "barcheck" will be carried out at regular intervals in sheltered areas with minimum water depths of 8-10 m. (b) Sound velocity is defined by measurements of water temperature (and salinity in the tidal areas) with the S4 instrument. The S4 meter is pre-calibrated at the consultants calibration facility.

Though bathymetric survey work was initially planned to start in phase 2, already by the end of phase 1 a (test) programme will be realised near Bahadurabad. There methods of surveying and data-processing will be further elaborated. In fact the same holds for the inter-calibration of bathymetric and topographic surveys.

During bathymatric cross-profile measurements of the dry parts of the river like chars and shoals will be covered by topographic surveying. The actual cross-profile alignment will be marked in the field and the profile will be measured either by conventional levelling or with the aid of a modern tachymeter, see further Volume II.

Q6 : Reduction method?

- o Which method will be used for the reduction of local sounded depths?
- o Which datum will be used?
- o How is the datum determined in the tidal areas?

For the purpose of preparing the hydrographic charts, the sounding depths are to be reduced to the standard low water level of the sounding area. For the determination of standard low water (SLW) in Bangladesh, it has been assumed that it is acceptable that during 5% of the time i,e on an average during 18 days per year the actual water level lower than SLW. This can be read from the water level duration curve prepared for the various stations. Along the coast in the pure tidal areas the SLW is defined in a different way. There SLW is a function of MSL (mean sea level) and the main semi-diurnal constituents.

In the tidal part of the river, both effects, upland discharge and tide play their role and the former influence the latter. When the discharge is high, the effect of the tidal motion is reduced. Both the amplitude and the argument of the constituents are affected. So, in the tidal river, being a transition between up-river (non-tidal) and sea (pure tidal) SLW is also defined as a mixture between the non-tidal and tidal SLW's. Along the rivers the values of SLW are determined for different stations by BIWTA.

Q7 : Positioning method
What techniques are adopted by the consultant for positioning of the survey vessels (dynamic positioning)?

C7 : The consultant evaluated the different aspects of different positioning systems. Two systems (i) sextant and (ii) Decca radio positioning system are now being used by BWDB and BIWTA. The other system (iii) Differential global positioning system (DGPS) has been considered by the consultant better suited to meet the specification of the project. The GPS will be operated in the differential mode (DGPS) which will give the user capability to establish positioning accuracies between 2-8 meter. The DGPS set up includes the two main units (i) differential reference station on the river bank (ii) DGPS receivers aboard the vessels. In order to obtain acceptable positioning accuracies, the reference station is established at a geodetic known location.

The task of the reference station is:
(i) Receive GPS signals from the satellites in the space and calculate the GPS position. (ii) Compare the calculated GPS position with the known geodetic position and calculate the corrections (iii) Transmit the corrections by means of a UHF radio link to the vessel.

The tasks of the receivers aboard the vessels is:
(i) Receive the GPS signals from the satellites and calculate the GPS position
(ii) Correct the position using the correction data received from the reference station (iii) Store the satellite and correction data for post processing. The advanced post processing package will secure optional positioning accuracy to be maintained under conditions where radio transmission is interrupted or disturbed.

Q8 : Rating curve methods?
What methodology to be used for the preparation of the rating curves?

C8 : This issue is elaborated in Annexure 6 of this volume.

Q9 : Morphology and surveying ?
Questions here are for instance:
- o Which additional information should be measured for the interpolation of morphological changes (bed forms, slopes, flow patterns and so on)?
- o How to measure bed forms?
- o How affect bed forms the various type of surveys?

C9 : A first discussion on the subject is presented in Annexure 7.4 of this volume.

Moreover the questions will also be addressed during the special bathymetic measurements scheduled for May/June 1993. In general it holds that more detailed information may be requested for study purposes such as

- o More details about concentration vertical especially near bottom
- o More detailed hydraulic information for interpretation purposes
- o More details in charting for instance applying scales of 1:5,000 or 1:10,000

Q10: Training activities?
What are the minimum training activities, their frequencies, duration and content?

C10: Details of training for phase 1 have been presented in Annexure 8 of this report. The detailed training programme for phase 2 will be elaborated by the end of phase 1.

5.3 From RIR to Interim Report

In the period between the submission of the Revised Inception Report (RIR) and the Interim Report, say from October 1992 to February 1993, the River Survey Project developed progressively. Moreover the workplan was revised. These developments and differences may obviously be deducted by comparing both reports mentioned above. For easy reference the main developments and differences are summarized below:

5.3.1 <u>Activities</u>

o Mobilization

The mobilization was completed in October 1992 according to schedule

o River surveys
- the field tests were done in October in mid flow conditions
- straight afterwards early November the first (HW) routine measurements were executed
- the first dry season survey of December was postponed as it was agreed to execute then additional test measurements on the Lower Meghna.

These survey activities are described in Volume II of this report.
- in January 1993 the first dry season routine measurements were done. Thereafter joined measurements were done with the BWDB to compare measuring techniques. The results of this survey work will be published separately.

o Land survey
- some work was done in 1992 near Bahadurabad
- main checking of staff gauges is done in February, March 1993

o Data-processing
- the data-processing office is operational from mid November 92 onwards
- the sediment laboratory started about the same time

o Studies
- the hydrological study started in September with data collection and produced in December a summary of preliminary findings, see further Annexure 6 of this volume
- the morphological study started by the end of 1992, see further Annexure 7 of this volume

- o Training (external)
  - on-the-job training for surveying is given during routine gaugings
  - a first course on sediment transport and hydraulic roughness was given in January, see further Annex 8 of this volume

- o Reporting
  - a first draft of the quarterly progress report was submitted in December covering the months September, October and November.
  - this interim report was postponed till February 93 for various reasons, see Volume I, Section 1.2.

5.3.2 Workplan

For both technical and administrative reasons the mobilization for Phase 2 has to be postponed from the first half of 1993 to the lean season after the monsoon period of 1993.

A brief outline of the workplan revisions is given in Volume I Chapter 8. For more details see Annexure 9 in this volume.

5.4 On the comments on RIR and RAS

By the end of 1992 comments were received from FPCO on two reports of the River Survey Project:

- o Revised Inception Report of October 1992 (RIR) and the
- o Report on Additional Survey of September 1992 (RAS)

These comments have been reproduced hereafter. Per comment the consultants reaction is provided in *italics*

GENERAL COMMENTS:

1. The Revised Inception Report (RIR) gives an account of progress made so far and the approach to the next activities under the project. Because of the uncertainty regarding Phase-II, it relates mainly to the current phase 1 of the project. Because of the delayed start of the project there is some anxiety regarding equipment, instruments and methods to be used for Phase-II. The report on the (delayed) test measurements that the consultants are to submit by the end of December, 1992, should give more clear indications.

   Though the RIR was written before the test measurements of October 1992 were done, it was already clear that the desired high flow conditions would not be available in the field partly because of the delayed project start and partly because of the relatively dry monsoon of 1992. Consequently, difficulties in selecting the techniques for phase II were envisaged. After the RIR and the October tests this became reality. Therefore additional test measurements were done in December. The results of test measurements of October and December were analyzed leading to a tentative selection of techniques, published in the Interim Report of February 1993. Final selection is envisaged after the last test gaugings in high flow conditions during the monsoon of 1993.

   The proposal of the consultant to allow more time for the acquisition of vessels etc. for phase-II and hence to set the date for the start of Phase-II as May 31, 1993, sounds reasonable and may be considered, provided the report of the test-measurements does not give indications to the contrary.

   A revised workplan is presented in the Interim Report. The main revision is that after the HW measurements of the monsoon of 1993 (with a kind of transition survey programme) the LW routine measurements of Phase 2 will start, during which additional vessel(s) and other equipment required for the monsoon of 1994 also will be mobilized.

The report Additional Surveys (RAS) presents an adequate account of measurement programme, which had been arranged in an attempt to cover the 1992 wet season to the maximum extent. Unfortunately the measurements had to be carried out at water levels which are not fully representative for wet season conditions. They are therefore not conclusive for discharge carried by the Jamuna at high stages.

Nevertheless the campaign has been worthwhile; it indicated that measured discharges are appreciably lower than those derived from the current BWDB rating curve. This is an important matter that needs further investigation. The consultants should consult with BWDB, attempting to enhance the accuracy of their current measurement programme as much as possible.

The matter has been made a study topic in the hydrological studies, leading to extensive analyses of rating curves and various field checks such as levelling of staff gauges and a first joined measurement of BWDB and FAP 24 survey teams. Further cooperation in this context is envisaged.

2. The consequences of the late start of the River Survey Project have not sufficiently been addressed in the Inception Report although the Consultant knew already in September 1992 that it would not be possible to realize all the high-water-period gaugings foreseen in the contract. At this stage, solutions should be sound in accordance to Art. 107 of the contract so as to avoid postponement of inception of Phase II. This should be further discussed in the forthcoming Interim Report on the basis of the scenarios presented in Section 3.1 "Milestones" (P. 16 and 17), especially on the number of gaugings he would be able to perform and how the survey programme accordingly could be re-arranged, including a possible phased mobilization for Phase-II.

   The uncertainties around the selection of equipment, as mentioned in the RIR and above, made further programming of the project only possible using the various scenarios. At the time of reporting it was preferred to wait for the results of the test measurements before elaborating the programme. In accordance with the above suggestions, solutions to overcome the consequences of the late start of the River Survey Project are elaborated in this Interim Report including a rearrangement of the survey programme.

3. The Consultant should have already prepared a draft section of the Interim Report for consultation between FAP 24, FPCO and the Project Adviser, addressing issues such as the transition from Phase I and Phase II, the programming of the test gaugings in the next monsoon season, how to consider the tests performed in October 1992. This may be discussed separately for resolving other related issues.

The Interim Report was originally scheduled to cover the first half of phase 1 including HW test gaugings and a proposal for survey techniques to be used in phase 2. Due to various reasons as outlined above as well as the additional tests of December, the Interim Report had to be postponed to January. The results of the test gaugings called for a considerable workplan revision affecting also the workplan of the second half of phase 1. It was decided to include the workplan (revisions) in the interim report, leading to a submission of the Interim Report in February 1993.

4. In case the Consultant would not be able to finalize his Interim Report in November 1992 because of acceptable reasons (e.g. due to late authorization for installing DGPS antenna), he should prepare a Progress Report containing sufficient information on his findings of discussion by FPCO and the Project.

   Later it was proposed to use the Progress Report mainly as a supporting document for invoicing.

5. The study programmes and findings are only according to the contractual provision and some theoretical indication. This programme would be finalized only on receipt of consultants proposal after verifying field test results and would be resolved by FPCO, PA and the Consultant.

   Tentative study topics have been generated in the proposal stage, forming the possible elements of the study programme. During the reporting period only a start was made with data collection so not much could be added that time. Since then hydrological and morphological studies have been taken up. Detailed study programmes for phase 1 have been developed. Further work on a tentative selection of study topics for phase 2 is on-going.

6. The Consultant would also submit a definite training proposal including schedule indicating subject, persons, sessions and places for the GoB personnel (FPCO, BWDB & BIWTA).

   A training programme for phase 1 has been elaborated (Interim Report). Some ideas for the phase 2 programme have been drafted. This programme should be finalized by the end of phase 1.

CATEGORY - I : SPECIFIC COMMENTS:-

1. A considerable part of the inception report has been devoted to describe some activities in Phase-I, for example verification tests (section 4.2), land and river survey (section 4.3). But items 2 and 7 in section 4.2 of the ToR have not been addressed adequately in the inception report. An important objective of the study

is the assessment of the morphological character of the rivers. This aspect has not been highlighted in the report.

A review of the present survey methods applied by BWDB and BIWTA was not highlighted in the RIR as during the time of reporting some intentions but no experience in this respect could be mentioned. In the second half of phase 1 (e.g. the joined measurements of BWDB and FAP 24) these aspects are gaining momentum.

The morphological study in phase 1 aiming at the definition of phase 2 study topics started by the end of 1992. The study includes the requested data collection and analysis, is addressing the impact of other FAP projects on the river system and is discussing the study topics of phase 2. Preliminary results of the study are presented in the Annexure 7 and Appendix 2 of this volume.

2. Page 2 - 3 and P-46

The works relating to River Survey Project FAP 24 will be based on highly improved technical and electronic methodology. Related Directorate of Hydrology Organization should take part in the river survey works for transfer of technology and improvement of river survey techniques. Transfer of Technology and training of concerned personnel of GoB (BWDB) should be ensured for improvement of future river survey work. This is necessary so that the new technology as well as the instrument can be used and maintained by the BWDB people in future.

The proposed training of BWDB staff may be done in well defined manner to acquire in-depth knowledge about the modern technology.

The importance of training is underscored by the consultant. Much more than asked for in the ToR (in phase 1: a phase 1 programme and initial training only) has been done already. A training programme has been presented in the Interim Report. As training is mostly on-the-job training the programme depends very much on the workplan of the River Survey Project. For obvious reasons the initial training was limited in the mobilization phase. Thereafter and especially in the second half of phase 1 the training activities will be intensified.

3. The results of these survey work may be compared with data of Hydrology Organization for quality control. River Survey work may be conducted maintaining liaison with the routine field measurement work of BWDB, so that accuracy of data can be compared. Copies of "Anwesha Survey, Technical Guidelines" may be made available to Hydrology for review and guidance.

Further cooperation with BWDB is envisaged. Important near future activities are *joined survey work and exchange of information and survey data. For the latter an agreement of the applied format will be sought. Copies of Anwesha Survey Technical Guidelines and papers and brochures of special instruments used in the River Survey Project have been sent to BWDB.*

4. Adaptation of methods, technology, equipment etc. to achieve the expected accuracy may be taken into account considering the involvement of task for operation and maintenance

   The FAP 24 techniques to be selected and applied in the project will not necessarily be the same as the sustainable techniques to be recommended and applied outside the project. Beside operation & maintenance aspects also the economy plays a role. The best choice is probably sufficient accuracy at the lowest cost. As the objectives and consequently the desired accuracy are different within and outside FAP 24 the optimum techniques may be quite different.

5. The different methods of flow and other measurement may be explained in detail to BWDB personnel and their results may be compared with results of conventional methods. Some relationship may be established between these sophisticated methods and the conventional method to use these relationship to achieve the desired accuracy in a simpler form.

   Exchange of information between BWDB and FAP 24 is on-going, see also Specific Comment no. 3. This is in fact a procedure also used within the FAP 24 project to optimize the survey work. The target is to establish relationships between schematic data (measured with relative simple equipment) and very detailed information (collected with sophisticated equipment). If this relation is sufficient reliable the bulk of the measurements are done with the simple equipment. Thus the amount of expensive equipment can be restricted.

6. The results of these survey work and the results of FINMAP may be made available to Hydrology Organization for necessary correction, updating the preservation of data for future use.

   It was agreed that in principle all survey results will be made available to BWDB. The most appropriate format has to be elaborated (see also hereafter under comment no. 8).

7. Periodical review of results of those measurements may be made during project period to take decision by the appropriate authority regarding its future development.

   Development of measurements may include review of locations, frequencies and *methods.*

8. Page-4

Computer Center of SWH-2 may be selected as location of external data base of all survey results so that these can be used by different project of BWDB and other organizations.

Selection of SWH-2 computer center as the location of the external data base seems very logical. This is also important in view of the format to be applied to transfer the survey data to BWDB (as mentioned earlier). Format means in this respect layout of survey report, kind of tables or graphs, kind of raw data, hard copy and/or tape, compatibility in view of type of data base, etc.

9 Page-10

One of the DHA vessels was constructed in 1956. The age of the vessel may be taken into consideration for the sake of its performance.

The DHA vessel was constructed in 1956 but the engines were recently overhauled and a high quality steering-machine and a sophisticated computerized autopilot system have been installed to prepare the vessel for the river conditions in Bangladesh. This system is functioning very well and the manoeuvrability of the DHA appeared to be excellent especially in course keeping while crossing irregular flow fields. Obviously the vessel is not yet tested in the peak flow conditions.

10. Page-13

While selecting data processing software its compatibility with hydrological data bank should be considered for exchange of data.

The data-processing system (hardware and software) of the River Survey Project was procured in June, tested in July and sent to Bangladesh in August 1992. It is understood that in 1993 SWH-2 will get a new data-processing and data base system under the WRIS project. Compatibility between the systems of FAP 24 and SWH-2 was discussed in the past, but need further attention (see also under Specific Comment no. 8).

11. RIR P.15: The proposed date for the start of Phase 2, viz. May 31, 1993, may be considered, provided the report on the test-measurements contains no indications to be contrary.

This comment is rendered out of date by the recent events leading to revised workplan as described in the Interim Report (see further General Comment no. 1)

12. RIR P. 46, Section 4.7: The Consultant is urged to take the initiative to establish effective working relations with the agencies that have an interest in training, including BWDB-Hydrology and BIWTA.

    For the various training activities of phase 1 (for training programme see also the Interim Report) participants from BWDB and BIWTA are invited via FPCO. So far staff of these organizations participated in field survey and a training course on morphological aspects.

13. RIR P. 48, Section 4.8: The seminar is an important component of the project, the effective organization of which will require considerable time and effort. The Consultant is requested to submit immediately notice preliminary proposals for the seminar.

    The organization of the international workshop is done by the PA. At his request the consultant support him with issues like timing, special invitations, set-up and subjects.

14. P. 4, para 2: The necessity to establish separate low-discharge rating curves for the two separate channels at Bahadurabad is an important matter. The Consultant should discuss with BWDB to consider the possibility for BWDB to adopt this suggestion as soon as possible. The same observation applies with respect to p.4, section 3.4.

    On the one hand there is much logic in having two rating curves near Bahadurabad at lower river stages. On the other hand one rating curve seems alright for the higher stages which are more important in the FAP context. This issue will be further discussed in the hydrological study and thereafter discussed with BWDB staff. The need for regular checks of the measuring sites especially in highly morphologically active river sections was discussed with BWDB. An appropriate procedure for such checks will be developed after the monsoon of 1993.

15. RAS P. 8, section 3.5.5: The conclusion that the measured discharges are significantly below those derived from the current BWDB rating curve is a serious matter, which requires immediate attention. Efforts should be made to verify this as soon as possible. If confirmed, this could have serious consequences for FAP on a number of issues, e.g. mathematical modelling.

This conclusion led to extensive analyses of rating curves and Q/H measuring points. An important discrepancy in the higher flow ranges was observed between the points before and after the flood of 1988. This conclusion needs confirmation and if possible further clarification (see also under general comments no. 1)

16. RIR P. 14, section 2.6: The Consultant should clarify how the ownership of equipments etc, could affect the training programme.

    If a certain type of equipment, e.g. an instrument is only used within FAP 24, is not selected for the sustainable technique and reexported at the end of the project, the need for external training on such an instrument is questionable.

17. RIR P. 16/17 : A relationship should be established between the listed (im)possibilities and the 3 scenario's e.g. if the mentioned impossibilities arise, will it then still be possible to select a suitable type of vessels.

    The recent developments: the revised workplan indicating the selection of equipment including vessel(s) after the monsoon of 1993, make this comment less relevant.

18. Page 34, line 11: Indirect methods for estimating the peak discharge (in the extrapolation range) should also be considered along with the rating curve. If the consultant could suggest correction or improvement in the rating curve method using results of sophisticated methods, then it would be advantageous from sustainability point of view.

    Some improvements for the method of establishing rating curves have been suggested in the mean time. The additional data to be collected in the coming monsoons, may lead to further improvements in the rating curve part for the higher flood ranges.

19. Page 34, line 4 from bottom: How the accuracy of different instruments would be compared since the true discharge is not known in the field? What are the criteria for accuracy comparison and acceptability ?

    The accuracy of the different instruments is judged per point and/or per vertical. By exchanging the instrument positions and measuring simultaneously the variability of nature is eliminated. The overall accuracy of the discharge is a different issue, in which the accuracy of the various types of instruments is only part of the story. Other sources of uncertainties such as the limited spatial density may be much more important. For the discharge measurements the required uncertainties are set in the TS to be within 10 per cent at the 95 per cent confidence level. For low flow conditions 5 per cent should be attempted.

5.5 List of FAP 24 reports, notes, etc.

1 Proposal for Additional Survey Bahadurabad
July 1992.

2. Inception Report
22 August 1992

3. Anwesha Survey, Technical Guidelines
September 1992

4. Revised Inception Report
20 October 1992

5. Additional Survey, September 1992
31 October 1992

6. Proposal additional field tests December 1992
28 November 1992

7. Lecture notes on sediment transport and hydraulic roughness.

8. 1° Interim Report
February 1993

Volume I	:	Main Report
Volume II	:	Annexures on survey work
Volume III	:	Annexures on studies, etc.

9. 1° Quarterly Progress Report
February 20, 1993

60

Annexure 6

Hydrological study

6 Hydrological study

The hydrological study consists of two distinctive parts. In Phase 1 of the River Survey Project a general review and validation of data and methods is envisaged. At the end of Phase 1 specific issues will be selected to be studied in more detail in Phase 2 (ref. Annexure 7, the presented matrix of study topics).

In line herewith also two hydrological reports are envisaged: the Phase 1 report and the Phase 2 report.

The objectives of the hydrological study in Phase 1 are:

- o Studies and improvement of methods and procedures for hydrological data collection, -analysis and- quality control
- o Establishment and updating of database with historical hydrological time series to the extent necessary to fulfill the requirements of the studies specified in the ToR (e.q. frequency curves for stations in main rivers)
- o Planning of Phase 2 studies

The hydrological study programme Phase 1 consists of the following main activities:

- o Identification and review of existing hydrological data, studies and databases relevant for FAP 24
- o Analysis of results of additional survey of September 1992
- o Collection and processing of historical data
- o Analysis of data quality
- o Frequency analyses
- o Study of water-level profiles
- o Identification of Phase 2 study topics
- o Reporting

Being halfway Phase 1 at the moment this first Interim Report is compiled, in this Annexure the tentative interim results of the hydrological study are presented.

6.1 Review of existing information

A number of agencies have been approached to obtain information on past and ongoing hydrological studies and projects related to the objectives of Fap 24. Reports and available data have been collected and reviewed, and information on current procedures for collection, processing, checking and storage of hydrological data have been obtained.

The agencies visited are:

- Directorate of Surface Water Hydrology I (SWH-I) of Bangladesh Water Development Board (BWDB)
- Directorate of Surface Water Hydrology II (SWH-II) of Bangladesh Water Development Board (BWDB)
- Flood Modelling and Management (Fap 25)
- Surface Water Modelling Center (SWMC)
- River Training Studies of the Brahmaputra river (BRTS, Fap 1)
- Bank Protection and River Training (AFPM) Pilot Project (Fap 21/22)
- Jamuna Bridge Project
- Bangladesh Inland Water Transport Authority (BIWTA)
- Water Resources Planning Organization (WARPO)

In the following a short description is given of the information obtained from the various agencies and the studies, reports and data reviewed in relation to the objectives of FAP 24. An inventory of the collected data is given in Section 6.2.

6.1.1 SWH-I (BWDB)

SWH-I is responsible for hydrological field work in connection with the BWDB network of hydrometric stations.

Water-level observations

BWDB operates about 47 water-level stations in the main rivers of which 5 are also discharge stations. At all these stations the water-levels are measured from wooden staff-gauges five times a day, at 6.00, 9.00, 12.00, 15.00 and 18.00 hours. According to the variation of the water-levels it is often necessary to raise or lower the gauge. A new gauge is fixed close to the previous one and the relation between data of the two gauges is determined through simultaneous readings. These frequent shifts may generate some uncertainty in the observation, in particular when several shifts of the gauge occur between two check-levelling from a bench-mark.

Another type of gauge shifts which may create even higher uncertainty occur some times due to bank erosion or non-accessibility to the gauge site during high flows. Often, within a year, the position of the gauge may be shifted upstream or downstream over a stretch of one kilometer (ref. FAP 25, June 1992). Significant differences in water-level may be expected when shifting from one gauge to the other.

Check-levelling of the gauge datum from a nearby bench-mark is carried out weekly or fortnightly, and water-level corrections resembling from these checks are carried out at a field office before the mean daily water-levels are completed and transmitted to SWH-I in Dhaka. The Flood Hydrology Study (FAP 25, June 1992) has raised serious doubts as to which extent the check-levellings have actually been carried out for the last years (at least at the important station Bahadurabad).

Discharge observation

The discharge measurement at the 5 discharge stations in the main rivers are scheduled to have a frequency of once per week during the monsoon period (May-November) and once per fortnight between November and May. However, at Hardinge Bridge the measurements are carried out every day. Daily measurements are also carried out at Bahadurabad since 1 October 1992.

The difficulties for discharge measurements for the large main rivers in Bangladesh have been appreciated by BWDB and noted in former studies. The potential sources of error in discharge measurements in the Jamuna have been elaborately discussed in the First Interim Report of the Brahamatputra River Training Study (FAP 1, April 1991) (ref. Subsection 6.1.5). A variety of potential sources of error have been acknowledged including micro changes in river morphology during measurement which usually takes at least 48 hours. During rising and falling stage, the bed may change its configuration substantially owing to migrating bed forms. Under such conditions, surveys, requiring periods longer than a few hours, can result in unreliable measurements. Coleman (ref. Coleman, J.M.,, August 1969) commented that until the mechanics and pattern of bed form movement can be more thoroughly documented, any discharge measurement in the Brahmaputra may need to be treated as an estimate.

BWDB measures the flow velocities from a survey boat by non-directional Ott current meter at 0.2 and 0.8 depth of the verticals. The number of verticals applied varies according to the actual flow conditions, but a rule of thumb used by BWDB is that one vertical should not represent more than 10% of the total flow in a channel. The required number of verticals becomes often very high and it takes usually about two days to complete one measurement of the total discharge. This implies, in addition to the effect of changing bed forms mentioned above, uncertainty in the relationship between measured discharge and the corresponding water-level (used for rating curve development), in particular during rising and falling stage.

The flow direction at each measurement point across the river is not measured directly. Only the direction of flow in the surface layer is traced by floats at each vertical after completion of the current meter measurements. The float positions are measured with sextants.

Other sources of errors are:

- o Velocity measurements made from non-anchored boats may not have perfectly fixed position
- o Inaccurate measurements of depths, especially when measured by current meter instead of echo-sounder, which may lead to an overestimation of depth (i.e. discharge), in particular during high current

6.1.2 SWH-II (BWDB)

SWH-II is responsible for the processing of the field data measured by SWH-I, e.g.:

- o Calculation of total observed discharge
- o Development of rating curves
- o Conversion of mean daily water-levels to mean daily discharges with the aid of rating curves
- o Storage and publication of data (water-levels and discharges)

Observed discharge

The total discharge is calculated from the velocity measurements by the conventional velocity-area mid-section method including flow angle-corrections based on surface float measurements.

Rating curves

Rating curves are developed for each hydrological year based on the actual Stage/Discharge (H/Q) measurements during that year and also some values (especially extreme values) from the previous years for consistency and extrapolation purposes. The H/Q data are plotted on log-

log paper, and the correct offset (point of zero flow) is determined by trial and error until the lower H/Q observations form a straight line to the extent possible. Several segments of the curve are considered, but a fixed offset is assumed for all segments which is usually not the case. This can be seen from the log-log plots where the lower part of the H/Q-points may follow a straight line whereas the upper H/Q-points plot as one are two curves. Assuming a fixed offset for all segments is equivalent to fit a straight line through the curved H/Q-points. This will usually lead to unrealistic extrapolations.

Shift corrections

When calculating mean daily discharge from observed water-levels and derived rating curves BWDB apply regular shift corrections. Usually a shift correction is applied when the rating curve changes with time due to change in cross-sectional characteristics along the control section. A shift correction is applied to the stage of a discharge measurement to bring it in accordance with the derived mean rating curve. The procedure inherently assumes that the discharge measurements are true, without error. If this is not the case, application of shift correction may introduce new errors. The Flood Hydrology Study (FAP 25, June 1992) has given examples which illustrate that the current application of shift correction by BWDB is questionable.

Storage of data

Most of the historical data on water-levels and discharges are available in BWDB only in paper format (hard-copies). However, in the recent years BWDB has introduced computerized databases for storage and retrieval of data. At present only the most recent years of data are stored in the computer database of BWDB.

FAP 25 (ref. FAP 25, June 1992) recently noticed the lack of a proper data directory at BWDB. Thus FAP 25 developed such a directory based on data available from BWDB and other sources, e.g. WARPO. The directory contains very useful information on station name, code and length of records for all water-level stations and most discharge stations in Bangladesh (ref. FAP 25, June 1992, Volume 2, Annex 1).

6.1.3 Flood Modelling and Management (FAP 25)

This project has carried out the most recent and comprehensive study of existing hydrological data of the main rivers in Bangladesh. The data used and the study carried out by FAP 25 are well documented in the Main

Report of the Flood Hydrology Study (FAP 25, June 1992). In the following only a short description of the database and studies with direct relation to FAP 24 will be given.

FAP 25 has established a computerized database with the following data:

- o Mean daily water-levels: 25 years of data (1964-89) from 50 water-level stations including selected main stations in major rivers
- o Mean daily discharges: 25 years of data (1965-1989) from 22 discharge stations including all the six (FAP 24) stations in the main rivers (Bahadurabad, Hardinge Bridge, Baruria, Mawa, Bhairab Bazar and Gorai Railway Bridge)
- o Observed discharges (i.e the H/Q field measurements): 25 years of data (1966-1990) from 10 discharge stations including all stations in main rivers except Gorai Railway Bridge

Water-level time series

Systematic checking and correction of water-level time series by means of correlation methods have been carried out for selected stations on the Jamuna and Ganges for the years 1964-1989:

- o Jamuna: Chilmari, Kholabari char, Kazipur, Sirajganj, Porabari, Bahadurabad
- o Ganges/Gorai: Hardinge Bridge, Sengram, Gorai Railway Bridge, Kamarkhali

Rating curves

New annual rating curves (1965-1989) have been established for three stations: Bahadurabad, Hardinge Bridge and Baruria.

The procedure used is similar to the procedure used by BWDB (ref. Subsection 6.1.1), and the new rating curves are not much different from BWDB rating curves. The magnitude of shift of the annual rating curves were analysed and appeared to be considerable. The exact reasons for these shifts were not analysed but assumed to be caused by morphological changes, systematic errors in discharge measurements and long term shifts in gauge locations.

Discharge time series

New discharge time series (1965-1989) have been calculated for the three stations above on the basis of the corrected water-level time series and the new rating curves. FAP 25 found the BWDB procedure of shift application questionable and did not apply any shift corrections (ref. Subsection 6.1.2).

Statistical analysis of observed data

FAP 25 has carried out frequency analyses of annual peak water-levels, annual maximum discharges and average seasonal discharge for various stations and has recommended which probability distributions should be used for the various types of data in Bangladesh.

The statistical representatives of the period 1965-1989 for the whole country have been studied based on long term records of hydrological variables (rainfall, water-levels and discharge) from various stations. Trend analyses and peak-frequency analyses indicate that the hydro-meteorological conditions in Bangladesh during the last 25 years are fairly representative for the longer term. In general one may consider the 1965-1989 period as a slightly conservative basis for design, when compared to the last 50-100 years.

6.1.4 Surface Water Modelling Center (SWMC)

SWMC has developed regional hydrodynamic models for all the 6 regions of Bangladesh as well as the General Model (GM) covering the main rivers in the whole country (ref. MPO, July 1992).

The MIKE 11 databases of SWMC cover at present the period 1985-1991 only, and the hydrological data used for boundary conditions and internal comparison points are basically the water-level and discharge time series supplied by BWDB (SWH-II). SWMC carries out a few basic checks of the water-level input data before using them in the model (plotting of time series and simple comparison of adjacent stations). However, the modelling process itself is considered by SWMC as the most rigorous check of the data quality. Furthermore SWMC has developed rating curves for the most recent years of the boundary discharge stations on basis of BWDB's field measurements.

A special version of the General Model was applied by Fap 25 for long term simulations 1964-1989 (ref. FAP 25, June 1992). The boundary stations used in the two model versions are nearly the same, but the most important boundary input data (discharges at Bahadurabad and Hardinge Bridge) were corrected by FAP 25 (ref. Subsection 6.1.3). The corrections proved to be a major step forward in the validation of the General Model.

This exercise illustrates the importance of implementation of rigorous data checking procedures of the input data to the various mathematical models. The quality of the output from a model will never be better than the quality of the input data even for very advanced models.

6.1.5 Brahmaputra River Training Study (Fap 1)

FAP 1 has carried out a comprehensive hydrological study for the Brahmaputra river (Jamuna) (ref. FAP 1, April 1991).

The hydrological study was based on the historic hydrological data collected by BWDB. Rainfall, water-level and discharge data for selected stations were collected and stored in a computer database (Lotus-worksheets). For most stations the collected daily data had records back to 1964 or 1965.

Check and analyses of water-levels

For selected water-level stations along the Jamuna river the BWDB, time series of mean daily water-levels were checked thoroughly by plotting and comparison of adjacent stations. The annual maximum water-levels were also screened by various rigorous procedures and suspicious data were detected before use in various analyses, which included:

- o Frequency histograms and curves for each month over the year
- o Frequency histograms and curves for each 10-day period over the year
- o Long term trend analyses of peak flood water-levels
- o Specific gauge analyses of water-levels of Bahadurabad
- o Frequency analyses of annual peak water-levels
- o Water surface profiles along Jamuna for selected events

Discharge analysis

The observed discharges from BWDB at Bahadurabad and the BWDB rating curves were collected and used to illustrate the range of fluctuations in Jamuna flows for the same water-level.

The mean daily discharge data from BWDB at Bahadurabad were used for the following analyses to define the general discharge characteristics of the Jamuna:

- o Frequency histograms and curves for each month
- o Frequency distribution of mean daily flows (flow duration curve)

- o Long term trend analysis of peak discharges
- o Frequency analysis of annual peak discharge

Analysis of discharge measurements, potential errors

FAP 1 has carried out a detailed assessment of potential errors involved in discharge measurements on the Jamuna (ref. FAP 1, April 1991). The assessment is based on consecutive discharge measurements over one week carried out by the FAP 1 survey team. The measurement technique was traditional directional current meter measurements in 0.2 and 0.8 depths, and the depths over the river cross-section was recorded by an echo-sounder.

With the applied measurement technique the errors of the discharge measurements were often 20-30%. It was concluded that the estimation of discharge in the Jamuna would need to be based on at least 4 consecutive measurements if it is to be determined within a standard error of less than 2000 m^3/s.

6.1.6 Bank protection and river training (FAP 21/22)

The hydrological studies carried out in connection with this project are very limited as the purpose only was to establish hydrological design condition at a few test sites along the Jamuna. The data used and the type of analyses carried out were quite similar to the FAP 25 data analyses already reported above (ref. FAP 21/22, July 1992).

6.1.7 Jamuna Bridge Project

The project has carried out various hydrological analyses for the stations in the Jamuna river with the aim to establish the hydrological design conditions for the potential bridge project. The analyses are described in the Feasibility Report (JBP, August 1989).

Based on BWDB data on water-levels from 7 stations along the Jamuna river and the discharges from Bahadurabad frequency analysis of maximum annual water-levels and discharges have been carried out assuming Gumbel extreme value distributions.

An average rating curve at Bahadurabad was fitted by a quadratic equation. Rating curves for 6 water-level station along the river were developed assuming same discharge at all the stations as at Bahadurabad.

In addition to the hydrological analyses very interesting morphological studies have been carried out by the project. Some of the results will be referred to in following sections.

6.1.8 BIWTA

BIWTA operates 45 water-level gauges mainly in the tidal areas of Bangladesh. BIWTA carries out tidal analysis and publishes tidal prediction chart tables. The data from the tidal areas from BIWTA are not directly relevant to the hydrological studies but are relevant to the morphological studies and part of the FAP 24 survey activities.

6.1.9 WARPO

WARPO (Water Resources Planning Organization) carries out studies and planning of water resources in the whole country, mainly on the basis of BWDB data on surface and ground water observations. Various frequency analyses of maximum annual water-levels and discharges have been carried out, and a report on surface water availability has been published. The report is not yet in hand of FAP 24 but is probably not directly relevant for the FAP 24 hydrological studies of data for the main rivers only.

6.2 Collection and processing of historical data

An up to date overview of all historical data collected by FAP 24 is given in Table 6.1 through 6.3. These data have been transfered to HYMOS database. Available hardcopy data will be added shortly.

Other data could not be collected till to date. Some of them are not available at all (e.g. 1971). Availability of others is being checked.

6.3 Preliminary results

6.3.1 Survey data of September 1922, Bahadurabad

As already mentioned in Volume I of the Interim Report a substantial difference was found between FAP 24 discharge measurement in September 1992 and the updated rating curve for 1992, based on the BWDB H/Q-measurements.

The conclusions of the investigation of survey results have been given in Volume I. Further details of this study will follow here. For a detailed description of the survey itself reference is made to the survey report (FAP 24, 31 October 1992).

Comparison of discharge during Anwesha Survey

An updated rating curve based on the available BWDB H/Q-measurements during the 1992 monsoon from the Bahadurabad station has been established (ref. Figure 6.1). The measured Q-point from the Anwesha Survey has also been shown (Q = 25.600 m^3/s while H = 17.82 m/PWD). The difference in discharge between the Anwesha Survey and the rating curve at the water-level of 17.82 m/PWD on 15-16 September 1992 is about 9000 m^3/s, which represents a difference of 9000/34500 = 26% of the rating curve value or 9000/25.600 = 35% of the Anwesha Survey value.

A more direct comparison of the difference between the BWDB and Anwesha measurements is possible, as BWDB measured the discharge on 14 September, only one day before the Anwesha measurements, at a slightly lower water-level H = 17.76 m/PWD. The measured discharge was Q = 34230 m^3/s. This H/Q-point is included in Figure 6.1. The large difference in the results (about 9000 m^3/s) remains.

Check of discharge estimates from the Anwesha Survey

The discharge estimates, according to the Additional Survey September 1992 (FAP 24, 31 October 1992), based on the current meter measurements during the Anwesha Survey, have been checked by using the original files of the survey available at the FAP 24 office. The checks give the following results:

- o Right channel (measured 15/9)
  The estimate Q = 10.800 m^3/s is correct
- o Left channel (measured 16/9)

Q = 14.300 m^3/s may be a little high due to an incorrect angle correction in vertical no. 6
Q = 13.000 m^3/s is a better estimate based on the measured data

- o Left Channel (measured 19/9)
Q = 16.800 m^3/s is very close to the re-estimated value (16.000 m^3/s)

Thus, no major errors in the estimates of the discharges have been found. The minor error above only increases the observed deviation from about 9.000 m^3/s to about 10.000 m^3/s.

Possible sources of deviation

There are many potential sources of deviations between the Anwesha Survey results and the discharge measured by BWDB at Bahadurabad, e.g.:

- o The measurements are taken in different cross-sections of the braided river. This makes a direct comparison between the two surveys very difficult as the flow conditions (velocities and directions of flows, number of channels etc.) and the change of the cross-sections during the 1-2 days surveys due to sediment transport and local erosion, may be very different at the two sites
- o Different instruments applied for positioning and measurements of flow directions
- o Different methods for bathymetric survey of cross-section profiles
- o Different number of verticals/depths for velocity measurements (i.e. different sampling)
- o Different methods of taking the direction of flows into account when calculating discharge

It is not possible here to investigate all these or other potential sources of deviations. Some of the issues above may introduce random deviations, others may give rise to systematic overestimation of discharge. It is believed that the last mentioned issue accounts for the major part of the observed deviation as explained below.

Direction of flow

During the Anwesha survey the velocities were measured by the Ott current meters of BWDB, and the flow direction at each measuring point was determined by the Planeta/Jacobson meter at the same time. The measured angles between the measurement base line across the river and the flow directions are used to calculate the effective velocity in each point, i.e. the velocity component perpendicular to the base line, used in the calculation of discharge.

The BWDB measurement procedure at Bahadurabad is, however, different as the flow directions are not measured at each measurement point because BWDB at Bahadurabad does not have the required equipment for measuring flow directions below the water surface. Only the flow direction at the water surface of each vertical is measured by floats after the current meter measurements. This surface flow direction is then used to correct the velocities measured at two depths of each vertical.

This BWDB procedure may, even when carried out carefully, result in a considerable uncertainty of the calculated discharge. This is because the flow directions at the surface and in the various depths of the cross-sections may be very different. In many cases this is due to the very irregular cross-sections, including a number of bars and chars around which the flow will be diverted into different directions. Very detailed measurements of velocity distribution and flow directions across a river cross-section at Bahadurabad, carried out by FAP 24 in October and November 1992 with the advanced ADCP-method, show that in general the flow directions at the surface are more regular and follow the main river direction better than the flow directions below the surface. If this is also the case at the BWDB cross-section at Bahadurabad, the BWDB angle correction procedure applied will result in an overestimate of the discharge.

One method to quantify the overestimate due to this procedure would be to apply the BWDB procedure on the Anwesha Survey results to quantify the effect of correcting for the angles on the basis of float measurements at the surface only. However, the float measurements during the Anwesha survey were very few so that the surface flow directions measured were not representative for the various positions of the verticals.

6.3.2 Rating curves

Improved method for rating curves

The procedure for fitting rating curves as used at FAP 24 is based on ISO standards (ref. MWEM, 1979 and ISO, 1982). It is assumed that each rating curve may consist of more than one segment. If so, offset values (H_0) should be determined for each segment separately (see Figure 6.2 for an impression of the effect of different offsets on a rating curve). Following, a step by step description is given of the procedure.

- o For each of the 6 H/Q-stations plots are made year by year of the available H/Q-measurements (ref. Table 6.1). This is done on linear scale as well as on log-log scale
- o On the linear plots:
  - an approximate rating curve is drawn by hand
  - non-reliable points (far away from the curve) are marked
  - the approximate rating curve for each year is compared with the curve of the year(s) before and after in order to determine if similar curves might be used for successive years or if major changes have occured
  - for each year the maximum mean daily water-level is marked on the plot in order to asses the importance of extrapolation
  - the need for extra points for extrapolation is determined. Extra points are derived from the years before or after rating curve if these seem similar
- o On the log-log plots:
  - the approximate location of breakpoints and the number of segments (maximum 3 in HYMOS) is determined
  - the approximate values of H_0 for each segment are determined using following guide lines:
    - * if the H/Q-points for a segment plot as a straight line, the apporximate H_0 is the selected offset on the H-axis
    - * if the H/Q-points for a segment plot as a concave curve H_0 > offset
    - * if the H/Q-points for a segment plot as a convex curve H_0 < offset
    - * usually H_0 gets higher for upper segments (also see Figure 6.3)
- o Fitting rating curves with HYMOS:

With the preliminary results of activities 2 and 3 for each year in mind, the "standard procedure" of HYMOS is used to fit a rating curve for each year based on the power function, i.e.:

$$Q = c(H+a)^{b} = c(H-H_0)^{b}$$

Before starting the fitting of a curve the non-reliable H/Q-points are inactivated.

- HYMOS has the options "offset(s) not fixed" and "offset(s) fixed". First "offset(s) not fixed" is used. This means the program will calculate the values for a (= $-H_0$) after the number of segments and their boundaries have been given by the user. An overlap around the estimated breakpoints is required.

The calculated curves are plotted linear as well as on log-log scale. These plots give an impresion of the goodness of fit. On the log-log plot the points of the lowest segment should have an unbiased fit to a straight line. If not, the offset for this segment is not correct.

The option "Error Analysis" gives the calculated breakpoints and the values for parameters a, b and c. The parameters are evaluated. For b, values should usually range between 1.5 and 3.0. If b is too high, H_0 should be larger. Of course, experience from other years is used to asses reasonable values for the offset(s).

"Error Analysis" also gives an overall standard error. This value is merely used as an indicator.

- Now option "offset(s) fixed" is used. The a-values are customized for each segment.

The fit of the curve is evaluated using new plots and "Error Analysis". If this is not the procedure, the location of breakpoints can be modified by changing the overlap of neighbouring segments. Also a-values can be changed, b- and c-values can never be set by the user.

The quality of fit is particularly judged by the fit in the uppermost segment, used for extrapolation

6.3.3 Analyses of rating curves at Bahadurabad

During the preliminary analyses of rating curves at Bahadurabad some very interesting observations have been done, which may have important implications.

Before the major flood at the end of August 1988, the rating curves vary up and down from year to year within a limited range (as also shown by FAP 25 (ref. FAP 25, June 1992)). After the 1988 flood, however, a systematic shift of the BWDB H/Q- measurement points has occurred. This is illustrated in Figure 6.4 and Figure 6.5, where the estimated average rating curve for 1988 (based on all H/Q- points measured in 1988) is compared with several years of H/Q-measurements before and after the flood in August 1988. Before this flood all measurements are on or above the curve and fairly consistent (i.e. only small changes from year to year), whereas after the flood almost all measurements are located under the curve and more scattered, in particular for the high level range, representing the river flood plains. The points for 1992 still remain very low, four years after the major 1988 flood.

Figure 6.6 and Figure 6.7 show the similar plots for the station at Hardinge Bridge and Figure 6.8 and 6.9 for the station at Baruria. At these two stations there is no systematic major shift of H/Q- points after the 1988 flood as observed for Bahadurabad.

Furthermore, Figure 6.10 and Figure 6.11 show some curves from before the 1988 flood and the rating cuves for the years after 1988 in relation to the 1988 rating curve. The last is based on H/Q- measurements before the flood in August.

The considerable shift at Bahadurabad has several potential explanations, e.g.:

- o Considerable morphological changes (deepening and widening) of Jamuna river from Bahadurabad and a long reach downstream controlling the stage-discharge relationship at Bahadurabad
- o Systematic error (overestimates) in discharge measurements at Bahadurabad since the major flood in August 1988
- o Systematic error (underestimates) in the water-level readings or datum at Bahadurabad since the 1988 flood
- o A combination of the issues above

At the present stage of the FAP 24 studies it is not possible to arrive at a firm conclusion on these issues, but some strong indications based on the present studies and knowledge are given below. It is important that these issues are further addressed in the future field measurement programme and hydrological and morphological studies, as the implications will be very important.

For example, if it can be confirmed that the second or third issue above is the most important reason for the observed major change of the H/Q-points since the 1988 flood, it would imply that all the rating curves used by BWDB since 1988 would be inadequate as they would be based on inadequate H/Q-measurements. This would further imply that the resulting time series of mean daily discharge since the 1988 flood would also be inadequate (i.e. too high). In that case it would also be inadequate to estimate new rating curves for the years 1989, 1990, 1991, 1992 on the basis of the inadequate H/Q- measurements since the 1988 flood.

Regarding the first issue above: this should be investigated during the morphological study component of FAP 24, in order to clarify if such a considerable change of the Jamuna river has really occurred since the 1988 flood (e.g. by studying satellite images before and after 1988, changes in river planforms and cross-sections along the river).

The second and third issue can be further addressed especially when new FAP 24 discharge measurements at Bahadurabad become available, in particular for the higher water-level range during the next 1993 monsoon. At the present stage various indications point in the direction of the second issue:

- The first FAP 24 discharge measurements in 1992 at Bahadurabad executed with BWDB equipment resulted in a measured total discharge much less (approximately 30%) than the corresponding discharge measured by BWDB. The resulting FAP 24 H/Q-point is shown in Figure 6.4 and Figure 6.5. The 1992 point is within the range of H/Q-points before the 1988 flood but outside the range after this flood
- Figure 6.12a shows the total volumes discharged at Bahadurabad during the flood season (May and November) for the years 1965 through 1992. The volumes for the years 1965-1991 have been calculated using FAP 25's and BWDB's mean daily discharge series and intergrating them from May to November for each year.

  As BWDB's mean daily discharges for 1992 are not yet available, the 1992 volume has been calculated differently. Based on the 1992 rating curve of Figure 6.1 and the mean daily water-levels received from BWDB, a discharge time series has been derived for the 1992 flood season. This has been used for calculation of the 1992 flood season discharge volume in the same way as for the other years. An illustration of the calculation is given in Figure 6.13 and 6.14.

Figure 6.12a shows that from 1965 to 1988 the seasonal flow volumes vary up and down without any significant trend. After 1988 the seasonal volumes in the years 1989, 1990 and 1991 are far above the normal range of variations.

The flood season volume of 1992 is much lower. However this does not mean a change in trend. To illustrate that, Figure 6.12b shows the flood season volumes of 1986 to 1991 together with the volumes in these years based on the 1992 rating curve. The conclusion is that the lower value for 1992 is due to lower water-levels in that year (ref. Figure 6.12c) and that the systematic shift of the H/Q-points still occurs.

Also the flood season discharge volumes for stations Hardinge Bridge and Baruria have been calculated. Figures 6.15 and 6.16 show these volumes for the years 1965 resp. 1966 through 1991. These plots confirm that the major shift following from Bahadurabad measurements has occurred neither at Hardinge Bridge nor at Baruria

o In Table 6.4 below the BWDB data on annual peak water-levels and discharges for the stations Bahadurabad, Hardinge Bridge and Baruria are shown for the year 1988 and a year before and after, namely 1987 and 1991 taken as examples only.

Station	1987		1988		1991	
	Max H (m)	Max Q (m^3/s)	Max H (m)	Max Q (m^3/s)	Max H (m)	Max Q (m^3/s)
Bahadurabad (46.9L)	19.68	71.000	20.61	98.600	20.08	110.000
Hardinge Bridge (90)	14.79	76.000	14.87	72.300	14.65	56.000
Baruria (91.9L)	9.04	113.000	9.35	132.000	8.49	100.000

Table 6.4 (Data Source: BWDB)

According to Table 6.4:

- usually the peak discharge at Bahadurabad is much less than at Baruria, which is located downstream the confluence of Jamuna and Ganges. This is the case in 1987 and 1988 but not in 1991 according to the BWDB peak discharge estimate at Bahadurabad for 1991. (110.000 m^3/s)

- the 1991 peak discharge estimate at Bahadurabad is higher than the 1988 peak estimate at Bahadurabad, while the corresponding water-level was much lower in 1991 than in 1988
- at the two other stations the 1991 peak discharges (and water-levels) were much lower than in 1988. This difference between the Bahadurabad and the two other stations is even more pronounced when comparing 1991 with 1987

These observations indicate that the 1991 peak discharge estimate at Bahadurabad is far too high. It is based on the BWDB rating curve for 1991 which again is based on the 1991 H/Q-measurements

o December 1992 levelling work executed by FAP 24 revealed that the zero of the gauge near Bahadurabd is correct (accurate within a few cm). A systematic error on datum and water-levels (third issue) seems unlikely

Conclusions

The various observations discussed above all indicate that the second issue, i.e. systematic overestimate in discharge measurements at Bahadurabad since the major 1988 flood, may be the main reason for the observed shift in BWDB's H/Q-data after the 1988 flood. Such overestimates could for example be explained by a substantial local change of the planforms, channel pattern and cross-section at BWDB's measurement cross-section during the high 1988 flood which may have resulted in a more skew velocity distribution than before the flood. As the BWDB does not have the equipment at Bahadurabad for measuring the flow direction at each measurement point of the cross-section, the effect of such a skew velocity distribution on the discharge estimates may have become much more important. It would imply that BWDB's procedure for correction for flow directions based on surface floats only (ref. Section 6.3.1) may give much more uncertain results (overestimates) now than before the 1988 flood.

If this preliminary conclusion can be confirmed through the further FAP 24 field measurements and hydrological and morphological studies, it implies that the rating curves based on these measurements since the 1988 flood at Bahadurabad and thus the resulting discharge time series are overestimated to a large extent, probably between 20-40%.

On the other hand, the above observations also indicate that the H/Q-measurements at Bahadurabad and thus the resulting discharge time series before the 1988 flood are much more reliable and consistent than after the flood, and the approach to develop annual rating curves based on the actual H/Q- measurements each year seems justified for all the years before 1989. This also yields for all years up to 1991 for the two stations Hardinge Bridge and Baruria looked into up to now.

It further implies that the various statistical analyses (e.g. frequency analyses of design floods etc) carried out by FAP 25 in the Flood Hydrology Study (FAP 25, June 1992) on the basis of long data series up to 1988 will not be affected significantly.

It is, however, recommended that BWDB's discharge time series from Bahadurabad for 1988-1991(92) are not used uncritically as they might be overestimated by 20-40% in the higher flow ranges. At the present stage it would probably be better, as a first "best estimate", to establish new discharge time series for 1988-1991(92) for Bahadurabad on the basis of the FAP 24 rating curve for 1987.

92

It is also recommended that BWDB should be supplied with the required equipment for measuring flow direction at each measurement point of their cross-section at Bahadurabad as soon as possible.

6.3.4 Water-level time series

Eight types of errors were detected by FAP 25 (ref. FAP 25, June 1992), i.e.:

- o Missing data
- o Daily erroneous data
- o Shifted data for a few days
- o Shifted data for a few weeks
- o Shifted data for longer periods
- o Inconsistent trends
- o Static water-level
- o Reliability of bench-marks

Based on these error types and FAP 25 guidelines checking of water-level data has been started up. The procedure used is as follows (ref. Figure 6.17):

- o For each station to be checked at least 2 other stations are chosen for comparison
- o Water-level time series for each station are plotted for every year together with the time series of comparison stations (Figure 6.17a). Differences in trend are detected from these plots visually
- o Plots of the difference in water-level between the station to be checked and comparison stations are made (Figure 6.17b). This is based on the idea that the differences in water-level should be more or less constant. On these plots a range is indicated of the mean difference plus and minus 2 times standard deviation. If the difference lies outside this range it is marked. The range is chosen based on experience with water-level data at Bahadurabad, but is arbitrary. It can be changed to any other value if that is more practicable. This will not affect the form of the curve
- o Furthermore, plots are made of the change in difference (Figure 6.17c). The idea is that the difference in water-level can be larger than the range mentioned above, but that it is suspicious if this difference changes too suddenly. Also here a range is kept of the mean plus or minus 2 times standard deviation

The last two plots are merely used as an indication. If water-level data are out of range the data marked are double checked.This procedure emphasizes the first five error types as mentioned above.

List of references

- Coleman, J.M.,
  Brahmaputra river: Channel Process and Sedimentation. Sediment Geology, Volume 3, No. 2/3
  Coastal Studies Institute, Louisianna State University
  August 1969
- FAP 1
  First Interim Report, Annex 1: Part 4 - Analysis of discharge measurements / Brahmaputra River Training Study
  Sir William Halcrow and Partners Ltd.
  April 1991
- FAP 1
  First Interim Report, Annex 2: Hydrology / Brahmaputra River Training Study
  Sir William Halcrow and Partners Ltd.
  April 1991
- FAP 21/22
  Interim Report, Volume I, II and III / Bank Protection and River Training
  Consulting Consortium FAP 21/22
  July 1992
- FAP 24
  Additional Survey September 1992 / River Survey Project
  DELFT HYDRAULICS & Danish Hydraulic Institute
  31 October 1992
- FAP 25
  Flood Hydrology Study, Main Report and Annex 1 and 2 / Flood Modelling and Management
  Consulting Consortium FAP 25
  June 1992
- ISO
  International Standard ISO 1100/2, Liquid flow measurements in open channels - Part 2: Determination of the stage-discharge relation
  International Standard Organization
  1982
- MPO
  Surface Water Simulation Modelling Programme, Phase II: General Model Verification Report
  Master Plan Organization
  July 1992
- MWMEM
  Manual on Procedures in Operational Hydrology, Volume 4: Stage-discharge relationships at stream gauging stations
  Ministry of Water Energy and Minerals, Tanzania
  1979

1/2

WATER YEAR (April–March)	STATION: 46.9L Bahadurabad First OD	Last OD	Status	Source with #OD's	STATION: 90 Hardinge Bridge First OD	Last OD	Status	Source with #OD's	STATION: 91.9L Baruria First OD	Last OD	Status	Source with #OD's
66	5 apr	27.mar	H	B48 (F39)	10 apr	30 mar	H	B48 (F48)	10 apr	27 aug	H	B21 (F21)
67	3 apr	25 mar	H	B53 (F39)	5 apr	27 mar	H	B54 (F54)	6 apr	28 mar	H	B53 (F53)
68	1 apr	25 mar	H	B52 (F38)	3 apr	29 mar	H	B77 (F77)	11 apr	27 mar	H	B50 (F50)
69	1 apr	3 mar	H	B49 (F38)	2 apr	28 mar	H	B79 (F79)	3 apr	26 mar	H	B53 (F53)
70	7 apr	24 mar	H	B49 (F38)	1 apr	13 feb	H	B61 (F61)	2 apr	21 jan	H	B34 (F34)
71	–	–	–	–	–	–	–	–	–	–	–	–
72	2 may	28 mar	H	B33 (F33)	7 apr	14 mar	H	B41 (F41)	7 apr	29 mar	H 42	B41 (F41)
73	3 apr	27 jan	H 34	B33 (F33)	5 apr	27 mar	H	B46 (F46)	5 apr	28 mar	H	B41 (F41)
74	3 apr	23 feb	H	B16 (F13)	3 apr	23 mar	H	B40 (F56)	4 apr	27 feb	H	B29 (F29)
75	1 jul	17 feb	H	B25 (F25)	2 apr	15 mar	H	B47 (F163)	5 apr	18 mar	H	B29 (F29)
76	6 apr	29 mar	H	B49 (F38)	1 apr	26 mar	H	B60 (F215)	1 apr	31 mar	H	B52 (F52)
77	5 apr	20 mar	H	B41 (F38)	2 apr	29 mar	H	B52 (F254)	–	–	–	–
78	17 apr	19 mar	H 36	B35 (F35)	5 apr	27 mar	H	B51 (F174)	–	–	–	–
79	–	–	–	–	3 apr	22 jan	H	B45 (F96)	5 apr	24 jan	H	B32 (F32)
80	8 apr	16 mar	H 26	B25 (F22)	1 apr	30 mar	H	B45 (F134)	–	–	–	–
81	1 apr	27 mar	H	B31	–	–	–	–	9 apr	25 mar	H	B37 (F37)
82	7 apr	28 mar	H	B29 (F29)	–	–	–	–	8 apr	31 mar	H	B35 (F35)
83	12 apr	19 mar	H	B39 (F38)	7 apr	31 mar	H	B51 (F130)	13 apr	29 mar	H	B36 (F36)
84	4 apr	25 mar	H	B33 (F33)	7 apr	31 mar	H	B51 (F142)	12 apr	29 mar	H	B36 (F36)
85	8 apr	24 mar	H	B32 (F32)	17 apr	31 mar	H	B48 (F131)	11 apr	20 mar	H	B36 (F36)
86	7 apr	30 mar	H	B41 (F38)	2 apr	25 mar	H	B49 (F137)	3 apr	28 mar	H	B41 (F41)
87	12 apr	21 mar	H	B32 (F32)	2 apr	29 mar	H	B50 (F118)	10 apr	31 mar	H	B36 (F36)
88	11 apr	20 mar	H 32	B30 (F30)	6 apr	30 mar	H	B49 (F130)	14 apr	30 mar	H	B37 (F37)
89	3 apr	19 mar	H 36	B35 (F35)	5 apr	31 mar	H	B49 (F144)	13 apr	22 mar	H	B37 (F37)
90	2 apr	25 mar	H	B30 (F30)	1 apr	31 mar	H	B147	5 apr	28 mar	H 35	B36 (F35)
91	8 apr	30 mar	H	B32	1 apr	30 mar	H	B144	11 apr	31 mar	H	B37
92	13 apr	8 oct/10 nov	H/hc	B28/+10	1 apr	27 dec	hc	B139	16 apr	24 sep	hc	B21

Status: H = Data transfered to HYMOS, with number of data if different from source:
– if more, extra point(s) added for fitting of rating curve
– if less, suspicious data have been disregarded.
hc = Data available only on hardcopy.

[–] = DATA REQUIRED

Source with #OD's: B = data available from BWDB
F = data available from FAP 25
(1st source mentioned is used for analysis)

FAP 24 DELFT-DHI — RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Observed discharge data collected by FAP 24 (1/2)	
File:	Date:	1° Interim Report February 1993	Table 6.1
Scale:	Inlt:		

WATER YEAR (April–March)	STATION: 93.5L Mawa (tidal)				STATION: 99 Gorai Railway Bridge				STATION: 273 Bhairab Bazar (tidal)			
	First OD	Last OD	Status	Source with #OD's	First OD	Last OD	Status	Source with #OD's	First OD	Last OD	Status	Source with #OD's
66	2 dec	31 mar	H	F18	1 apr	29 mar	hc	B46	–	–	–	–
67	7 apr	29 mar	H	F52	–	–	–	–	24 jun	11 nov	H	F17
68	5 apr	28 mar	H	F52	2 apr	31 mar	hc	B77	17 jun	9 nov	H	F22
69	4 apr	27 mar	H	F52	3 apr	30 mar	hc	B62	14 jun	1 nov	H	F20
70	3 apr	24 mar	H	F52	6 apr	22 feb	hc	B48	–	–	–	–
71	–	–	–	–	–	–	–	–	–	–	–	–
72	6 apr	28 mar	H	F44	3 apr	27 mar	hc	B34	3 jul	30 oct	H	F18
73	11 jul	26 oct	H	F16	9 apr	25 mar	hc	B32	29 may	6 nov	H	F21
74	13 jun	13 mar	H	F20	18 jun	24 mar	hc	B37	27 jun	6 nov	H	F20
75	9 apr	31 mar	H	F16	–	–	–	–	–	–	–	–
76	7 apr	9 mar	H	F49	5 apr	21 mar	hc	B53	–	–	–	–
77	13 apr	30 mar	H	F47	–	–	–	–	–	–	–	–
78	12 apr	21 mar	H	F36	–	–	–	–	–	–	–	–
79	4 apr	27 mar	H	F52	–	–	–	–	–	–	–	–
80	2 apr	19 mar	H	F32	–	–	–	–	19 apr	15 nov	H	F28
81	–	–	–	–	–	–	–	–	17 jun	7 nov	H	F14
82	8 apr	29 mar	H	F32	–	–	–	–	19 jun	4 nov	H	F10
83	14 apr	27 mar	H	F28	11 apr	28 mar	hc	B53	30 may	10 nov	H	F13
84	11 apr	20 mar	H	F25	4 apr	27 mar	hc	B53	25 may	28 mar	H	F16
85	5 apr	26 mar	H	F23	4 apr	26 mar	hc	B52	1 apr	31 mar	H	F22
86	11 apr	31 dec	H	F32	2 apr	30 mar	hc	B43	13 apr	30 mar	H	F24
87	2 jun	27 oct	H	F19	16 apr	30 mar	hc	B38	16 apr	19 mar	H	F28
88	7 jun	25 oct	H	F19	13 apr	29 mar	hc	B39	4 apr	24 dec	H	F29
89	7 jun	25 oct	H	F19	12 apr	28 mar	hc	B37	25 may	2 nov	H	F23
90	13 jun	31 oct	H	B20 (F21)	11 apr	20 mar	H	B37	24 may	29 nov	H	B26 (F27)
91	17 jul	30 oct	H	B14	10 apr	20nov/25mar	H/hc	B29/+11	16 may	28 nov	H	B27
92	3 jun	28 oct	hc	B19	–	–	–	–	4 jun	26 nov	hc	B26

Status: H = Data transfered to HYMOS, with number of data if different from source:
– if more, extra point(s) added for fitting of rating curve
– if less, suspicious data have been disregarded.
hc = Data available only on hardcopy.

[–] = DATA REQUIRED

Source with #OD's: B = data available from BWDB
F = data available from FAP 25
(1st source mentioned is used for analysis)

FAP 24 RIVER SURVEY PROJECT
Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland
DELFT-DHI

Observed discharge data collected by FAP 24 (2/2)

File: | Date: | 1° Interim Report February 1993 | Table 6.1 contd.

Scale: | Inlt:

1/2

WATER YEAR (April–March)		STATION: 46.9L Bahadurabad		STATION: 90 Hardinge Bridge **		STATION: 91.9L Baruria		STATION: 93.5L Mawa (tidal)	
		Status	Source	Status	Source	Status	Source	Status	Source
64		–	–	H	F	–	–	–	–
65		H	F	H	F	–	–	H	F 186
66		H	F*	H	F*	H	F*	H	F
67	L	H	F*	H	F*	H	F*	H	F
68		H	F*	H	F*	H	F*	H	F
69		H	F*	H	F*	H	F*	H	F
70		H	F*	H	F* 11	H	F*	H	F 7
71	L	–	–	–	–	–	–	–	–
72		H	F*	H	F*	H	F*	H	F
73		H	F*	H	F*	H	F*	H	F
74		H	F*	H	F*	H	F*	H	F
75	L	H	F*	H	F*	H	F*	–	–
76		H	F*	H	F*	H	F*	H	F
77		H	F*	H	F*	H	F	H	F
78		H	F*	H	F*	H	F	H	F
79	L	H	F	H	F*		Only parameters available	H	F
80		H	F*	H	F*	H	F*	H	F
81		H	F*	H	F*	H	F*	H	F
82		H	F*	H	F*	H	F*	H	F
83	L	H	F*	H	F*	H	F*	H	F 41
84		H	F*	H	F*	H	F*	H	F 43
85		H	F*	H	F*	H	F* 2	H	F 98
86		H	F*	H	F*	H	F* 39	H	F 90
87	L	H	F*	H	F*	H	F*	H	F 218
88		H	F*	H	F*	H	F*	H	F 224
89		H	F* (B)	H	F* (B)	H	F* (B)	H	B 224
90		H	B	H	B	H	B 13	H	B 219
91	L	H	B	hc	B	hc	B	hc	B
92		–	–	–	–	–	–	–	–

Status: H = Data transfered to HYMOS
hc = Data only on hardcopy

Source: B = data available from BWDB (with number of missing days)
F = data available from FAP 25
(1st source mentioned is used for analysis)

* Rating curve parameters also available
** Also available 60 – 63

– = DATA NOT AVAILABLE at BWDB

FAP 24 DELFT-DHI

RIVER SURVEY PROJECT
Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland

Mean daily discharge data collected by FAP 24 (1/2)

File: | Date:
Scale: | Inlt:

1° Interim Report
February 1993

Table 6.2

WATER YEAR (April–March)		STATION: 99 Gorai Railway Bridge		STATION: 230.1 Bhairab B Rw.Br. (tidal)		STATION: 273 Bhairab Bazar (tidal)	
		Status	Source	Status	Source	Status	Source
64		H	F	–	–	H	F 170
65		H	F	–	–	H	F
66		H	F	–	–	H	F
67	L	H	F	–	–	H	F
68		H	F	–	–	H	F
69		H	F	–	–	H	F 2
70		H	F	–	–	H	F 12
71	L	–	–	–	–	–	–
72		H	F	H	F 243	H	F
73		H	F	H	F 243	H	F
74		H	F	H	F 257	H	F
75	L	H	F	H	F 274	H	F 213
76		H	F	–	–	H	F 212
77		H	F	H	F 273	–	–
78		H	F	H	F 267	–	–
79	L	H	F	H	F 225	–	–
80		H	F	H	F 211	–	–
81		H	F	–	–	H	F 221
82		H	F	H	F 253	H	F 226
83	L	H	F	–	–	H	F 202
84		H	F	–	–	H	F 197
85		H	F	–	–	H	F 266
86		H	F	–	–	H	F
87	L	H	F	–	–	H	F
88		H	F	–	–	H	F 134
89		H	F (B)	H	B 244	H	F 203 (B 203)
90		hc	B	–	–	hc	B
91	L	hc	B	–	–	hc	B
92		–	–	–	–	–	–

Status: H = Data transfered to HYMOS
hc = Data only on hardcopy

Source: B = data available from BWDB (with number of missing days)
F = data available from FAP 25 "
(1st source mentioned is used for analysis)

[–] = DATA NOT AVAILABLE at BWDB

FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI	Mean daily discharge data collected by FAP 24 (2/2)
File:	Date:
Scale:	Inlt:
1° Interim Report February 1993	Table 6.2 contd.

STATION NO.	NAME OF STATION	TYPE	NAME OF RIVER	STATUS OF DATA	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
								L				L				L				L				L				L				L	
15J	Mathurpara		Brahm. Jamuna																												B	–	
45	Noon Khawa		Brahm. Jamuna																												B	–	
45.5	Chilmari		Brahm. Jamuna	H	–	F	F	F	F	F	F 33	F 70	F	F	F	F	F	F	F	–	F	–	–	F	F	F	F	F 60	F	FB	FB 1	B	–
46	Kamarjani		Brahm. Jamuna																												B	–	
46.7L	Kholabarichar		Brahm. Jamuna	H	–	F	F	F	F	F	F	–	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	FB	B	B	–
46.9L	Bahadurabad		Brahm. Jamuna	H	F	F	F	F	F	F	F	–	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	FB	FB	hc	–
46.9R	Fulcharighat		Brahm. Jamuna																												B	–	
48	Jagannathganj		Brahm. Jamuna																												B	–	
49	Shirajganj		Brahm. Jamuna	H	F	F	F	F 1	F	F	F	–	F	F	F	F 1	F	F	F	F 1	F	F 61	F	F 1	F	F	F	F 1	F	FB	FB	B	–
49A	Kazipur		Brahm. Jamuna	H	–	–	–	F	F	F	F	–	F	F	F	F	F 13	F	F	F 2	F	F	F	F	F	F	F	F	F	FB	B	B	–
50	Porabari		Brahm. Jamuna	H	F	F	F	F	F	F	F	–	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	FB	B	hc	–
50.3	Mathura		Brahm. Jamuna	H	–	F	F 4	F 1	F	F	F	–	F	F	F	F	F	F 7	F	F	F	F 122	F	F	F	F	F	F	F	FB	B	hc	–
50.6	Teota		Dhaleswari																												B	–	
88	Rampur Boalia		Ganges																											B	B	–	
89	Sardah		Ganges																												B	–	
90	Hardinge Bridge		Ganges	H	F	F	F	F	F	F	F 11	–	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	FB	FB	B	–
91	Talbaria		Ganges																												B	–	
91.1	Sengram		Ganges	H	F	F	F	F	F 7	F	F	–	–	F	F	F	F	F	F	F	F	F	–	F	F	F	F	F	F	FB	FB	hc	–
91.2	Mahendrapur		Ganges	H	hc	F	F	F	F	F	F	–	F	–	F	F	F 1	F	F	F	F	F 16	F	F	–	F	F	F	F	FB	FB	hc	–
91.9L	Baruria		Padma	H	F	F	F	F	F	F 2	F	–	F	F	F	F	F	F	F	F	F	F	F 2	F	F	F 2	F	F	F	FB	FB	hc	–
91.9R	Goalundo Transit		Padma	H	F	F	F	F	F	F	F	F 1	F	F	F	F	F	F 43	F 34	F 151	F 132	F 121	F 185	F	F	hc	hc	hc	F 201	FB	B	hc	–
93.4L	Bhagyakul	T	Padma	H	–	–	–	–	F	F	F	F	F	F	F	F	–	F	–	–	–	F	–	F 1	F 1	F	hc	hc	hc	hc	B	hc	–
93.5L	Mawa	T	Padma	H	–	F 61	F	F	F	F	–	–	F	F	F	F	F	F	F	F	F	F	F	F 1	F	F 122	F	hc	F	FB	B	hc	–
94	Tarpasha	T	Padma																												B	–	
95	Sureshwar	T	Padma																												B	–	
98	Gorai Railway Bridge		Gorai	H	F	F	F	F	F	F	F 4	–	F	F	F	F	F	F	F	F 1	F	F	F	F	hc	hc	F	F 91	F	FB	B	B	–
230.1	Bhairab Bazar Rly. Br.	T	Old Brahmaputra	H	F 116	F	F	F	F	–	F 11	–	F	F 1	F	F 122	F	F	F	F	F	F 4	F	F	F	F	F	F	hc	B	B	hc	–
272	Madna	T	Surma–Meghna																												B	–	
272.1	Austagram	T	Surma–Meghna																												B	–	
273	Bhairab Bazar	T	Surma–Meghna	H	F	F	F	F	F	F	F 11	–	F	F 8	F	F	F	F	F	F	F	F	hc	F	F	F	F	F	F	FB	B	hc	–
274	Narsingdi	T	Surma–Meghna																												B	–	
275	Baidyer Bazar	T	Surma–Meghna	H	–	–	–	–	F	F	F	F	F	F 1	F	F	F	F	–	F	F	F	F	F 1	F 1	F	F	–	F	FB	B	hc	–
275.5	Meghna ferry ghat	T	Surma–Meghna	H	–	–	–	–	F	F	F	F 67	F 1	F 1	F	F 1	F	hc	–	–	F	hc	hc	hc	hc	–	F	F	F	FB	B	hc	–
276	Satnal	T	Surma–Meghna																												B	–	
277	Chandpur	T	Surma–Meghna																												B	–	

(shaded) = DISCHARGE/WATERLEVEL STATION

TYPE : T = Tidal station

STATUS : H = Data transfered to HYMOS

Remarks: – In case of incomplete years, additional data are not available at BWDB.

WATER YEAR: L = Leap year

(shaded) = DATA AVAILABLE FROM: B = BWDB (with number of missing days)
F = FAP 25 "
(1st source mentioned is used for analysis)
hc = only on hardcopy, not transfered to HYMOS

[–] = DATA REQUIRED

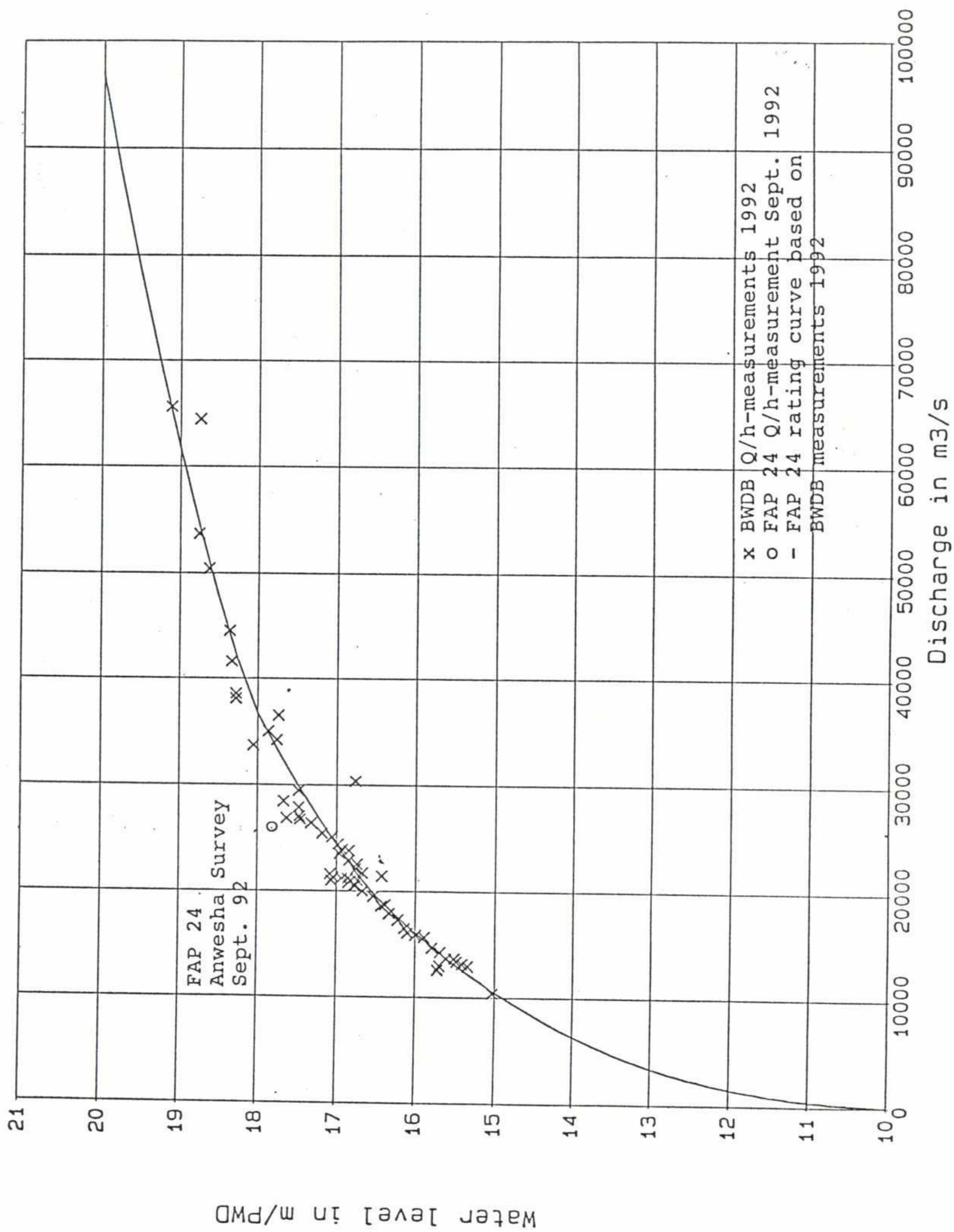
FAP 24 RIVER SURVEY PROJECT
Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland
DELFT-DHI

Mean daily water level data collected by FAP 24

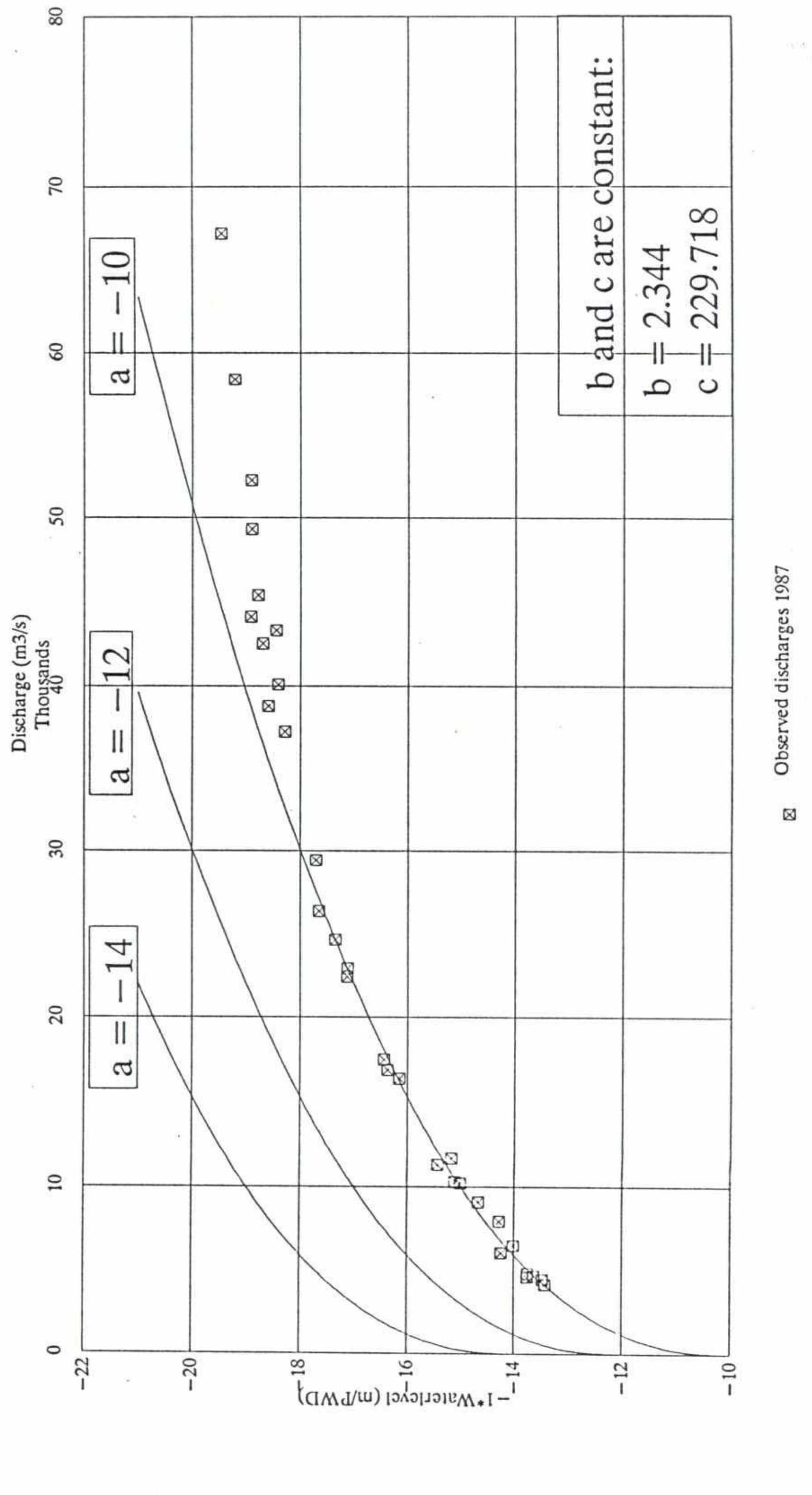
File: | Date:
Scale: | Inlt:

1° Interim Report
February 1993

Table 6.3

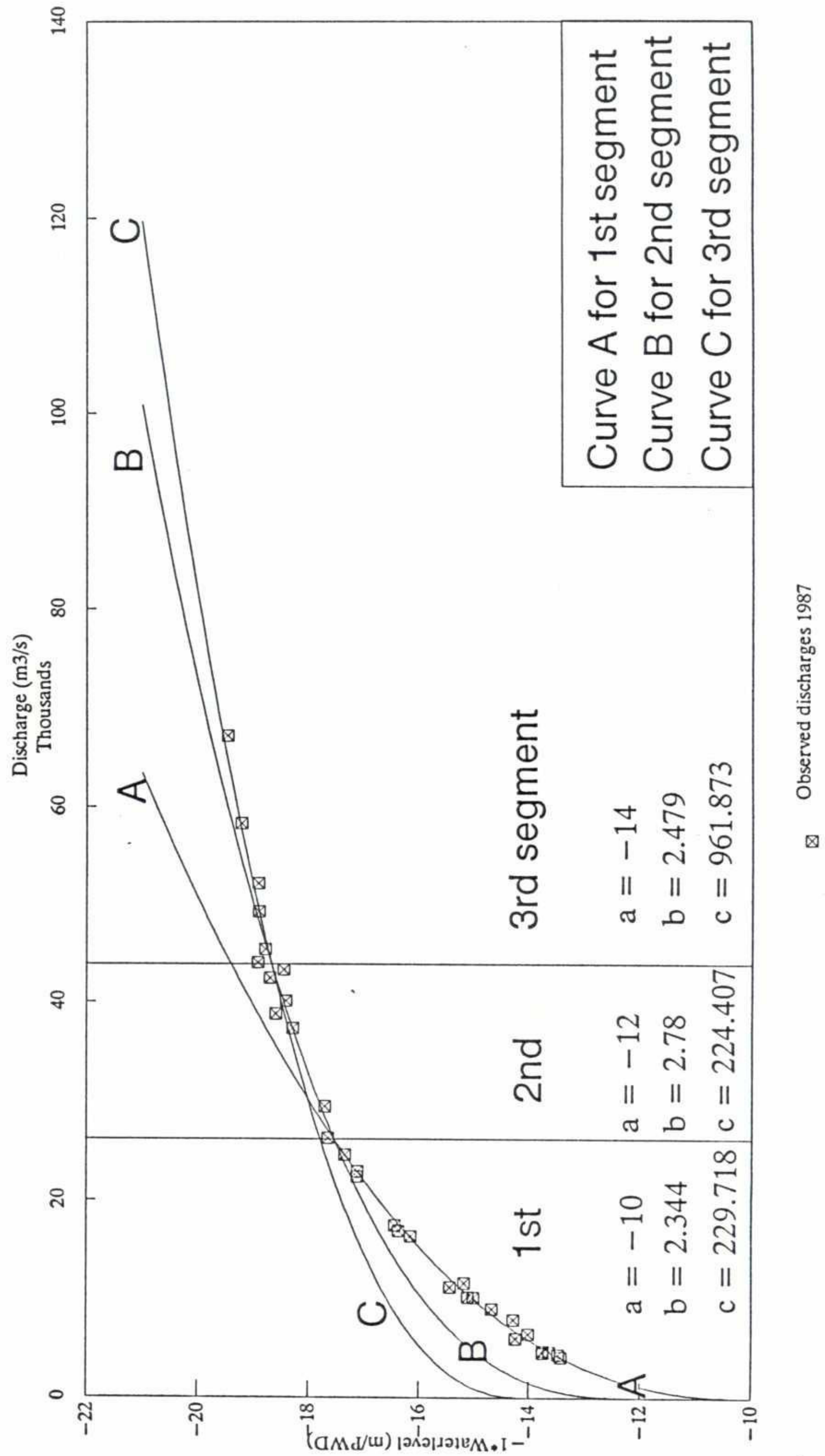


FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Discharge measurements and rating curve Bahadurabad 1992	
File:	**Date:**	1° Interim Report February 1993	**Fig. 6.1**
Scale:	**Inlt:**		



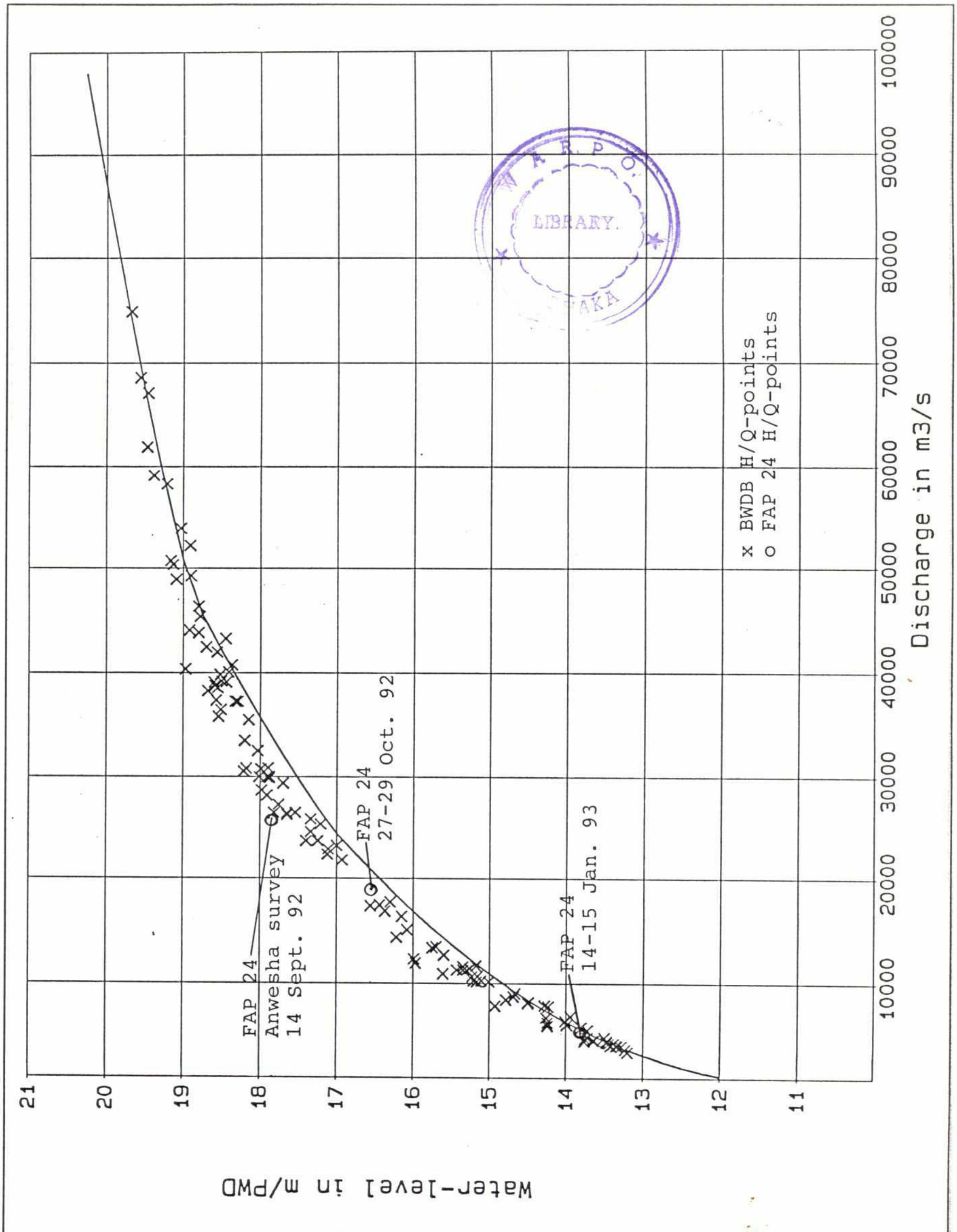
Remarks: - Configuration of the figure requires negative values for the water-levels. The minus signs can be ignored.

FAP 24 RIVER SURVEY PROJECT DELFT-DHI Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland		Fitting of rating curves; effect of change in offset (a)	
File:	Date:	1° Interim Report February 1993	Fig. 6.2
Scale:	Inlt:		

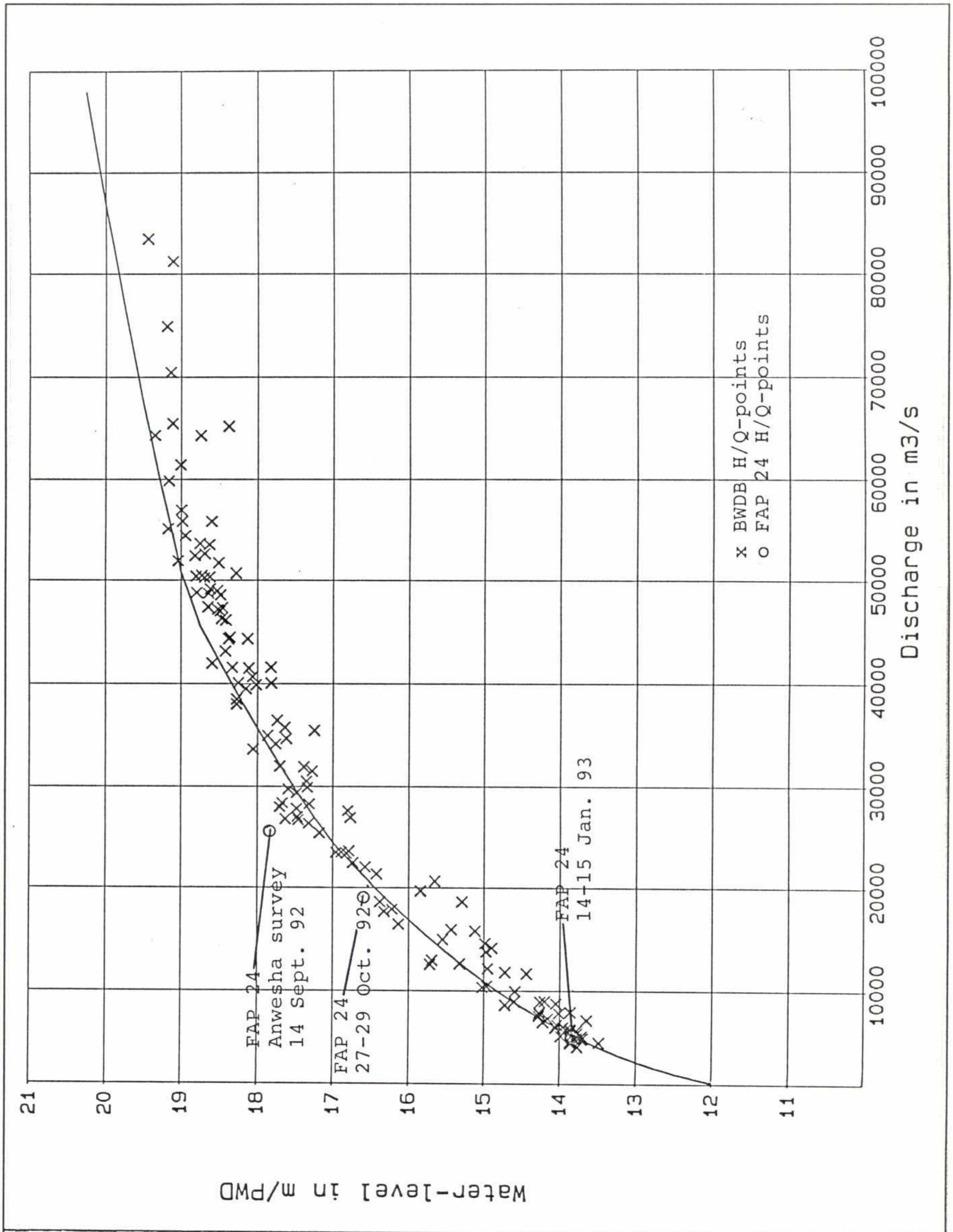


Remarks: – Configuration of the figure requires negative values for the water-levels. The minus signs can be ignored.

FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Fitting of rating curve; as fitted for Bahadurabad 1987	
File:	Date:	1° Interim Report February 1993	Fig. 6.3
Scale:	Inlt:		

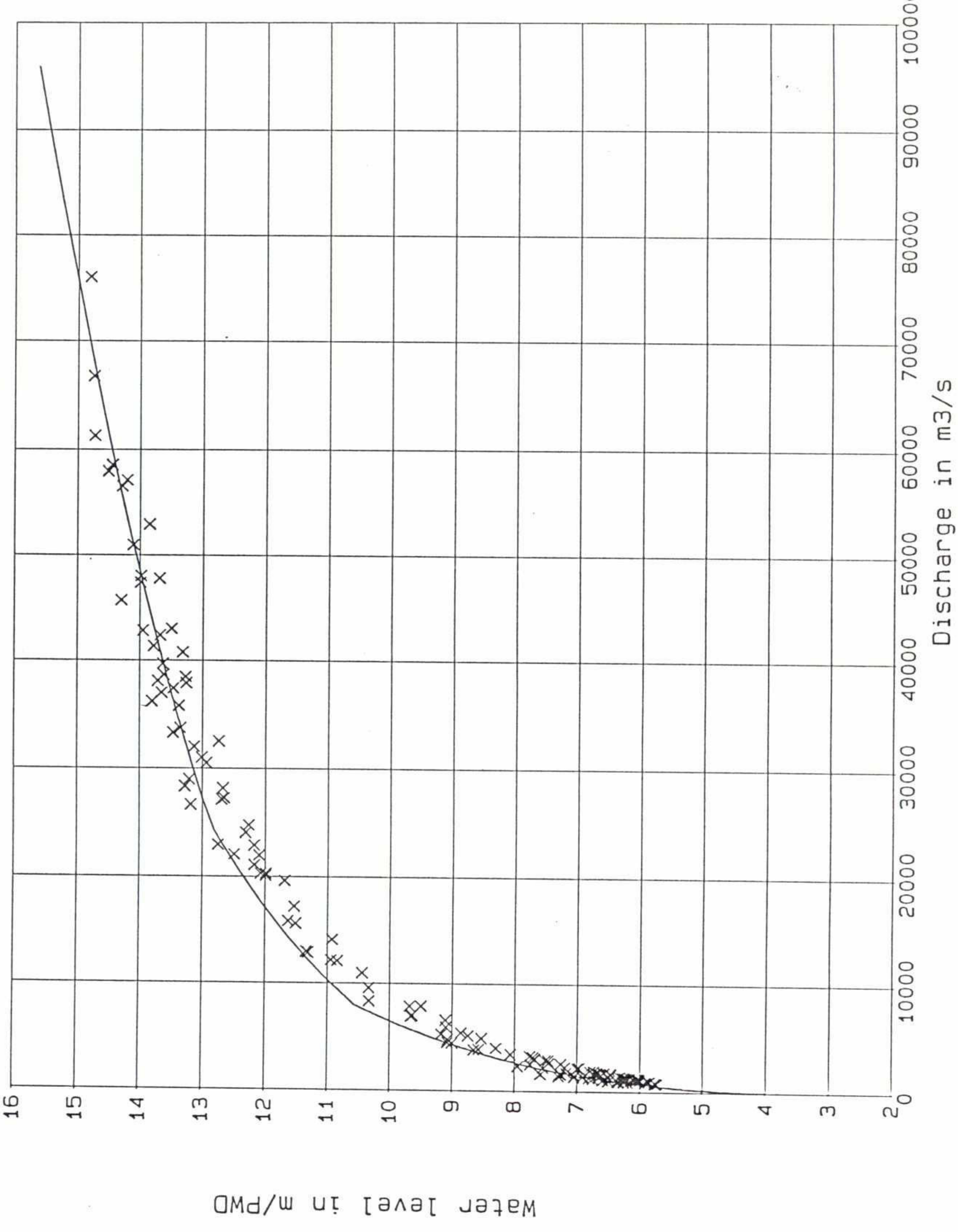


FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Bahadurabad average rating curve 1988 compared withQ/h-measurements from 1985 to 1988 (before August flood)	
File:	**Date:**	1° Interim Report February 1993	Fig. 6.4
Scale:	**Inlt:**		

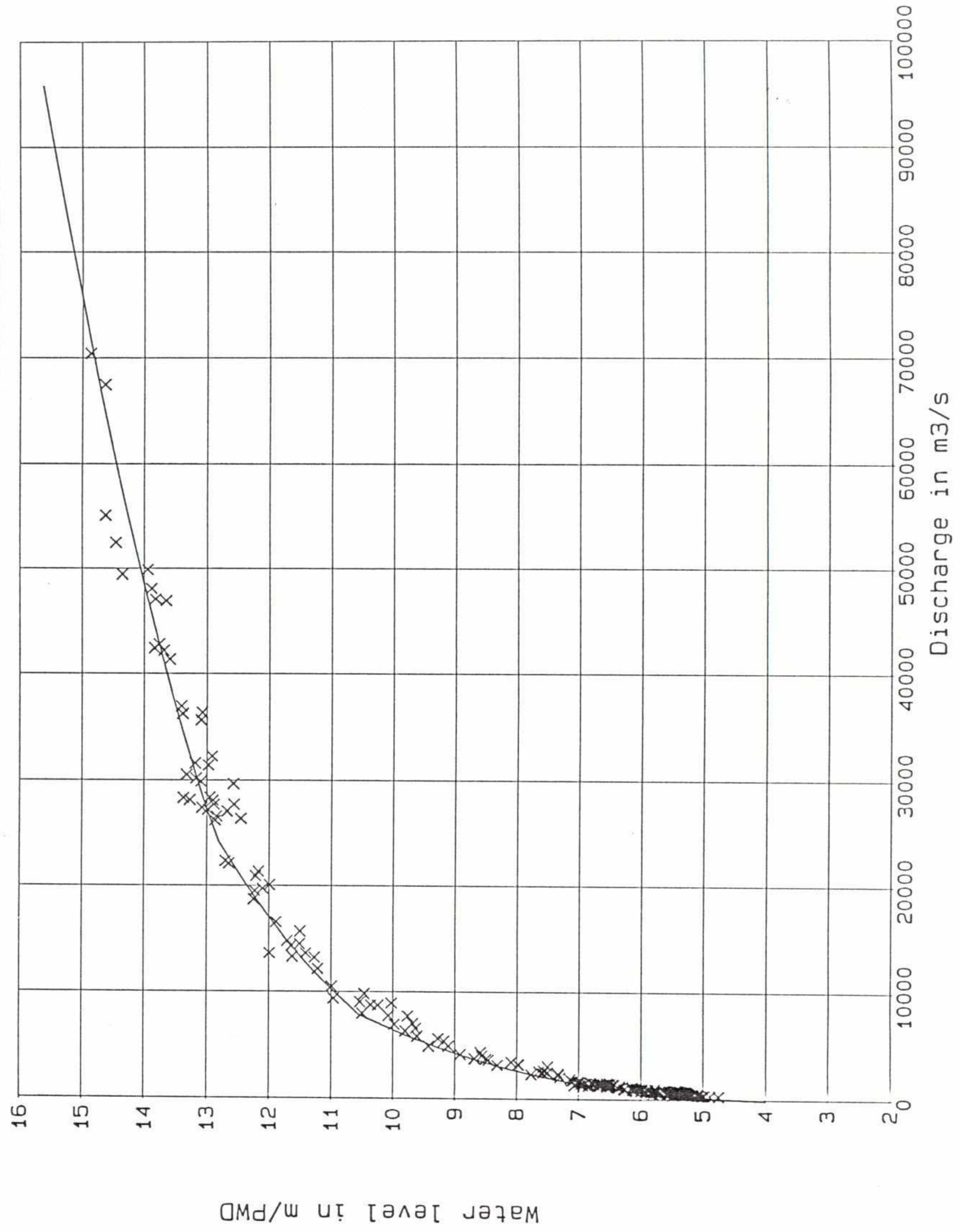


FAP 24 **RIVER SURVEY PROJECT** Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI	Bahadurabad average rating curve 1988 compared with Q/h-measurements from 1988 (after flood) to Nov. 1992

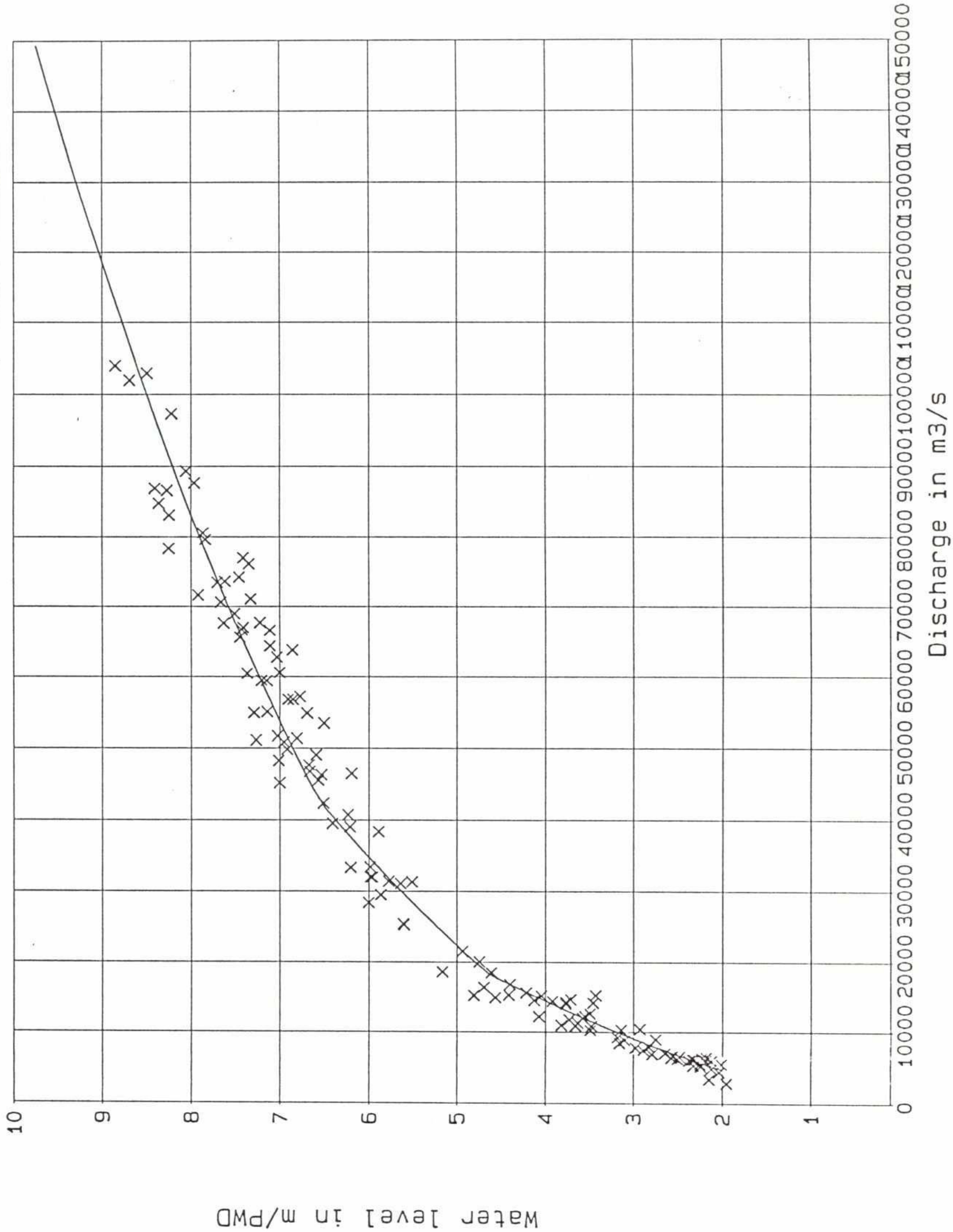
File:	Date:	1° Interim Report February 1993	Fig. 6.5
Scale:	Inlt:		



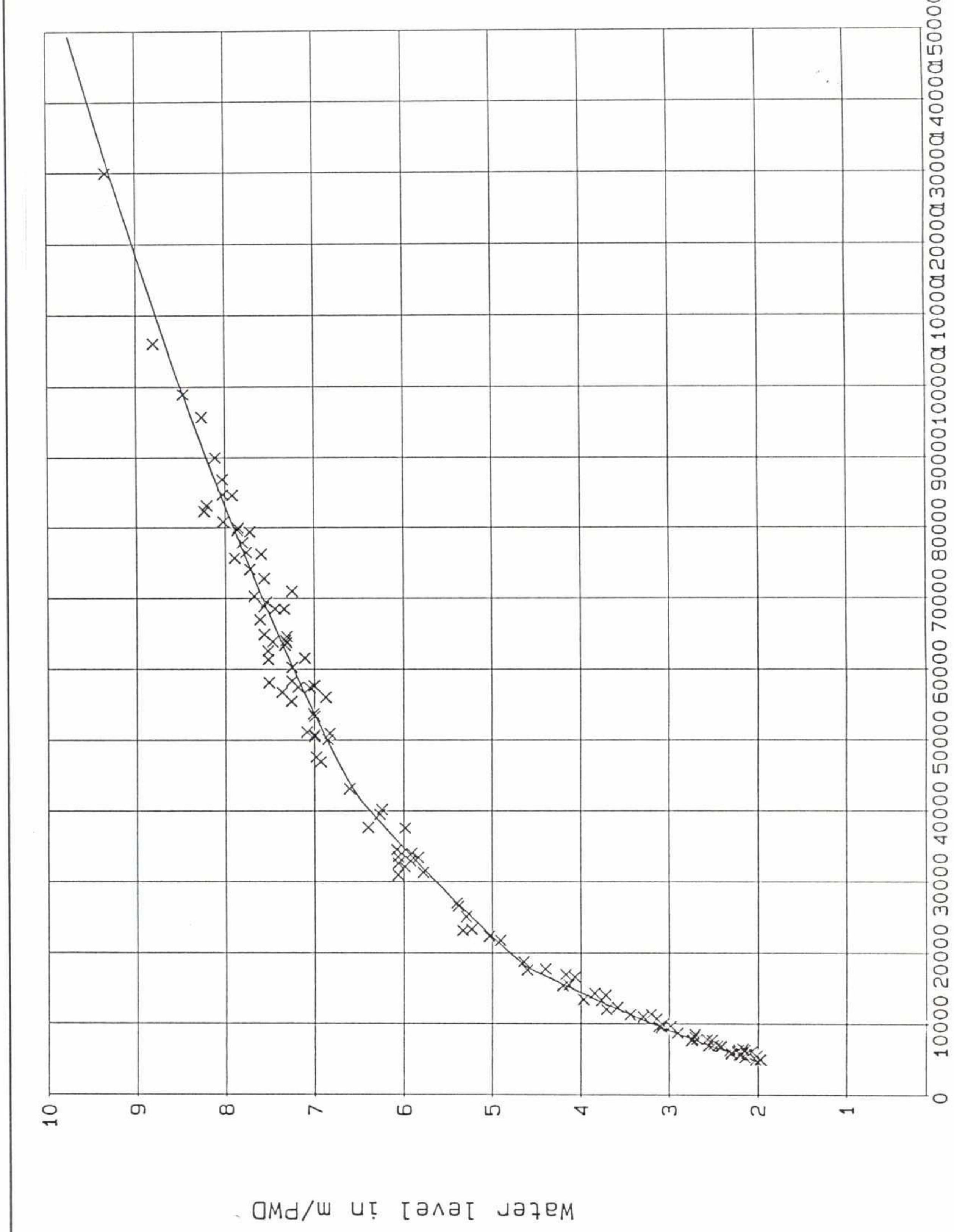
FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Hardinge Bridge rating curve 1988 compared with Q/h measurements from 1985 to 1988 (before flood)	
File:	Date:	1° Interim Report February 1993	Fig. 6.6
Scale:	Inlt:		



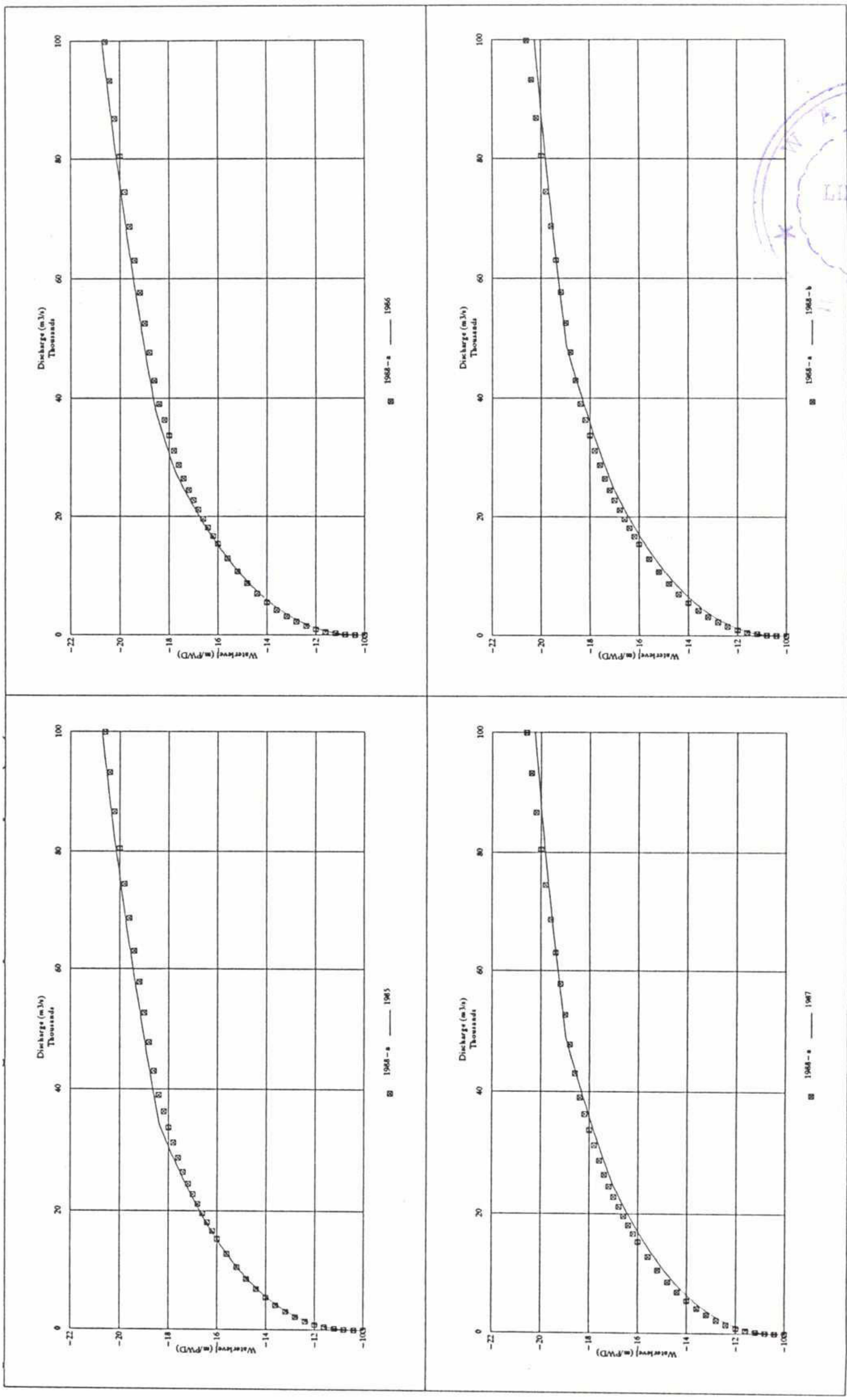
FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Hardinge Bridge rating curve 1988 compared with Q/h measurements from 1988 (after flood) to March 1992	
File:	Date:	1° Interim Report February 1993	Fig. 6.7
Scale:	Inlt:		



FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Baruria rating curve 1988 compared with with Q/h measurements from 1985 to 1988 (before flood)	
File:	Date:	1° Interim Report February 1993	Fig. 6.8
Scale:	Inlt:		

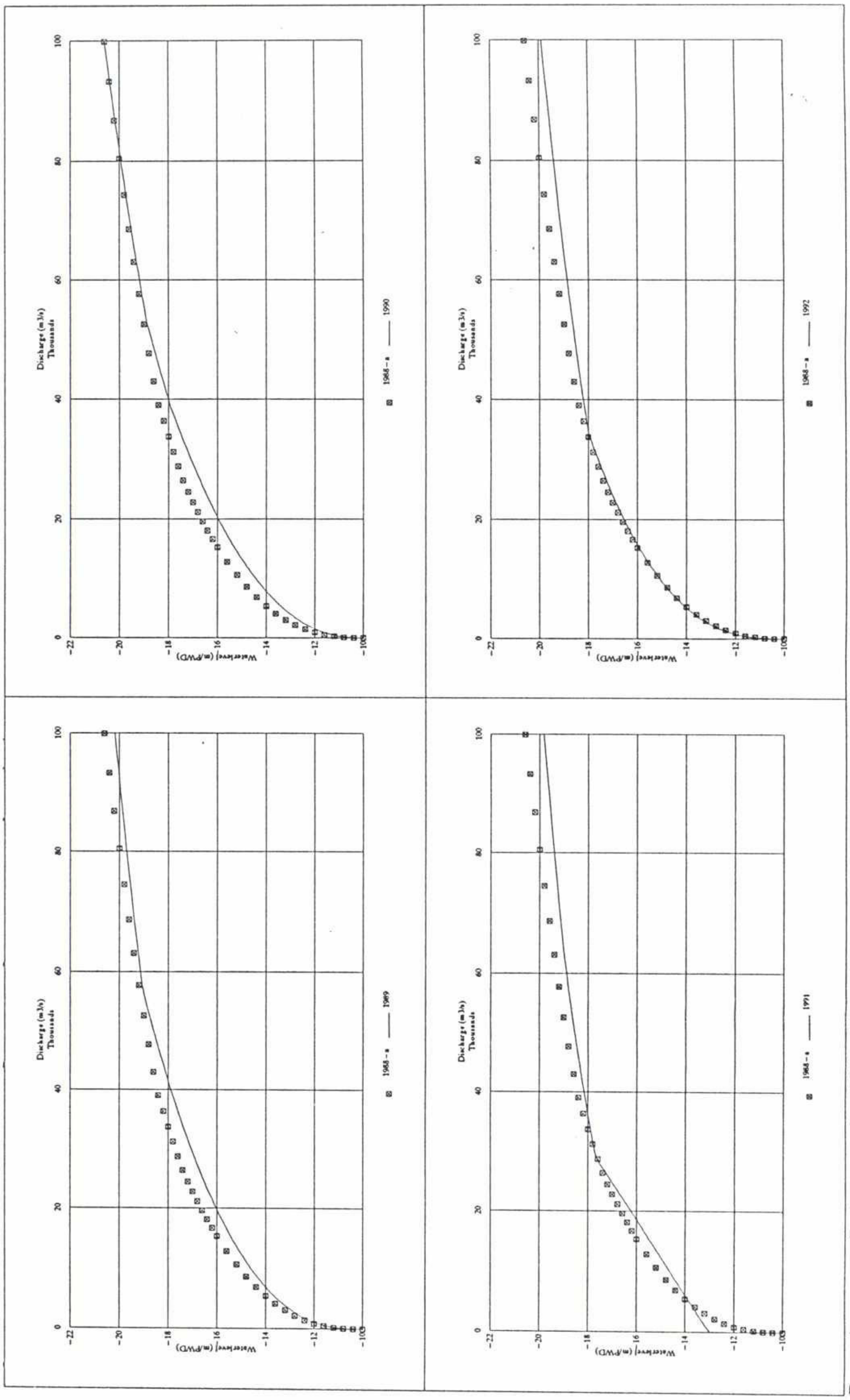


FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Baruria rating curve 1988 compared with Q/h measurements from 1988 (after flood) to March 1992	
File:	Date:	1° Interim Report February 1993	Fig. 6.9
Scale:	Inlt:		



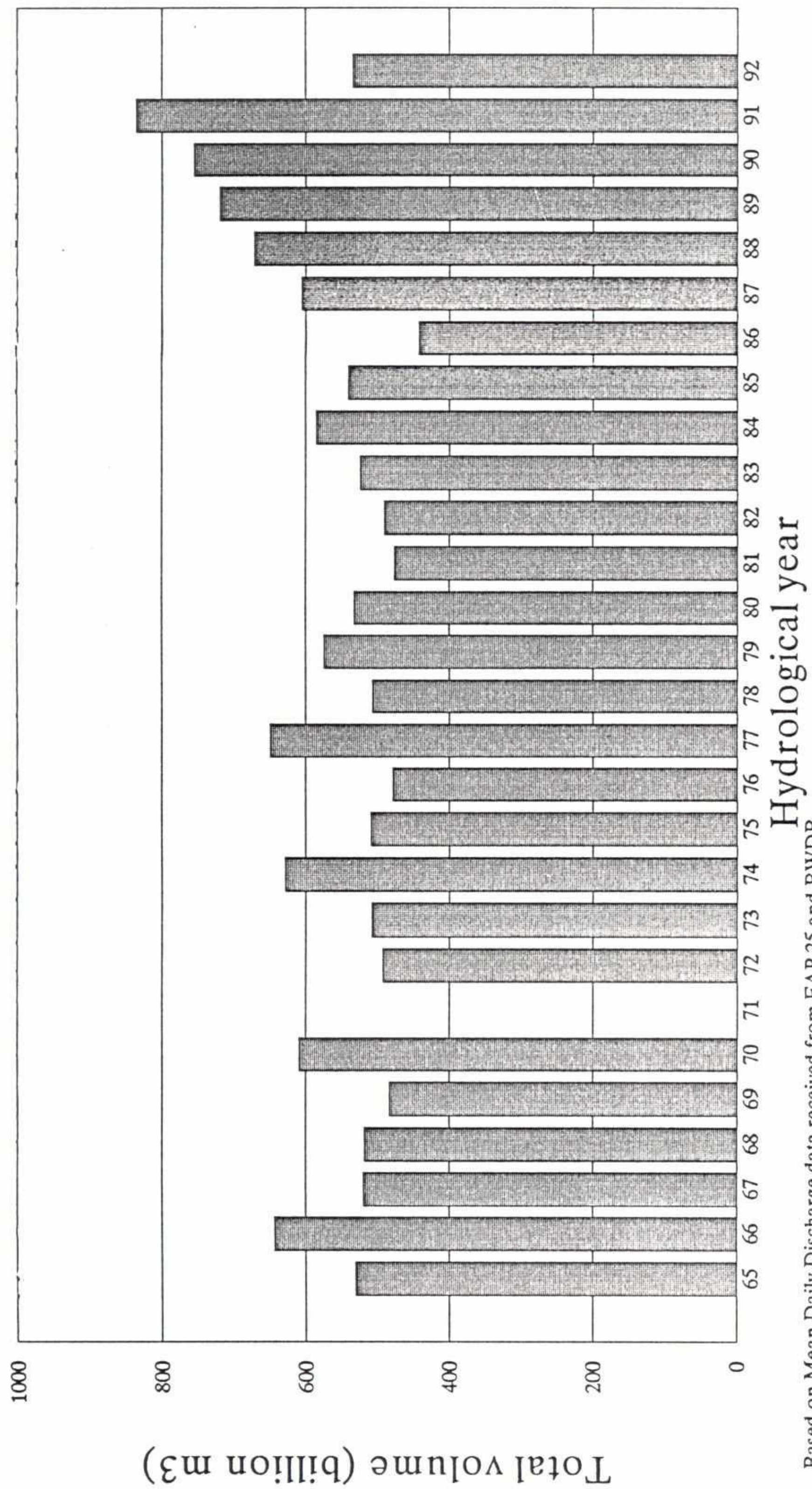
Remarks:
- Rating curve for 1988-a is based on observed discharges from 1 Apr. 1988 to 28 Aug 1988.
- Rating curve for 1988-b is based on observed discharges from 1 Apr. 1988 to 31 March 1989.
- Configuration of the figure requires negative values for the water-level. The minus signs can be ignored.

FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Bahadurabad, 1988-a rating curve compared with other years (1/2)	
File:	Date:	1° Interim Report February 1993	Fig. 6.10
Scale:	Inlt:		



Remarks:
- Rating curve for 1988–a is based on observed discharges from 1 Apr. 1988 to 28 Aug 1988.
- Rating curve for 1992 is based on observed discharges untill 8 Oct. 1992.
- Configuration of the figure requires negative values for the water–level. The minus signs can be ignored.

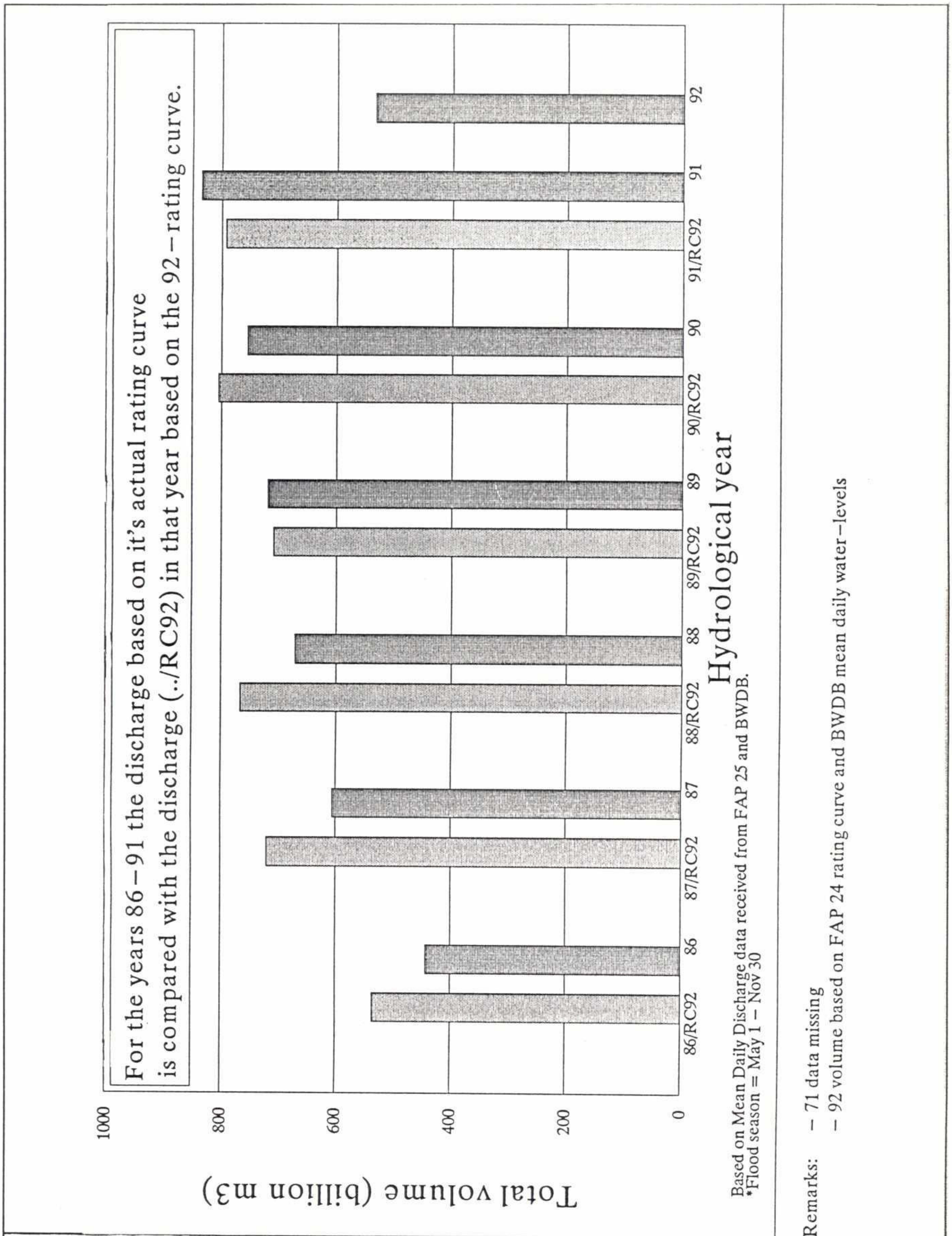
FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris, Approtech, Hydroland DELFT-DHI		Bahadurabad, 1988-a rating curve compared with other years (2/2)	
File:	Date:	1° Interim Report February 1993	Fig. 6.11
Scale:	Inlt:		



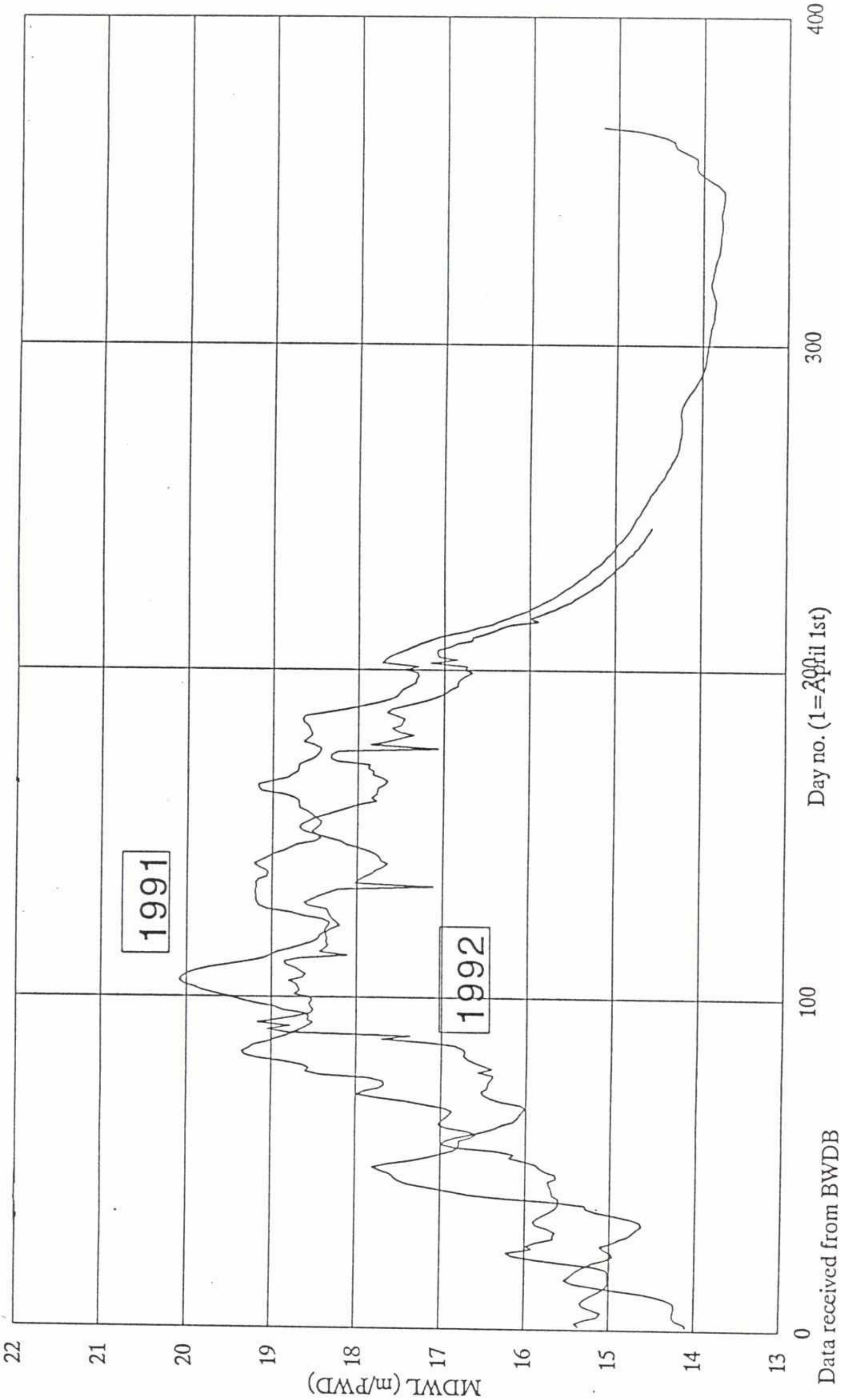
Based on Mean Daily Discharge data received from FAP 25 and BWDB.
*Flood season = May 1 – Nov 30

Remarks:
- 71 data missing
- 92 volume based on FAP 24 rating curve and BWDB mean daily water–levels

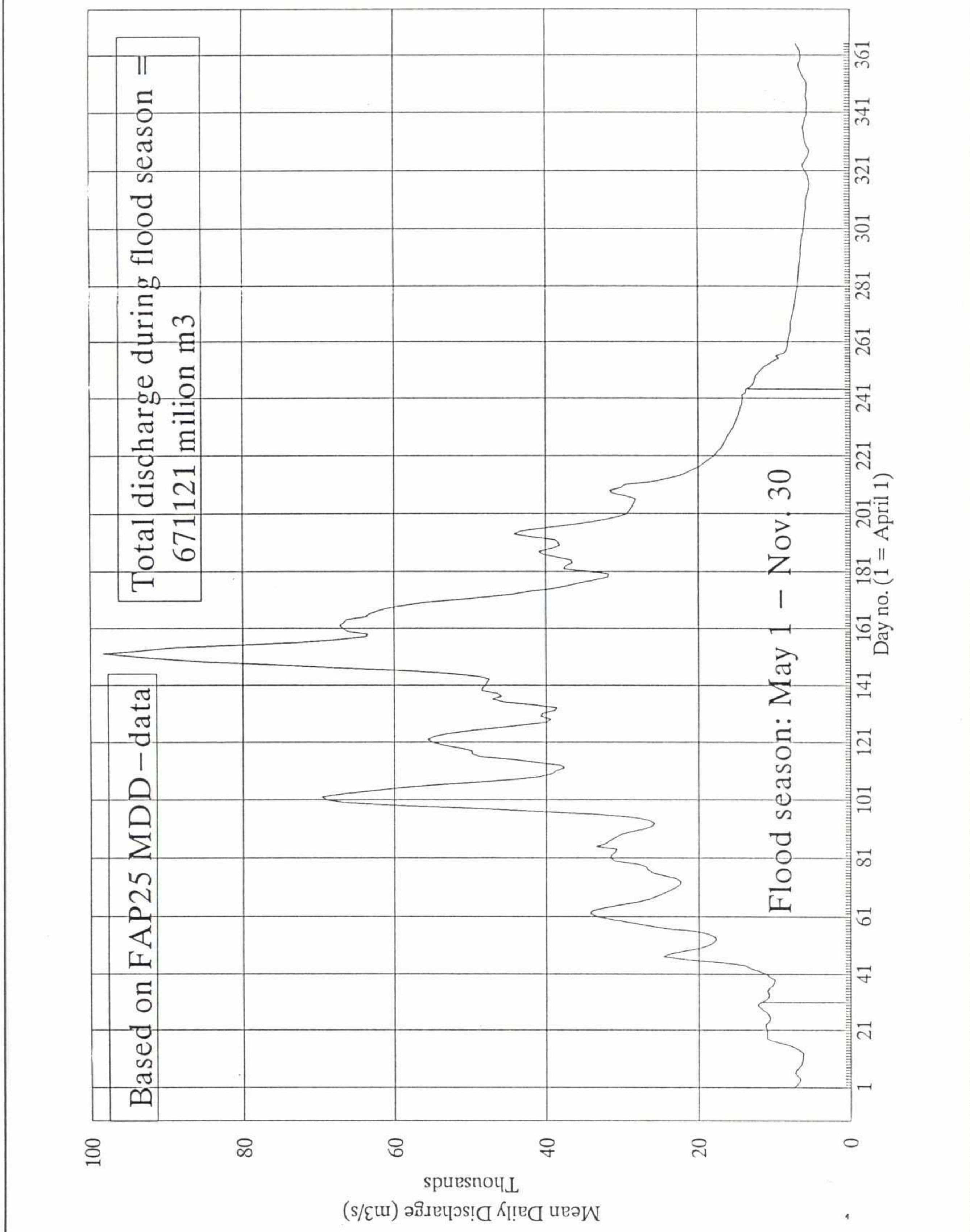
FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Bahadurabad, discharge volume of flood season*	
File:	Date:	1° Interim Report February 1993	Fig. 6.12a
Scale:	Inlt:		



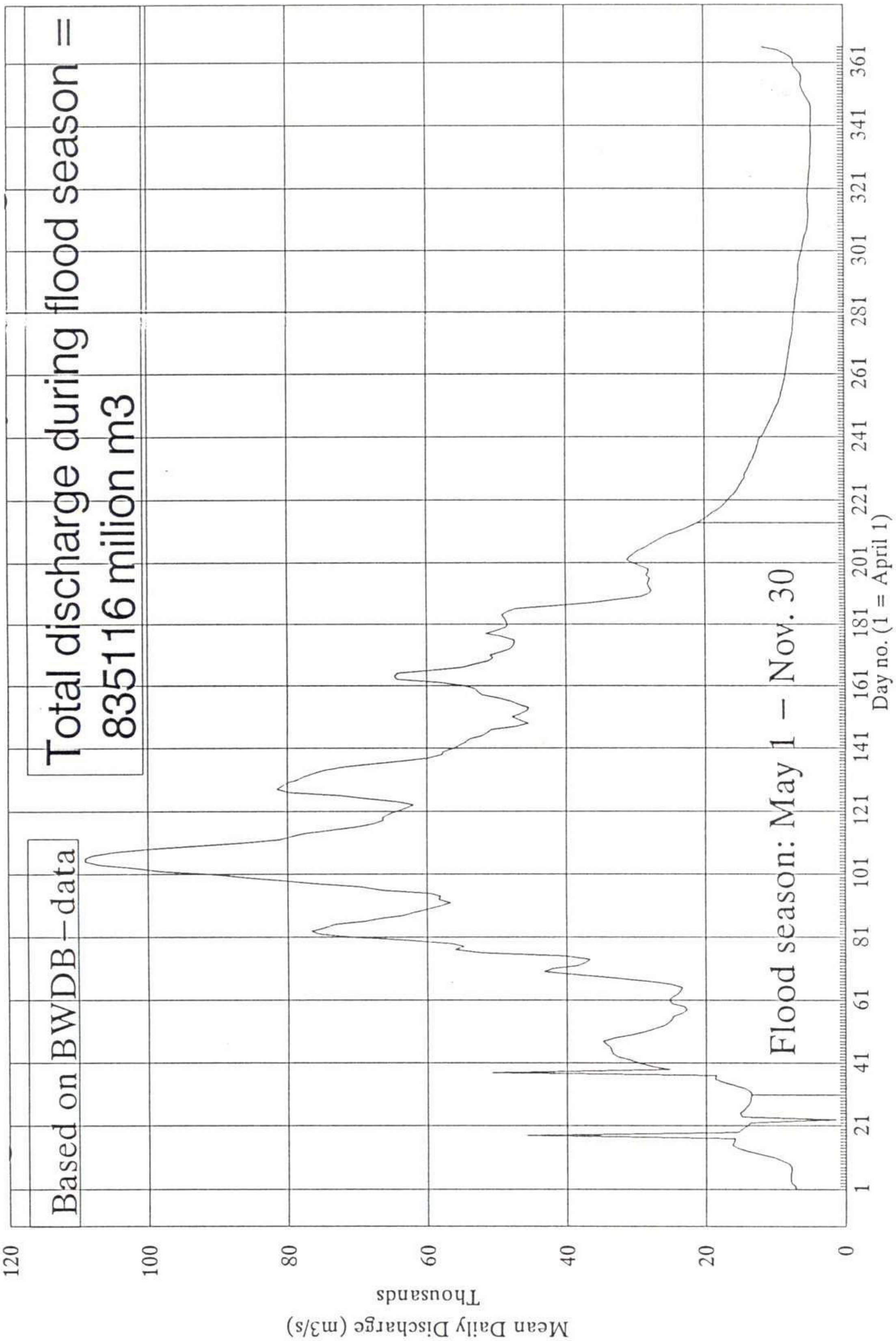
FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Bahadurabad, discharge volume of flood season*	
File:	Date:	1° Interim Report February 1993	Fig. 6.12b
Scale:	Inlt:		



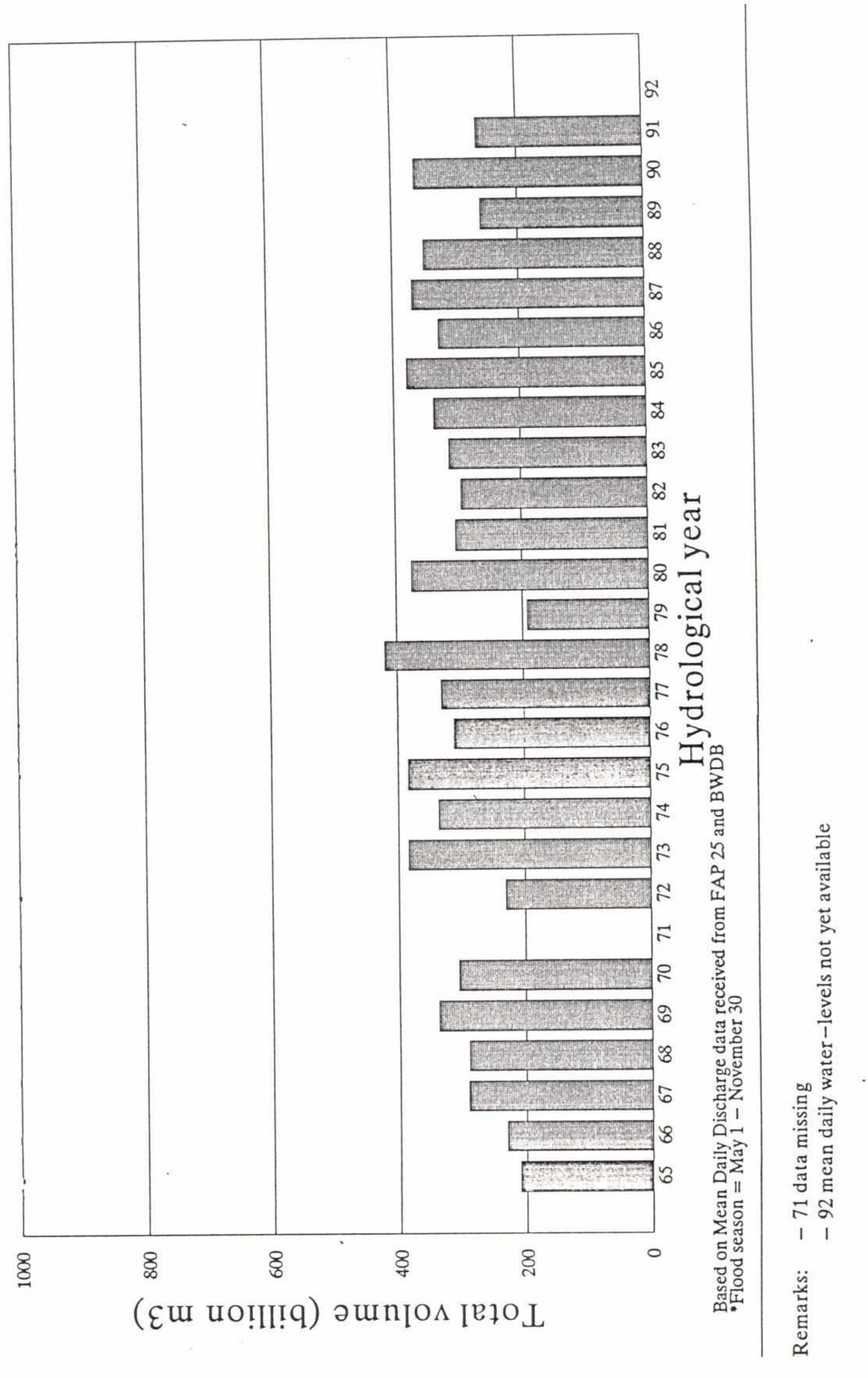
FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Mean daily water-levels at Bahadurabad	
File:	Date:	1° Interim Report February 1993	Fig. 6.12c
Scale:	Inlt:		



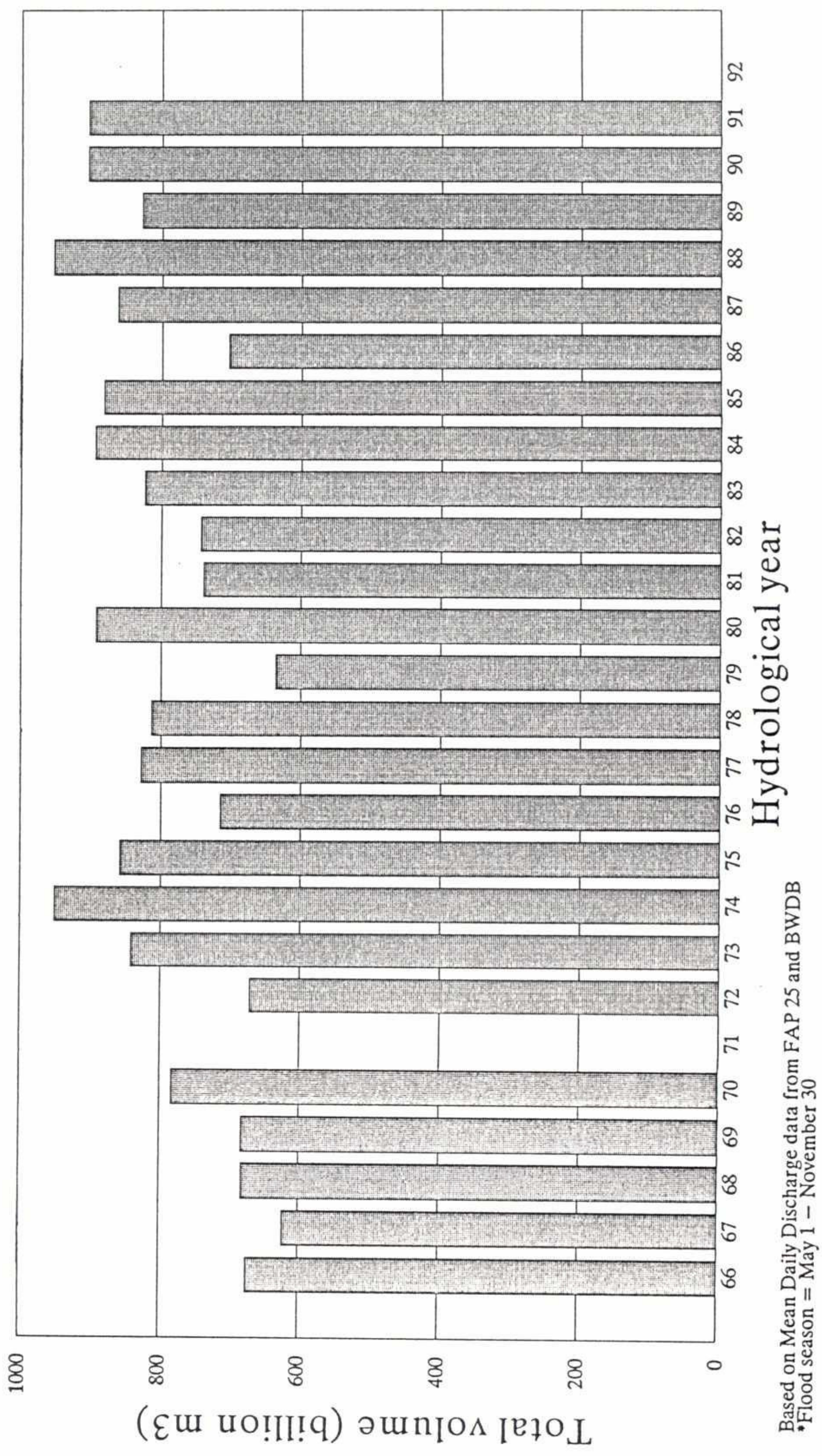
FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Bahadurabad mean deaily discharge, 1988	
File:	Date:	1° Interim Report February 1993	Fig. 6.13
Scale:	Inlt:		



FAP 24 DELFT-DHI	**RIVER SURVEY PROJECT** Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland	Bahadurabad mean daily discharge, 1991	
File:	Date:	1° Interim Report February 1993	Fig. 6.14
Scale:	Inlt:		



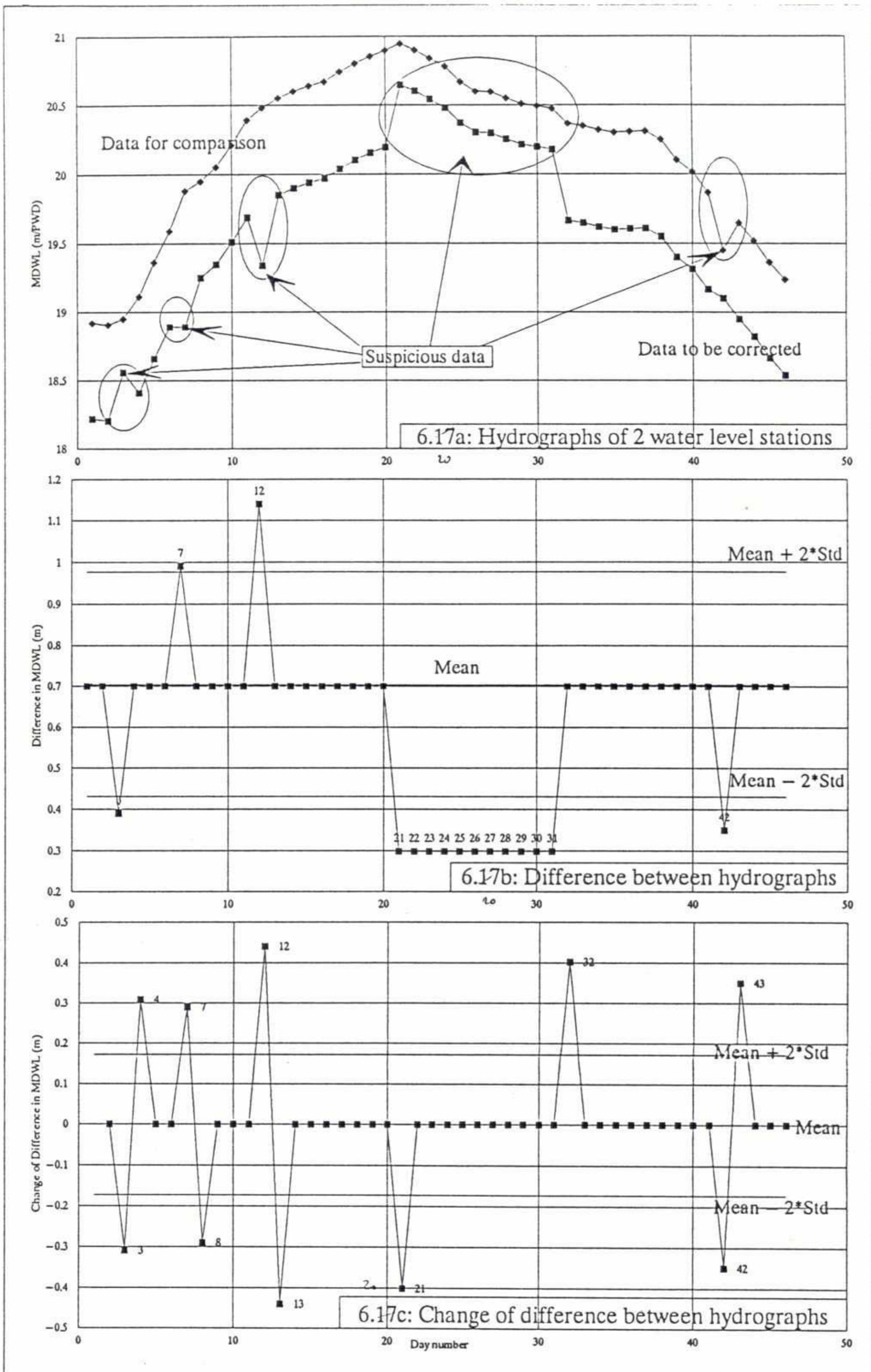
FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Hardinge Bridge, discharge volume of flood season*	
File:	Date:	1° Interim Report February 1993	Fig. 6.15
Scale:	Inlt:		



Based on Mean Daily Discharge data from FAP 25 and BWDB
*Flood season = May 1 – November 30

Remarks:
- 71 data missing
- 79 volume based on FAP 24 provisional rating curve and BWDB mean daily water–levels
- 92 mean daily water–levels not yet available

FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Baruria, discharge volume during flood season*	
File:	Date:	1° Interim Report February 1993	Fig. 6.16
Scale:	Inlt:		



Remarks: Plots in this illustration do not cover a whole year's data.
However, values for the mean and the standard deviation are based on a full year.

FAP 24 RIVER SURVEY PROJECT Delft Hydraulics/Danish Hydraulic Institute in association with Osiris/Approtech/Hydroland DELFT-DHI		Illustration of procedure of water-level checking	
File:	Date:	1° Interim Report February 1993	Fig. 6.17
Scale:	Inlt:		

98

Annexure 7

Morphological studies

7. Morphological studies

7.1 Introduction

In this annexure the morphological studies to be carried out under FAP 24 are discussed in more detail than was possible in Chapter 6 of the Main Report. Still however these studies to be performed under Phase 1 and Phase 2 have not yet been elaborated in full detail. This is the case for two reasons. First of all until now the expatriate morphologist has worked on the project only for one month, concentrating ititially on measuring methods (as reported upon in Annexure 4) and on the validation of the historical data only. Secondly it is not possible in this stage to elaborate already in full detail the approach to be taken for the study topics for Phase 2, because still many discussions have to be held with involved parties (FPCO and its Panel of Experts, the other FAP's, SWMC, etc.).

Here a short overview is given of the activities carried out until now. A distinction is made between the validation of the historical data, including a critical review of the measuring methods used, and a review of the reports and other literature found. These are discussed in the Chapter 7.2 (notably the Sections 7.2.1 and 7.2.2). Furthermore the process of identifying and selecting topics for study under Phase 2 has been initiated. Some details are given in Chapter 7.3. One study topic has to be taken up already in Phase 1: the overall impact of the FAP's on the morphology of the main rivers. The first activities under this study topic are described in Section 7.2.3, where both the approach to estimate the ultimate effects and the approach for the coming say 50 years are discussed. As only a start could be made with the morphology studies in the months January and February and the bulk of the activities still has to be carried out, an overview of the remaining activities for Phase 1 is given in Sections 7.2.4 and 7.3.5. The first implications of the morphology studies for the surveys, especially the requirements on the basis of our own studies and the requirements derived from discussions with the other FAP's is presented in Chapter 7.4.

7.2 Study programme Phase 1

7.2.1 Validation of morphological data

Morphological data are available in Bangladesh in different formats and at different places. One of the important issues under the Phase 1 studies is that these data have to be reviewed and validated. This means that first of all the availability of the data has to be established and next their quality has to be discussed.

Availability of data

In this first stage we have attempted to get an overview of the availability of data that are related to the morphology of the rivers in Bangladesh. In Table 7.1 an overview is given of the most relevant morphological data on the main rivers in Bangladesh, as far as identified until now. Data on stages, discharges and slopes, though essential for river morphology, are discussed in Annexure 6.

Type of data	Organization			
	BWDB	RRI	BIWTA	Others
Planform characteristics			Charts since 1966	Satellite images (Jamuna Bridge studies, FAP 1, FAP 9B, FAP 19, FAP 21/22
Bed material	Hydrology-2	Report on grain size analysis		FAP 1, FAP 4(?) FAP 9B
Cross-sections	Morphology Department since 1966			
Bed topography	Detailed soundings		Chats since 1966, BIWTA (1989)	FAP 1, FAP 21/22
Sediment transport	Hydrology-2			FAP 1
Composition of transported sediments	Hydrology-2; coarse/fine	Reports on size analysis		
Bank material				FAP 1

Table 7.1 Availability of data on the main rivers in Bangladesh

It should be noted here that these data are not available for all rivers concerned and for every year starting the measurements. Part of these data are computerized and available in databases. We are in the process of acquiring the most relevant data.

Validation of morphological data

In this early stage we have limited ourselves to data on sediment transport in the major rivers of Bangladesh. Some early observations are given below. It is stressed that some of the preliminary conclusions still have to be verified. We are presently in the process of doing this.

To predict morphological processes of the rivers, one needs information on both suspended load movement and bed load transport. No effort has yet been made to estimate bed load movement. It has been felt during various studies that there are inconsistencies in the data of measured suspended sediment transport which could not be explained. FAP 24 will try to identify those discrepancies and will come up with possible explanations, possibly allowing that collected data could be used for morphological prediction. The final result of the validation of sediment data are described hereafter.

Review of existing studies on sediment analysis

Information on a wide variation of the yearly sediment transport loads is given in Table 7.2 as is estimated (Bruk, S., March 1992) from the short inspection of the data contained in the available references.

River/Station	MPO	FEC	Coleman	China / Bang Rep
Brahmaputra/ Bahadurabad	387	431	607	499
Ganges/ Harding Bridge	212	338	478	196
Padma/Mawa	563	769		581

Table 7.2 Sediment load (in million tons per annum)

As established in the report (China-Bangladesh Joint Expert Team, March 1992), the relation between the daily sediment transport rate and daily discharge from 1968 to 1980 for Bahadurabad station, reflects remarkable variations of the relation from year to year. The average correlation coefficient is 0.887. This report indicates that the period 1968-70 suggest a significant higher sediment transport than for the 1982-88 data. It is also noticed that most sediment transport models predict transport rate which agree better with the 1968-70 data than with the 1982-88 data. Above explanation are based on the analysis of available coarse suspended sediment transport.

It is estimated in the report (China-Bangladesh Joint Expert Team, March 1992) that the average annual sediment load at Mawa station is much higher than that of Baruria station without any reasonable explanation. This is strange as both the stations are on the Padma river.

The report (FAP 9B, March 1990) on Meghna River Bank Protection mentioned that only a limited number of data on suspended coarse load are available for the Upper Meghna. Also no records are available for the Lower Meghna river.

FAP 6 has analysed sediment data for Bhairab Bazar and found them very unreliable and scattered. No correlation Q_{water} vs. $Q_{sediment}$ could be established.

Availability of sediment data

It is mentioned in many studies that sediment data are collected since 1968 but going through sediment reports in Hydrology II, it is apparent that the data collection was started in 1957 at Bahadurabad Station and later years for other stations. Actually the present method of suspended sediment collection with the aid of Brinkley Sampler started since 1966.

Stations which are important for morphological studies under FAP 24 are shown in Table 7.3.

Sl.No	Station name	River	Station No
1	Bahadurabad	Brahmaputra-Jamuna	46.9L
2	Hardinge Bridge	Ganges	90
3	Goalundo	Ganges	91.9R
4	Pakshy	Ganges	89.9L
5	Baruaria	Padma	91.9L
6	Mawa	Padma	93.5L
7	Gorai Railway Bridge	Gorai-Modhumati	99
8	Jagir	Dhaleshwari	68.5
9	Mymensingh	Surma-Meghna	228.5
10	Bhairab Bazar	U Meghna	273
11	Sheola	Kushiyara	173

Table 7.3 Sediment measurement station

The Table 7.4 shows a tentative overview of the availability of measured sediment data for different stations with Hydrology II, BWDB.

Year	Station its Number and name of the river										
	Bahadba 46.9L Jamuna	Har.Brg. 90 Ganges	Baruria 91.9L Padma	Goaland 91.9R Ganges	GoraiR.B 99 Gorai	Mawa 93.5L Padma	Mymensi 228.3 O-Brah	Bhal.Bzr 273 U Meghn	Jagir 68.5 Dhalesh	Sheola 173 Kush	Pakshy 89.9L Ganges
1957	T*										
1958	T	T								T	
1959	T*	T						T			
1960	T	T		T	T		T	T		T	
1961	T	T			T		T	T		T	
1962	T	T			T		T	T		T	
1963	T	T			T		T	T		T	
1964	T	T		T	T		T			T	
1965	T				T						
1966	C Fm	C		C Fm	C		C Fm				C
1967	C Fm	C		C Fm	C Fm		C Fm		C Fm		C Fm
1968	C Fm	C	C Fm	C Fm	C Fm	C	C Fm		C Fm		C Fm
1969	C Fm	C	C Fm	C Fm	C Fm	C	C Fm		C Fm		C Fm
1970	C Fm	C	C Fm	F	C Fm			F*		C F	C Fm
1971	F	F			F	F	F		F		F
1972	F		C F	F		F	F	F	F	C F	
1973	F	F	C F	F	F	F		F	F		F
1974	F	F	C F	F	F			F		C F	F
1975	F	F	C F	F	F	F	C F	T		C F	
1976	F	C F	C F	C	F	C F			F		
1977			C	C		C					
1978	F	C F	C F	C F	F	C F		F	F		
1979		C	C			C					
1980	F	C F	C F	C F	F	C F		F		C F	
1981	F	C F	C F	C F	F	C F		F		C F	
1982	C F	C F	C F	C F	F	C F				C F	
1983	C F	C F	C F		F	C F		F		C F	
1984	C F	C F	C F		F	C	F	F		C F	
1985	C F	C F	C F		F	C	F	F		C F	
1986	C F	C F	C F		F	C		F			
1987	C F	C F	C			C		F			
1988	C F	C F	C			C	C	F			
1989	C	C	C		C	C	C				
1990	C		C				C				
1991	C		C								
1992	C										

Note:
C - Coarse suspended sediment
F - Fine suspended sediment < 60 microns
T - Totat suspended sediment
* - No discharge (Water) measurement
Fm- Monthly fine sediment transport
In most cases data are not available for all the months of a year

Table 7.4 Tentative suspended sediment data available with Hydrology II

Sediment data which are supplied by Hydrology II to FAP 24 as an computer output are indicated in Table 7.5.

Year	Station and river name				
	Bahadbad 46.9L Jamuna	Baruria 91.9L Padma	Goalando 91.9R Ganges	Mawa 93.5L Padma	Mymensing 228.3 Surma
1968	C	C		C	
1969	C	C		C	
1970	C	C			
1971	F				
1972	F	F			
1973	F	F			
1974	F	F			
1975	F	F			
1976	F	C	C	C	
1977		C	C	C	
1978	F	F	C	C	
1979		C		C	
1980	F	C	C	C	
1981	F	C	C	C	
1982	C F	C	C	C	
1983	C F	C F		C	
1984	C F	C F		C	
1985	C F	C F		C	
1986	C F	C F		C	
1987	C F	C		C	
1988	C F	C		C	C
1989	C	C		C	C
1990	C				C
1991	C				
1992	C				

Note:
C - Coarse suspended sediment
F - Fine suspended sediment < 60 microns
T - Totat suspended sediment
In most cases data are not available for each months of a year

Table 7.5 Sediment data supplied by Hydrology II

Comparing Table 7.4 and 7.5, it is evident for Bahadurabad station, that the measured data in Table 7.5 for the period 1968-70 are only coarse sediment whereas Table 7.4 indicates both coarse and fine sediment for the same period. Hence, one of the reasons for the discrepancy mentioned earlier between the two periods can be explained as follows: A recent review of sediment data in Hydrology II, BWDB, reflects that the sediment data which is published for the period 1968-70 is for both coarse and fine sediment transport, whereas for the period 1982-1988 it is for coarse suspended sediment. The fine suspended sediment data for the period 1982-88 has been published by the River Research Institute later on, and these are not considered in the analysis. Therefore this could be the reason of higher sediment transport in 1968-70.

Measurement of suspended sediment transport

The Binkley Sampler (Figure 7.1) is being used by BWDB for catching suspended sediment in the river.

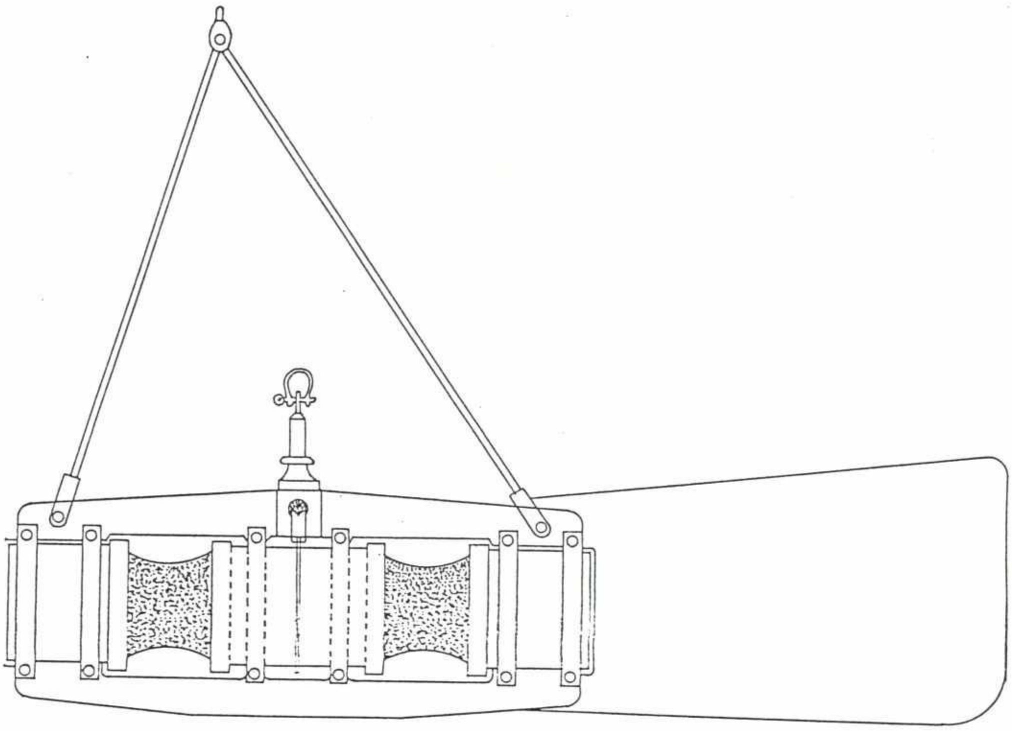


Figure 7.1 Brinkley Sampler

The Straub method is being followed for determination of average sediment concentration. In this method samples are taken at 0.2 and 0.8 depth and the values are weighted 5/8 and 3/8 respectively as given below:

$$\overline{C_m} = \frac{3}{8}C_{0.8d} + \frac{5}{8}C_{0.2d}$$

In which $\overline{C_m}$ = the sediment concentration in mg/l averaged over the vertical.

The sampler is lowered to a required depth. After entrapping sediment mixed water the sampler is closed and raised to the surface, opened and emptied into the elutriator where coarse and fine sand are separated.

In order to avoid large drag angles due to relatively high river velocity, the gauging craft is to be taken to a point a short way upstream of the transit line and then speed is reduced with the craft heading upstream and the instrument lowered to the required depth. The craft is then allowed to drift slowly backward across the transit line and then the sample is closed. In this way the drag angle is minimized.

Sediment samples are collected from alternate verticals at which velocities are measured. The weighing and computation of sediment load are carried out at field level. Suspended discharge is calculated by multiplying the dry weight for the vertical by the liquid discharge of the two adjacent pockets. The dry volume is determined with the aid of the specific gravity bottle.

Some possible sources of error

In the whole process from sediment sampling until calculation of sediment discharge, there are many possibilities in particular where any mistake can give erroneous result. The following sources are discussed here:

- Drag Angle:
  It was noticed by SWMC that, while entrapping a sediment sample, the cable of the Brinkley sampler was making an angle with the vertical due to current and therefore the required depths (0.2 and 0.8 times water depth) for sampling were not reached. As a consequence of this, the rate of sediment transport will be lower than in reality
- The Straub method:

This method has been developed for Missouri river, having a moderate slope. It is best suited where the vertical sediment distribution curve approximates a straight line and the velocity distribution is fairly constant. If the sediment distribution is logarithmic, this method is not sound theoretically. The accuracy and reliability for calculating the concentration is completely depending on the agreement between the actual and the assumed sediment and velocity distribution

o Separation of fine and coarse sediment:
The elutriator is used to separate suspended bed load transport by allowing sediment to fall for 100 seconds. This method provides a cutoff at around 0.05mm to 0.06 mm for 1 litre sample. This 100 seconds has been determined by tests which can be called as "force of circumstances" have not been to laboratory standards. It was observed that after testing one sample the elutriator was not cleaned and within the previous sample (with fine particles), the new sample was poured and thus it will give faulty result.

After separation of coarse sediment, the samples are contained in a series of glass tubes in reference racks. It was also noticed that no reference tag was maintained on the rack

o Weighing by specific gravity bottle:
Transfer of sample from glass tube to the density bottle might be difficult

o Selection of verticals:
Suspended sediment discharge is computed by summing the products of q_s and section width for each of the verticals. Proper arrangement of the verticals in the cross-section has considerable influence on the accuracy if the transverse sediment distribution is uneven.

There are different methods for selecting verticals. Going through the field sheets in Hydrology II, neither equidistant nor equidischarge method is followed for selection of verticals

o Condition of instruments:
Dirty and rusty instrument can give wrong results.

A fairly complete list of possible sources of error in sediment transport data is given hereafter:

o Instruments:
- performance and efficiency sampler

- condition sampler
- determination of vertical position
- determination of concentration
- determination of size distribution (both fine and coarse sediments)

o Methods:
- "duration" of measurement in one point
- number of verticals
- numbers of points in the vertical
- location on dune in longitudinal direction
- separation between bed material and wash load

o Processing:
- adjustment factors (including different assumptions for diffusion coefficient)
- unsampled zone
- effect of dune
- computation of load from discharge
- entering into database

Typically these different sources of error will be investigated over the coming months. A list of proposed activities in this respect is given hereafter:

o Visit of field measurements BWDB and inspection of processing
o Discussion with local staff (also retired ones!)
o Discussion with staff in Hydrology office (do), inclusive inspection of the data procession + entering into database
o Random checks on data processing and data storage
o Theoretical study on concentration verticals (correction factors, literal diffusion)
o Very detailed measurements allowing to study numbers of point in a vertical and number of verticals (and duration?)
o Assessment of accuracy of the measurements (studying all absolute and relative errors and "summing up")
o Comparative measurements between BWDB and FAP 24
o Entering in own database, and analysis on outlets, trends, etc.
o Sediment balances
o Comparisons with changes in average bed levels

A critical review of data was started recently with checks on the sediment transport rates. Some older and more recent data are being entered in a first version of the data storage and processing program MORDAT, that in due time can be linked to the hydorlogical data handling package HYMOS.

The program MORDAT allows to compare sediment transport data mutually and to compare them with sediment transport predictors. In the present applications the measured sediment transport rates per vertical were used. From the original measuring forms these observed sediment transport rates can be obtained. Because also the depth and the partial discharge is given it is possible to link the sediment transport to the depth and also to compare it with e.g. Engelund-Hansen sediment transport predictor. Some results are presented in Figure 7.2, where predicted sediment transport rates are plotted versus the observed sediment transport for the year 1982 and for a more recent year 1992.

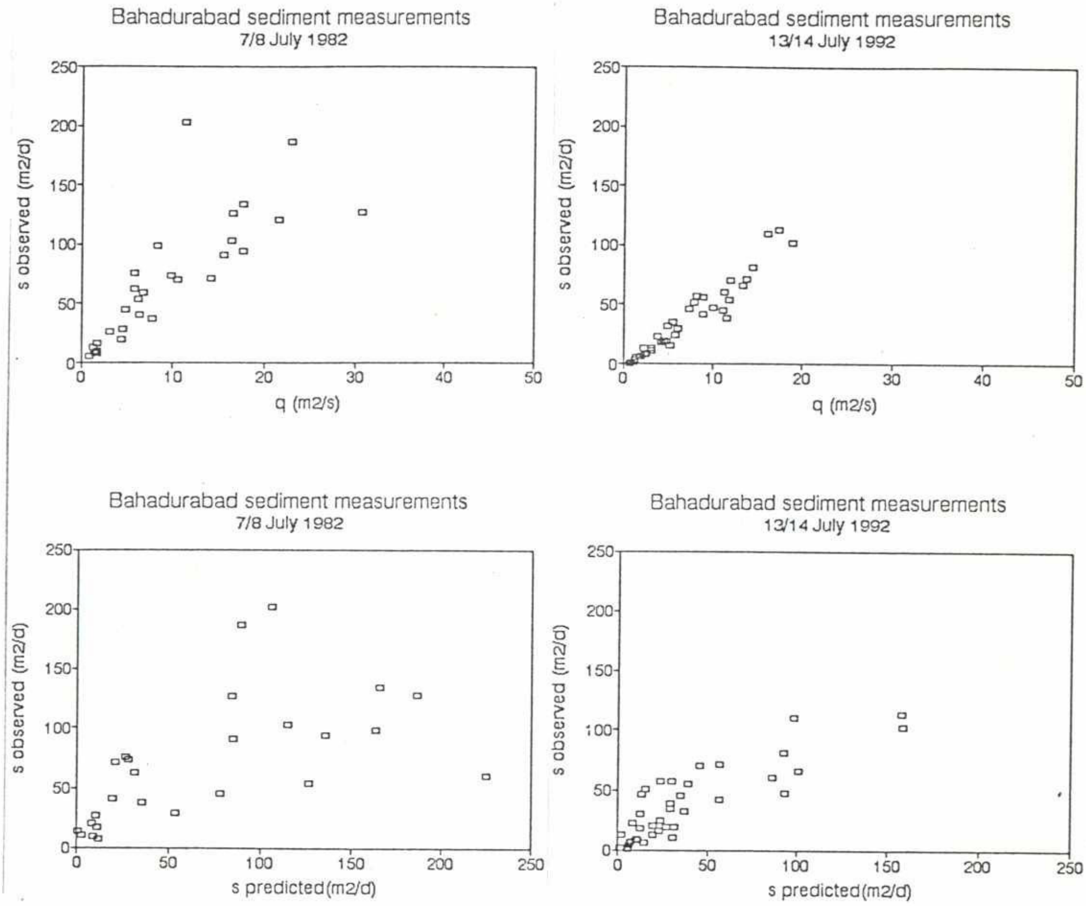


Figure 7.2 Analysis of sediment transport data at Bahadurabad

It has been observed that the sediment transport rates in 1968 were about 4 times larger than recent transport. This observation was made during the Jamuna Bridge Study and later by FAP 1. A possible cause for this discrepancy was already discussed before (the older data are probably total loads, while the more recent data are for the sand fraction alone. We intend to investigate this discrepancy in an attempt to make maximum use of the data collected in the past. Similar investigations will be carried out for the other stations where sediment transport is being measured.

In a further step also the various cross-sectional data will be assessed via a number of checks. In doing this due attention will be given to the bench-mark histories as available with the Hydrology Department of BWDB. In addition an attempt will be made to mutually compare the cross-sections of BWDB with soundings of BIWTA. To do this a selected set of cross sections and soundings will be acquired and processed. In a later stage also other morphological data will be assessed as far as their quality is concerned.

7.2.2 Review of relevant studies

Over the past decades many studies have been carried out on the different main rivers in Bangladesh, mostly within the frame-work of feasibility studies or design of structures. In Table 7.6 an overview of the most relevant studies is given for the different rivers. In many of these reports the basic data as listed in Section 7.2.1 have elaborated, though a formal quality check was often not carried out.

River	Consultancy report
Ganges River	Nedeco (1968), Rehabilitation Ganges-Kobadak project (1983), FAP 4 (1993)
Brahmaputra/Jamuna River	Nedeco (1968) JICA (1976), Jamuna Bridge (1986, 1987), FAP 1, Bangladesh-Chinese Joint Investigation Team (1991), Char land study = FAP 3.1 (1992), FAP 21/22 (1992, 1993)
Old Brahmaputra/Lakhya River	Nedeco (1968), FAP 3 (1993)(?) FAP 6 (199)(?)
Dhaleshwari River	Nedeco (1968), Jamuna Bridge (1990), Dhaleshwari Mitigation Study
Upper Meghna River	Nedeco (1968), FAP 9B (1992)
Padma River	Nedeco (1968), FAP 9B (1992), FAP 4 (?)
Gorai River	Nedeco (1968), FAP 4 (1993)
Arial Khan/Dubaldia River	Nedeco (1968), FAP 4 (1993)

Table 7.6 Most important consultancy reports dealing with the main rivers in Bangladesh

In addition a number of publications (to start with the bench-mark paper of Coleman (1969)) have been identified as far as relevant for the project these are in the process of being collected.

7.2.3 Impact assessment of FAP

General

In the Terms of Reference it is specifically indicated that in Phase 1 a first assessment has to be made on the overall impact of the combined FAP projects as far as their morphological consequences is concerned. To make such an assessment it is required to have a basic understanding of the morphology of the main rivrs. For this it is also required to understand the hydraulic conditions during floods and during lower discharges, as the hydraulic conditions trigger the morphological changes. Hence the first attempt will be to integrate all available knowledge on the hydraulics and, in a second step, on the morphology of the main rivers in Bangladesh. Attention will also be given to the bifurcations where the water and sediment is distributed and to overland flow as a possible sink and source in the system. In addition attention will be paid to the sedimentation of fine sediments on the floodplains of the rivers and to what extent this balances possible subsidence due to tectonic effects.

Once such a basic understanding has been acquired (the level of understanding of course depending on how well the data on the rivers match), the different scenario's for river development under FAP will be assessed as far as their impact is concerned. It is intended to do this in a two-step approach. In the first step the ultimate effects will be assessed. In the second step a 1-dimensional morphological model will be applied to study the effects of all the FAP projects in combination.

Ultimate effects

In the first step the ultimate effects will be assessed. For the time being it is intended to use the approach which has been developed under FAP 21/22. This approach has the advantage that in addition to changes in water depth and slope also the effect on the width of the channels, the planforms, the braiding and meandering characteristics can be estimated.

Some details about the method proposed to apply are given hereafter. In particular some of the emperical equations were used, which were developed especially for the Jamuna River, but these can be used with proper modifications to the other main rivers in Bangladesh as well. The philosophy behind the development of such prediction method was that if and when possible a theoretically based predictor should be used, but if not available an emperical predictor would be applied. Here also a Table is copied from the FAP 21/22 report, (1) to clarify the step taken in the development, and (2) to indicate which parameters were considered as independent and which as dependent, and which equations are used in the method (ref. Table 7.7).

The method applied here can be summarized as follows:

- o Prediction of slope of river for given Q, V (the sediment transport integrated over the year) and D, via:
  - the continuity equation of the water, which in elementary form read as:

    $$Q = B\,h\,u$$

    but which for bankfull conditions and for k channels read as:

    $$Q_b = k\,U_b\,h_b\,B_b$$

  - the sediment transport equation via:

$$S_b = \frac{V}{\alpha_Q * 365 * 86{,}400}$$

$$S_b = \frac{S_b}{B_b\,k}$$

and

$$S_b = \alpha_s \sqrt{g \; \Delta \; D^3} \; \frac{0.05}{1 - \epsilon} \left(\frac{h_b \; i_b}{\Delta \; D} \right)^{\frac{5}{2}} \frac{C^2}{g}$$

- the equation of motion for the water which for uniform steady flow reads as:

$$u_b = C \sqrt{h_b \; i_b}$$

- a hydraulic roughness predictor
  $C = C\,(h,\, i_b,\, \Delta,\, D,\, \ldots)$
- a regime equation for the width, for which the Jamuna predictor is taken:

$$B_b = 16.1 \left(\frac{Q_b}{k} \right)^{0.53}$$

o Prediction of the sinuosity via:

$$p = \frac{i_v}{i_b}$$

o Prediction of the total width of the braided system via:

$$B_t = 2\,k\,A + B_b$$

where

$$\lambda = 10\, B_b$$

and λ (and α) are determined via geometric relationships:

$$\alpha \;via\; P = \frac{\alpha}{\sqrt{2(1 - \cos\alpha)}}$$

and

$$A = \frac{\lambda/2}{\sqrt{2(1 - \cos\alpha)}} \; (1 - \cos\alpha)$$

ᒍ8

Step number	Parameters			Equations			
	Independent	Dependent	Additional independent	Theoretical	Emperical	Additional theoretical	Additional emperical
1: fixed bed width fixed straight channel	Q,B,D, i_b	C, u, h		Continuity equation Equation of motion	Nikuradse roughness Chézy coefficient as function of roughness height		
2: movable bed, width fixed, straight channel	Q, B, D, i_b	C, u, h, s,		Do	Nikuardse roughness not applicable; instead to be used alluvial roughness predictor		
2a: movable bed, width fixed, straight channel, but now slope as independent variable	Q, B, D, S	C, u, h, i_b		Do	Do		
3: as 2a, but with width as dependent variable	Q_b, D, V	Q_b, C, u, h_b, i_b		Do	Do		Regime equation for width
4: as 3, but with curved channel	Q_b, D, V	B_b, C, u, h_b, i_b, p	i_v	Do	Do	Geometrical equation for sinuosity	
5: as 4, but with more than 1 Channel	Q_b, D, V, i_v	B_b, C, u, h_b, i_b, p, k		Do	Do	Do	Number of channels k maximum
6: as 5	Q_b, D, V, i_v	B_b, C, u, h_b, i_b, p, k B_t				Geometrical relation for total width	Meander length as function of e.g. discharge

Table 7.7 Development of prediction method for response of Jamuna River

o Repeated computations for different values of k until the maximum value of k is found for which still the sinuosity p is (slightly) above 1.

The following remarks (also partly copied from the FAP 22 report) are made regarding the development of the method used here:

- o Steps 1 through 2a in Table 7.7 correspond to the "normal" non-disputed approach, although it involves two emperical relations, notably analluvial roughness predictor and a sediment transport predictor. The difference between step 2 and 2a is the selection of dependent and independent parameters
- o The steps 1 through 2 are valid for any value of the discharge. Accepting the slope of a river as a dependent varianble can only be done if an equation for the slope is used . Here "dominant" conditions are considered and for the time being the bankfull discharge is accepted here as dominant discharge for the channel dimensions. Hence

$$B_b = f\,(Q_b)$$

- o In the equations a factor α_Q is applied. This factor represents the influence of the hydrograph. Usually less sediment is transported over a whole year if the full hydrograph is considered compared with the case that the dominant discharge would be present during the whole year. Hence the sediment transport during bankful discharge is determined by dividing the average sediment transport over the year by the factor α_Q, which is always less than 1
- o The calibration factor α_S takes care for the deviation of the actual transport compared with sediment transport predictors. For the Jamuna River it was found that α_S corresponds to about 2.75, but for other rivers this factor can be different
- o The equation for the total width is derived from geometrical considerations (see Annex 1 of Final Report of FAP 22, Figure 7-14). It is felt that this corresponds to the minimum total width. The presence of permanent chars would increase the total width of the braided system. It would also mean a transition to a more anastomosing system
- o From the sinuosity the amplitude A of the curved channels can be determined. Also this is related to geometry (see Annex 1 of Final reportof FAP 22, Figure 7-15). The used equation holds only for real circles, but is probably a good approximation for low sinuosities
- o An important parameter is the wave length as this wave length determines the total width. It would be logic to relate the wave length λ to the bankfull discharge Q_b, but such a relation is not available. From the literature some relationships between the wave length λ and the channel width B_b are available (see e.g. Leopold et al, 1976 or Jansen 1979). Here a relationship proposed by Leopold & Wolman (1960) is used. This relation reads:

$$\lambda = 10.1\, B_b^{1.01}$$

In FAP 22 a simplified expression was proposed, reading

$$\lambda = 10\, B_b$$

In combination with the regime equation for the width this formula can be read as:

$$\lambda = f\left(\frac{Q_b}{k}\right)^{0.53}$$

Hence, for a given value of Q_b the wave length λ is a function of k only.

In addition the following observations are made, based on a further reflection of the method described above

- o In the method presented the valley slope is considered as an independent variable, while the sinuosity and the number of channels being variables depending of this valley slope. It may be argued however that the sinuosity of a river system is determined by how quickly cutoffs take place (at which cutoff ratio see Klaassen & van Zanten, 1989). Hence it would be determined by a combination of the valley slope and the consistency of the floodplain which in itself again is a function of the washload and bed material characteristics. The reasoning would then be that the river is increasing its valley slope, until the perferred sinuolity corresponds to the ratio between the ultimate valley slope and the slope of the river. It is intended to explore this avenue of reasoning over the coming months
- o As independent variable still the bankfull discharge has to be imposed on the method. We are presently considering whether it is possible to determine the bank full discharge also as a dependent variable
- o In applying the method to other rivers a more simplified approach is possible as these rivers are meandering ones

The above method still needs to be calibrated before it can be applied to estimate the response of the river system to the river training scenarios. Overviewing the method above the following independent input data are needed:

- o Bankfull discharge Q_b
- o Frequency distribution of the discharges f(Q) to determine α_Q (for

the time being it is assumed that all discharge is conveyed in the channels, neglecting the flow in the floodplain and over the chars; this is the first good approximation and would if assumed otherwise only result in a slightly different value of α_Q)

- o Yearly volume V of bed material load to be transported
- o Characteristic particle size of the bed material D
- o Valley slope i_v

The dependent variables for freely flowing river systems are the hydraulic roughness C (in principle a function of Q), the bankfull depth h_b, the bankfull width B_b, the number of channels k, the average slope of the channels i the sinuosity p of the channels, and the (minimum) total width B_t of the river. Checking the equations proposed above for the prediction of the river behaviour, it can be concluded that there is only one calibration parameter left,notably α_S. Hence a value of α_S has to be found that results in all dependent values to obtain fair values. This is less risky than it seems because for some of the dependent variables (roughness, sediment transport, width) relationships are proposed that will be derived on the basis of emperical data.

Once the method has been verified and calibrated for the other rivers in Bangladesh it can be applied to estimate the impact of the combined FAP's proposals. In doing this different scenario's of development will have to be used.

Intermediate effects

In the second step a 1-dimensional morphological model will be applied to study the effects of all the FAP projects in combination for intermediate conditions also. This implies that not only the ultimate consequences of the combined FAP projects are determined, but also their development in time. Discussions with SWMC are on-going to assure their assistance and to establish the main characteristics of the mathematical model to be used. For the time being a fairly simple model will be used, while it is intended to study in Phase 2 the effects of the FAP projects in combination in more detail. It has to be remarked that a full-fledge simulation of the impact of the FAP's in combination appears to be far in excess of the study capabilities of FAP 24, even in Phase 2. Hence the recent conclusions of the CAT-mission, calling for adding a morphological component to FAP, are underscored here.

An important aspect for a 1-dimensional model is which scenario's have to be used for the impact assessment. For the time being some scenario's as used by FAP 25 for the simulation of the hydraulic impacts will be used. In the discussions with the different FAP project, as carried out under the activities described in Section 6.5, it is also verified to what extent the different scenario's are still providing a fair reflection of the current ideas within the various projects. In this respect it is important to realize that for morphological modelling a scenario should not only comprise a number of possible natural developments and possible projects, but also the timing of their implementation. The reason for this is that morphological changes take quite some time to reach their full magnitude (decades and centuries rather than months and years). Hence this matter will be approached in a way similar to the Jamuna Bridge Study, where scenario's were used consisting of measures (like embankments and major diversions) and "natural" developments (like sea level rise) and when they become effective and/or noticeable in time.

7.2.4 Further activities

Further activities can be divided in:

- o Review and validation of the historical data on sediment transport and bed topography
- o First assessment of impact of FAP projects on the main rivers of Bangladesh. Hereafter these main activities are divided in a number of sub-activities

Review and validation of the historical data on sediment transoprt and bed topography

The following activities are foreseen:

- o Further identification of available data (bed material, sediment transport, bed topography, planform, etc.)
- o Collection of historical data as indicated above as far as deemed necessary
- o Investigation into methods used in the past, including both the actual measurements and processing
- o Discussion with Hydrology staff (both Hydrology, BWDB and BIWTA) including local personnel on both aspects
- o Draw preliminary conclusions as to the need for improving the measuring methods
- o Store sediment data into database (MORDAT or spreadsheet programs)
- o Analyse stored data as far as trends, consistency, etc is concerned
- o Prepare sediment balances
- o Identify, collect and study (other) reports dealing with sediment

transport, bed topography and sediment balances
- o Draw conclusions as to the reliability of the historical data and their relevance for the studies to be carried out
- o Suggest improvements for the BWDB and BIWTA measurements, which should be sustainable also after the finalization of FAP 24

First assessment of impact of FAP projects on the main rivers of Bangladesh

The following activities are foreseen:

- o Collect FPCO scenario's for future developments of river training, etc.
- o Discussion with FPCO and the other FAP's on the relevance of these scenario's and required improvements, including their phasing in time
- o Selection of most likely scenarios
- o Study methods for assessing the impact of FAP projects
- o Selection of assessment method
- o Make preliminary assessment based on most likely scenario and using selected method
- o Indicate sensitivity on assumptions and basic data
- o Specify need for additional surveys to improve understanding of river systems in Bangladesh and their response to river training

7.3 Study programme Phase 2

7.3.1 Approach

A start was made with identifying the study topics for Phase 2. During preparation of the proposal, FAP 24 had already prepared a tentative list of study topics. This tentative list was slightly extended, further on recent studies in which we were involved and upon screening recent reports prepared by others.

This list was sent to the different FAP projects who could be interested in additional studies, notably FAP 1 through FAP 6, FAP 17, FAP 17, FAP 18, FAP 20, FAP 21/22 and FAP 25, with the request to reflect on these topics. Next, most of the Team Leaders of the FAP projects and also SWMC were interviewed regarding their ideas on the possible study topics and related surveys needed. Also FPCO and its Project Adviser will be interviewed formally and the same holds for the local and expatriate members of the Panel of Experts of FPCO. As these interviews are still going on, no final recommendations could be derived from those.

7.3.2 Possible study topics

During the proposal phase a list was prepared on tentative study topics. This list was included in our proposal in Annexure 6. Here an updated list is presented.

The list in Annexure 6 of the proposal was prepared from the outcome of meetings between the staff of DELFT HYDRAULICS and Danish Hydraulic Institute, which had substantial experience in a number of projects in Bangladesh. At the time proposal was prepared, an insight was obtained from working-experience with the following projects.

- o Ganges Kobadak Rehabilitation Project
- o Jamuna Bridge Project
- o Bangladesh Inland Water Transportation Master Plan Studies
- o Assistance to Surface Water Modelling Center in modelling the main rivers of Bangladesh, as part the General Model
- o FAP 1: Brahmaputra River Training Studies
- o FAP 9B: Meghna River Bank Protection Studies

This experience, together with the suggestions in the Terms of Reference, allowed to prepare an extensive list of tentative study topics.

Since quite some time has elapsed between the preparation of the proposal and the writing of this Interim Report, it seems appropriate to update the list of possible study topics. This is done on the basis of continued experience of Consultants in other projects in Bangladesh and, more recently, on the basis of discussion within the framework of FAP 24. Recent projects of relevance in which Consutalts were or still are involved are:

- o FAP 4: South West Regional Study
- o FAP 21/22: Bank Protection and River Training (Active Flood Plain Management) Pilot Project

The updating has resulted in a total of 39 potential study topics. In Appendix 2 these topics are described in some detail. Furthermore per topic the possible approach and the required study tools, a tentative ranking, the expected results and the required input are listed in addition. In Table 7.8 an overview of the potential study topics is given.

Number	Subject	Sub-number	Topics	Tentative ranking
1	Hydrology	1.1	Water surface slopes	1
		1.2	Water balances	2
		1.3	Changes in rating curves	1
		1.4	Loops in rating curves	1
		1.5	Extrapolation of rating curves	1
		1.6	Overland flow	1
2	Sediment transport and river aggradation and degradation	2.1	Screening and review of existing data	1
		2.2	Sediment balances	2
		2.3	One-dimensional morphological modelling	1
		2.4	Subsidence and sedimentation	2
3	FAP impact on river system	3.1	Formulation of scenario's	1
		3.2	Simulation of river response	1
4	Planform characteristics and channel characteristics	4.1	Planform classification and meandering and braiding characteristics	2
		4.2	Channel dimensions	1
		4.3	Bank erosion rates	1
		4.4	Outer bend scour	1
		4.5	Channel cufoff	1
		4.6	Effect of tectonics on planform characteristics	2
		4.7	Prediction of medium-term planform changes	1
		4.8	Influence of cohesive material on planform characteristics	2
		4.9	Local slope differences and its effect on planform changes	1
5	Bifurcations	5.1	Discharge and sediment transport distribution	1
		5.2	Seasonal variation of deposition and erosion	2
		5.3	Long-term development of river branches	1
		5.4	Influence of bars	1
		5.5	Influence of bed-forms	3
6	Confluences	6.1	Erosion and deposition of out-of-phase floods	2
		6.2	Influence of bars and bed-forms	3
		6.3	Confluence scour	3
7	Sand bars	7.1	Occurance, dimensions and dynamics	1
		7.2	Time dependency	2
8	Bed-forms	8.1	Occurance, dimensions and dynamics	1
		8.2	Time dependency of bed-form dimensions	1
		8.3	Three-dimensionality of bed-forms	2
		8.4	Bed load transoprt via dune-tracking	2
9	Local scour	9.1	Dimensions of local scour around structures	1
		9.2	Time dependency of local scour	2
		9.3	Influence of bed-forms	2
		9.4	Combination with other type of scour	2

Table 7.8 Potential study topics

The tentative ranking was done during the proposal phase on the basis of the experience from the other projects, and does not neceissarily indicate our present preference for study topics under FAP 24. See further Subsection 7.3.4.

Topics 1 and 2, Hydrology and Sediment Transport, are fundamental. They have a high priority and will partly be taken up during the Phase I study. Topic 3, FAP impact on river system, is considered a major task with a high priority for the overall Flood Action Plan. During Phase I of the project this topic has already taken up as to arrive at a preliminary, quantitative assessment of the response of the river system to the implementation of the various flood control schemes. During Phase II the impact simulation will be further developed to arrive at a quantative assessment.

The other study topics are not less important. They will improve the understanding of the specific behaviour of rivers in Bangladesh, which certainly will contribute to the quality of the impact assessment. The priority of these topics also depends on the river study requirements of the other FAP components. For that reason it is already assumed that topic 4, Planform Characteristics and Channel Dimensions, have high priority.

Some of the topics will be looked into by other projects as well, in particular FAP 1, FAP 9B and FAP 21/22. During Phase I of the project the extent to which these topics will be studied by the other projects, will be carefully investigated in order to avoid duplications. Topics covered during Phase I are not included in this Annex. Which concerns topics like data collection and analysis, review of other studies and the establishment of the database.

7.3.3 Selection criteria

It is obvious that not all possible study topics can be addressed within Phase I and Phase 2 of FAP 24. Hence a selection has to be made. For this selection creteria have to be applied. Hereafter follows a list of possible selection criteria:

- Required for the impact assessment of the combined FAP's ("impact criterion")
- Of interest for the feasibility but more often the detailed design phase of the regional FAP's ("regional plan criterion")
- Required for the FAP components that are dealing with bank protection and river training works ("river training cirterion")
- Can be studied in much more detail with the up-to-date surveying

possiblities of the FAP 24 vessels ("availability criterion")
- o Study can be done with fairly low investment in manmonth ("investment criterion")
- o Contribute to a better understanding of the behaviour of the river system ("understanding criterion")
- o Is of academic interest ("research criterion")
- o Is emphasizing the overall behaviour above local phenomena ("aggregation criterion")

Based on these and possibly other criteria, a selection out of the "possible study topics" has to be made.

It is remarked here that the final decision for which study topics will be included can only be made after the workshop on "morphological characteristics of the main rivers in Bangladesh", probably to be held in the fall of 1993. However, it is felt that before the monsoon of this year a pre-selection of study topics has to be made, in order to be able to plan the surveys well in advance, to buy additional instruments if required and to test these during the monsoon period of 1993. However, some flexibility in the selection of the study topics will be kept, even during Phase 2, to be able to re-direct some of the studies if necessity arises.

It is stressed that the study topics should also be used for updating the survey programme for Phase 2. Once the study topics have been established the proposed survey programme for Phase 2 will be scrutinized and if required proposals will be made for adjustments. See also Chapter 7.4

7.3.4 Tentative ranking

In the recent discussions with Team Leaders of the different FAP's their interest in the different possible study topics was sounded out and in addition their reports are in the process of being reviewed. Based on that we have prepared a tentative table (Table 7.9) in which the potential interest of the different FAP's is indicated. This table is the first attempt only and still has to be scrutinized thoroughly in forthcoming discussions.

sub-number	Topic	1	2	3	3.1	4	5	6	9B	16	19	21/22	25
1.1	Water surface slopes	+							+			+	+
1.2	Water balance	+	+		+				+			+	+
1.3	Changes in rating curves	+										+	
1.4	Loops in rating curves	+							+			+	
1.5	Extrapolation of rating curves	+	+	+	+	+	+	+	+			+	+
1.6	Overland flow	+	+	+	+	+	+	+	+	+	+	+	+
2.1	Screening and review of existing data	+		+		+			+			+	+
2.2	Sediment balances	+							+			+	+
2.3	One-dimensional morphological modelling	+	+	+	+	+	+	+	+			+	+
2.4	Subsidence and sedimentation	+	+	+	+	+	+	+	+			+	+
3.1	Formulation of scenarios	+	+	+	+	+	+	+	+			+	+
3.2	Simulation of river response	+	+	+	+	+	+	+	+	+	+	+	+
4.1	Planform classification and meandering and braiding characteristics	+	+	+	+	+	+	+	+		+	+	
4.2	Channel dimensions	+				+							
4.3	Bank erosion rates	+		+	+	+			+		+	+	
4.4	Outer bend scour	+				+			+			+	
4.5	Channel cutoff	+				+			+			+	
4.6	Effect of tectonics on planform characteristics	+							+		+	+	
4.7	Prediction of medium-term planform changes	+							+			+	
4.8	Influence of cohesive material on planform characteristics	+							+			+	
4.9	Local slope differences and its effect on planform changes	+							+			+	
5.1	Discharge and sediment transport distribution	+		+	+	+			+			+	
5.2	Seasonal variation of deposition and erosion	+		+	+	+			+			+	
5.3	Long-term development of river branches	+		+	+	+			+			+	+
5.4	Influence of bars	+		+	+	+			+			+	
5.5	Influence of bed-form	+		+	+	+			+			+	
6.1	Erosion and deposition of out-of-phase floods	+	+						+				
6.2	Influence of bars and bed-forms		+										
6.3	Confluence scour	+							+			+	
7.1	Occurance, dimensions and dynamics	+				+			+			+	
7.2	Time dependency	+				+			+			+	
8.1	Occurance, dimensions and dynamics	+							+			+	
8.2	Time dependency of bed-form dimensions	+							+			+	
8.3	Three-dimensionality of bed-forms	+							+			+	
8.4	Bed load transport via dune-tracking	+							+			+	
9.1	Dimensions of local scour around structures	+							+			+	
9.2	Time dependency of scour	+							+			+	
9.3	Influence of bed-forms	+							+			+	
9.4	Combination with other type of scour	+							+			+	

Table 7.9 Potential study topics and the possible interest of the different FAP's

Some tentative conclusions are:

- o Most of the interest appears to be in the simulation of the river response on local, on more regionalized or country wide scale
- o Also overland flow appears to be an important and until now unsettled issue, that needs further attention
- o More understanding seems to be required into the role of bifurcations in determining the long term the "fate" of different distributaries
- o There are a number of topics that are not of interest for the regional studies, but that are considered very important by the three FAP component dealing with the major rivers: FAP 1, FAP 9B and FAP 21/22

7.3.5 Further activities

As far as the selection of the study topics is concerned, the following activities are foreseen:

- o Discuss possible topics with FPCO, BWDB, SWMC and other institutions
- o Finalize the discussion of the possible topics with relevant FAP's and other projects in Bangladesh
- o Complete list of possible topics on the basis of these discussions
- o Make a priority ranking using the criteria listed in Section 7.3.4 and possibly others
- o Make a first estimate of the time for study and additional survey required for each of the most highly ranked study topics
- o Propose on this basis the study topics to be included in Phase 2
- o Specify need for additional surveys and/or instruments
- o Communicate with BUET, DUT, IHE, University of Leeds and possibly other academic institutions on their possible contribution

7.4 Survey requirements

An important interaction between study and survey is envisaged. On one hand studies are required to support the selection and optimization of applied survey techniques, as discussed in Annexure 4.3. On the other hand the surveys provide the data requirement for various study topics. Besides the data from the routine surveys, also special data may be required to be collected during supplementary surveys. These special additional surveys are the subject of this section.

8D5

7.4.1 Own study programme

Although all interviews with various FAP projects, FPCO and other involved parties have not been finalized, nevertheless a tentative picture emerges from the interviews held until now. This picture can be obtained from Table 7.9. It seems that the following study topics are felt to be important:

- Rating curves
- Overland flow
- 1-d morphological modelling of the main river system
- The prediction of the impact of the total of the FAP projects
- Sedimentation of floodplains and the interrelationship with subsidence
- Offtake and their importance for the main distributaries

In addition there is quite a number of topics that are of particular interest for three FAP projects specifically dealing with river processes and river training/defence works (FAP 1, FAP 9B and FAP 21/22).

Comparing with the tentative measuring programme for the 1993 flood and the subsequent years show that a lot of emphasis is put on measurements of the bed topography at bifurcations, which seems in line with the above importance felt for offtakes as study topic. It may however be that the type of measurements to be done at offtakes is not sufficient. It is felt that the water and sediment distribution at different discharge levels is an important issue. It may also be that not all offtakes should be measured in full detail, the offtake of the Gorai anyhow to be included in the campaign though. Furthermore it is observed that confluences are not considered as an important issue. In this respect a question may be raised whether inclusion of the Ganges-Jamuna confluence together with the Huresegar in the regular measuring campaign should not be reconsidered. The bathymetric survey programme need a critical review.

In this context the bathymetric measurements of May/June 1993 near Bahadurabad are important to mention. The objectives of these measurements are to:

- Test and optimize the bathymetric and topographic measuring techniques (in combination)
- Assess the relevance of water-level slope measurements and elaborate the required survey methods
- Collect special data acquired for morphological analysis
- Collecting data to support the monitoring of a FAP 21/22 test site

More balanced observations on the requirements of the forthcoming survey campaigns can only be made once the various interviews and discussions with the different parties involved have been finalized, and a tentative list of study topics has been drafted. This will be in May of this year. Only then the consequences for the survey campaigns can be assessed. Obviously other demands may emerge afterwards.

7.4.2 Other FAP projects

One of the issues specifically addressed during the interviews with Team Leaders of the different FAP projects was to what extent FAP 24 could assist in the acquiring of data which are vital for the projects involved.

The following suggestions were made:

- Investigations into the sources of sediment depositing in the polders in the South West Region (FAP 4)
- Techniques for measuring flow under conditions that the flow velocities are less than 0.1 m/s, as occurs in the Ganges River during low flow conditions (FAP 4)
- Possibilities for measurements on chars which have heavy vegetation, also in the Ganges River (FAP 4)
- More detail flow measurements in the Old Brahmaputra especially near the offtake in view of drainage problems (FAP 6)
- More detailed sediment measurements in Bhairab Bazar and on nearby tributaries for analysing the downstream conditions of the Northeast region (FAP 6)
- Measurements for determining the local scour around groynes and near revetments, and the sedimentation in the areas between groynes (FAP 21)
- Measurements of damage that may happen with any of the bank protection works along the Jamuna and Meghna Rivers (FAP 21)
- Investigations into the value of the Chézy coefficient in the main rivers in relation to the bed-form dimensions (SWMC)

Once all suggestions will have been collected and the study topics under FAP 24 have been established at least tentatively, possibilities to include these surveys and investigations will be assessed, either as part of "regular" FAP 24 or as a separate study.

7.4.3 Further activities

The following activities are foreseen for the remaining part of Phase 1:

- o Assess need for additional surveys from different FAP's based on a.o. ongoing interviews
- o Assess need for additional surveys from tentatively selected study topics, notably for the prediction of the impact of the total of the FAP projects; collect interest of other FAP's in special studies (as tentatively listed in Section 7.4.2)
- o Compare these with proposed survey programme and, if appropriate, suggest changes
- o Specify particular of bathymetric survey (area, spatial bathymetry, frequency, etc.)
- o Propose tentative selection of methods to be applied this year
- o Elaborate special surveys for other FAP's as far as they cannot be included in the regular FAP 24 surveys, and investigate possible funding
- o Advise on short-term improvement of the survey techniques of BWDB and BIWTA, on the basis of their present instruments and measuring methods

List of references

- Bruk, S.,
  Sediment Budget and Sediment Management of the Bangaldesh River System
  UNESCO
  March 1992
- China-Bangladesh Joint Expert Team
  Study Report on Flood Control and River Training Project on the Brahmaputra River in Bangladesh
  Analytic Study on Hydrology and River Morphology of the Brahmaputra River
  March 1991
- FAP 9B
  Final Report / Meghna River Bank Protection Short Term Study
  HASKONING, DELFT HYDRAULICS, Bangladesh Engineering & Technological Services
  March 1990
- FAP 21/22
  Draft Final Report Planning Study / Bank Protection and River Training Pilot Project
  Consulting Consortium FAP 21/22
  January 1993
- FAP 24
  Technical Proposal \ River Survey Project
  DELFT HYDRAULICS & Danish Hydraulic Institute
  September 1991
- Klaassen, G.J., & Zanten, B.H.J. van,
  On cutoff ratio's of curved alluvial channels
  Proc xxiv th IAHR conference, Ottawa, Canada
  1989
- Yuqian, L.,
  Manual on Operational Methods for the Measurement of Sediment Transport
  World Meteorological Organization, WMO report - no. 886
  1989

220 D

List of symbols

Symbol	Meaning	Unit
B	Channel width	(m)
B_b	Bankfull width	(m)
B_t	Exponent of power-law sediment transport formula	
C	Chézy's roughness parameter	($m^{1/2}/s$)
D	Bed material size	(mm)
E	Annual erosion	(mm)
f	Lacey's silt factor	
$f(\Theta_0)$	Cross-sectional average of function for the influence of gravity pull along a transverse bed slope	
G	Erodibility coefficient	
g	Acceleration due to gravity	(m/s^2)
H	Outer bank height	(m)
H_{fb}	Free board of bank above water-level	(m)
h	Average water depth	(m)
h_0	Cross-sectional average water depth	(m)
h_b	Bankfull depth	(m)
h_w	Water depth near bank	(m)
h_{wer}	Critical water depth near bank	(m)
i	River slope	
i_b	River slope at bankfull stage	
i_v	Valley slope	
k	Streamwise wave number	
m	Transverse mode, indicating the number of channels per cross-section	
n	q_s/S_e, $\Delta Q/Q$, $\Delta S/S$	
p	Sinuosity	
Q	River discharge	(m^3/s)
Q_b	Bankfull discharge	(m^3/s)
R	Radious of curvature of bend	(m)
R_h	Hydraulic radious	(m)
S	Sediment transport	(m^3/s)
S_b	Sediment transport at bankfull discharge	(m^3/s)
T	Time	
u	Flow velocity	(m/s)
u_b	Flow velocity at bankfull discharge	(m/s)
u_w	Flow velocity near bank	(m/s)
V	Sediment transport integrated over the year	
W_{wer}	Critical flow velocity	(m/s)

z	Side slope	
z_b	Bed level	(m)
α	Angle of attack	(degree)
η	Ratio of water depths	
λ	Cutoff ratio	
ν	Sediment distribution	
ξ	Coefficient for the effect of streamwise bed slope	
π	3.14159	
ρ	Density of water	(kg/m^3)
Ω	Stream power	(N/s)
φ	Bank slope	

22

Annexure 8

Training

8.1 Introduction

General

The training must cover the entire scope of the project and the transfer of knowledge must promote interest, involvement and enhancement of capability. In addition, a well-defined training programme will meet the long-term project objective to guarantee sustained upgraded capabilities in the fields covered by the project. Technology transfer is the covering activity for the two other project components viz. survey and study, and these are all mutually interrelated. Technology transfer implies transfer of knowledge and skills, in combination with available and developed tools, to institutions and individuals.

Objective

The main objective of the training is to upgrade the institutional and individual capabilities in Bangladesh for river hydrology and morphological data collection and studies. Training will mostly take the form of on-the-job training, but will be supplemented by seminars and workshops (FAP 24, 20 October, ToR).

In Phase 1 only initial training is envisaged and a training programme for Phase 2 needs to be developed in conjunction with the relevant organizations (ref. Technical Specifications, Section 3.5).

Target organizations

As defined in the ToR (FAP 24, 20 October 1992, Subsection 4.2.c and 4.3.c) the training should be given to:

- o BWDB staff
- o BIWTA staff
- o Staff of associated local consultants and contractors

Consequently, training is given both as an internal training (for FAP 24 staff, including associated staff) and as an external training (BWDB, BIWTA, etc.).

Within the frame-work of "in house" capacity building it is considered as very important to train the local staff of the project. It was decided to do this already in an early stage of the project to benefit from the increased level of understanding of the local staff over the full period the project is running. In addition it was decided to invite staff members of FPCO, BWDB and BIWTA to take part in these training sessions.

Target groups

For the training activities, the following target groups can be distinguished:

- o Survey vessel crew
- o Surveyors/hydrographers
- o Instrument engineers
- o System analysts/data handling specialists
- o Sediment analysts
- o River engineers/hydrologists/morphologists

8.2 Curriculum development

- o Ship handling, manoeuvering, maintenance
- o Surveying
- o Instrument engineering
- o Data-processing & storage
- o Sediment analysis
- o Hydrology, hydraulics, sediment transport and river mechanics

The last item mentioned comprises training given in the form of lectures in the FAP 24 office.

The curriculum for this training should reflect the present and future activities of the local staff in Phase 1 and Phase 2. Based on the assessment of the items for which additional training would be required and on an inventory of interest amongst the potential participants it was decided to run in total five short but intensive courses. The topics of these courses are listed below:

- o Basic hydraulics refreshment course
- o Hydrology
- o Sediment transport & hydraulic roughness
- o River dynamics
- o Advanced river dynamics

Some more details on these courses are provided hereafter.

Basic hydraulics refreshment course

(lecturer Nielsen, lecture notes Breusers: River Hydraulics Chapter 1-8)

- o Basic equations: continuity equation in its different appearances; Navier-Stokes equations; Bernoulli and momentum equation as resulting equation for defined cases; hydro-static pressure distribution

- o Uniform steady flow: velocity profiles; hydraulic smooth and rough; Chezy and Manning resistance laws; roughness coefficient for plane beds; roughness of vegetated floodplains; hydraulic radius versus water depth; different expressions for hydraulic radius
- o Non-uniform steady flow: flow profiles; flow over long crested weirs and short crested spillways; effect of curvature of flow
- o Unsteady flows: floods; interaction low water bed and floodplain; rating curves; Jones effect; translatory waves and characteristics

Hydrology

(lecturer Nielsen, lecture notes not yet available)

- o Measurement of stages and discharges
- o Screening of data
- o Rating curves

Sediment transport & hydraulic roughness

(lecturer Klaassen, lecture notes Breusers: River Hydraulics, Chapters 9-13)

- o Properties of sediment
- o Initiation of motion: Shields curve; stability on slopes
- o Bedforms: types of bedforms; influence on hydraulic roughness and sediment transport; typical bedforms in Jamuna River
- o Alluvial roughness: major difference between mobile and stable beds (influence of bedforms); particle roughness and form roughness; prediction methods for uniform conditions; hydraulic roughness of Bangladeshi rivers; effect of unsteady conditions on rating curves
- o Sediment transport: transport capacity and actual transport; bed material and wash load; bed load and suspended load; basic relation between sediment transport and effective shear stress; ripple factor; sediment transport formulae for sand bed rivers; armouring; sediment transport formulae for gravel-bed rivers; sediment transport in Bangladeshi rivers

River dynamics

(lecturer Klaassen, lecture notes De Vries: Engineering Potamology)

- o Function and use of rivers
- o Independent parameters: climate, geology, vegetation ←→ discharge, sediment yield
- o Dependent river characteristics: planform, river slope, particle size, alluvial fans, channel dimensions, floodplains, estuaries, delta's

- o Changes in rivers: natural and human induced
- o Elementary river dynamics (steady conditions and constant width): combination of Chezy and sediment transport equation; simple cases of one channel and constant width: narrowing, water diversion, sediment mining; bifurcations and confluences
- o Effect of hydrographs (but still for steady conditions and constant width)
- o Unsteady conditions (and still for constant width)
- o Riverine ecosystems (not included in lecture notes)
- o Environmental impact assessment (not included in lecture notes)

Advanced river dynamics

(lecturer Klaassen, lecture notes not yet available)

- o Width and planform of rivers: independent variables and dependent variables, methods for determining the width and other parameters: regime equations and external hypotheses; application to Bangladeshi rivers
- o Flow and sediment transport in bends: helical flow; sediment transport in bends; axi-symmetric bend profile; conditions in the beginning of a bend; relaxation lengths and time scales; effect of bank erosion; conditions in Bangladesh
- o Bank erosion and planform changes: bank erosion mechanisms; prediction of bank erosion; cut-offs as balancing mechanism; criteria for occurrence of cutoffs; complications for braided rivers; conditions in Bangladeshi rivers
- o Scour and deposition: different types of scour; regime approach; combined scour: bend scour, confluence scour, constriction scour, local scour, etc.; deposition on floodplains and on point bars; sedimentation in canals and reservoirs

Lecture notes for these courses are made available to the participants.

The courses are organized as intensive courses. Lectures are given every day (except on Fridays) from 9:00h to 10:00h. The duration of the courses varies between 2 to 4 weeks. The participants are stimulated to do some homework as our philosophy in training is that only if lectures are accompanied by exercises the participants will be able to grasp the full meaning of the lecture contents.

8.3 Training approach

Many of the required skills might effectively be transferred through close and cordial collaboration during the survey activities themselves. However, a full programme of on-the-job training during the actual surveys is anticipated not to come in effect because of the pressure of workload and limitations induced by working space aboard vessels and available accommodation. Therefore, separate training sessions are suggested as well, in which the survey techniques and related items will be reviewed and more theoretical background information can be dealt with.

In addition, separate training surveys can be conducted, focussed on instructional training and self-practice. Field trips can also be fruitful in that they present instructive examples of problems and solutions of applied techniques to deal with the extreme Bangladesh conditions and to exchange experiences with other professionals and instructors.

Overseas training for counterparts, e.g. at international institutes as the Asian Institute of Technology in Thailand (AIT) and the International Courses on Hydraulic and Environmental Engineering in the Netherlands (IHE) are not expected to be essential for the project; however, if the need arises such a training might be slotted in as well, provided the required resources can be found.

The transfer of technology aimed at, will capitalize as much as possible on the presence of short-term experts.

In addition, separate training activities will be concentrated on the low-intensity measurement periods (i.e. well beyond the monsoon periods).

During the first phase initial training will be given on introductory items and attention will be paid to the institutional enhancement aspects of the related parties. The positive spin-off of such an early training is the possibility of "team building" through joint discussions and participation of the trainees in the subsequent approach of phase 2.

8.4 Phase 1 programme

The training programme in Phase 1 is summarized in the following schedule:

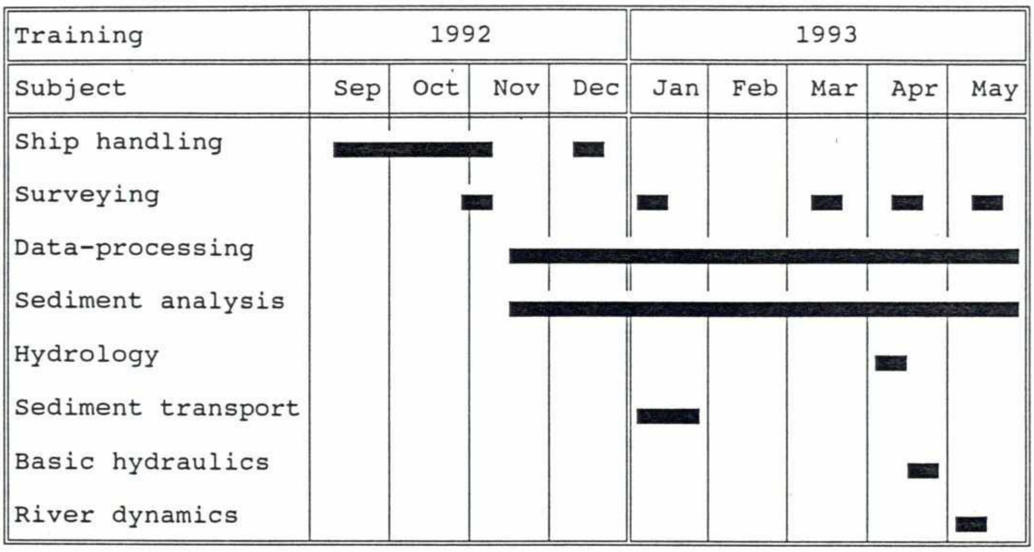


Figure 7.1 Training programme Phase 1

The training on ship handling maintenance and manoeuvering was especially arranged for the local crew of the survey vessels.

The training on surveying, data-processing and sediment analysis is given in the form of on-the-job training, whereas the training on hydrological and morphological aspects is given in the form of lectures, workshops or seminars. For all training subjects (except the first one) invitations have been sent to and via FPCO.

Training activities phase 1

Introductory training on survey techniques including:

- o Ship handling instructions for survey vessels
  - basics in ship handling, maintenance and repair
  - instructions on the new vessels
- o Introductory seminar/workshop on hydrographic survey techniques and related items
  - project outline
  - entire process (data measurement. data handling, engineering and simulations)
  - general/basic hydrographic survey techniques
  - outline of new developments
  - possible concepts for River Survey Project
- o In-field pilot survey-training session
  - illustration/instruction of existing and basic hydrographic survey techniques
  - self exercise in basic surveying
  - basic data-handling techniques (real-time and off-line)
- o Field trips to relevant sites
  - illustrative examples of surveying problems and solutions typical for Bangladesh conditions
- o Course on hydrology, hydraulics, sediment transport and river mechanics (see curriculum in Section 8.2). In September 1993 a course on advanced river dynamics will be given

8.5 Phase 2 programme

Training on advanced surveying techniques (including data-handling) and river study aspects (indicative programme and possible training items)

- o Seminars/workshops on advanced surveying techniques and data handling
  - advanced surveying techniques:
    - * positioning systems
    - * measuring systems on board
    - * measuring stations
  - data handling
    - * data collection and storage
    - * data-processing
    - * data retrieval
    - * database management/information systems
- o Seminar/workshops on river hydraulics and river morphology
  - river hydraulics
  - river morphology (emphasis on monsoon type rivers)
  - mathematical modelling
- o In-field surveying training sessions (gradually integrated in actual survey programme)
  - mastering basic and advanced hydrographic survey techniques
  - subsequent in-field training for step-by-step mastering

As a concrete result of the transfer of technology, instruction manuals will be implemented dealing with hydrographic surveying techniques, equipment handling (operation, maintenance and repair), data collection and processing (including database managements). In addition, lecture notes will be developed on river hydraulics and river morphology (supplementary to the international workshop proceedings).

The computer programs used for the studies maybe transferred to the parties involved, if asked for, and hands-on training can be given upon implementation of the programs.

Note: Expatriate man-months for training are p.m. in the ToR and no separate budget for training is made available. This generates quite some restrictions on the training possibilities.

Annexure 9

Workplan and staffing

9.1 Introduction

On February 3, 1993, during a meeting at FPCO's between FPCO staff including the PA, members of the Panel of Experts and the Consultant on the status of the River Survey Project - FAP 24 the need was acknowledged to review the project workplan. The Consultant was requested to draft a revised workplan at short notice. As also the activities in phase 1 are affected, the revised workplan should be inserted in the Interim Report.

Hereafter, the reasons to modify the existing workplan are explained (Section 9.2). Then the revisions are described in broad lines (Section 9.3) and later in more detail (Section 9.4). The results of the revisions are discussed in view of the objectives of the project (Section 9.5). Thereafter a detailed workplan covering the second half of phase 1 is given (Section 9.6). At the end of this Annexure staffing schedules for the second half of phase 1 are given.

9.2 Reasons for changes

There are two main reasons to adapt the workplan of the project:

- Technical reasons
- Administrative reasons

This is elaborated in the following sections.

9.2.1 Technical reasons

In the ToR testing in the higher flow ranges (25.000 to 40.000 m^3/s) was asked for in order to select the appropriate survey technique(s) viz. equipment (including vessels and instruments) and measuring methods.

Due to both the late start of the project and additional delay in importing of equipment as well as the relatively small discharges during the monsoon of 1992, the test measurements were done by the end of October 1992 in mid flow conditions (discharge of about 20.000 m^3/s near Bahadurabad).

Obviously this created quite some uncertainties in the selection. To overcome at least a part of these uncertainties it was agreed to execute additional test measurements in December to support a tentative selection, to be verified in final test measurements during the flood of 1993.

The results of the additional tests showed that the Acoustic Doppler

Current Profiler (ADCP) may loose bottom track in the higher flow ranges with high sediment concentrations. This triggered investigations and developments to overcome this problem, but also showed the need for some verification tests to be carried out in flood conditions.

Also in December 1992 reconnaissance visits were made to some of the phase 2 measuring sites. The main observation was that the sites are very different not only regarding dimensions but probably also regarding flow and morphological characteristics - the difference becomes most pronounced in the dry seasons.

In fact this put question marks behind the assumption that it is possible to select the appropriate techniques and optimize the composition of survey spread for the entire river system on basis of test measurements in Bahadurabad only.

Besides during the recent site reconnaissance near Bahadurabad (with the participation of the PA) it was discussed that there may develop a need to move a significant part of the bathymetric survey into the flood season. In this case a revision of the overall survey spread may also be required maybe in form of an additional bathymetric survey launch.

To keep the project on schedule the selection of equipment, especially the determinations of the specifications of the additional vessels, was required by the end of 1992. Flood season coverage is critical.

Summarizing, it can be stated that verification of methods in the higher flow ranges and additional information of the other sites is preferred before selecting the final survey spread configuration.

9.2.2 Administrative reasons

Early September 1992 the River Survey Project was granted a project passbook for tax exemption of re-exportable project equipment. The passbook got a validity of half a year only.

In a circular of 17 October 1992 the Member (Taxation) of the NBR canceled the passbook per November 1. December 19, 1992 the EC Delegation sent a letter to the Secretary of the Economic Relations Division of the Ministry of Finance stating amongst others that:

- The CEC will certainly not pay taxes and duties
- Tax exemption should be granted according to the CEC-GoB Framework Agreement

- o A serious re-assessment of the project will have to be made if this problem is not solved
- o The case needs to be clarified before any further equipment can be imported

Early January 1993 these problems were discussed in Brussels and, as a solution is not likely at short notice, the Consultant is requested to elaborate a workplan assuming that only phase 1 equipment is available during the flood period of 1993.

At the date of this reporting (February 93) the issue is not yet solved and the crucial date for ordering vessels to be used during the 1993 monsoon has been passed already.

9.3 Implications and scope of revisions

If the inception of phase 2 should be maintained on June 9, 1993, the limited equipment during the monsoon of 1993 would force a reduction of the measurements in that period. This means that the number of floods getting a 100% coverage is reduced to two (1994 and 1995 only). Therefore it is considered not to terminate the project just before the monsoon of 1996 but after peak flow of the monsoon. This means in broad terms that:

- o The phase 1 measurements are not affected. Gaugings missed in 1993 are shifted
- o Between phase 1 and phase 2 viz. June 1 and Oct 31, 1993 a transition phase of five months is proposed with a mixed survey programme comprising:
    - HW test gauging
    - HW routine gaugings at all sites but with a lower frequency (about monthly at the main stations instead of fortnightly). At the end of this phase the final survey spread configuration will take place
- o Phase 2 starts with a mobilization period and covers still three years, with a hardly affected measuring programme (which means that the first LW measurements need to be done with phase 1 equipment only). During the last monsoon the routine gaugings aim at catching the rising phase and the peak flood only (in 1996)

The main revisions can be summarized as follows:

- o Shifting the comparative test gaugings from 1992 to 1993
- o About halving the HW routine gaugings (and corresponding bed load measurements) in 1993
- o Shifting the remaining HW routine gaugings of 1993 to 1996

- o If desired, extending the project period with 5 months (about 3 months survey and 2 months demobilization) provided the available resources permit

Maintaining the number of surveys according to the Bill of Quantities

Some secondary revisions are:

- o Further reconnaissance survey work
- o Shifting the installations of some AWLR stations partly from phase 2 to phase 1
- o Starting earlier with the bathymetric survey work (already before the floods of 1993) at one site only, in order to define the final need and optimize this type of survey work

The above listed main and secondary revisions are mainly dealing with the survey component of the project. The study and training component will be affected where they are related with surveying. Therefore, the discussion on the revisions is focussing on the survey component. The revisions proposed in this section are summarized in the revised survey workplan hereafter.

9.4 Revised survey workplan

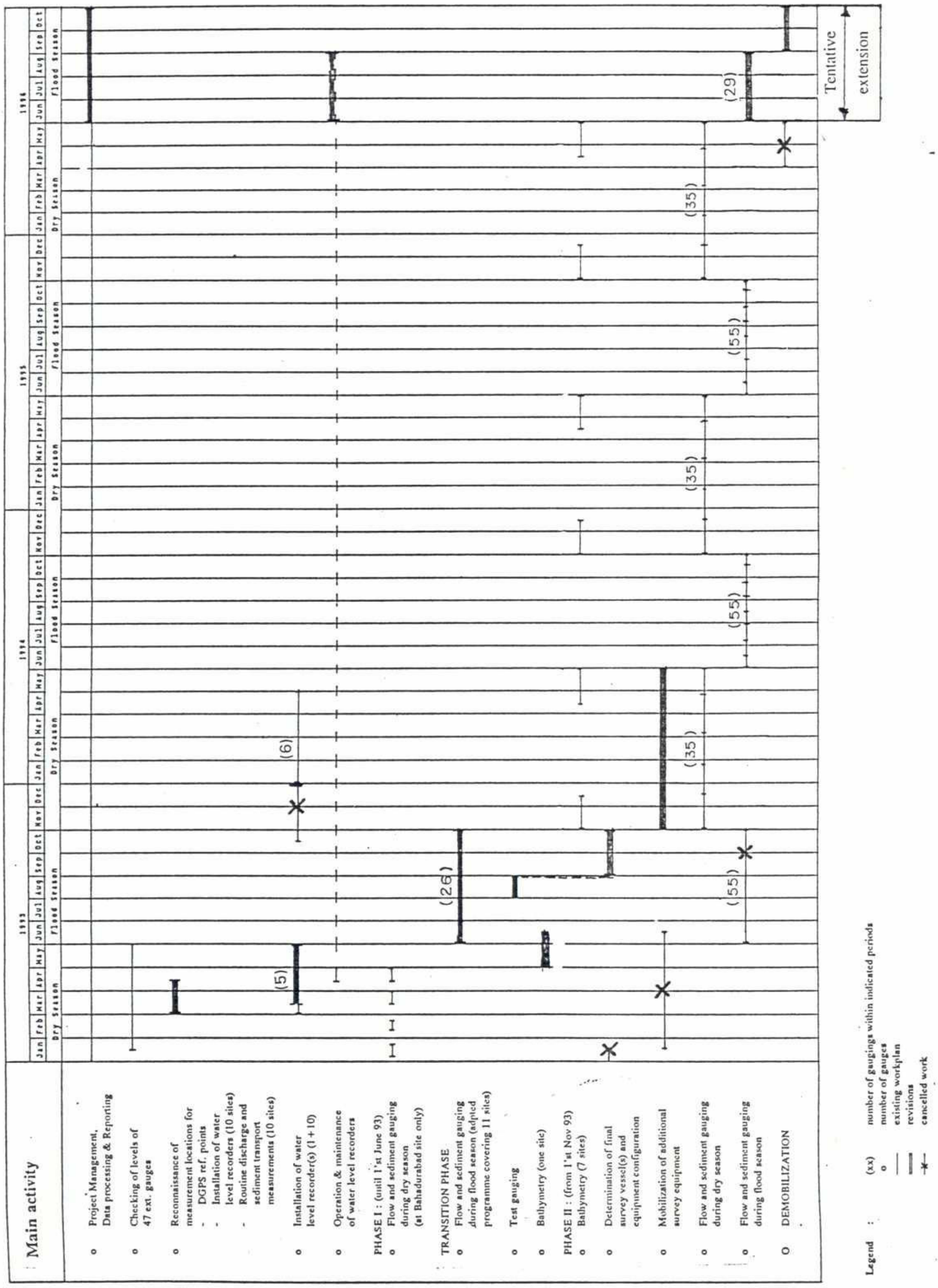


Figure 9.1 Revised survey workplan, February 1993

The revised workplan introduced in the previous section and outlined in Figure 9.1 is described in more detail in the following sub-sections.

9.4.1 Reconnaissance

As mentioned before (section 9,2.1) in December 1992 reconnaissance visits were made to some phase 2 measuring sites. The main objective of these visits was to asses which combination of boats and equipment would be appropriate for these sites. After some visits it became clear that the differences between the various sites are substantial in particular during the dry season. This means that the optimal techniques to be selected will most probably vary per site - at least between main and small rivers. Moreover, the techniques may vary per season because of the strong varying hydrographs.

Now since the selection of the additional spread is proposed to be postponed (see previous chapter) use will be made of the extra time available to execute more detailed reconnaissance surveys for various reasons such as:

- o Selection of locations of DGPS reference stations
- o Selection of location and type of water-level recorder
- o Familiarization with the bathymetry and topography of the areas for selection of appropriate spread for routine gaugings

9.4.2 Water-level recorders

According to the contract one water-level recorder has to be installed in phase 1 (in Bahadurabad) and another 10 in phase 2. It is proposed to advance the activities as far as possible. The target is to install about half the number in "obvious" locations before the flood season and the remaining part after the flood season of 1993.

9.4.3 HW routine gauging

The main revision takes place in the monsoon season of this year, as the present equipment is not sufficient to cover 100% of the scheduled HW routine gauging and an extra HW test gauging.

The 100% HW routine gauging comprises flow and sediment measurement (including suspended load and bed load) at 11 locations. At 4 out of these 11 stations the measuring frequency is fortnightly. These are the main stations Bahadurabad, Serajganj, Hardinge Bridge and Baruria, see the following table.

River	Station	No of gaugings in monsoon of 1993	
		Contract	Proposed
Jamuna	Bahadurabad Serajganj Aricha	8 8 2	3 3 2
Ganges	Hardinge Bridge	8	3
Padma	Mawa Baruria	2 8	2 3
Meghna	Bhairab Bazar	3	2
Old Brahmaputra	Mymensingh	4	2
Dhaleswari	Tilly	4	2
Gorai	Kushtia	4	2
Arid Khan	Off-take	4	2
Totals		55	26

Table 9.1 Revised programme

With the present spread, one cycle, visiting all 11 sites, will take 6 weeks, provided mixed techniques may be applied. These techniques will be discussed in Volume II of this report. Such a cycle leads to the following schedule:

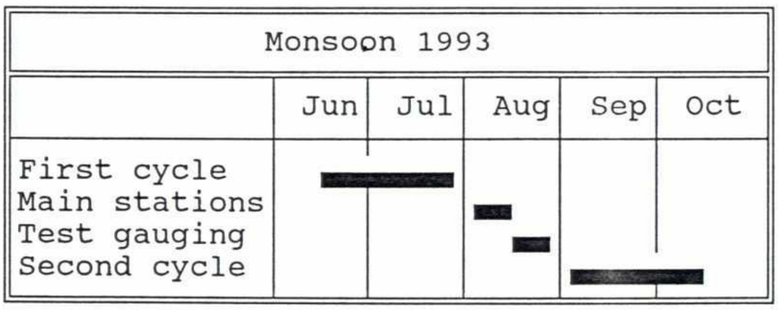


Figure 9.1 Workplan monsoon 1993

If possible the test gauging will be done earlier (in case of an early flood). The main stations are the four stations with the highest measuring frequency. In the indicated period only routine gaugings at the main stations will be executed.

9.4.4 Test gauging

The test gauging will be executed in Bahadurabad. The gaugings will be done in the higher flow range, possibly encountered in August 1993. An intensive measuring campaign, comparing the various techniques for flow and sediment gauging will be executed. This campaign will take about 2 weeks.

9.4.5 Bathymetry

The locations and frequency of measurements are given in the contract indicatively. The measurements were scheduled to start in phase 2.

It is proposed to start the first measurements already before the flood during the rising stage of the river. However these first measurements will be restricted to one site only. For the site a stretch of the Jamuna is proposed near Bahadurabad just upstream of the FAP 21/22 test site.

The main objectives of these activities are:

- Early start of bathymetric data collection for study purposes (own studies and support of FAP 21/22 activities)
- Testing of various surveying methods in order to optimize the work.

Together with the morphologists a special bathymetric programme will be elaborated considering aspects such as:

- Sounding area, density and frequency
- Contour (water line) measurements
- Topographic methods
- Connections with remote sensing techniques

9.4.6 Selection and mobilization

The results of the test measurements will be analyzed (data-processing office, sediment laboratory) and a proposal will be made for the survey techniques of phase 2.

After getting the approval of FPCO (including PoE and PA) and CEC the mobilization of phase 2 will start.

After the monsoon of 1993 the LW routine measurements will be executed. It is assessed that these measurements can be done with the slightly adapted phase 1 spread, which means that the lean season programme need no revision.

9.4.7 Extension (tentative)

It is considered to maintain a phase 2 period of three years, which implies an extension of the project of 5 months (the duration of the transition period) consisting of about 3 months of surveying and 2 months for reporting and demobilization.

Main purpose of the extension is to catch the flood of 1996 thus compensating for the reduced flood measurements of 1993.

There are arguments to consider the revised workplan better than the existing one. As the project started in June 1992, the first monsoon coincided with the mobilization period and consequently there are only HW gaugings during three monsoons. In the revised workplan measurements over four monsoons are envisaged. Considering that the River Survey Project should emphasize the floods, it seems rather logical not to terminate the project just before the flood of 1996 but just after the flood.

At the moment of reporting the extension is only considered tentatively.

9.4.8 Financial consequences

Obviously, the revisions have financial consequences. Aspects to be considered are for instance:

- Earlier installation of a number of AWLR causing a longer O&M period
- Additional bathymetric survey of May/June 1993
- Postponement of mobilization, delaying optimization and procurements and extending period of rent.
- Postponement of measurements ; the test gaugings of 1992 to 1993 and the HW gaugings (including corresponding bed load measurements) from 1993 towards possibly 1996?

However, the financial consequences hereof are expected to be minor, which means that they are not important for decisions about the workplan and will be addressed later. This conclusion holds as long as amount of survey work and project period do not change substantially.

9.5 Expected results

The impact of the forced delayed mobilization for phase 2 is used in such a way that the project profits from it as much as possible:

- o The results of the final test gaugings can be used for selecting the appropriate techniques
- o The experience gained at other locations than Bahadurabad can be used for the selection
- o There is time for additional testing (e.g. the bathymetric survey techniques)
- o There is a better coverage of the floods

Summarizing:

It may be stated that the revised workplan serves the project objectives better.

9.6 Detailed workplan

The revisions of the overall survey workplan have been incorporated in the following detailed workplan of the River Survey Project covering the second half of phase 1 (in accordance with sub-section 4.4.2 of the ToR).

Main Activity	1992	1993					
	Dec	Jan	Feb	Mar	Apr	May	Jun
1. Project Management	■	■	■	■	■	■	■
2. Studies							
o Hydrological	■	■	■	■	■	■	
o Morphological	■	■	■	■	■	■	■
3. River Survey							
o Reconnaissance				■	■		
o Installation AWLR				■	■	■	
o LW gauging Phase 1		■	■	■	■		
o HW gauging							■
o Bathymetry						■	■
o Additional tests	■						
4. Land Survey		■	■	■	■	■	
5. Training							
o Initial	■	■	■	■	■	■	
o Programme Phase 2						*	
6. Reporting							
o Interim			*				
o Quarterly progress	*			*			*
o Hydrology Phase 1						*	
o LW surveys Phase 1						*	
o Land survey							*

Figure 9.3 Detailed workplan (second half Phase 1)

9.7 Staffing schedules

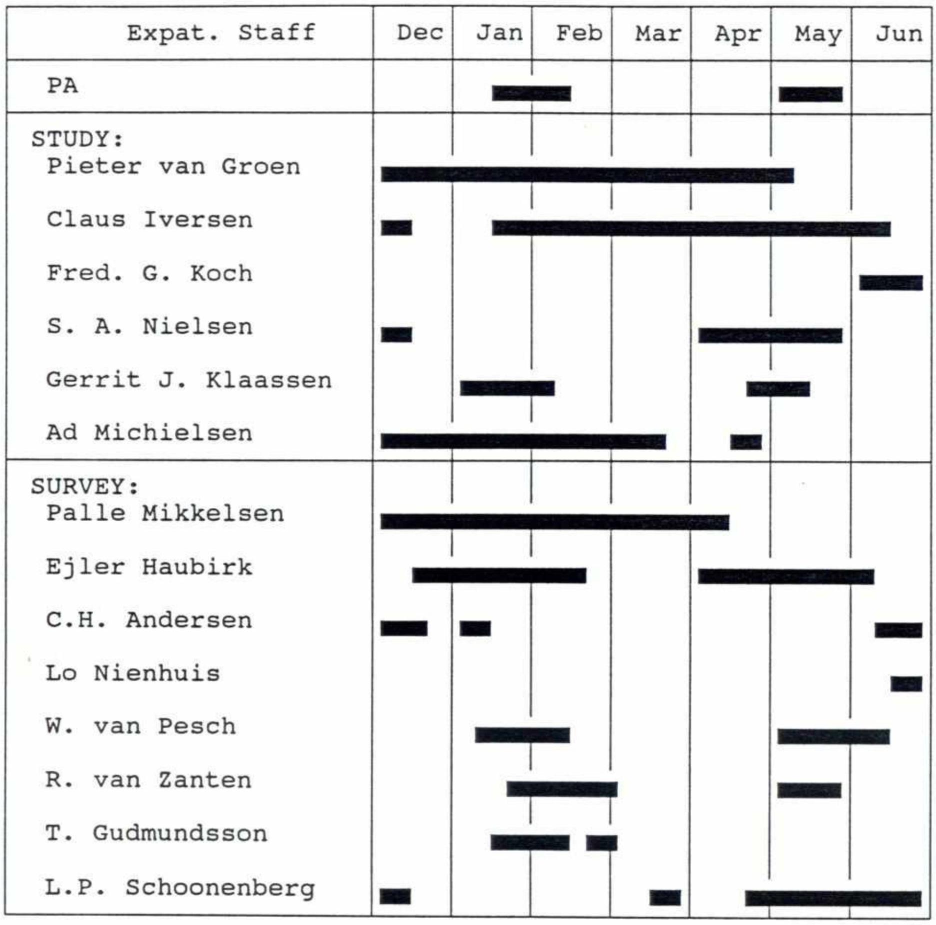


Figure 9.4 Expatriate staffing

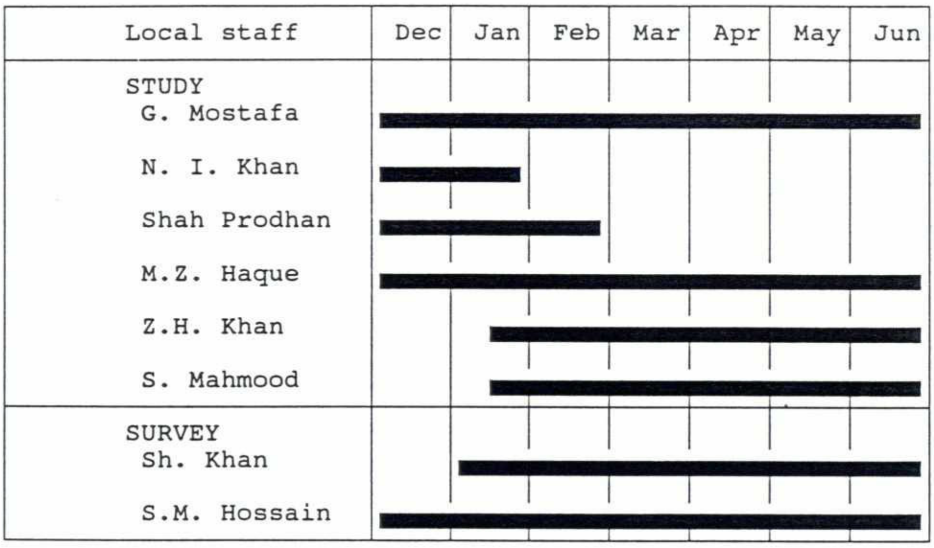


Figure 9.5 Local staffing

208

Appendix 2

Tentative study topics and approaches

Contents

Introduction

During the proposal phase a list of tentative study topics was prepared. This list was included in the proposal of September 1991 as Annex 6. Here an updated list is presented.

The list in Annex 6 of the proposal was prepared during meetings of staff both of DELFT HYDRAULICS and DANISH HYDRAULIC INSTITUTE, which had substantial experience in a number of projects in Bangladesh. At the time the proposal was prepared, the insight obtained from working in the following projects was "pooled":

(1) Ganges Kobadak Rehabilitation Project,
(2) Jamuna Bridge Project
(3) Bangladesh Inland Water Transportation Master Plan Studies,
(4) Assistance to Surface Water Modelling Center in modelling the main rivers of Bangladesh, as part of the General Model,
(5) FAP 1: Brahmaputra River Training Studies, and
(6) FAP 9B: Meghna River Bank Protection Study

This experience together with the suggestions in the Terms of Reference, allowed to prepare an extensive list of tentative study topics.

Since quite some time has elapsed between the preparation of the proposal and the writing of this Interim Report, it seems appropriate to update the list of possible study topics. This is done on the basis of continued experience of Consultants in other projects in Bangladesh and, more recently, on the basis of discussions within the framework of FAP 24. Recent projects of relevance in which Consultants were or still are involved are:

(7) FAP 4: South-West Regional Study, and
(8) FAP 21/22: Bank Protection and River Training (Active Flood Plain Management) Pilot Project.

The updating has resulted in a total of 39 potential study topics. In the following pages these topics are described. Furthermore per topic the possible approach and the required study tools, a tentative ranking, the expected results and the required input are listed in addition.

The tentative ranking was done on the basis of the experience from the other projects, and does not necessarily indicate the preference of Consultants for study topics under FAP 24. The procedure how to select study topics under FAP 24 is described in Chapter 6 of the main report and in more detail in Annexure 7 of this volume.

Topics 1 and 2, Hydrology and Sediment Transport, are fundamental. They have a high priority and will partly be taken up already during the phase 1 study. Topic 3, FAP impact on river system, is considered a major task with a high priority for the overall Flood Action Plan. During phase 1 of the project this topic will already be taken up too so as to arrive at a preliminary, qualitative assessment of the response of the river system to the implementation of the various flood control schemes. During phase 2 the impact simulation will be further developed to arrive at a quantitative assessment.

The other study topics are not less important. They will improve the understanding of the specific behaviour of rivers in Bangladesh, which certainly will contribute to the quality of the impact assessment. The priority of these topics also depends on the river study requirements of the other FAP components. For that reason it is already assumed that topic 4, Planform Characteristics and Channel Dimensions, has a high priority.

Some of the topics will be looked into by other projects as well, in particular FAP 1, FAP 9B and FAP 21/22. During phase 1 of the project the extent to which these topics will be studied by the other projects, will be carefully investigated in order to avoid duplications. Topics covered fully during phase 1 are not included in this Annex. This concerns topics like data collection and analysis, review of other studies and the establishment of the data base.

Topic-methodology matrix

	INDICATIVE STUDY TOPICS	Project Phase I / II	Priority ranking 1/2/3	METHODOLOGIES: 1 field investigations	2 desk studies	3 hydrological analysis (HYMOS)	4 one-dimensional mathematical modelling	a. flow simulation	b. sediment transport simulation	5 two-dimensional mathematical modelling	a. flow simulation	b. sediment transport simulation	6 bank erosion modelling (MIANDRAS)	7 physical scale modelling	8 remote sensing techniques	related FAP river studies
1	hydrology															
1.1	water surface slopes	I II	1	X	X	X										10.25
1.2	water balances	I II	2		X	X		X								
1.3	changes in rating curves	I II	1		X	X										25
1.4	loops in rating curves	I II	1	X	X			X								25
1.5	extrapolation of rating curves	I II	1		X	X		X								25
1.6	overland flow	I(II)	1		X			X							X	
2	sediment transport and river aggradation or degrad.															
2.1	screening and review of existing data	I	1		X											1.98.21/22
2.2	sediment balances	II	2		X				X							
2.3	one-dimensional morphological modelling	II	1	X	X				X							
2.4	subsidence and sedimentation	II	2	X	X				X			X				
3	FAP impact on river system				X											
3.1	formulation of scenarios	I(II)	1		X											whole FAP
3.2	simulation of river response	I II	1		X			X	X							1.10.22
4.	planform characteristics and channel dimensions															
4.1	planform classif and meander and braiding characterist.	II	2		X								X		X	21/22
4.2	channel dimensions	II	1	X	X										X	22
4.3	bank erosion rates	II	1	X	X								X		X	1.22
4.4	outerbend scour	II	1	X	X							X	X	(X)	X	1.98.21/22
4.5	channel cutoffs	II	1	X	X				X				X		X	1.21/22
4.6	effect of tectonics on planform characteristics	II	2	X	X											21/22
4.7	prediction of midium-term planform changes	I	1		X								X			1.98.21/22
4.8	influence of cohesive materials on planform changes	II	2		X								X			1.98.21/22
4.9	local slope changes and its effect on planform changes	II	1	X	X	X					X					1.98.21/22
5.	bifurcations															
5.1	discharge and sediment transport distribution	II	1	X	X			X	X		X	X			X	1.22
5.2	seasonal variation of deposition and erosion	II	2	X	X			X	X		X	X			X	22
5.3	long-term developement of river branches	II	1		X			X	X						X	22
5.4	influence of bars	II	1		X			X				X			X	22
5.5	influence of bed forms	II	3		X			X			X					
6	confluences															
6.1	erosion and deposition for out of phase floods	II	2		X						X	X			X	
6.2	influence of bars and bed forms	II	3	X	X			X							X	
6.3	confluence scour	II	3	X	X								X		X	
7	sand bars															
7.1	occurence dimensions and dynamics	II	1	X	X								X		X	1.22
7.2	time dependency	II	2	X	X										X	1.22
8	bed forms															
8.1	occurence dimensions and dynamics	II	1	X	X				X			X				
8.2	time dependency of bed form dimensions	II	1	X	X				X			X				
8.3	three dimensionality of bed forms	II	2	X	X											
8.4	bed load transport via dune tracking	II	2	X	X											1
9	local scour															
9.1	dimensions of local scour around structures	II	1	X	X									(X)	X	1.98.21/22
9.2	time dependency of local scour	II	2	X	X									(X)	X	21/22
9.3	influnce of bed forms	II	2	X	X											
9.4	combination with other types of scour	II	2	X	X											1.21/22

1. Hydrology

Topic 1.1 Water surface slopes

Description:
Identification of water surface slopes in the rivers is an important issue for several reasons, e.g.

- Check of water level data
- Check of bench marks
- Assessment of hydraulic capacity of the rivers
- Design of embankments along the rivers

Approach and study tools:
Water surface slopes can be determined on the basis of the water level measurements carried out along the rivers. Historical data as well as new data may be used for identification of water surface slopes at different discharges at different times of the year. The study of water surface slopes will help in identification of river reaches and gauging stations with obvious data quality problems, i.e. errors in water level measurements or bench mark connections. Thus the study will provide information on which stations and bench marks will have the highest priority in the field checking programme. In addition, it may provide methods to correct historical water level data.

Ranking: 1

Expected result
The study will provide the basis for increased quality of water level data and water surface slopes used in for example design of river embankments and calibration of mathematical models.

Required input:
Hydrologist/hydraulic engineer 1 manmonth

Topic 1.2 Water balances

Description:
Water balance studies provide an increased insight into the hydrological behaviour of the river systems and form the basis for data quality check of discharge time series and rating curves.

Approach and study tools:
Comparative studies of discharge time series from various stations in the river system can provide information on the water balance for the area between the stations. By such studies for different discharges and different times of the year the reliability of the

discharge time series and rating curves can be checked, and information on inflow/outflows to the river system under the various conditions can be obtained.

Ranking: 2

Expected result
Increased knowledge about the quality of discharge time series, rating curves and inflows/outflows to the river system under various hydrological conditions.

Required input:
Hydrologist 1 manmonth

Topic 1.3 Changes in rating curves

Description:
A frequent problem in gauge-discharge measurements are the changes in the stage-discharge relation (rating curve) due to changes in the physical factors that form the hydraulic control of the gauging stations. It is assumed that different bed forms (e.g. ripples and dunes) cause a considerable change in rating curves for the rivers in Bangladesh with their fine sediments. Cut-offs and moving bars could also play a considerable role. The controlling features may be modified by a number of factors, e.g. scour and sedimentation, growth and decay of bed form and decay of aquatic vegetation and variable backwater effects.
Detailed studies of shifting rating curves are frequently required in order to obtain correct discharge estimates based on stage measurements.

Approach and study tools:
The study of changing curves in alluvial rivers must be based on the available corresponding stage-discharge measurements from the gauging stations. A plot of stage against discharge will very often scatter widely and thus be intermediate. Sometimes it is possible to obtain an improved hydraulic relationship by changing variables, e.g. replacing stage by hydraulic radius and discharge by mean velocity.

Various correction methods for variable rating curves are available, e.g. the Stout method for making adjustments for shifting control. If variable backwater occurs at a gauging station an additional variable, slope or change of stage, will have to be included in order to define the discharge rating.

In the second phase the effect of bed forms, cutoffs and moving bars (see topics 5, 7 and 8) will be incorporated by establishing relationships between these phenomena and the rating curves.

Ranking: 1

Expected result:
The study will result in improved rating curves for all gauging stations and thus more reliable discharge time series.

Required input:
Hydrologist 1½ manmonths, sediment transport expert 1 manmonth.

Topic 1.4 Loops in rating curves

Description:
At river gauging stations located in a reach where the slope is very flat, the stage-discharge relation is frequently affected by the superimposed slope of the rising and falling limb of a passing flood wave, i.e. rapidly changing discharge. During the rising stage, the velocity and discharge are greater than they would be for the same stage at steady flow conditions. Similarly, during the falling stage, the discharge is less for any given stage than it is when the discharge is constant. In addition, time lag effects in the adaptation of bed form dimensions (see topic 8.2) will introduce hysteresis in the rating curves. Corrections for such loop effects are important for assessment of the discharges during large floods. For the Bangladeshi rivers the problem is even more complicated as the loop also depends on the retarded adaptation of the bed forms.

Approach and study tools:
The normal method in developing rating curves is to draw a median curve through a scatter of plotted discharge measurements. This method gives a correct result when all discharge measurements are made at steady or nearly steady conditions. In fact, if each plotted measurement had been tagged as to whether it had been measured on a rising or falling stage, the curve would have taken the shape of a loop. This effect is especially noticeable for large rivers having very flat slopes with channel control extending far downstream and in rivers with heavy sediment loads.

The looping effect is due to several causes. The first of them is channel storage between the measuring section and the downstream control. A correction for the channel storage has to be applied to the measured discharge. The second reason for the looping of rating curves is the variation in surface slope which occurs as a flood wave passes a gauging station. The third one and the most important, is caused by time-lag in the bedform development which will have to be studied integrated with study topics 8.1 and 8.2. Discharge measurements taken on either side of a flood wave may be corrected to the theoretical steady state condition by well known methods thus providing corrected steady state rating curves.

It should also be noted that mathematical unsteady-flow (one-dimensional) models may be very useful in the study and explanation of loop effects in rating curves.

Ranking: 2

Expected result
Increased knowledge about loop effects in rating curves and thus an improved basis for assessment of maximum discharges.

Required input:
Hydrologist 1 manmonth, mathematical modelling expert 2 manmonths.

Topic 1.5 Extrapolation of rating curves

Description:
Extrapolation of the upper part of the rating curves is almost always required to obtain flood design criteria. Only in very few cases discharge measurements have been obtained at about the highest flood peak observed.

Approach and study tools:
Various methods for rating curve extrapolation exist. Logarithmic extrapolation is a reliable method for shorter extensions. However, care should be taken if the rating curve consists of more than one segment. For extended extrapolations other methods may be more reliable, e.g. the stage-velocity-area method or the Manning-formula method.

Finally, one-dimensional mathematical models should be mentioned as an advanced tool for extrapolation of rating curves. In general the model can predict quite accurately the stage for high discharges, using the measurements of discharge at low and medium stages for calibration of a hydrodynamic and sediment transport river model. However, for such an application the phenomenon of changing bed forms and its effect on riverbed roughness has to be analysed first. In the case of Bangladesh this impact can be considerable. Therefore is is proposed to integrate this study topic with topics 8.1 and 8.2.

Ranking: 1

Expected result:
The study will provide an improved basis for extrapolation of rating curves for all stations and for all years of measurements. Thus more reliable discharge time series will be obtained.

Required input:
Hydrologist 2 manmonths

Topic 1.6 Overland flow

Description:
In some rivers during floods a considerable amount of the flood water is becoming flood plain overland flow. In special cases the overland flow may even enter into another river

system. Little information on the flood plain flows during floods is available, and the study aims at providing such information. This information is especially required because the planned flood control schemes will change the characteristics of the flood plain, which might affect the whole river behaviour. In connection with morphological impact assessment of embankment schemes, it is essential to know how much water is routed as overland flow.

Approach and study tools:
As direct field measurements of flood plain overland flows during floods will be very difficult, the first attempt to provide information on such flows will be based on the water balance studies described in Topic 1.3. Comparisons of flood discharges between neighbouring stations may detect river reaches where water disappears from the river. If possible, field measurements along such reaches may be carried out in order to confirm the outflows and to determine the amount, location and direction of the overland flow. Remote sensing techniques can be used for river hydrometry and pattern recognition, which includes mapping of the flood plain and the extent of flooding.

Ranking: 1

Expected result:
Increased knowledge about locations and amount of flood plain overland flows in the river systems, which is required for the simulation of the river behaviour.

Required input:
Hydrologist 1 manmonth, field engineer 2 manmonths.

2. Sediment transport and river aggradation and degradation

Topic 2.1 Screening and review of existing data

Description:
Analysis of the sediment transport data from Bahadurabad at Brahmaputra carried out under FAP 1 (BRTS) has revealed apparent inconsistencies in the data. A discharge-sediment transport relation based on data from before 1972 indicates significantly higher (a factor of 3) sediment transport rates than the corresponding relation based on data from after 1972.

It is not likely that such a shift in the discharge-sediment transport relation is associated with physical changes in the river (e.g. sediment plugs, see Topic 5.2), since the rating curves and cross-sections at Bahadurabad do not show any significant change. It is most likely that it is caused by a change in the data collection or data processing procedures used.

This example illustrates the need for a review of the methods used for data collection and processing and of the existing data itself.

Approach and study tools:
The review of the existing data on sediment transport will, as a first step, focus on obtaining an insight into the procedures which have been used at the main sediment transport data collection sites (Bahadurabad, Hardinge Bridge, Mawa and Bhairab Bazar. This will include a compilation of technical manuals and descriptions of the procedures used for data collection and processing as well as interviewing the BWDB staff involved in the sediment transport data collection. Based on a technical assessment of these procedures the data will be classified according to their reliability. Reprocessing of some of the data could also be a possibility if the raw data are still available.

In addition to the data collected on a routine basis by BWDB on the main rivers, additional data have been collected in connection with many of the projects which have been carried out in Bangladesh. These data should be compiled and cross-checked against the BWDB data. The data will be organised in the morphological river database (MORDAT) developed by the Consultant. For this project MORDAT will be integrated with the hydrological data base HYMOS and if required adapted for data specific for the Bangladeshi rivers.

Ranking: 1

Expected result:
The output of this study component will be a screened and checked dataset on sediment transport in the main rivers. This is a prerequisite for reliable morphological modelling of the river system in Bangladesh.

Required input:
Sediment transport expert 2 manmonths, data base expert 1 manmonth.

Topic 2.2 Sediment balances

Description:
Sediment balances can form a useful check on data on sediment transport rates and, provided the data are sufficiently accurate, they can also give an indication of the long-term development of the river system.

Approach and study tools:
It is proposed to use the data from the sediment gauging stations at the main rivers for a sediment balance analysis. A distinction will be made between bed load material and wash load. An estimate for the daily sediment transport rate will be worked out by interpolation of the observed (and checked, see Topic 2.1) sediment transport rates using available discharge and water level data (rating curves). These data will then be used for the sediment balances. In the balances it will also be necessary to estimate sediment load from tributaries and from bank erosion (this may be important in the Brahmaputra River).

Ranking: 2

Expected result:
The accuracy of the observed sediment data and estimate of sediment load from tributaries and bank erosion may be too small to make any firm conclusions regarding the long term development (erosion or deposition) in the main river. The main outcome of this study topic is a re-check and verification of the sediment transport data.

Required input:
Morphologist 1 manmonth, data base expert 1 manmonth.

Topic 2.3 One-dimensional morphological modelling

Description:
Very little is known about the sensitivity of the Bangladeshy river system in terms of morphology. At the same time, several very ambitious schemes have been proposed for the river system, including huge embankment schemes, diversion of river water, barrages etc. without any consistent morphological impact assessment having been carried out. In addition the effect on the morphology of the entire river system of a possible sea-level rise, further deforestation in the catchment etc. has not been investigated in detail.

It is proposed to establish a mathematical modelling tool for the investigation of the sensitivity of the river system and for the morphological assessment of various large scale schemes. In this way it will be possible to define limits for what is feasible in terms of human interference with the river system.

Approach and study tools:
The General Model (GM) developed at the 'surface water modelling centre' will form the basis for this morphological study. In this model various schemes with corresponding boundary conditions can easily be introduced and the long-term development simulated.

Ranking: 1

Expected result:
The output of this study topic will be an important insight into the sensitivity of the river system along with general guidelines for the expecting river response to different types of intervention.
In addition, a tool will be established in which the effect of the schemes proposed by the various FAP schemes can be tested. See also Topic 3.
Required input:
Mathematical modelling expert 3 manmonths, river morphologist 2 manmonths.

Topic 2.4 Subsidence and sedimentation

Description
Subsidence may be of considerable influence on the main river systems in Bangladesh. Some indications of recent subsidence are:
(1) the major avulsion of the Brahmaputra River to its present Jamuna course which may very well be explained in terms of the susidence;
(2) the present trend of erosion along the right bank of the Jamuna River between Bahadurabad and Sirajganj;
(3) the continued lowering of the beel area in the upper reaches of the Meghna River in Bangladesh.

Also when studying satellite images of Bangladesh quite often faults can be observed, which could be signs of subsiding areas.
The possibility exists that this subsidence is in some places balanced by sedimentation of fine sediments, partly originating from the main river system. Embankments could disturb this balance by disrupting the supply of fine sediments. This could in due time lead to lowering of the embanked areas and increasing drainage problems.

Approach and study tools
A study into subsidence and the balancing effect of sedimentation should addres both components of the balance. Subsidence can be studied on the basis of satellite images in combination with topographic maps and by studying boring profiles. Preferably special borings should be done and the age of deposits should be determined with special techniques. In addition available literature on the recent geology of Bangladesh and the surrounding countries will be studied. This will allow to get a rough estimate of the subsidence rate in the past being a first estimate of the present rates as well.

Sedimentation of fine sediments can be studied by making sediment balances for the fine sediments. In particular for the overland flow. This approach is not an easy one, and before applying it on a larger scale, order of magnitude estimates will be made to check on the accuracy that can be obtained.

Ranking: 2

Expected results
Although this appears to be an important study for the FAP, it is felt that with the limited resources of FAP 24, and the kind of studies needed not really suited to the FAP 24 set-up only rough estimates of subsidence rates for the different regions of the country will be obtained. The same holds for the sedimentation rates.

Required input
Geomorpholist 2 manmonths. Geologist 1 manmonth. River morphologist 2 manmonths.

3. River response to FAP implementation

Topic 3.1 Formulation of scenarios

Description:
The large-scale flood control schemes being prepared as part of the Flood Action Plan will certainly interfere with the present river system and could change the characteristics of the system. Interventions will be embankments that reduce the flood plain, closing of offtakes (for example, the Daleshwari), increased water withdrawal from tributaries (for example the Teesta) which will affect the discharge and sediment transport capacity of the main river, withdrawal of more water from the main river (for example, Gorai, Arial Khan and Ganges-Kobadak intake) and river training works reducing the width of the flow channel.

In order to assess the reponse of the river system to the impact of these interventions, they have to be considered in combination with the autonomous changes taking place and other external events. Autonomous changes are a result of, for example, sea-level rise, tectonic subsidence and changes in precipitation in the catchment area. External events are deforestation and large-scale water withdrawal in the catchment area outside Bangladesh.

Approach and study tools:
In order to assess the response of the river system to the FAP interventions an understanding of the autonomous developments is required. Various scenarios for the autonomous developments will be worked out to be combined with various development options resulting from the Flood Action Plan. For that purpose an inventory of possible interventions will be made during phase 1. Planning of some schemes will be in the initial stage, and for those projects the possible interventions will be indicative only while requiring updating during phase 2.

The inventory will be based on structured interviews with the different FAP components. The different autonomous development scenarios and the development options wil be presented in a report. After having been approved by the FPCO this report will serve as the basis for the assessment of the response of the river system to the planned FAP schemes. During phase 2 some updating of the report might be required.

Ranking: 1

Expected result:
An inventory of the possible scenarios of different autonomous developments and possible development options that will be the basis for the assessment of the response of the river system.
Required input:
Water resources engineer 1 manmonth

Topic 3.2 Simulation of river response

Description

The main river characteristics that will be affected by the interventions of the various large-scale flood control schemes are water levels and riverbed levels. Flood levels could increase and low river stages could increase and low river stages could decrease as a result of riverbed degradation. An assessment of the variations that can be expected is a first prerequisite before a decision on the implementation of the schemes can be taken.

Approach and study tools

Water level variations cannot be predicted without taking into account the morphological changes, especially those related to the morphology of the riverbed. This could clearly be concluded from the first simulations made with the General Model (GM) of the Surface Water Modelling Centre (SWMC). Using a different model (RIVMOR) the Consultant predicted already long-term bed and water level changes for different scenarios for the Jamuna river over a reach of 1000 km.

During phase 1 of the study it is proposed to make a preliminary assesment of the river response impact based on hydrodynamic simulations with the existing GM (without major model refinements) in combination with desk studies of the effect on sedimenet transport conditions and river regime. In view of the detailed experience of the local staff at the SWMC, the desire for coordination and the time constraints during phase 1 the hydrodynamic simulations can most conveniently be commissioned to the SWMC, whereas the desk study assessment will be conducted by the project's river morphologist.

In phase 2 of the study more detailed predictions of the morphological changes will be carried out with full dynamic morphological model simulations. Some of the model simulations may require model setup refinements, for which it is proposed to transfer the GM to the project, and do both model refinements and model simulations within the project.

Ranking: 1

Expected result:

A tool to predict the response of the behaviour of the river system to the impact of different interventions as a possible result of the planned FAP flood control schemes, tking into account present autonomus developments. The predicted response will be an essential decision criterion for the implementation of the schemes.

Required input:

Phase 1: Mathematical flow simulations at the SWMC and a river morphologist for 2 manmonths.

Phase 2: Installation of the one-dimensional model, river morphologist 12 manmonths and mathematical modelling expert 12 manmonths.

4. Planform characteristics and channel dimensions

Topic 4.1 Planform classification and meandering and braiding characteristics

Description:
Some of the FAP components are resulting in changed conditions in the Bangladeshy rivers. This may result in changes in planform characteristics (changes braiding towards meandering, increased meandering, etc). To predict these changes classification methods are available, but these methods are derived from field data of rivers outside Bangladesh. Because the determining factors are not fully known, the applicability of these methods is doubtful. Classification methods for Bangladeshi conditions is urgently needed. The same holds for prediction methods for braiding characteristics and meandering dimensions.

Approach and study tools:
Braiding and meandering characteristics can conveniently be determined from satellite images taken during low flow conditions. In addition, old maps and aerial photographs can be used. Furthermore, data on discharges, slopes, bed material size etc are needed. These data should be processed in combination. It may also be required to study satellite images taken during higher stages to investigate the time-dependency.

Ranking: 2

Expected result:
1mproved classification methods and predictors for braiding and meandering characteristics, verified for Bangladeshi conditions.

Required input:
River morphologist: 2 manmonths

Topic 4.2 Channel dimensions (regime equations)

Description:
Embankments may change the total width of Bangladeshi rivers and the contribution of the flood plains in the conveyance of the floods. Hence, the embankments will affect the dimensions of the channels. This can be estimated if regime equations are available, as these equations relate these dimensions to bankfull discharge. Regime equations for rivers are, however, probably affected by the sediment loads in the rivers. Hence, regime equations for the Meghna River may be different from the regime equations for the Jamuna River. Regime equations are also useful as a basis for the estimation of e.g. outer bend scour, confluence scour and local scour.

Approach and study tools:
Regime equations can be derived by analyzing the BWDB cross-sections and BIWTA

soundings. For an analysis of the cross-sections, especially for the braided Jamuna River but also for the meandering rivers, satellite images should be used to correct for the deviations from the perpendicularity of the cross-sections from the river axes. Also the results of sediment transport measurements should be used in the analysis.

Ranking: **1**

Expected result:
Regime and at-a-station equations for Bangladeshi rivers, possibly including the effect of the sediment transport rate (during flood).

Required input:
River morphologist 3 manmonths

Topic 4.3 Bank erosion rates

Description:
Bank erosion rates along Bangladeshi rivers are only approximately known. Nevertheless, it is important to be able to estimate the bank erosion rates over the next years to decide on the necessity of bank protection or to decide on the alignment of embankments retired in relation to the present river alignment. It may be assumed that these bank erosion rates are related to local conditions (river characteristics and bank material characteristics).

Approach and study tools:
Bank erosion rates can be studied using multi-temporal analysis (different years) of satellite images. Sufficient geometrical control allows for estimates with a fair accuracy. Local river characteristics can also be determined from satellite images, but additional measurements of cross-sections etc. should be done. Also velocity measurements should be done to relate "excess velocity" to bank erosion rates. Special observations can be made to study the bank erosion phenomena during and after floods and to determine the importance of groundwater levels after floods. Analyses of bank material characteristics should also be done, and the results should be analysed together with the other observations.

Ranking: **1**

Expected result:
1mproved methods to predict the erosion rates along meandering and braided rivers in Bangladesh.

Required input:
Hydrologist 1 manmonth, river morphologist 2 manmonths, soil mechanics expert 1 manmonth. Special measurements 2 months per year over 3 years.

Topic 4.4 Outer bend scour

Description:
During the Jamuna Bridge project and FAP 1 it was found that bank erosion products do have a significant effect on the scour in outer bends. The larger the bank erosion rates, the smaller the outer bend scour. Bank protection works do, however, block this supply of bank erosion products and this will lead to increased scour. Insight in this phenomenon is very important in view of the maximum depth in front of the bank protection works. An important input parameter will be the celerity of bank erosion, hence there is a close link with topic 4.3.

Approach and study tools:
In this study field measurements (including historical data), the analysis of satellite images, theoretical analyses and two-dimensional mathematical model studies can be combined. The field measurements will provide cross-sections in eroding banks, field measurements of bank erosion can be extended with measurements from satellite images, whereas two-dimensional morphological (mathematical) models can be used to calibrate some coefficients in the predictive equations. Theoretical studies are required to interprete the results and to "simplify" the results obtained to predictors for the effect of bank erosion on the scour depth in outer bends.

Ranking: 1

Expected result:
1mproved predictors for outer bend scour, in which the effect of bank erosion is included. This will allow the estimation of the increase in bank erosion due to the blocking of this source of sediment supply by bank protection works.

Required input:
Morphologist 2 manmonths, mathematical modelling expert 2 manmonths. Special measurements during a number of months per year (could be combined with topic 4.3).

Topic 4.5 Channel cutoffs

Description:
Cutoffs are the balancing mechanism of channels outflanking too much and thus threatening embankments along braided and meandering rivers. Artificial cutoffs can help to mitigate the attack of these outflanking channels. Limited understanding is available on the onset of cutoffs and their development in time. This information is required (1) to predict when cutoffs will occur and (2) for the design of artificial cutoffs. For the latter distinction should be made between a cutoff in a braided river like the Jamuna River where the bed material is essentially loose sand, and in a meandering river where the cohesion of the floodplain deposits may be important.

Approach and study tools:
It is proposed to study the time-depended development of a number of cutoffs, both historical ones and ones that are occurring over the study period. For the historical ones satellite images should be combined with existing soundings, hence is the availibilty of sounding data an overriding factor in the selection of the cutoffs to be studied. For the cutoffs in the study period special measurements are needed, not only in the cutoff but also in parallel channels especially during and after the flood. Flood plain characteristics like the composition and the erosion behaviour of the flood plain soils also have to be determined. In addition a one-dimensional branched morphological model and analytical models can be useful in interpreting the results and in deriving predictive equations for the occurrence of cutoffs.

Ranking: 1

Expected result:
Predictors for the occurrence of cutoffs, including the celerity of the cutoff process and of the silting up of the channel that is being cut off, which is an indication for the duration and extent of eroding channels. Appropriate rules for the design of artificial cutoffs, for both braided and meandering rivers.

Required input:
Morphologist 2 manmonths, soil mechanical expert 1 manmonth. Mathematical modelling expert 2 manmonths. Sampling of flood plain soil samples. Special measurements during some years.

Topic 4.6 Effect of tectonics on planform characteristics

Description
As discussed under topic 2.4, there is some evidence that subsidence may be important for the main river systems in Bangladesh. Not only because of the subsidence but possibly also because it may affect the planform changes of the rivers. This would mean that (1) the location of more permanent chars, (2) the frequent occurrence of some chars at the same location and (3) preferred bank erosion in some areas, and (4) old channels being occupied could be all determined by tectonic effects. Within the frame-work of FAP 21/22 a limited study has been done into the effect of tectonics and the first results demonstrate that there may indeed be some effect. This should be explored further.

Approach and study tools
The limited study under FAP 21/22 was based on the interpretation of satellite studies. Due to time and budget constraints only a few satellite images could be studied. The study proposed here would have to be based on the analysis of more images, in combination with fiield visits.

Ranking: 2

Expected results
A report discussing the importance of tectonics for planform changes, together with recommendations how to incorporate this aspect into modelling concepts for planform changes of main braided and meandering rivers in Bangladesh.

Required input
Geomorphologist 6 manmonths, including 1 month field visits. River morphologist 1 manmonth.

Topic 4.7 Prediction of medium-term planform changes

Description
There is a need for tools to estimate planform changes of braided and meandering rivers over medium-term time periods. Here medium-term is used in relation to the celerity of the morphological processes. Hence medium term means 1 to 3 years for braided rivers. For these rivers such a medium-term prediction is needed for the planning of river defence works like groynes and revetments, and for decisions regarding maintenance e.g. for the future Jamuna Bridge. For meandering rivers, where the morphological processes are proceeding at a a lower speed, the medium term would be in the order of 10 years. Under FAP 21/22 a begining has been made with the development of a prediction methodology for braided rivers, but this methodology should be extended to a computer model because of the stochstic approach that necessarily has to be taken. For meandering rivers a mathematical model exists, but this should be tested for its applicability for the conditions in Bangladesh.

Approach and study tools
The approach taken for braided river is described in Klaassen et al (1993). It involves the development of a mathematical model with as a core a number of modules related to bank erosion, mid-channel bar formation, cutoffs, etc. and as a shell pre- and post-processing on the basis of satellite images. For meandering rivers the mathematical model M1ANDRAS could be used. Its applicability to e.g. the Dhaleswari River could be tested. Probably it will be required to adapt the program to take into account the input of bank erosion products.

Ranking: 1

Expected results
Dedicated version of mathamatical models that can be used for planning and management of braided and meandering rivers at medium-term intervals.

Required input
River morphologist 12 amnmonths. Remote sensing specialist 3 manmonths.

References

Klaassen, G.J. & G. Masselink (1992), Planform changes of a braided river with fine sand as bed and bank material, Proc. 5th Intern. Symposium on River Sedimentation, Karlsruhe, F.R. of Germany,

Klaassen, G.J., E. Mosselman and H. Brühl (1993), On the prediction of planform changes in braided sand-bed rivers, Proc. Intern. Conf. on Hydroscie ce and Engineering, Washington, U.S.A.

Topic 4.8 Influence of cohesive material on planform changes

Description

According to Coleman (1969) there is quite some influence of cohesive material on the erosion of the banks of the Jamuna River. This seems in contradiction with findings under the Jamuna Bridge Study (no difference in erosion rate between chars and "old" land) and with the bank material sampling of FAP1. Still this issue has to be resolved, in particular as far as the possible consequences for planform changes and their prediction is concerned.

Approach and study tools

The best way to study this aspect would be by collecting primary evidence via borings. This, however, is not foreseen within FAP 24. In a number of FAP's though borings have been carried out in relation to foundations (Jamuna Bridge, FAP1, FAP 9B, FAP 21/22 and possibly more). The results of these borings should be collected and be studied in the present light. In addition discussions to be held with Geological Survey of Bangladesh and satellite images to be studied to identify differences in reflection, moisture and vegetation, which could indicate differences in soil composition.

Ranking: 2

Expected results

Report with indications of the presence of cohesive sediment along the main rivers and their relevance for bank erosion processes.

Required input

Soil scientist 2 manmonths. River engineer 1 manmonth. Geomorphologist 1 manmonth.

Topic 4.9 Local slope changes and its effect on planform changes

Description

There are indications that the prediction of planform changes in braided rivers can be improved by including the local water level slope and its variation into the different modules of the modelling methodology outlined under 4.7. A field study into the order of magnitude of these changes could provide indications to what extent it may be advisable to include this variation in prediction methods. From the field observations in combination with the development of the planform where the measurements are being done, it may be possible to develop more refined modules for prediction of planform changes.

Approach and study tools
A number of gauges will be installed in one or several of the locations where the bathymetric surveys are carried out. The gauges will not only be installed along the river, but also at a number of keypoints in the river itself, though at locations which are assumed not be eroded. These gauges will be connected by precise levelling. During one or several monsoons the gauges will be read. Fluctuations in water level slope will be analysed. If substantial, the planform developments as observed from satellite images over these years will be interpreted in the light of local water level slopes.

Ranking: 1

Expected results
Better insight water level changes over short distances and their role as indicators for planform development

Required input
River morphologist 1 manmonths. Land survey team for 2 * 2 = 4 months. River engineer 1 manmonth. Gauge reader estimated for 20 (locations) * 6 months * 2 years = 240 manmonths. Alternatives to be considered.

5. Bifurcation

Topic 5.1 Discharge and sediment transport distriubtion.

Description:
Distributions of discharge and sediment transport at river offtakes and bifurcations in the braided system is one of the keys to the long-term morphological development of the bifurcating branches as well as to the flood levels along these.

The discharge distribution at bifurcations is to a large extent determined by the hydraulic capacity along the entire bifurcating branches. The relative discharge distribution can therefore be strongly stage dependent, as for instance at the Gorai offtake from the Ganges River. The sediment transport distribution, on the other hand, is strongly influenced by the local planform and bathymetry at the bifurcation.

Approach and study tools:
An increased insight into the mechanics and dynamics of bifurcations can be achieved by studying series of bathymetric charts in conjunction with flow and sediment transport data. Differential charts will be produced from digitized bathymetrical charts in order to investigate the development of the bathymetry at the bifurdations (see also topics 5.2 and 5.4.). It is proposed also to use two-dimensional mathematical models of the flow and sediment transport at the bifurcations in order to gain insight into the sensitivity of the processes governing the sediment transport sensitivity of the processes governing the sediment transport distribution.

The Gorai offtake from the Ganges River is of particular importance for the conditions in the South West Region of Bangladesh, as the saling intrusion in that region is strongly dependent on the discharge in the Gorai. The planform at the Gorai offtake is relatively stable which facilitate data interpretation and mathematical modelling. It is therefore proposed to study this offtake intensively and use the findings obtained here, at other similar bifurcations at a later stage in the study.

Also the Dhaleswari offtake from the Brahmaputra River is of particular importance, since the flood levels around Dhaka to a large extent can be influenced by the conditions at the offtake. The Dhaleswari offtake consists of a number of minor channels, which can change rapidly from year to year. This make the use of mathematical models doubtful, since the geometry is poorly defined. It is therefore proposed, as a first step, to investigate this offtake using satellite imageries and the survey data (bathymetrical charts, flow and sediment data).

Ranking: 1

Expected result:
The integrated approach proposed for the study of offtakes will give valuable insight into the bifurcation mechanism and will improve the possibilities to predict mathematically the sediment and discharge distribution at offtakes. This is a prerequisite for a reliable prediction of the long- term development of the bifurcating branches.

Required input:
Mathematical modelling expert 5 manmonths, river morphologist 4 manmonths, computer facilities.

Topic 5.2 Seasonal variation of erosion and deposition

Description:
The discharge and sediment transport distribution at bifurcations and offtakes can be strongly stage dependent during some parts of the year (see Topic 5.1). One implication of this is that in parts of the year a distributor may be overloaded with sediment (depositing) whilst during another part it may have a sediment deficit (eroding). This variation can induce "pulses" or "plugs" in the sediment transport in a distributor. The extreme case is when a distributor is inactive during the dry season and is eroding a new channel during the rising stage.

Approach and study tools:
It is proposed that the seasonal variation of erosion and deposition be derived from series of bathymetric charts, and that the effect on the sediment transport conditions in the distributor be derived from time series of cross-sections in the distributor, if sufficent cross-sectional data are available.

In addition, the seasonal variation of the bifurcation can be modelled using a two-dimensional mathematical model. Transport of sediment "plugs" through a river can be modelled with detailed one-dimensional model setups of the distributors. An increased understanding of this problem can be achieved via a sensitivity analysis with the mathematical model.

Ranking: 2

Expected result:
The expected output from this study topic is an increased understanding of the bifurcation mechanism in general and, in particuar, the seasonal variation. This will improve the ability to model the short-term (seasonal) development of the bifurcations and the distributors. In addition, an improved understanding of "pulsation" of sediment transport will be obtained.

Required input:
Mathematical modelling expert 1 manmonth, river morphologist 1 manmonth.

Topic 5.3 Long-term development of river branches

Description:
The distribution of sediment and discharge at bifurcations is a boundary condition for the development of the bifurcating branches. Provided this boundary condition is known, the long- term development of such a distributor can be modelled mathematically with some confidence. In order to make long-term predictions of the development of the branches it is therefore necessary to gain insight into the long-term development of the sediment transport and discharge distribution at the off-take, and hence an understanding of the development of the bathymetry and planform at the bifurcation (see Topic 5.1).

At present the understanding of the processes governing the long-term development of the bifurcations is poor, especially in braiding rivers, and there is no reliable prediction tool for this.

Approach and study tools:
It is proposed to study this topic using satellite imagery and available cross-sectional, discharge and water level data. It is proposed to select two offtakes which are representative of the conditions in a meandering and in a braiding river.

The conditions around bifurcations are subject to seasonal variation (see topic 5.2) and variation due to migrating bars (see topic 5.4). Thus, in order to determine long-term developments from field data, it is necessary to have access to a large dataset.

Historic satellite imagery, can be used to determine long-term development of the planform around bifurcations. In addition, satellite imageries taken at different stages in conjunction with water level data can be used to produce contour maps of the areas above minimum water level at the bifucations.

Cross-sections at the bifurcations or in the upstream parts of the distributors, and discharge and water level (in conjunction with reliable rating curves) data will reflect any changes at the bifurcation. Analysis of such data will therfore give an indirect indication of the changes taking place at the bifurcation.

Simulation of the long-term development of the bifurcating branches will be based on one-dimensional mathematical models.

Ranking: 1

Expected result:
It will not be possible to develop a detailed prediction tool for the development of a bifurcation, but some realistic ranges for the variability of the sediment transport and discharge distribution at bifurcations can be achieved. This will have a significant impact on the reliability of long-term morphological predictions of the river system.

Required input:
Mathmatical modelling expert 4 manmonths, river morphologist 2 manmonths.

Topic 5.4 Influence of bars

Description:
At the Gorai offtake from the Ganges River there are indications that a bar is located in front of the offtake partly blocking the inflow to the Gorai. There is evidence that this bar is part of a system of bars slowly migrating with a certain periodicity.
The variation of the inflow to the Gorai has a large impact on saline intrusion into the South West Region and on the morphology of that region. These bar systems seem to be an essential element governing the bifurcation mechanism.

Approach and study tools:
The cyclic behaviour of bars at offtakes can be analysed by studying discharge and water level data in the offtake channel and in the main river. In addition, the position of such bars can be determined from low stage satellite imagery of the bifurcation, hence it will be possible to determine the migration speed directly from a series of satellite imagery. It is, moreover, proposed to use two-dimensional mathematical modelling to investigate the dynamics (migration speed, growth and decay) of the bars in detail. This will contribute to the understanding of bar
dynamics. The model setup of the Gorai offtake proposed under Topic 5.1 can form the basis for this model investigation.

Ranking: 1

Expected result:
The output of this study topic will be an improved understanding of the influence of bars around bifurcations which is a prerequisite for long-term predicti of the functioning of river branches such as the Gorai and the Dhaleswari. For the Gorai this is related to the saline intrusion and morphological conditions in the southwest region. At the same time, an improved understanding of migrating bars in large rivers will also be gained. The improved understanding will also allow a better assessment of the efficiency of dredging operations at river offtakes and irrigation water intakes (for example, Ganges-Kobadak scheme).

Required input:
Remote sensing expert 2 manmonths, mathematical modelling expert 2 manmonths, hydrologist 1 manmonths, river morphologist 2 manmonths.

Topic 5.5 Influence of bed forms

Description:
Bed forms have a substantial influence on hydraulic resistance. The dimensions of the

bed forms depend on the flow conditions and sediment properties and may change significantly in time. At high flow rates bed forms can vanish altogether and the hydraulic resistance will decrease significantly.

At a bifurcation, various bed forms may develop in the bifurcating branches. For instance, transition to flat bed may take place in one branch while the bed in the other branch is covered with dunes. This will induce a change in the discharge distribution, which may not be insignificant. As a consequence, also the sediment transport distribution is likely to change.

Approach and study tools:
The dimensions of the bed forms and their variation can be obtained from the soundings from the bathymetric survey around the bifurcations. The applicability of the use of the side scan sonar for the collection of data on bed forms will be studied. An analysis of these data will give a first indication of whether the problem described is significant for the prevailing conditions in the main rivers of Bangladesh.

If it proves to be important, modelling of the bed form dimensions and the associated hydraulic resistance can be included in both the one-dimensional and two-dimensional mathematical models proposed in study topics 5.1 to 5.4.

Ranking: 3

Expected result:
The expected output of this study topic will be an improved description of the distribution of flow and sediment transport at bifurcations.

Required input:
Provided Study Topic 8.1 and 8.2 are running parallel:
Sediment transport expert 1 manmonth.

6. Confluences

Topic 6.1 Erosion and deposition for out-of-phase floods

Description:
The stages in a river reach upstream of a confluence are determined not only by the discharge of this river reach itself, but also by the discharge in the other confluencing river. Especially when the rivers are not in phase (as is the case with the Jamuna and the Ganges Rivers), this may induce complicated scour and deposition processes. In addition, also the actual planform of the two rivers will interfere causing the actual confluence to change constantly its location. This also induces a very unstable behaviour. A study of bank erosion near confluences should take these aspects duly into account.

Approach and study tools:
This study will use satellite images, soundings of the bed topography, and possibly mathematical modelling. From the satellite images the locations of scour and of deposition and of bank erosion can be determined and this should be combined with soundings. In addition, it can be considered to apply a two-dimensional (mathematical) flow model to predict the flow pattern and a two-dimensional (mathematical) morphological model to test these models for their predictive power for these conditions.

Ranking: 2

Expected result:
1mproved insight and possibly predictors for the erosion and deposition and of the bank erosion at confluences. Apart from the relevance for some FAP components, the results may be useful for BIWTA with respect to some ferries that are traversing the river at the confluence of the Ganges and the Jamuna Rivers.

Required input:
Hydrologist 0.5 manmonth, morphologist 1 manmonth, mathematical modelling expert 3 manmonths. Soundings of confluences.

Topic 6.2 Influence of bars and bedforms

Description:
It may be that bars and bedforms have a significant effect on the development of confluences, especially due to the time-dependent behaviour of the riverbed. The actual bed topography and channel alignments during low flow conditions may be significantly affected by the actual location of bars at the end of a flood. The bed topography of the major river at the confluences with a smaller river will have a strong effect on the discharge capacity of the smaller river like the Atrai/Hurasagar confluence with the Jamuna.

Approach and study tools:
The effect of bars and bedforms can be studied by doing special soundings during the flood season and afterwards. Also satellite images can yield additional (historical) information. Also the use of a riverbed profile (such as a sideways-looking sonar) can be appropriate to study the 3-dimensional characteristics of bars and bedforms and to derive transport patterns from multi-temporal soundings. Special attention will be paid to the complicated situation of the Hurasagar/Atrai confluence with the Jamuna river.

Ranking: 3

Expected result:
1mproved insight into the possible effect of bars and bedforms on the conditions of confluences.

Required input:
Morphologist 2 manmonths. Special measurements throughout the flood season but also in receding stages.

Topic 6.3 Confluence scour

Description:
Downstream of confluences deep scour holes occur. These scour holes can occur near bank protection works in rivers that are not fully trained. They are also important for the scour depth near bridge piers. It seems that the depth of these scour holes is determined by the conditions in the confluencing channels, while also the angle between the two channels is important. The causes of this confluence scour are not fully known. Neither is the effect of the controlling factors (dimensions of both upstream channels, sediment transport rate, time dependency).

Approach and study tools:
The proposed approach is an analysis of existing soundings at confluences. In addition, special measurements should be done of not only the bed topography at confluences, but also of the discharges and the sediment transport in the confluencing channels. These measurements should be done during the flood period, but also in the receding stage. It may be of interest to include also results from other studies in different types of braided rivers, to test the results for a wider range of conditions.

Ranking: 3

Expected result:
1mproved predictors for confluence scour.

Required input:
Morphologist 2 manmonths. Special measurements during the flood and the recession during some years.

7. Sand bars

Topic 7.1 Occurrence, dimensions and dynamics of bars

Description:
In the major channels of braided rivers like the Jamuna, but also in rivers like the Padma and the Lower Meghna substantial bars are present. These bars have probably a major influence on various morphological phenomena such as the distribution of water and sediment at bifurcations (see Topic 5.4), the occurrence of cutoffs and bank erosion phenomena. There is hardly any information on these bars that travel through the river system. Nowadays some prediction methods for occurrence, dimensions and dynamics are becoming available, but application of these methods to Bangladeshi rivers results in unrealistic predictions. Hence, there is a need for the development of predictors especially suited for Bangladeshi conditions. This will enable doing a better prediction of the development of the river systems a number of years ahead.

Approach and study tools:
This study should be based on the confrontation of present-day predictors and field measurements. The analysis of a series of satellite imagery taken during low river stages will allow a description of the bar characteristics. Further to historical data, special measurements will be needed (as the historical data were not especially done to identify and study bars). These special measurements will be required at different intervals during the flood and during the recession of flood waves. In addition, analytical methods including non-linear effects will be used. Finally, the application of two-dimensional (morphological) models may be appropriate to test the understanding that will emerge from the preceding confrontation and the subsequent refinement.

Ranking: 1

Expected result:
1mproved predictors for bar occurrence, dimensions and dynamics, that in turn will yield improved understanding of the morphological system over the years.
Required input:
Morphologist 4 manmonths, mathematical modelling expert 2 manmonths. Special field measurements.

Topic 7.2 Time dependency of bars

Description:
It may be that time-dependency is an important characteristic of the bars in systems like the Jamuna and the Padma/Meghna rivers. This time-dependency is introduced by the discharge hydrograph. To study this, a detailed investigation of some bars may be required.

Approach and study tools:
Special field measurements, possibly in combination with some theoretical analyses and mathematical modelling with a two-dimensional morphological model.

Ranking: 2

Expected result:
Understanding of the importance of the time-dependency on bar formation. This may lead to an adaptation of the approach followed in topic 7.1.

Required input:
Morphologist 1 manmonth, mathematical modelling expert 1 manmonth. Special detailed measurements of some bars during the onset of, and the recession of the floods.

8. Bed forms

Topic 8.1 Occurrence, dimensions and dynamics

Description:
The main rivers in Bangladesh have large bed forms. In the Brahmaputra river the bed forms can be several meters high and more that 100 metres long. The bed forms have a large influence on the hydraulic resistance, sediment transport and scour at structures in the river.

The size of these bed forms varies both temporally (see Topic 8.2) and spatially. In connection with the design of structures in rivers it is of great importance to know whether the large bed forms also occur where the larges scour (e.g. at bends and confluences) is found. The spatial and temporal variation of the bed forms is also of great importance for the modelling of the hydraulic resistance and hence flood levels.

Approach and study tools:
It is proposed to extract the bed form dimensions from the echo soundings used for the bathymetric surveys. These data will form the basis for a classification of the various bed form types. Analysis of these data, in conjunction with flow and sediment transport data, will be used to develop a prediction tool for the occurrence and dimensions of the various types of bed forms. This prediction tool can be implemented in both the one-dimensional and two-dimensional mathematical models and form the basis for a sensitivity analysis of the interaction between flow and bed forms leading to an incrased understanding of the river response to changing flow conditions.

Ranking: 1

Expected result:
The output of this study component will be a classification of the bed forms found in the mian rivers and a prediction tool for the dimensions of the bed forms. This will improve the design basis for structures in the rivers (bed form scour), and improve the ability to predict the hydraulic resistance and the associated flood levels in the rivers.
Required input:
Sediment transport expert 2 manmonths, mathematical modelling expert 2 manmonths

Topic 8.2 Time dependency of bed forms

Description:
During low flows very large sand dunes, compared to the water depth, are found in the main rivers. This is reflected in very high hydraulic resistance. The equilibrium dunes for these flow conditions are small. This is a 'time lag' phenomenon. The dunes are formed during high flow or falling stage, but the time required for modification of the dune dimensions is much larger than the time available.

During very high flow transition to flat bed may take place in some parts of the river, resulting in a smaller hydraulic resistance. In some rivers this transition results in a water level drop while the discharge is increasing (i.e. a local maximum on the rating curve). This phenomenon has, however, not been documented for any of the Bangladeshi main rivers.

An important implication of the time lag is that for the same discharge during rising and falling stage the dune configuration at the riverbed can be significantly different, hence the hydraulic resistance and the water level will be different. This is reflected in the rating curves as loops (hysteresis effects), see also Topic 1.4.

Approach and study tools:
The dimensions of the bed forms and their variation can be extracted from the echo soundings used for the bathymetric surveys. These data should be analysed in conjunction with the flow and sediment data in order to assess the importance of the time lag phenomenon.
Both the proposed one- and two-dimensional models have the provision for calculating the dynamic development of the bed form dimensions and the associated hydraulic resistance. The field data mentioned above can be used to calibrate these model formulations if the initial analysis shows that the effect is singificant for the morphological development of the river system.

Ranking: 1

Expected result:
It is expected that this topic will result in a tool for the prediction of the hydraulic resistance and its variation during the hydrological year. This will contribute to an improved understanding of the flow pattern as well as of the sediment transport conditions in the rivers.

Required input:
Sediment transport expert 2 manmonths, mathematical modelling expert 3 manmonths.

Topic 8.3 Three-dimensionality of bed forms

Description:
There are several indications that the bed forms of the Brahmaputra are highly three-dimensional, i.e. short-crested. Directional flow-velocity data collected in the Brahmaputra River under FAP 1 show large variations in direction close to the riverbed. In addition, a theorectical model for the calculation of the hydraulic resistance from observed dune height and length tend to significantly overestimate the observed resistance. This theoretical model is based on long-crested dunes (two-dimensional) and has performed well in rivers with those type of dunes. The three-dimensionality of the dunes also has an impact on the interpretation of dune tracking data and on the sediment

transport conditions. It is, therefore, important to get insight into the extent of this three-dimensionality, to assess the influence on the sediment transport and to modify existing models for long crested dunes to account for the three-dimensionality dunes.

Study tools:
It is proposed to base this study on interpretation of field data in conjunction with a theoretical desk study of the processes involved. The application of the side scan sonar could add valuable information required for this study.

Ranking: 1

Expected result:
This study will lead to an improved understanding of the bed form pattern and an improved description of the hydraulic resistance and sediment transport in the mathematical models.

Required input:
Sediment transport expert 2 manmonths.

Topic 8.4 Bed load transport via dune tracking

Description:
Bed load transport is traditionally calculated from dune tracking data by assuming that all sediment depositing on the lee side of the sand dunes is bed load. However, theoretical analysis of dune tracking and suspended load data from the Brahmaputra River carried out under FAP 1 (BRTS) has indicated that up to 80 per cent of the lee side deposits originate from suspended load. This finding was also supported by the fact that the lee side of the sand dunes are less steep than found in rivers with smaller suspended sediment transport rates.

This implies that bed load transport can only be determined from dune tracking data if the part of the lee side deposits originating from suspended load can be determined accurately. This is extremely difficult to do from field data, since it depends very much on the processes in the thin high concentration layer close to the bed. On the other hand, the possibility for determining bed load transport in any other way in a huge river like the Brahmaputra, where the bed forms can be several meters high, are very limited.

Approach and study tools:
It is proposed to make a theoretical analysis of the concentration and velocity profile close to the bed in order to obtain an insight into how much suspended sediment will be trapped at the lee side of the dunes. With this information the bed load transport can be derived from dune tracking data.

Ranking: 2

Expected result:
The output will be an order of magnitude estimate of the bed load transport during different flow conditions, and an improved capability for the calibration of a bed load sediment transport model in connection with mathematical modelling of river response.

Required input:
Sediment transport expert 1 manmonth.

9. Local scour

Topic 9.1 Dimensions of local scour around structures

Description:
Around bank protection works such as groynes and revetments local scour occurs. The depth of this local scour depends on the local depth, on the flow field near the structure (and thus on the bed topography), on the bed-material size and on the dimensions (planform slope) of the bank protection works. Prediction methods for local scour are available but they have not been tested systematically against field observations in the major rivers of Bangladesh.

Approach and study tools:
Special field measurements should be done near existing bank protection works (Rashahi, Sirajganj, Bhairab Bazar, Chandpur) and near works to be erected shortly (e.g within the frame- work of FAP 21). The results of these measurements should be compared with existing predictors and, if necessary, these predictors should be modified to arrive at predictors suited for Bangladeshy conditions.

Ranking: 1

Expected result:
1mproved predictors for local scour around bank protection works.

Required input:
Local scour expert/morphologist 2 manmonths. Special measurements especially during the flood season, but also during lower stages.

Topic 9.2 Time dependency of local scour

Description:
Local scour may show a time-dependent behaviour because of the variation in discharge. It may thus be that the maximum local scour as found in scale-model investigations, is not reached in reality because the floods have only a limited duration.

Approach and study tools:
To measure the local scour around some selected bank protection works during a full flood, so including the rise and the fall. Comparison of the local scour at the same stage will provide insight in the time-dependency. A comparison can be made with analytical expressions for the time-dependent behaviour (as developed in e.g. the Jamuna Bridge project).

Ranking: 2

Expected result:
An answer to the question whether time-dependency can be taken into account when predicting the local scour around bank protection works. If yes, then lower-cost designs may be possible.

Required input:
Local scour expert/morphologist 1 manmonth. Special measurements during a whole flood cycle.

Topic 9.3 Influence of bed forms

Description:
Bed forms in the major rivers may have very large dimensions (in the Jamuna River dunes up to 10 m high have been observed). There is some doubt as to whether these bed forms are also noticeable near structures or that bed forms are not present in local scour holes. This is important for the determination of the minimum level of the protection works.

Approach and study tools:
Special measurements may be done near bank protection works, but concentrating on the possible occurrence and the dimensions of the bed forms. This can be done by longitudinal soundings, although a better (but more expensive) alternative is a side scan sonar device.

Ranking: 2

Expected result:
An answer to the question whether bedforms should be taken into account in estimating deepest scour holes near bank protection works.

Required input:
Local scour expert/morphologist 1 manmonth. Special measurements.

Topic 9.4 Combination with other types of scour

Description:
There is some doubt as to how different types of scour have to be combined with local scour around bank protection works. Within FAP 21 there will be a special scale-model study to investigate the combination of bend scour and local scour. There is, however, the need for field testing of the different proposals for how to combine these different types of scour, notably bend scour and local scour, and confluence scour and local scour. This can only be done in combination with topics 4.4, 6.3 and 9.1, as these topics will provide field predictors for the individual types of scour.

Approach and study tools:
Special measurements near bank protection structures. The locations should be selected on the basis of the criterion that they are located along an outer bend or near a confluence. The results have to be compared with local scour predictions of confluence scour and outer bank scour alone.

Ranking: 2

Expected result:
1mproved understanding of how to combine different types of scour. This may lead to safer and lower-cost designs for bank protection works.

Required input:
Local scour expert 1 manmonth, morphologist 1 manmonth. Special measurements at selected locations.