

GOVERNMENT OF THE PEOPLE'S REPUBLIC OF
BANGLADESH

Flood Plan Coordination Organisation

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FAP-25
FLOOD MODELLING AND MANAGEMENT



Krüger Consult
in association with
BCEOM

Governments of
Denmark, France,
The Netherlands and
United Kingdom

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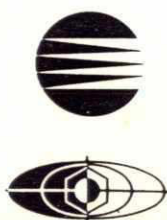
FAP-25
FLOOD MODELLING AND MANAGEMENT



COORDINATION ADVISORY TEAM
SECOND MISSION REPORT

SEPTEMBER 1991.

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
BWDB	Bangladesh Water Development Board (under MIWDFC)
CAT	Coordination Advisory Team.
Danida	Department for International Development Cooperation of the Ministry of Foreign Affairs ,Denmark
DHI	Danish Hydraulic Institute
FAP	Flood Action Plan
FAPMCC	FAP Modelling Coordination Committee
FHS	Flood Hydrology Study
FPCO	Flood Plan Coordination Organisation (under MIWDFC)
FMM	Flood Management Models
GM	General Model
GOB	Government of Bangladesh
HME	Hydraulic Modelling Engineer
MIWDFC	Ministry of Irrigation, Water Development and Flood Control.
MPO	Master Plan Organisation (under MIWDFC)
NCRM	North Central Regional Model
NERM	North East Regional Model
NWP	National Water Plan (under MPO)
NWRM	North West Regional Model
POE	Panel of Experts
RMC	Resident Model Coordinator
SCRM	South Central Regional Model
SERM	South East Regional Model
SOB	Survey of Bangladesh

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SWRM	South West Regional model
SWMC	Surface Water Modelling Centre (under MPO)
SWSMP	Surface Water Simulation Modelling Programme
SWSMC	Surface Water Simulation Modelling Committee (under MIWDFC)
TOR	Terms of Reference
UNDP	United Nations Development Programme

1. INTRODUCTION

1.1 General

Component 25 of the Bangladesh Flood Action Plan (FAP 25), **Flood Modelling and Management**, consists of the following three project components:

- i) A Coordination Advisory Team (CAT)
- ii) A Flood Hydrology Study (FHS)
- iii) A Flood Management Model (FMM)

The project is executed by the Flood Plan Coordination Organisation (FPCO) with the Danish Ministry of Foreign Affairs (DANIDA) as the lead donor. The donor agencies of United Kingdom, France and the Netherlands also contribute to the project.

The first two of these project components, CAT and Flood Hydrology Study, are ongoing, under the supervision of the Resident Model Coordinator (RMC), who took up his assignment in Bangladesh in January 1991.

Final Terms of Reference for the Flood Management Model are still to be prepared.

The Advisory Team of Short Term Experts of the CAT held their first meeting in Bangladesh in October 1990, producing an **Inception Report** dated November 1990. During this meeting it was decided that the second visit of the Team would take place in April 1991, under Terms of Reference as contained in Appendix 4 of the Inception report.

The overall Terms of Reference of the CAT, as stated in the detailed Terms of Reference for the FAP 25, are:

- i) To achieve consistency, compatibility and continuity in all related modelling activities
- ii) To coordinate the supply of models as tools to the various FAP projects and the feedback of relevant data and information from various FAP projects to the Surface water Modelling Centre (SWMC)

The primary objectives of the second visit of the Team have been to advise FPCO on necessary steps to be taken in the further coordination of FAP modelling activities, and to review progress on the Flood Hydrology Study.

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The Terms of Reference for the visit are contained in Appendix 1.

The Team of Short Term Experts of the CAT are:

Mr. Marcel Ramette	FRANCE
Mr. Johan Grijzen	THE NETHERLANDS
Dr. Rodney White	UNITED KINGDOM
Dr. Torkil Jønch-Clausen	DENMARK (Team Leader)

The Resident Model Coordinator of the CAT, Mr. W. Tuck, worked closely with the Team of Short Term Experts during their stay in Bangladesh.

Whenever the CAT is mentioned in this report, reference is made to the Team of Short Term Experts.

The team worked in Bangladesh in the period 6-16 May 1991 and presented their conclusions and recommendations to FPCO on 16 May 1991.

The programme of the visit is included in Appendix 3, and a list of key persons met during the visit in Appendix 2.

The CAT would like to express its appreciation to all officials and individuals met for the kind support and valuable information which the team received during its stay in Bangladesh, and which highly facilitated its work.

All proposals presented in the report are subject to approval by the Government of Bangladesh and the donor countries concerned.

1.2 Comments to the Draft Report

A draft report containing the views and recommendations of the CAT was submitted at the end of the mission. Comments have been received from GOB and the Panel of Experts (POE) and taken into consideration in the preparation of the final version of this report.

One major concern, reflected in several comments, was related to the revised methodology of the Flood Hydrology Study, which to a large degree depended on simulations with the General Model (GM) for 25 years. Though very relevant at that time, this concern has since been overruled following the successful simulations with GM for the period 1964-89

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2. CONCLUSIONS AND RECOMMENDATIONS

2.1 General

The findings and recommendations of the Coordination Advisory team (CAT) are presented in the following chapters. Specific recommendations given in these chapters are not repeated here. As a brief summary of the most important recommendations, the CAT wishes to emphasize the following points:

2.2 Modelling technology

A number of issues related to modelling technology were raised in the CAT inception report. The CAT has followed up on progress with the envisaged enhancements to the modelling systems with the SWMC and is satisfied that appropriate action has been or is being taken on most of these issues (ref. Chapter 4).

Models supplied from the SWMC to the various FAP projects are generally being adapted and modified by these projects to suit their specific purposes (as e.g. the General Model by FAP 1 and the NW model by FAP 2). Hence several versions exist of the General Model and some of the Regional Models. The CAT recommends that a standard version of all models must be maintained by the SWMC which, based on feedback from FAP and other projects, will update each model at least once a year. The individual FAP projects may use their own adapted versions and the FAP 25 Resident Model Coordinator (RMC) will keep informed about the current status of the different versions in use.

A simplified version of the General Model is required for the purposes of the Flood Hydrology Study in order to enable repeated runs of long historic time series. The CAT has requested the SWMC to look into this with a view to enable runs with larger time steps, and hence shorter run times.

The development of operational morphological models at the SWMC has been delayed due to problems of data collection. As a result the regional studies will apply their own methods for morphological studies (with or without models) until verified models become from the SWMC. FAP 25 will follow this development closely.



2.3 Provision of data

Timely delivery of data from GOB sources is still a constraint for the FAP projects which for some purposes have to either collect their own data or tailor their studies to actual data availability. The CAT recommends that the RMC and his counterpart, the Hydraulic Modelling Engineer (HME), assist the FAP projects in a coordinated dialogue with the Government agencies supplying data.

The new Government policy of charging for data is in conflict with the agreed Terms of Reference and contracts for the FAP projects. This has not been envisaged in the budgets and donor contributions. This is a matter between the donors and GOB but is of concern to the CAT in that this difficulty may cause delays to the projects. It also may have a significant impact on the budget for the Flood Management Model of FAP 25.

2.4 Timing of Model Development

While most of the FAP projects have been delayed the programme of the SWMC has continued with minor delays. Hence no major problems exist in supplying hydraulic models to the FAP projects as required. As already mentioned the morphology component of the SWMC is behind schedule and it is important that the Regional Study consultants are free to use other techniques and models for morphological aspects.

The CAT has discussed modelling progress with the ongoing FAP projects (FAP 1,2,3 and 5) as reflected in Chapter 5. Apart from the already mentioned points, some specific but no significant general issues have emerged from these discussions.

2.5 Flood Hydrology Study

The most important issue for the present CAT visit has been the Flood Hydrology Study (FHS). Some difficulties have been encountered in the initial phase of this study for which reason the CAT has decided to prepare a detailed methodology and work plan for the remainder of the study. This is described in outline in Chapter 6 of this report, and in detail in Appendix 6.

The main conclusion of the CAT at this stage is that analysis of return periods, hydrologic design criteria and boundary

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conditions for the regional studies should be based on analysis of historic events generated by repeated runs with the General Model over the last 25 years. The representativeness of this period will be checked through statistical analyses of available data.

The CAT recommends a programme for the FHS which in an initial phase from May to September 1991 will generate approximate boundary conditions for the regional models, followed by a thorough statistical analysis to be completed by the end of 1991. Further analyses based on runs with the General Model for alternative nation-wide flood protection scenarios will be carried out in 1992.

The proposed programme is based on the assumption that a new expatriate Flood Hydrologist be recruited for 6 months starting in August 1991, and the two local Hydrologists be extended to the end of 1991. The contribution from the SWMC in running the General Model has been discussed and agreed.

The CAT has discussed the proposed programme with the regional studies concerned who find the proposed time table acceptable.

The CAT wishes to emphasize the importance of the FHS as the basis for decisions on very large investments in Bangladesh. The study should therefore be given the time and resources necessary to produce results which can be applied with confidence.

2.6 Flood Management Model

The CAT has considered and discussed once again the provisional Terms of Reference for the Flood Management Model (FMM), including a draft concept paper prepared by the RMC.

With the delay of regional studies not enough information is available on which to base an analysis of the need for and specifications of a FMM for Bangladesh.

The CAT finds that the most likely uses of the FMM will be for off-line simulation of flood events to determine optimum flood control strategies, and to investigate design changes which may be proposed after the planning of the FAP has been completed. A possible use of the FMM in the future may be on-line simulation to guide control procedures during flood events.

Before firming up the Terms of Reference for the FMM, the CAT considers that the views of potential users of the model must be sought and understood. This evaluation, which the CAT

proposes to be carried out by a Senior Short Term Consultant in cooperation with the RMC and potential donors, should include a detailed Plan of Operation and revised budget for the project. Close liaison must be maintained with the interested donors (Denmark ,France ,and to some extent the Netherlands).

The CAT proposes that the Terms of Reference for the FMM be finalised in time for consideration of the Technical Committee meeting in September or October 1991.

2.7 Model Coordination

Some difficulties have been encountered in the initial phase of FAP 25 during which the RMC has had to spend considerable time on supervision of the Flood Hydrology Study and making all logistic arrangements for the project. A major constraint on the coordination activities has been the absence of the counterpart the the RMC, the Hydraulic Modelling Engineer to be seconded from GOB.

The CAT strongly recommends that final arrangements be made for the secondment of the HME as a matter of urgency. Assuming this to be the case, and assuming that the FHS will proceed according to the proposals of the CAT, the coordination activities of FAP 25 should improve significantly.

The CAT has made quite specific recommendations as to the scope and procedures of model coordination (Chapter 8). It is stressed that these activities, to be effective in the daily running of the FAP, must include regular contacts between FAP 25, the SWMC and the FAP projects, at the formal as well as at the informal levels. A particularly useful coordination mechanism will be monthly meetings between the RMC/HME, the SWMC and the modellers and hydrologists of the relevant FAP projects.

The CAT has attended the inaugural meeting of the FAP Modelling Coordination Committee (FAPMCC). The main conclusions from that meeting are given in Chapter 8 and draft minutes of the meeting in Appendix 4.

On the question of overall coordination the CAT wishes to emphasize the role of FAP 25 as a component for Flood Modelling and Management. It is not equipped to analyse the combined effects of various development scenarios on the morphology of the main rivers, nor is it equipped to advise Regional Studies on design standards for engineering works.

2.8 Approvals and Procedures

The CAT is concerned that the Agreement for FAP 25 between GOB and DANIDA has not yet been concluded, and that the Resident Model Coordinator so far has been approved only to September 1991. These and other pending approvals, as discussed in Chapter 9, should be finalized as a matter of urgency.

The proposed plan for the finalization of the Flood Hydrology Study involve extensions in time and manpower input. These are matters to be agreed to and approved by GOB, DANIDA and the French Government. If the FHS is to proceed as proposed and produce results which meet the requirements of the regional and other FAP studies, negotiations between the concerned parties must be taken up as a matter of urgency.

The proposed input of a Short Term Consultant to assist in the finalization of the Terms of Reference for the Flood Management Model also require timely approval by GOB and DANIDA.

2.9 Next visit of the CAT

The CAT proposes to make its next visit to Bangladesh in December 1991. Proposed Terms of Reference are included as Appendix 5 of this report.

One of the CAT members will visit Bangladesh in September 1991 to review and guide the Flood Hydrology Study.

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3. BACKGROUND

3.1 Flood Action Plan

The Bangladesh Flood Action Plan has been prepared by the Government of Bangladesh in close cooperation with the World Bank. The Flood Action Plan has been prepared on the basis of several studies undertaken in the wake of the disastrous floods hitting Bangladesh in 1987 and 1988. The Action Plan aims at the identification, planning, design and construction of high priority flood control projects which are technically, economically, environmentally and socially feasible. It has been decided by the GOB that the hydrodynamic models being developed under the Surface Water Simulation Modelling Programme (SWSMP) will be used in the FAP studies.

3.2 The Surface Water Simulation Modelling Programme

The SWSMP was established because of the widespread recognition that the effective control and utilization of water resources in Bangladesh is vital to the economic and social development of the country. Mathematical models of the complex river system are in this respect indispensable tools for an integrated approach to planning and design.

The objectives of the first phase (SWSMP-1) were i) to develop the local capability in surface water simulation modelling, including a sustainable institutional setup within a permanent MPO; ii) to develop a structured approach to modelling with a General Model covering the whole country.

The first phase of the programme finished at the end of 1988. The ongoing second phase (SWSMP-II) will have a duration of four years from 1989 through 1993.

The Surface Water Modelling Centre (SWMC) under MPO is implementing the programme with technical assistance from DHI, and with financial assistance from DANIDA.

3.3 FAP 25 Component

The objective of the FAP 25 Component is to coordinate, optimize and operationalize the use of the SWSMP/MPO models for the purposes of the Flood Action Plan. This is being achieved by :

- 
- The introduction of proper coordination measures, including the formation of a Coordination Advisory Team (CAT)
 - undertaking a Flood Hydrology Study (FHS)
 - the development of a Flood Management Model (FMM)

4. MODELLING TECHNOLOGY

The inception report of the Coordination Advisory Team, November 1990, briefly reviewed the MIKE 11 River Modelling System, to identify its strengths and limitations and to comment on its applicability to the regional and other studies.

The purpose of this chapter is to follow up issues which were raised in the inception report and to note progress with the envisaged enhancements to the modelling system.

4.1 Mike 11 River Modelling System

The Unix version of Mike 11 is now available to the FAP studies. This version allows larger models to be built and facilitates more advanced graphical output. The DOS version is restricted to approx 800 nodes whereas the General and Regional models could exceed this size. For a given size of model, run times of the Unix version differ little from those of the DOS version. Some of the facilities in the DOS version are not yet available in the Unix version including the NAM and Morphological modules.

Catchment Run-Off

Some minor enhancements, including the development of an irrigation module, have been made to the NAM model. Only in a few areas has it been possible to calibrate NAM against runoff; otherwise groundwater has been the sole calibration parameter.

River Flows

The steady-state module (for simulation of long-term morphological changes) has been developed by DHI but is not yet available in Dhaka. Supply is expected shortly.

Sediment Transport

SWMC is informed that the sediment transport module has been enhanced by DHI to include multi-sediment grain sizes and that the cohesive sediment module now includes routines for flocculation, varying erosion over the cross-section and for updating bed levels in line with calculated erosion or deposition rates. These should also be available in Dhaka shortly.



Structures

By modern standards Mike 11 allows the user only a limited range of hydraulic structures. However, DHI has introduced additional facilities including the option of altering the hydraulic performance during flood simulations.

Scientific Documentation

The CAT inception report commented that the scientific documentation for Mike 11 was out of date and of only limited value to the FAP regional modellers. DHI has said that a revised version, which will include details of the recent enhancements, will be available by the end of May 1991.

4.2 Mike 11 General Model of Bangladesh

The question of the regular updating of the General Model was discussed with SWMC. FAP 1 have indicated that changes have been made to the General Model in the light of additional detailed data which has been collected as part of that project. SWMC also makes changes to the General Model as new information becomes available, usually once every year.

The CAT considers that the SWMC should be notified of any changes made in the Regional Studies and that a regular update of the General Model should be issued to all users, say once every twelve months, incorporating those changes which SWMC considers desirable.

The General Model has been calibrated/verified on recent major flood events. It is likely that a General Model will be required to produce the boundary conditions for the Regional Models and that simulations going back 25 years or so will be required. Hence the CAT considers that the General Model should be run for earlier, less major, floods in order to examine how well these simulations fit the observed data. This will be part of the Flood Hydrology Study (FHS), see Chapter 6 and Appendix 6.

4.3 Simplified version of the General Model

Currently the General Model has approx 800 nodes. It includes the Teesta and several tributaries at the head of the Meghna. 120 rainfall stations are used and the land area is divided into 55 zones for the purposes of NAM simulations. Under these circumstances the model has to be run with a time step of 1 hour and takes approx 50 mins running time to simulate one month.

The CAT believes that there should be no viable reason for the

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need to run the GM with such small time steps under the prevailing conditions in the main river system of Bangladesh. The present version of the GM is impractical in the light of time and resource constraints within the Regional studies and the FHS. SWMC has agreed to consider ways of simplify the model and of introducing some artificial base flows in the lesser rivers. This will enable the model to be run with a much longer time step (up to 12 or even 24 hours). This version of the General Model should be used to generate consistent boundary conditions for the Regional Studies.

4.4 Boundary Conditions

Some of the regional studies are, of necessity, using level variations with time as their upstream boundary condition. This method is acknowledged to be less satisfactory than discharge variations with time, but the CAT was advised that checks on computed discharges are made against measurements within the model area and also at the downstream boundary. It would be wise to carry out a sensitivity analysis to check the effect of variations in the assumed upstream water levels against discharges generated within the modelled area.

4.5 Time Steps for General and Regional Models

The Current need to use small fine steps in simulations with the models puts severe constraints on their use for the regional studies. The SWMC should be asked to study the reasons of instabilities using larger timesteps in-depth. The CAT come to the understanding that these reasons are not well understood and believes that a substantial increase of the time step should be possible. If not, then the SWMC should consider creating an option in the model, which allows an automatic temporary adaptation of the time step at critical points in time, for example in relation to fast changes in water levels and flows, or at the time overbank flow commences.

5. PROGRESS AND PROBLEMS ON MODELLING IN FLOOD ACTION PLAN COMPONENTS

5.1 Timing of Modelling Inputs

The first CAT report defined the requirements relating to the adaption of the Surface Water Simulation Modelling Programme - Phase II (SWSMP-II) to the Flood Action Plan.

The latest estimated programme of development as given by the Surface Water Modelling Centre (SWMC) is as follows :

	90	1991	1992	1993
Model/FAP	OND	JFMAMJJASOND	JFMAMJJASOND	JFMAMJJASOND
GM		V		
NWRM/FAP2	A	P* P	F V	
NCRM/FAP3		C	P	F V
NERM/FAP6			A P	F V
SWRM/FAP4		P* P	F V	
SCRM/FAP4			A P	F V
SERM/FAP5		V		

C: Course Pilot Model

A: Accelerated Pilot Model

P: Pilot Model

P*: Pilot Hydrodynamic Model

F: Full Model

V: Verified Model

There has been some slippage in this programme as compared to that in the first CAT report. The morphological component of the General Model and regional models has been delayed due to the lack of a morphologist at SWMC at the early stage.

5.2. Progress of Model Development at SWMC

General Model

The General Model has been developed and verified for 1986, 1987, 1988 and 1989 hydrological years, and the data and analysis from the regional NAM catchments (for rainfall runoff modelling) have been incorporated with the exception of the South Central region.

Salinity Intrusion Model : A Pilot Model has been set up for the Lower Meghna Estuary and HD calibration is in progress. Boundary conditions have been generated by tidal analysis, and further refinement awaits System 21 Bay Model results. More field data are needed for calibration of the Salinity Intrusion Model. Salinity data (samples) for the 1990/91 dry period were lost in the recent cyclone; new data cannot be collected till 1991/92.

Morphological Model : As the Mike 11 module for morphological analysis has not been received , a reviewing and analysing sediment data for a Coarse Pilot Model has been set up to commence trial runs.

North West Regional Model

The pilot model development has been completed (including NAM), in which 9 sub models have been developed and fairly good calibration results have been achieved, but further data collection is needed. Work will start now to combine the submodels, after finalizing the interim report.

North Central Regional Model

A Coarse Pilot Model has been developed and limited calibration done. Further data collection is being initiated to improve the calibration

North East Regional Model

The NAM Catchment has been delineated and preliminary runs carried out. In addition, river schematization has been completed. Topographic surveys and hydrometric data collection is in progress.

South East Regional Model

The hydrodynamic model (composed of 2 submodels) has been verified for 1986, 1987, 1988 and 1989 hydrological years as well as for the 1990 monsoon period. Further data collection

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in progress. The sediment data is being reviewed for Morphological model.

South West Regional Model

This model is being developed with 3 sub-models (Northern, Central and Sundarban). NAM Pilot Models have been calibrated, and the central sub-model (pilot) calibration is completed. Field data collection is in progress.

South Central Model

The model setup is in progress.

Supporting Activities & Applications

NAM Pilot Studies in three catchments of the country (NW, NC and SW regions) are in progress.

Flood Forecasting and Warning : A special version of General Model (GM1) has been developed and tested for 1990, and a newer version is being developed for 1991.

Support to several FAP as well as non-FAP studies is on-going.

5.3 Regional Studies

FAP 2 NW Regional Study

The pilot model for the NW Region was completed in early May 1991, the calibration being based on 1990 data. Although improvements could be made by incorporating more data this will not be undertaken by the consultant as the model is required for assessing flood control and drainage options at the beginning of June. The consultants have requested SWMC to undertake calibration runs using data from April 1986 to September 1990 in order to include high return period events.

The NW Regional consultants have expressed concern over the lack of compatibility and consistency between the DOS and Unix versions of Mike 11. It is likely that FAP 2 will revert to the DOS version in order to use the NAM and Morphology components and to avoid some of the initialisation problems which have been experienced with the Unix version .To do this the NW Regional Model will be reduced in size and hence will differ from the one held by SWMC. In view of the tight schedules for most of the regional studies this is likely to become a common occurrence, hence this problem should be resolved by the SWMC.



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If they are to use the Morphological component (not strictly required by their TOR) the NW Regional consultants require a calibrated morphological model of the NW Region from SWMC by 1 Jan 1992.

The NW Regional consultants have expressed concern over the timing of the FHS. They will have to make their own analyses in the early stages of their study and will use the final results from the FHS during the project preparations in 1992. The method of approach has been discussed and agreed between FAP 25 and FAP 2 in outline.

FAP 3 NC Regional Study

In April 1991 FAP 3 has delivered its report on the calibration of the coarse regional model, developed by the bridging hydrologist. The report puts much emphasis on the lack of adequate topographical data and underlines the discrepancy between river water levels observed by the Consultants and those issued by BWDB (ref. FAP 18).

The further development of the coarse model is pending in the absence of new topographical information. Since such information is not likely to become available at short notice, consultants will have to rely on their own survey data and whatever else may become available. Obviously, the accuracy of their regional model will be affected accordingly.

The NC regional model uses water levels, derived from the General Model, as upstream boundary conditions along the Brahmaputra river. Flood flows into the region as calculated with the General Model are necessarily of a very approximate nature. One may expect somewhat better results in this respect from the regional model, and a feed back of regional model results may well benefit the calibration of the General Model.

The methodology proposed by the CAT for the FHS has been discussed and agreed between FAP 25 and FAP 3 in outline. It was also agreed that the consultants themselves need to use the General Model for a detailed analysis required for the design of the Left Bank along the Brahmaputra river. The joint impacts of nation-wide flood protection works on water levels and flows in the main river system will be subject to analysis under FAP 25.

However, the impacts on the river morphology of such projects, including the Brahmaputra Left Bank, will not be considered by FAP-25. This question should be referred to FPCO and POE. Up till now it seems that in this respect no coordinated effort is undertaken as part of any of the FAP projects. The results

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of any study taking place as part of the River Survey Project (FAP 24) will certainly not become available in time to fill this crucial gap in the FAP. The FPCO should pay due attention to this issue soon(see Chapter 8.4).

FAP 4 SW Regional Study

The consultancy agreement for this study is being processed by the Asian Development Bank and UNDP. The Government also has to finalize their approvals for this project. It is expected that a commencement of this project will occur within the next few months. (ie by July - August 1991)

FAP 5 SE Regional Study

The SE Regional Study commenced in October 1990. Priority projects are to be identified by the end of June 1991, a feasibility study of these projects to be completed by December 1992 and tender documents by 1993.

Mike 11 modelling is being undertaken as an aid to identifying the priority projects and, as an interim measure, the 1988 flood event has been used to provide boundary conditions to the Regional Models. Hydrological factors are being considered as a matter of priority by FAP 5 in order that phase 1 of the project may be completed by the end of June. FAP 25 has been made aware of the methodology being used.

FAP 5 was one of the earliest Regional Studies to commence and is well advanced. As such the FAP 5 consultants will see little benefit from the FHS during phase 1 of their project.

During the feasibility study (phase 2 of the project) some modelling will be undertaken. In particular the Regional Model may be extended southwards to investigate the possibility of getting fresh surface water close to the coastal zone. The FHS will provide useful information during this phase and will not cause delays if the FHS study is completed before 1 Jan 1992.

Early work by the FAP 5 consultant has indicated that there is limited scope for viable river flood protection works in the region.

The SE region is a highly cyclone prone area and measures to protect the area against storm surges from the Bay of Bengal are obviously a high priority concern. This, however, is outside the scope of FAP 25.

FAP 6 NE Regional Study

The start of this project has been delayed owing to a requirement for revision of the contract documents. Consultants have been selected some time ago and it is expected that this study will commence within the next few months. (by July - August 1991)

5.4 Others Studies

FAP 1 Brahmaputra Right Embankment Protection Scheme

This project started in March 1990 and an inception report was issued in May 1990. Since then a working paper on 2-D modelling (Dec 1990) and an interim report (April 1991) have been issued.

The project can be broadly divided into three phases

- Data collection ending April 1991.
- Modelling and geomorphological assessment ending December 1991.
- Refinement of Master Plan and the detailed design of short term works ending December 1992.

The project involves 1-D modelling using a modified version of the SWMC General Model. Modifications include the repositioning of some cross-sections and water level gauges and the introduction of extra cross-sections along the Brahmaputra. Boundary conditions have been derived by the consultant in a pragmatic way, including a preliminary assessment of the effects of a left bank embankment. 2-D modelling is also being undertaken to give a general understanding of the behaviour of braided channels.

The numerical modelling is being augmented using physical models at Faridpur. Originally these models were to be site specific but it has now been agreed that these models will be used to look at general principles relating to revetment works.

Coordination of the FAP 1, FAP 2 and FAP 3 modelling is essential if misunderstandings and duplication are to be avoided. In particular the introduction by FAP 3 of a left bank embankment would have major effects on the hydraulic

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boundary conditions to be assumed by FAP 1 (levels in the Brahmaputra) and FAP 2 (levels in the lower Atrai basin)

It is the impression of the CAT that consultants from the three studies are indeed exchanging information and views on a regular basis.

As all numerical modelling in FAP 1 has to be completed by 1 Jan 1992 the full FHS findings are unlikely to be available in time for this particular Regional Study.

FAP 7 The Cyclone Protection Project.

This project is a ongoing BWDB project incorporated into the FAP. The consultants have prepared an inception report in December 1990. The recent cyclone event, which has caused such extensive loss of life and damage, may lead to major changes in this project.

Hydraulic Modelling in this project has been confined to a two dimensional storm surge analysis using System 21, which is a mainframe program developed by the sub-consultant for FAP 7. A preliminary model has been developed and the first part of the study is to test this model, but refinement will be necessary. The model is applied to primarily studying the interaction between tides and a cyclonic surge, and, until the recent cyclone, was limited by the absence of available and reliable data.

Drainage inside the embankment has been designed to fairly severe design criteria but the interaction of surface water flows with the other factors of tides and surge has not been investigated as this could be a time consuming and complex investigation. Hence for the time being there is no direct link between the activities of FAP 7 and the SWMC, and little role for FAP 25

FAP 8A Great Dhaka Protection Project.

The JICA consultant has submitted his inception report. The report contains no details of any hydraulic modelling. However FAP 8A have had a modeller at the SWMC for a period of 6 months, who has now returned to Japan. Data was assembled for a model and use of the southern portion of the North Central Regional Model (coarse pilot version) was investigated. It is unclear as to whether the consultant intends to do further modelling work but a copy of Mike 11 was hired for 3 months from April 1991 for use in their Japan office. The CAT team was unable to discuss with consultants from the FAP 8A team,

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but RMC will follow up the model related developments on this project.

FAP 8B Dhaka Integrated Flood Protection

ADB have appointed a consultant, who has prepared an inception report dated February 1991. Although the inception report addresses many of the issues addressed in the Regional Studies with respect to design criteria for flooding, there is no reference to carrying out hydraulic modelling in this study. Instead a concentration on embankment protection and basic drainage design is expected. The RMC will keep informed on further developments.

FAP 9A Secondary Town Protection Project.

The ADB Technical Assistance agreement has been signed and a proposal have been received from the consultants. It is unclear at this stage what type or level of modelling will go into the studies. The RMC will follow up on this matter

FAP 9B Meghna River Bank Protection Study

The FAP 9B develops according to schedule and is expected to be completed by the end of 1991. Designs for river bank protections at 8 locations along the Meghna and Lower Meghna are made for currently prevailing hydraulic conditions. Nation-wide flood protection schemes may well alter these conditions substantially. Such changes are not taken into account at present (not included in TOR) and should certainly be addressed at some point in time. The results of the FHS, in particular of stage 3, will be relevant in this respect.

FAP 10 Flood Forecasting and Warning

The Flood Forecasting and Early Warning project is continuing by short term extensions of the UNDP/WMO project BGD/88/013, presently until January 1992. The FAP 10 project is not yet finally approved by GOB, but it is hoped that there will be a smooth and uninterrupted transition from BGD/88/013 to FAP 10.

The present WMO Chief Technical Adviser started work in January 1991 (for a one year period). His activities are primarily concerned with data acquisition, organisation and procurement, while consultants from DHI (under contract with WMO) support the modelling activities. The present DHI involvement expires in June 1991, but extension is being negotiated.

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The flood forecasting modelling system of the Flood Forecasting and Warning Centre of BWDB (FF&WC) is based on an adapted (reduced) version of the General Model from the SWMC, and the system includes updating procedures, real time data etc. The FF model has been tested on previous floods, including the 1990 flood season, and will be applied for real time forecasting in the 1992 flood season. FF&WC staff are presently being trained in Denmark and will return by the end of June 1991.

The development and testing of the FF model takes place in direct cooperation between the FF&WC and the SWMC and coordination through FAP 25 and the RMC is not required for this purpose.

However, close coordination between FAP 10 and FAP 25 will be required for the planning and development of the FMM as described in Chapter 7.

FAP 18 Surveys and Mapping

The availability of up-to-date reliable topographic information is crucial for a proper performance of the regional studies. The calibration of the regional models, cornerstones for the design of flood protection schemes, relies heavily on the availability of adequate topographical data, both in terms of quantity and quality.

The presently available topographical maps at scale 1 : 50,000, in connection with aerial and satellite photographs may be acceptable for the development of coarse models, but they are certainly not adequate for the development of the verified models. The Consultant of FAP 3, for example, carried out its own topographic survey along various rivers in the region and measured water levels at the same time. Serious discrepancies with levels provided by the BWDB for nearby locations were discovered, even in the order of 1 m.

The CAT interviewed the staff of FAP 18 and came to the conclusion that progress has been made with the supply of aerial photographs and satellite imagery to the regional consultants. However, a realistic estimate of the time of completion of most of the secondary levelling work, to be undertaken (or in progress) by FINMAP and SOB is 1993, hence too late to be of much use for the regional studies. It was mentioned that SOB will undertake the second order levelling in the NW and NE region, with support of the Government of Japan. Any attempt to start these surveys in the 1991-1992 dry season should be made and FPCO should pursue the matter to the maximum if the results of these surveys are to be of any use

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for the FAP. FINMAP has completed the second order levelling for the NC region but the time of release of the data is uncertain. Moreover, confusion and uncertainty exist about the proper datum for this area.

The preparation of updated topographical maps, based on 1983 aerial topography, is said to make good progress. However, due to financial constraints, the printing of most of these maps is pending, with the exception of those for the NC region.

Although a massive programme is undertaken to provide sufficient topographical data to the regional consultants, a realistic perspective is that the most important topographical information, including updated levels of bench marks and zero levels of gauges, will only become available upon completion of the Regional Studies. Hence the results produced from regional model investigations at this stage must be interpreted with due regard to the uncertainties resulting from the quality of available topographical information.

In summary, the CAT remains very concerned about the timely delivery of the output of FAP 18 for the benefit of the various regional studies. FPCO should therefore give the highest priority to this FAP component, to ensure that its output can still benefit to some extent the FAP studies.

FAP 19 Geographic Information System.

The original time scale set out in the terms of reference for FAP 19 suggested a starting date of July 1990. This has slipped to April 1991 and the consultants expect to have their inception report complete by June 1991.

The information and systems generated by FAP 19 will be useful and in some cases essential to other FAP components. The FMM will be producing a Digital Terrain Model (DTM) as one of its modules and preliminary liaison has revealed that the systems could be the same for topographic data. The software for this project has been determined and will be procured shortly. Most of the software packages can be procured for FAP 25 to ensure compatibility, as the intended hardware will be very similar for both projects.

FAP 19 intends to have a link-up with the SPARSSO network and their system will be designed to be compatible with this, which means that FMM can incorporate this compatibility also.

The size of the study team in FAP 19 precludes any active involvement in other studies but they will provide a Research and Development facility to other FAP studies.

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A demonstration project is scheduled immediately after the Inception Report to be completed by October 1991. The SWMC models and associated data provide a possible subject for this demonstration project. Continuous liaison should be maintained with FAP 19 to investigate this possibility.

The CAT recommends that the FMM be developed with the same DTM software as FAP 19, when appropriate and possible, or at least compatible with that software. It is important that all FAP studies work with DTM software, data storage and handling software that is fully compatible with FAP 19.

FAP 20 Compartmentalization Pilot Project

The consultants for FAP have started their mobilization in May 1991 and will start their field work, including the hydrological survey, in June. The remarks as stipulated in the CAT's Inception Report are still relevant. The proposed mission for the definition of the FMM should liaise closely with the FAP 20 team with regard to the FMM requirements.

It is understood that any contribution of the Government of the Netherlands to the development of compartment models as part of an FMM will be materialized under the umbrella of FAP 20.

6. FLOOD HYDROLOGY STUDY

6.1 Introduction

As from early January 1991 FAP-25 has undertaken the Flood Hydrology Study (FHS) along the lines indicated in the TOR in the CAT's Inception Report. Progress of the study in its early stage was seriously hampered by the time required for data collection and subsequent entering of the data into the data base, which was still ongoing at the time of the CAT's second mission. A second handicap for the team was that an adequate and straightforward methodology had not been prescribed at the start of the study nor in the CAT Inception Report. Both reasons have prompted the CAT mission to reconsider the objectives of the FHS, to develop a concise methodology which can be immediately and efficiently implemented, and to review the required staff resources to complete the remainder of the FHS at the earliest.

It is the CAT's firm opinion that the FHS is crucial for the success of regional studies, not the least because very large projects will be designed on the basis of results of the FHS in terms of design flood hydrographs. Therefore, due attention must be given to the subject and the CAT has concluded that the original anticipated input of only 6 manmonths of an expatriate Flood Hydrologist is not adequate for a proper execution of the FHS, irrespective of experienced initial delays. The CAT therefore proposes to appoint a new expatriate Senior Flood Hydrologist for a period of 6 months until January 1992, who should work in close cooperation with a hydrodynamic modeller of the SWMC.

Preliminary design conditions for the present conditions are expected to become available at the latest in early September 1991. Refined results for the present conditions will become available by the end of 1991, and the reporting on stages 1 and 2 of the FHS can be completed in January 1992. This, of course, is on the assumption that necessary staff resources become available in time.

Hydraulic design conditions for potential nation-wide flood protection schemes, reflecting the joint impacts of developments in various regions on design water levels and flows in the main river system of Bangladesh, will be established as the needs arise, most likely on a quarterly basis in 1992. Some preliminary results can be produced in 1991, if needed. This activity, indicated as stage 3 of the FHS, will be undertaken in close consultation with the consultants of the regional studies and be conditional to the



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timely delivery to FAP-25 by these consultants of preliminary designs for realistic protection schemes. The role of the RMC is crucial in the performance of this task.

On-going regional study teams have expressed their support for the proposed methodology of FHS and it should therefore be implemented as soon as possible.

The CAT mission has identified the need for regular coordination at technical level between the FHS and the consultants for the regional studies, in particular between the respective hydrologists and hydrodynamic modellers. Therefore, working sessions will be held on a monthly basis (called by the RMC), where the progress of the FHS and its results will be discussed in-depth. This should ensure that the FHS will be fully geared to the needs of the regional studies and that all regional studies adopt the same methodologies concerning the selection of design events, design hydrographs and considerations with respect to the joint probability of extreme rainfalls in the regions and flood hydrographs on the main rivers.

6.2 Objectives of the Flood Hydrology Study

The terms of reference (TOR) for the Flood Hydrology Study (FHS) are contained within the TOR for FAP-25. The objective of the FHS was stated as 'to provide the hydrological basis for establishing unified engineering design events for the FAP', to be achieved by 'analyzing in depth the characteristics of flood hydrology in Bangladesh by taking into consideration among other things the joint probability of the simultaneous occurrence of the individual main causes of floods'.

The Hydrology Expert on the Local Panel of Experts(FPCO) proposed in early April 1991 the following specific issues to be addressed by the FHS:

- a. A unified methodology for estimating flood magnitude (discharge or water level) of given return period, i.e. design flood
- b. A unified methodology for developing a rainfall hyetograph of given depth-duration-return period, i.e. design rainfall
- c. A unified methodology for generating a hydrograph (water level or discharge) of given return period, i.e. design hydrograph
- d. Under conditions where joint probability analysis is important a unified methodology for joint probability analysis is required. The methodology should indicate how various variables like flows in upstream branches,

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- downstream water levels, time between peaks, duration of floods, tributary flows, backwater effects, tidal influence, etc. will be incorporated in the joint probability analysis according to their importance
- e. A method for incorporating the influence of proposed flood protection schemes (especially embanked rivers) in the estimation of design events
 - f. A unified methodology for assessing the reliability of the estimated design event considering data error, hydrologic uncertainties and hydraulic uncertainties

In general the consultants for the NW, NC and SE regions expressed the need to obtain series of historical flood season hydrographs, to which a specific return period can be assigned and which can be applied with the associated historical rainfall series. In addition they requested to consider characteristic design variables for 3 sub-seasonal flow conditions.

Finally, it is appropriate to recall the recommendation of the CAT inception report of November 1990 to execute the FHS in 3 stages, i.e.:

Stage 1:

Statistical analysis of historical rainfall, flow and water level data for a few selected strategic locations in the system to obtain a first estimate of design flows, levels and rainfalls

Stage 2:

Assuming that a fairly complete set of data may be available for a substantial period, the General Model could be run and the results analyzed statistically. Some sets of boundary conditions could then be selected, which produce flows and levels corresponding to selected return periods.

Stage 3:

Flood protection works may affect the design levels in the main river system, which act as boundary conditions for the regional models. Once the consultants have defined various protection works the effects thereof on design conditions in other areas have to be determined with the General Model.

The CAT has developed a methodology for completion of the FHS, as outlined in detail in Appendix 6, which complies with the above described objectives and requirements imposed with on the FHS. An early approval of the proposed methodology for the FHS by FPCO is requested to avoid any further delay in the progress of this study.

6.3 Methodology for Completion of the FHS

The main problem in a joint probability analysis of various causes of floodings is to incorporate the interaction of the physical system with these causes. It may well be possible to carry out such analysis for the main system in its present conditions, based on historical water level and flow data. However, such data generally do not exist for the major part of the regions, outside the main system. Moreover, results of such analysis for the main river system are also not applicable for potential future situations upon completion of a nation-wide flood protection scheme. Embankments along all major rivers may change the pattern and amount of spills substantially, and consequently induce significant changes in the probability distributions of water levels and flows, and in the joint probabilities of various flood causing factors.

The conclusion remains that a joint probability analysis as anticipated in the TOR for the FHS is extremely difficult and impracticable, in particular in view of the need to derive design hydrographs for potential future situations with major changes in the conditions of the main river system. Hence, the only practical and feasible option is to use the GM extensively to derive design hydrographs for the main system. A similar reasoning holds for the establishment of design conditions within the regions.

During the CAT's presence in Bangladesh the SWMC has kindly undertaken some tests aimed at reducing the running time of the General Model. It appeared that with some minor modifications in the model a running time of one hour for a full flood season can be achieved on a PC-486, which contributes substantially to the feasibility of the proposed methodology for completion of the FHS.

The proposed methodology for the FHS consists of three main components, i.e:

- a validation of the GM for the full period 1964-1989, statistical analysis of its results, supply of design boundary conditions to the regional consultants and some graphic display of return periods for selected historical floods, valid for specific design characteristics (e.g. annual maxima, sub-seasonal flood volumes); to be completed early September 1991
- base line statistical and joint probability analysis and similar type of studies with the aim to produce required design statistics, to determine the representativeness of the period 1964-1989 for the full century, to assess the quality of available data (i.e. a quality assurance

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- study) and to provide standard errors of estimate for specific design criteria
 - runs with the GM for the full period 1964-1985 for potential future situations after the implementation of alternative nation-wide flood protection schemes, including the analysis of results and supply of design boundary conditions to the regional consultants (mainly in 1992)

It is the CAT's opinion that this approach, which draws extensively on the use of the GM, is the only feasible option to establish reliable design boundary conditions for the regional studies. The study will mainly use observed flow, water level and rainfall data for the period 1964-1989, by all means the only available consistent set of data for Bangladesh. A very preliminary analysis revealed that this period is adequate to derive design conditions for return periods up to at least 50 years. All efforts must be undertaken to disclose at least some relevant hydrological data of earlier origin, as a check on the representativeness of this rather short period for the full century.

The detailed approach to the FHS and the planning of its completion are outlined in Appendix 6. The CAT does not consider the eventual impacts of cyclones, spring tides and increased sea level rise due to the green house effects will affect the conclusions of the FHS at this stage. However, the on-going discussions on the nature and probable magnitude of sea level rise, and its implications for Bangladesh, will be followed by the CAT.

6.4. Planning for Stages 2 and 3 of FHS

The planning for the completion of stages 1 and 2 of the FHS reflects the need to produce practical and useful results for the regional studies at short notice, at the latest in early September 1991. Improved results will gradually become available during the remainder of 1991.

A crucial point in the work planning is the success or failure of the validation of the General Model for the entire period 1964-1989. So far, the model has only been validated for the last four years in this period. In the event of a substantial failure in terms of a proper simulation of time dependent water levels for various key-stations along the main rivers of Bangladesh, all efforts must be undertaken to solve such problem at the earliest.

6.5 Input in Manpower for Completion of FHS

The planning for the completion of stages 1 and 2 of the FHS is based on the cooperation of the FAP Computational Hydraulic Engineer, working at the SWMC for the FHS. He will be primarily responsible for the development of the dedicated GM, and the running of the GM, whereas the Hydrologist of FAP 25 will be responsible for the baseline statistical and related studies, for the preparation of all input data and for the analysis of the results obtained with the GM.

FHS is expected to require an additional input of an expatriate Senior Flood Hydrologist for a period of 6 months, to starting as from August 1st, 1991, but preferably as from July 15th. Part-time input of a SWMC modeller is required for the remainder of 1991, and occasionally also during 1992. The input of the two hydrological assistants presently working for the FHS has to be extended to the end of 1991. It is anticipated that the provision of some input from an hydrological assistant during 1992 for the activities mentioned under stage 3 will be needed.

The expatriate Senior Hydrologist should have postgraduate qualifications, a length of experience of 7 to 10 years, be experienced with data processing and to some extent with the use of hydrodynamic models, and should above all be able to communicate easily on a professional level with hydrologists, hydrodynamic modellers and design engineers of the regional consultants.

7. FLOOD MANAGEMENT MODEL

In discussing the role and function of the Flood Management Model (FMM) it is essential that the objectives of FAP 25 are clearly understood.

FAP 25 has three components :-

- Co-ordination of Modelling within FAP
- the Flood Hydrology Study
- the Flood Management Model.

The CAT considers that the nature, use and development schedule for the FMM is not well understood. In particular the roles of the Modelling Coordination, the FHS and the FMM are being confused.

Modelling Coordination is a function which is designed to ensure the free passage of information on modelling between the various FAP components and to encourage a consistent approach to modelling.

The Flood Hydrology Study has, as its principal objective, the provision of suitable boundary conditions for the Regional Modelling Studies under present conditions and also under the conditions which will pertain once the FAP is brought to fruition. The Flood Hydrology Study will involve running the General Model to generate these boundary conditions and the use of the FMM is not required at this stage.

The FMM is an enhanced version of Mike 11 which could include the following features :-

- a digital terrain model, possibly embedded with in a GIS system, which will indicate more accurately flooded areas during the wet season
- more versatile representation of structures such that flows through barrages, sluices etc. can be better represented
- enhanced graphics to make the modelling more user friendly and to aid interpretation of results.
- the capability of defining operating rules for "movable" structures
- the capability of operating off and, possibly, on line.

The relative timing of FAP 25 and the Regional Studies means that the FMM will not be available for use by all the

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Regional Study consultants for design purposes. Most designs will be determined using the present Regional Models plus the General Model.

Likely uses of the FMM will thus be :-

- The off-line simulation of flood events to examine alternative flood control strategies
- To investigate design changes which may be proposed after the Regional Consultants have reported on their findings i.e. after the FAP Regional Studies.

A possible use of the FMM at some time in the future may be:-

- the on-line simulation of flood events to guide control procedures during flood emergencies.

Before firming up the TOR for the FMM, the CAT considers that the views of potential users of the model must be sought and understood. This evaluation should go into some detail such that the precise facilities required in the model are known. The need for training of GOB personnel to run the FMM should also be considered.

The CAT has had limited time during its second mission to consult widely but it has consulted FAP 10 and also has had internal discussions on the FMM. The CAT's views at the present time are as follows :-

- The ultimate FMM is likely to be large and complex if it is to fulfil its role in providing an off line capability of determining optimum flood control strategies. A regional FMM would probably contain several thousand nodes and a countrywide FMM would be an order of magnitude larger. A flood forecasting model has, by definition, to run quickly with a minimum amount of input data. There is thus a basic difference in the nature of FF and FM models. The CAT thus believes that, for the foreseeable future, separate, but well coordinated model developments should continue for Bangladeshi flood forecasting and flood management.
- Special purpose FMMs which are less demanding with respect to computing and data requirements may also be visualized. Such FMMs could range from detailed compartment level models to simplified regional or interregional models for examination of operating strategies for major structures.
- It follows from the above that the requirement specifications for the FMM should concentrate on its off

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line roles of (i) a means of establishing flood control strategies and (ii) a design aid.

- At some time in the future computing technology will advance to the point where more complex models can be run much more quickly. However, the use of the FMM on line will, in addition to the enhancements in computing power, still require much quicker and comprehensive on line data retrieval and processing systems. FAP 10 is unlikely to produce an adequate and proven system which will satisfy these requirements before 1995.
- The finalization of the TOR for the Flood Management project is difficult to achieve with the current resources to FAP 25. The CAT thus suggests that a senior expert, with engineering experience of flood control systems, is appointed to review Bangladeshi requirements and to formulate revised TOR. This expert should work closely with the RMC and consult relevant authorities, projects and FAP studies (eg FAP 2-6, FAP 8, FAP 10, FAP 19 and FAP 20). His input would be approx. 2 man months.

The CAT is concerned that donor interest in supporting the FMM development may have changed since the inception of FAP 25. It is suggested that the relevant donor countries for the FMM, (Denmark, France and to some extent the Netherlands) be actively involved in the finalization of the TOR for the FMM, which will also include possible revision in organisation, staffing and budget. The opinions of the CAT in this respect will be facilitated through the RMC. Upon finalization of the TOR tender(s) should be invited from qualified group(s) of companies.

Once the development of the FMM is completed it may be advisable to commission an engineering consultancy study to identify and evaluate specific flood control strategies in the light of the recommendations and proposals from the FAP Regional Studies. This will be a multi-disciplinary Study because flood control strategies cannot be considered purely in terms of hydraulic considerations. Land use practices, risks to life and livelihood, economics and environmental issues all affect what can and cannot be done in terms of flood control strategies. The study should make specific recommendations, with respect to the future use of the FMM, considering i.a. the outcome of the FAP 26 Institutional Study.

8. MODEL COORDINATION

8.1 Progress on Model Coordination

The initial effort on model coordination was made by the CAT during its first visit in October 1990. The Resident Model Coordinator (RMC) took up his assignment in Bangladesh in January 1991 at which time the continuous model coordination activities of FAP 25 could begin.

According to the TOR the RMC is supported by a Bangladeshi Hydraulic Modelling Engineer (HME), preferably seconded by the Government. The FPCO has nominated a candidate for this post but this nominee has not yet started work on the project.

According to the TOR "The RMC will work for the achievement of consistency, compatibility and continuity in all related modelling activities as well as for the coordination of the supply of models as tools to the various FAP projects and the feedback of relevant data and informations of various projects to the SWMC". In the inception report of the CAT this role was further described as "...the main role of the RMC will be to act, through the FPCO, as the pivot or link between the CAT team, the SWMC, the governmental agencies involved in the FAP and the FAP component consultants using modelling in their studies"

These functions have only partly been fulfilled by the RMC to date. Liaison with FPCO, SWMC and some of the FAP components has been maintained, but not to the degree originally intended. The reason for this has been lack of time due to other commitments of the RMC, such as

- establishment of office facilities, recruitment of local staff and other initial logistic arrangements for FAP 25. This activity has been quite time consuming.
- assistance to and supervision of the Flood Hydrologist for the Flood Hydrology Study (FHS). This activity has required more input by the RMC than originally envisaged.
- no support from a Bangladeshi counterpart (the HME)

The office is now established and it is hoped that arrangements for the HME to start work can be finalized very soon. Although the RMC still has to devote some of his time to the FHS, and some to the finalization of the TOR for the Flood Management Model, the CAT recommends that the RMC gives very high priority to the model coordination activities in future.

8.2 Model Coordination Activities

In order to meet the requirements stated above the RMC must maintain close contact with all relevant FAP components at the formal, as well as at the informal level.

The CAT finds that a precondition for effective coordination is that the RMC/HME remain up to date on model related developments in all FAP components, not just through formal meetings at certain intervals, but also through regular informal consultations in the offices of the various FAP consultants. Hence FAP 25 will function as a medium for sharing information and experiences between the SWMC and the FAP projects, and hopefully reduce unnecessary duplication of work and repetition of mistakes.

The types of information and experiences to be shared between SWMC and the FAP components through the RMC/HME include:

- issues related to data collection, processing and interpretation, as well as to data quality. FAP 25 may assist the FAP projects in establishing a coordinated dialogue between the FAP and the Government agencies providing data (BWDB, MPO, SOB etc.)
- adaptation of SWMC models to specific uses in FAP projects (such as e.g. the modified GM used in FAP 1, FAP 10 and the FHS), and feedback to SWMC who is responsible for holding 'basic' versions of all models. FAP 25 will maintain information on capabilities of special (modified) versions of models in the various FAP projects. These special versions will be retained by SWMC at the end of each Regional Study.
- application of morphologic modelling modules. Until the SWMC morphology modules are fully developed and tested different approaches to morphology studies (with or without models) are likely to be taken in various FAP components. FAP 25 will play a role in coordinating possible different modelling approaches.
- problems related to model applications and interpretation. FAP 25 will monitor problems encountered in running the models and, whenever possible, advise the FAP projects on how to solve them (in many cases, however, SWMC assistance may be required)
- requirements to and results from the Flood Hydrology Study, i.e. boundary conditions for regional models and hydrological design conditions.

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- requirements for and uses of Flood Management Models (FMM) for examining alternative operation strategies. In finalizing TOR for the FMM a dialogue with relevant FAP projects will be very important, as will the coordination once the FMM development is commenced, probably in early 1992 (see also Chapter 7)

With respect to the way in which the coordination activities are carried out by the RMC/HME, the CAT proposes the following mechanisms:

- regular informal discussions in the offices of the relevant FAP consultants and the SWMC, at least once every month for the regional studies
- monthly technical meetings, arranged by the RMC, between modellers and hydrologists of the FAP projects and representative(s) of SWMC. This was proposed and agreed at the inaugural FAPMCC meeting.
- regular briefings of the FPCO and the Chairman of the local Panel of Experts
- quarterly meetings of the FAPMCC

In addition to these activities the CAT will continue to provide overall supervision of FAP 25 through half-yearly visits to Bangladesh. The next visit of the CAT is tentatively scheduled for December 1991. Proposed TOR for this visit are included as Appendix 5 to this report.

8.3 The FAP Modelling Coordination Committee (FAMCC)

The CAT attended the inaugural meeting of the FAPMCC on 14 May 1991. Draft minutes of the meeting are included as Appendix 4 to which reference is made for details. Some of the main issues discussed at the meeting were the following:

- The TOR for FAP 25 were presented and discussed. The TOR were generally found appropriate.
- The progress of the SWMC activities, and the modelling requirements of the Regional Studies, were discussed. Apart from some uncertainty with respect to the requirements for morphological models for the Regional Studies (discussed above for each of the Regional Studies), no major problems exist with respect to the timely supply of models from the SWMC.

- The question of different versions of the General and Regional Models (at SWMC and in the various FAP projects) was discussed. It was generally felt that the SWMC shall hold an 'basic' version of each model, to be updated as appropriate, while special (modified) versions may be used by the individual FAP projects.
- Several FAP projects raised the procedural problems associated with data acquisition which delay project progress. They also pointed out that the newly introduced system of charging for data from Government agencies is incompatible with the agreed TOR and contracts for the FAP projects and creates problems in project execution.
- The need for model coordination, including the above mentioned monthly technical meetings, was stressed.

8.4 Overall Coordination in the FAP

The Flood Hydrology Study of FAP 25 envisages a series of a few runs with the General Model in which the overall effects on water levels and flows in the river system of alternative nationwide flood control measures will be analysed. This will be done to provide boundary conditions for regional models under various development scenarios.

The CAT wishes to emphasize, however, that the FAP 25 component has been designed for three specific purposes: model coordination, flood hydrology and flood management modelling, as outlined in the TOR. It is not equipped to analyse the combined effects of various development scenarios on the morphology of the main rivers, nor is it equipped to advise Regional Studies on design standards for engineering works.

This does not mean that the CAT finds such analyses unnecessary. On the contrary. It is indeed essential for the success of the FAP that proper attention be given to interregional interactions, and that repeated runs be made with the General Model to analyse the hydraulic and morphological implications of proposals from the regional studies. To do this, however, requires a range of expertise and resources in the planning and interpretation of such model investigations, which are not available within the FAP 25.

In other words, the CAT finds that the FAP presently appears to suffer from a missing component which would provide the overall link between the regional studies. In the absence of such a component only FPCO and the POE can attempt to provide this linkage.

9. STATUS OF FAP 25 COMPONENT

9.1 Formal Approvals

The FAP 25 project has received all necessary approvals from the GOB with respect to the coordination and flood hydrology components. The TOR for the flood management component are still provisional.

Formal request for assistance to DANIDA has been made by GOB but the Government Agreement (exchange of letters) is still pending. The lack of a formal Agreement between DANIDA and GOB is causing certain administrative problems for the project. The CAT recommends that this matter be resolved very soon.

The Resident Model Coordinator (RMC) took up his duties in January 1991. He has been approved by GOB for 9 months only, i.e. to September 1991. This is clearly unsatisfactory, and approval for the entire period should be given by GOB soon.

The Flood Hydrologist was approved by GOB in January 1991, but approval of the two local Hydrologists is still pending.

As described in Chapter 6, and elaborated in detail in Appendix 6, the Flood Hydrology Study needs to be extended to January 1992. A new expatriate Senior Flood Hydrologist needs to start work in Bangladesh in August 1991 for a six months period, and the two local Hydrologists need to be extended to the end of 1991 as well. These arrangements have been proposed by the CAT during the present visit, and necessary approvals by the donors and GOB have yet to be obtained. However, in recognition of the importance and urgency of the FHS, the CAT urges that the necessary approvals will be forthcoming soon.

Similarly, the CAT proposes that a senior expert be given the task of finalizing the TOR for the Flood management Model, in close cooperation with the RMC, for a two months period before September 1991. Necessary approvals by donors and GOB will be required.

The additional Computational Hydraulics Engineer for the FAP at the SWMC has received necessary approvals and is now fully operational.

9.2 Recruitment of Local Staff

A Hydraulic Modelling Engineer (HME) has been nominated by FPCO but due to administrative problems he has not yet been seconded to FAP 25. The CAT strongly recommends that this be settled as a matter of urgency as the absence of the HME is constraining the coordination function of FAP 25.

9.3 Logistics

An office for FAP 25 has been established in Gulshan (House 19, Road 102, tel. 882105/06), necessary support staff (administrative assistant, secretary, drivers) have been recruited, and computers and office equipment have been procured and installed. The office has the capacity required for the full project (i.e. including the FMM) and it is now fully operational.

9.4 Timing

The FAP 25 project has been set up at a time which has allowed it to provide some support in the initial phases of the Regional Studies (FAP 2 and 3) and also to FAP 1 and 5.

However, the FHS has experienced some initial delays, and it is now evident that this component of FAP 25 needs to be extended by approximately 6 months, i.e. to January 1992. In order to minimize adverse effects on the regional Studies due to further delays, necessary administrative arrangements for the continuation of the FHS need to be completed as a matter of urgency.

The CAT recommends that the TOR for the FMM component be finalized by September in order that necessary formalities can be completed in time for the FMM development to start in January 1992. It is noted that a detailed Plan of Operation and revised budget need to be prepared as a basis for negotiation with donors for final funding arrangements.

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Appendix 1 : Terms of Reference for the Second CAT mission

TERMS OF REFERENCE

for

Second meeting of Short Term Experts
on the Coordination Advisory Team

1. BACKGROUND

Component 25 of the Bangladesh Flood Action Plan (FAP 25), Flood Modelling and Management, consists of the following three project components:

- i. A Coordination Advisory Team (CAT)
- ii. A Flood Hydrology Study
- iii. A Flood Management Model (FMM)

The project is executed by the Flood Plan Coordination Organisation (FPCO) with the Department for International Development Cooperation (DANIDA) of the Danish Ministry of Foreign Affairs as the lead donor. The donor agencies of United Kingdom, France and Netherlands also contribute to the project.

The first two of these project components, CAT and Flood Hydrology Study, are ongoing, under the supervision of the Resident Model Coordinator.

Terms of Reference for the FMM are still to be finalized.

The Team of Short Term Experts of the CAT held their first meeting in Bangladesh in October 1990, producing an Inception Report dated November 1990. During this meeting it was decided that the second visit of the Team would take place in April 1991, under Terms of Reference as contained in Appendix 4 of the Inception report.

The present Terms of Reference for the second meeting of the Team are prepared in full accordance with those of the Inception Report.

2. OBJECTIVES

The overall Terms of Reference of the CAT, as stated in the detailed Terms of Reference for the FAP 25, are :

- i. To achieve consistency, compatibility and continuity in all related modelling activities.
- ii. To Coordinate the supply of models as tools to the various FAP projects and the feedback of relevant data and information from various FAP projects to the Surface Water Modelling Centre (SWMC)

The primary objective of the second meeting of the Team is to advise FPCO on necessary steps to be taken in the further coordination of FAP modelling activities, based i. a. on available Inception report from relevant FAP regional and supporting studies.

3. ACTIVITIES

In pursuance of the provisions of Clause 4.1 of the Terms of Reference for FAP 25, which specifies the responsibilities of the CAT, the work of the Team during their second visit should include following activities:

- a. Review the actions taken by FPCO and SWMC in the light of the CAT's inception report.
- b. Review progress on modelling in the regional and other FAP studies.
- c. In the light of (a) and (b) make recommendations for the continued coordination of modelling developments between SWMC and other FAP studies.
- d. Review progress on the Flood Hydrology component of FAP 25 and consider in detail how the results of this study should be applied to the regional FAP projects.
- e. Make recommendations on the Terms of Reference for the Flood Management Model component of FAP 25 to FPCO.
- f. Attend and contribute to be the inaugural meeting of the FAP Modelling Coordination Committee (FAPMCC).
- g. Review progress of the FAP 25 project organization and operation.
- h. Report to FPCO.

4. COMPOSITION OF THE TEAM

The expatriate advisory Team of short Term Experts will be composed as follows:

Dr. Rodney White (U. K.)



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Mr. Marcel Ramette (France)

Mr. Johannes G. Grijzen (Netherlands)

Dr. Torkil Jonch-Clausen, Team Leader (Denmark)

5. PROGRAMME OF THE VISIT

The Team will work in Bangladesh in the period 6.17 May 1991.

Prior to leaving for Bangladesh the Team will study available FAP Inception Reports, in draft or final form, as well as available results from the Flood Hydrology Study.

The Team will work closely with the FPCO, and hold discussions with relevant government agencies, FAP consultants and donor agencies.

The Team will present its findings to FPCO and DANIDA before its departure from Bangladesh.

6. REPORTING

The Team will prepare a draft report before the departure from Bangladesh. The final report of the Team will be submitted to FPCO, with copies to the World Bank and the donor agencies of Denmark, France, the Netherlands and U. K. before 20 June 1991.

Appendix 2 LIST OF KEY PERSONS MET

MIWDFC

Dr. A.T.M. Huda. Joint Secretary

FPCO

Mr. A.K.M. Nurul Huq, Chief Engineer

Mr. K.B.M. Shafiuddin, Superintending Engineer

Mr. Emaduddin Ahamed, Executive Engineer

Local Specialist Panel

Mr. Md. Nurul Huda, Chairman

MPO

Mr. Tutiar Rahman, Chief Engineer

FPCO. International Panel of Experts

Mr. J. Dempster, Chairman

DANIDA

Mr. P.E. Christensen, Counsellor

SWMC

Mr. M. Islam, Superintending Engineer

Dr. A. Macdonald, Team Leader

Dr. R. Galapatti

Mr. F. Hansen

Dr. G. Pandyal

DHI

Mr. P. Mortensen, Resident Manager

FRENCH EMBASSY

Mr. A. Van den Abeele

DUTCH EMBASSY

Mr. J.V.D. Laan, Ist Secretary

WORLD BANK

Mr. R. Wallace

FAP 1 : Mr. A.P.G. Russel, Team Leader, Halcrow
Mr. D. Webb, Modeller, Halcrow

FAP 2 : Mr. T. Franks, Team Leader, Mott Macdonald
Mr. F. Kaul, Hydrologist, Mott Macdonald
Dr. R. Bettess, Senior Morphologist, HR Wallingford
Dr. N. Walmsley, Hydraulic Modeller, HR Wallingford

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- FAP 3 : Mr. M. Morgan, Team Leader, Mott Macdonald
Mr. Fruchart
Mr. D. A. Walta, Euroconsult
- FAP 5 : Mr. J. Dunn, Team Leader, Mott Macdonald
Dr. A.F.M. Afzal Hossain
Mr. D.N. Moore, Matt Macdonald.
- FAP 7 : Mr. P.Basse, Project Manager
Mr. J.M. Lacombe, BCEOM
- FAP 9A : Mr. F. Carvajal
H. Laboyrie, Haskoning
- FAP 10 : Mr. J. Dent, Chief Technical Advisor
- FAP 18 : Mr. Hakim, FPCO.
- FAP 19 : Mr T. Martin
- FAP 20 : Mr. J. Van der Laan

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Appendix 3 : Programme for Second CAT Mission

In the programme below only organisations visited are indicated. A list of key persons met is included in Appendix 2.

Sunday	5 May		ARRIVAL (two members of CAT)
Tuesday	7 May	15:00	FPCO (First meeting)
Thursday	9 May		ARRIVAL (last two members of CAT)
Friday	10 May	14:00	Internal CAT
Saturday	11 May	11:00	SWMC
		11:00	DANIDA briefing
		15:00	FPCO Second meeting
Sunday	12 May	8:00	FAP 19
		10:00	FAP 2
		10:00	DHI
		13:00	Internal CAT with BCEOM
		15:00	FAP 5
Monday	13 May	9:00	FAP 10
		9:30	FAP 18
		11:00	FAP 3
		13:00	DANIDA
		14:00	FAP 1
		15:30	FPCO
		18:00	FAP 9B
Tuesday	14 May	8:30	Internal CAT (FMM)
		10:30	Meeting of FAPMCC
		15:30	BCEOM
		18:00	FAP 20
Wednesday	15 May	13:30	World Bank
		15:30	MIWDFC

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Thursday 16 May	9:00	DANIDA de-briefing
	10:00	FPCO concluding meeting
	pm	Reporting
Friday 17 May	10:00	Internal CAT (draft report)
		DEPARTURE

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FLOOD ACTION PLAN MODELLING COORDINATION COMMITTEE
INAUGURAL MEETING

MINUTES

Place : FPCO Conference Room
Date : 14 May 1991
Time : 10.30 a.m.

List of Attendees :

1. Tutiar Rahman	MPO
2. A. M. M. Nurul Huq	FPCO, Chief Engineer
3. Hasan Zubair, XEN	Chief Engineer (Planning) BWDB
4. M. Islam	Superintending Engineer SWMC/MPO
5. A. Macdonald	Team Leader SWMC/MPO
6. W. Tuck	Resident Model Coordinator
7. W. R. White	HR Wallingford
8. T. Jonch-Clausen	DANIDA/FAP 25 CAT
9. J. G. Grijzen	Delft Hydraulics/CAT
10. M. Ramette	CAT
11. J. W. Dunn	Sir M. Macdonald, FAP 5
12. J. E. Dent	W. M. O
13. A. P. G. Russell	Halcrow (FAP 1)
14. M. A. Hossain	Halcrow (FAP 1)
15. N. Walmsley	Hydraulic Research (FAP 2)
16. Tom Wagner	ISPAN (FAP 19)
17. M. J. Morgan	FAP 3
18. F. Fruchart	FAP 3
19. Dr. A. Hannan	BUET
20. K. B. M. Shafiuddin	FPCO
21. Jahir Uddin Chowdhury	BUET
22. S.S. Hossain	BWDB
23. G. N. Pandyal	SWMC
24. Azhar Ali	SWMC
25. Emaduddin XEN	FPCO
26. Fred Kaul	FAP 2
27. S. N. Anwar	FAP 2
28. Nurul Huda	POE (FPCO)

W Tuck
SECRETARY

Md Tutiar Rahman
Chief Engineer (MPO)
CHAIRMAN

Flood Action Plan Modelling Coordination Commt

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The Chairman, Mr Tutiar Rahman, opened the meeting and introduced the members. He then went on to explain the constitution of the Flood Action Plan Modelling Coordination Committee, for the benefit of this first meeting.

The Team Leaders of each of the FAP components/regional studies and supporting studies were identified.

The first item on the agenda was

Item 1. Examine the contents of the TOR

The secretary introduced the working paper handed out at the meeting, which summarized the terms of reference (TOR) and explained the three components of FAP 25, these being

1. Model Coordination
2. Flood Hydrology Study (FHS)
3. Flood Management Model (FMM)

The text of the working paper was as follows:

" FAP 25 has three basic areas of responsibility within the Flood Action Plan, all of which are related to the mathematical modelling of surface water flows in Bangladesh. These are :

1. Coordination of modelling activities.
2. A Flood Hydrology Study to provide a basis for engineering activities.
3. Development of a Flood Management Model.

The TOR define the source of mathematical models to be used in Bangladesh as those currently being produced by the Surface Water Modelling Centre (SWMC) and where possible to ensure consistency and compatibility the TOR direct the use of these models in the regional studies, and for the Flood Management model.

To assist in the coordination and direction of the work under FAP 25, a panel of short-term experts from 4 donor countries form a Coordination Advisory Team (CAT) with the Resident Model Coordinator and his local counterpart. The panel will visit Bangladesh periodically to oversee the coordination of modelling activities and to check on the progress of model production and input to FAP activities. Input to FAP activities includes the Flood Hydrology Study and in the later stages of the studies possibly, the Flood Management model may provide a data input.

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The Flood Hydrology Study is on-going at the present time. This study is expected to provide the hydrological basis establishing unified engineering design events. It is anticipated that the results of a series of model runs of the SWMC General Model will provide the boundary conditions for Regional Model and also give the design conditions at strategic points on the main river system. The methodology for doing this work will be recommended to the Regional Studies as the most appropriate for their work.

The third component of FAP 25 is the production of a Flood Management Model (FMM). The final terms of reference for this component are still under active consideration by the CAT team. The general concept of FMM is that it is a tool to assist decision-making on flood problems both in the areas of planning and design, and ultimately in on-line real situations.

The principle objective of FMM is to create a tool to examine alternative flood control strategies.

Additional areas could be to investigate design changes and possibly at a later date to use on-line to guide flood control procedures during flood emergencies.

The TOR also specify the how the Flood Action Plan Modelling Coordination Committee (FAPMCC) should be constituted. A photocopy this section of the TOR has been sent to potential members of FAPMCC. ""

FAP study Team Leaders were invited by the chairman to comment on this item.

J. Dunn FAP 5 asked whether FHS will consider sea levels rise as their hydrologist has some evidence to suggest this.

J. Grijzen (CAT) stated this was a job for each individual study but that the concept of sea level should be borne in mind, particularly for large projects with large investment.

J. Dunn (FAP 5) said Data Storage is proving to be a problem and asked whether a database can be created to provide data for later studies.

J. Dent (FAP 10) informed the meeting that UNDP were commencing a Data Processing project in Hydrology Unit .

Dr. Labadi (UNDP) questioned whether TOR should refer to gap filling in data series.

J. Grijzen & T. Clausen (CAT) said TOR should specify what should be done in outline but not do the work.

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The Chairman introduced item 2

Item 2. Scope and Responsibilities of FAP 25 in Model Coordination.

"" FAP 25 with respect to modelling coordination has the responsibility to coordinate the supply of models to the FAP studies from SWMC and to ensure consistency and compatibility in modelling activities.

FAP 25 will achieve these aims, by advising FPCO on coordination needs, reviewing TOR on modelling activities and through the medium of the FAPMCC. Continual liaison with all relevant FAP components and SWMC will be necessary.""

M. Morgan (FAP 3) put forward a resolution that small working groups should be formed for technical matters. Such groups should include the hydrologists and hydromodellers of each FAP component to discuss problems with modelling. Time intervals between 2 weeks and 2 months were suggested. This suggestion will be taken up by the Resident Model Coordinator.

J. Grijzen (CAT) suggested that the FHS would require similar liaison.

The Chairman introduced Item 3.

Item 3. Progress Model Development.

The secretary summarized the position.

"" Annex 1 shows the programme for model development contained in the FAP 25 TOR. There have been some changes in this programme and the meeting will be apprised of these developments by the Team Leader of the SWMC.""

A Macdonald (SWMC) stated that hydrodynamic modelling was on target but the morphological component is late in being incorporated.

G. Pandyal (SWMC) summarized model progress as follows:

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General Model (GM) recently updated with 1989 monsoon data.
 NAM model refinement to be place in GM.
 Salinity module development delayed by cyclone.
 Morphological model - data problem before this is completed.
 NWRM Course pilot model ready & calibrated (10 flow model) New data is being collected.
 NERM Extensive data collection taking place.
 SERM 1990 monsoon tested on this model. Model development was behind FAP 5 regional study.

Shafiuddin FPCO enquired from J. Dunn (FAP 5) as to whether their model will be extended to study southern-most drainage channels. J. Dunn confirmed this but details had not been worked out.

T. Clausen (CAT) pointed out that the World Bank had started the whole modelling programme when they requested a model for the South East.

R. White (CAT) asked whether the morphological module was available for modelling.

A Macdonald said that extensive data gathering was taking place.

R. White replied that data gathering, would have to be historical as morphological models are used to predict long term changes. In reply to Shafiuddin (FPCO), A. Macdonald confirmed that data (i.e. sample bottles) had been lost during the cyclone.

Mr. Morgan FAP 3 asked whether future development considerations were studied in SWMC and a Macdonald said this was not part their programme. A Macdonald stated that there were 5 stations in the country where suspended sediment is measured.

A Russell (FAP 1) they have collected suspended data and this has been published in their report.

A Russell asked A. Macdonald the difference between pilot and full model and the reply was, more data , more accuracy and more resolution.

G Pandyal reported progress on the SWRM which is composed of 3 subregions to fit into MSDOS operating system capabilities. Considerable discission on the morphological module took place with J U Chowdhury (BUET) and M Ramette (CAT) stating that morphology is an important question and would the model be able to predict changes over a long period. A Macdonald replied the the module should meet FAP requirements but A Russell outlined their much more detailed approach . N Huda(POE) asked why, if the requirements were identified in the CAT inception report, the

same questions were arising and CAT were requested to clarify this in their next report.

Emaduddin (FPCO) stated that first CAT report had exact requirements. Discussion took place on the adequacy of the expansion of the SERM to southern drainage areas.

R.White (CAT) asked regional studies whether their proposed work will affect the morphology of the rivers in their areas.

The status of model input into FAP studies in its bar chart form was requested from SWMC. N. Huda asked for original bar chart from TOR to be shown along with the revised version.

Item 4 Updating and Modification of the Model

" The SWMC is responsible for holding and providing the standard version of all models. Periodically, updated or recent topographic survey data or hydrometric data will become available which will be incorporated into the model. Such data, for example, is the hydrometric data collected within each hydrologic year. This updating or verification will take place at specific intervals of 12 months, or whatever, as a normal process and it is not anticipated that minor discrepancies will be accommodated between normal periodic reviews."

J. Dunn asked SWMC whether SERM had been updated to UNIX version, but G Pandyal stated that equipment for such updating has not arrived, but the Unix version will be used in the future.

J Dent (FAP 10) asked what the usual timeframe for model updating was.

A Macdonald replied that 9 months after the end of a hydrological year, the model is updated in case of General Model.

Regional models are much quicker as SWMC do a lot of the data analysis and some collection. The question of suitability of data bases was discussed.

The coverage of new surveys from regional Models and whether that data had been incorporated into model was answered by A Macdonald by stating that when new ordinance bench marks and countrywide verification is received from Finnmap or whoever, then they will be incorporated.

N Huda asked what is the difference between Teesta

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(drainage) model and the FAP 2 model, to which A Macdonald replied none.

N Huda asked what was liaison between FAP 2 and SWMC modellers and was informed by N Walmsley (FAP 2) that they all worked in the same room, and that the FAP2 model (NWRM) will expand to take in all data in the Teesta Model.

The Chairman asked the CAT to mention coordination between modelists and hydrologists.

N. Walmsley (FAP 2) said they will take the SWMC standard models and modify it for their purposes to investigate peculiarities of their region but he was concerned that later development (particularly with respect to the morphological model) in the SWMC should take account of their work, as the details of FAP 2 model and SWMC will be different.

A Macdonald and W Tuck will jointly examine the possible repercussions of this.

A Russel (FAP 1) asked what happens to models at end of study period and was informed that all models are expected to be returned to SWMC in their developed form.

R White (CAT) stated that FAP studies should be free to adapt their models to meet study deadlines.

T Clausen (CAT) stated that SWMC was not created to solve problems in the regional studies. These are for the FAP components themselves to resolve. SWMC supplied models to all government departments in addition to the FAP components.

J. Dunn explained the model expansion on the SERM.

Item 5. Model Adaption to meet FAP requirements

"" Annex 1 shows the adaptation of the Surface Water Simulation Modelling Programme (phase II) (SWSMP-II) to meet the requirement of the FAP studies. Some changes have occurred here and the Team Leader of SWMC will be called upon to report progress.""

R. White outlined the information the CAT team had received from SWMC as to the response of the SWMC to the recommendations of the CAT in its inception report, which briefly was that in respect of the morphology model, SWMC are introducing a quasi-

steady state model, a multifraction and multilayer analysis within the morphological analysis.

N Huda stated that Teesta Study had introduced irrigation modules.

Emaduddin enquired what the progress was, on cutting down the run time of the General Model.

A Macdonald replied that by cutting out the faster rivers such as the Teesta and those in the Upper Meghna catchment and using the new 486 computers, it is possible to get run times for the General Model down to 1 hour.

J Grijzen (CAT) felt that the model should be able to take time steps of one day and that runs of 15 minutes would greatly facilitate FAP studies.

A Macdonald replied that flood plain overspilling causes problems when large time steps are used.

Item 6. Coordination Process Adequacy.

"" The FAP team leaders will be called upon to specify what coordination processes they would like to see to meet their requirements. This item will deal specifically with coordination and not other requirements. ""

A Russel FAP 1) asked whether FAP 25 could review the hydrological section of their completed report and see if it conformed with the suggested output of the FHS. They would like confirmation of its adequacy.

N Huda said FAP 25 should give comments in their report.

Emaduddin, asked that FAPs studies send a copy of their reports (in respect of hydrology and hydraulic modelling) directly to FAP 25.

Item 8. Other Matters

N Walmsley (FAP2) asked for clarification whether models or data have to be paid for.

Chief Engineer (MPO) and Chairman, said that FAP studies will have to pay for data.

N. Islam stated that within SWMC, payments are reduced when FAP studies trade their data with SWMC.

Much discussion took place on their subject which included :

- recommendations from FAPMCC on charges.
- do rates go into the TAPP ?
- what is scope for reviewing Ministerial decisions.

Finally the Chairman, thanked everyone for their contribution and reminded the Resident Model Coordinator to set up the FAP technical meetings between hydrologists and hydro-modellers.

The purpose of FAPMCC is to ensure good cooperation.

Appendix 5 : TOR for Third CAT Mission

In pursuance of the provisions of clause 4.1 of the TOR for FAP 25, which specifies the responsibilities of the CAT, the work of the team during their third visit should include the following activities:

- a. Review the actions taken by RMC/HME, FPCO, SWMC and the FAP components in the light of the CAT's Mission Report of May 1991.
- b. Review progress on modelling in the Regional and other FAP Studies.
- c. In the light of (a) and (b) make recommendations for the continued coordination of modelling developments between SWMC and other FAP studies.
- d. Review progress on the Flood Hydrology Study and identify how the results of this study should be applied, in a unified manner, to other FAP components.
- e. Review the TOR and PLOP for the FMM (as considered by the Technical committee in September 1991) make recommendations with respect to the execution of this component..
- f. Attend a meeting of the FAP Modelling Coordination Committee (FAPMCC).
- g. Review progress of the FAP 25 component
- h. Report to FPCO.

The visit of the team will have a duration of 10 days in Bangladesh and will include liaison with FCPO, FAP consultants, SWMC and Government agencies. A formal report will be issued following the mission.

The international experts will require before their visit to Bangladesh progress reports on FAP components which involve modelling work up to, say, September 1991. The date of the third visit is provisionally set for December 1991.

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Appendix 6

Methodology and Planning for Completion of the Flood Hydrology Study

Contents

1. Introduction
2. Objectives of the Flood Hydrology Study (FHS)
3. Summary of Proposed Methodology for the FHS
 - 3.1 General Considerations
 - 3.2 Proposed Methodology
4. Detailed Approach to the FHS
 - 4.1 Data Checking and Completion
 - 4.2 Joint Probabilities of Main Stream Flows and Rainfall
 - 4.3 Representativeness of recent years for the Long Term
 - 4.4 Unified Methodologies for Statistical Analyses
 - 4.5 Dedicated Version of the General Model (GM)
 - 4.6 Boundary Conditions for the GM
 - 4.7 Sensitivity Analysis of GM Model results for Rainfall Input
 - 4.8 Validation of the GM and its Flow Boundary Conditions
 - 4.9 Application of the GM for the period 1964 - 1989
 - 4.10 Analysis of Simulation Results
 - 4.11 Acquisition of Software
 - 4.12 Methodology for Selecting Boundary Conditions for Project Design at the Regional Level.
 - 4.13 Analysis of Joint Impacts of Projects in Various Regions
 - 4.14 Miscellaneous Issues
5. Workplan and time Schedule for Completion of Stages 1 and 2
6. Input in Manpower for Completion of FHS

Annex 1: Overview of Achievements of Stage 1 of FHS

Annex 2: Some Notes on Observed Discharge Data and Extreme Flow Statistics for the Ganges at Hardinge Bridge

1. INTRODUCTION

As from early January 1991 FAP-25 has undertaken the execution of the Flood Hydrology Study along the lines indicated in the TOR of FAP-25 and in the Inception Report of the CAT, as summarized in Chapter 2. An overview of current achievements of the FHS is presented in Annex 1.

The progress of the study in its early stages was seriously hampered by the time required for data collection and subsequent entering of the data into the data base, which was still ongoing at the time of the CAT's second mission (6-17 May, 1991). A second handicap for the team was that an adequate and straightforward methodology was not available at the start of the study. Both reasons have prompted the CAT mission to reconsider the objectives of the FHS, to develop a concise methodology which can be immediately and efficiently implemented, and to review the required human resources to complete the remainder of the FHS at the earliest.

It is the CAT's firm opinion that the FHS is crucial for the success of regional studies, not the least because multi-billion dollar projects will be designed on the basis of results of the FHS in terms of design flood hydrographs. Therefore, due attention must be given to the subject and the CAT has concluded that the original proposed input of only 6 manmonths is not adequate for a proper execution of the FHS, irrespective of initial delays. The CAT therefore proposes to extend the activities of the Hydrologist until January 1991. A new expatriate Hydrologist has to be appointed, who should work in close cooperation with a hydrodynamic modeller connected for the purpose of FAP-25 to the SWMC.

The objectives of the FHS are discussed in Chapter 2. The input required to complete the study properly and to provide the consultants of the regional studies with sound design boundary conditions is presented in Chapter 5, and is estimated on the basis of the proposed methodology as summarized in Chapter 3 and described in detail in Chapter 4. An early approval of the proposed methodology for the FHS by FPCO is kindly requested to avoid any further delay in the progress of the study.

Preliminary design hydrographs for the present conditions are expected to become available at the latest in early September 1991. Refined results for the present conditions will become available by the end of 1991 and the reporting on stages 1 and 2 of the FHS can be completed in January 1992. Design conditions for potential nation-wide flood protection scheme, reflecting the joint impacts of developments in various

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regions on design water levels and flows in the main river system of Bangladesh, will be established as the needs arise, most likely on a quaterly basis in 1992. Some preliminary results can be produced in 1991 if needed. This activity, earlier indicated as stage 3 of the FHS, will be materialized in close consultation with the consultants of the regional studies and conditional to the timely delivery to FAP-25 by these consultants of (preliminary) designs for realistic protection schemes. The role of the RMC is crucial in the performance of this task.

The CAT mission has identified the need for regular coordination at technical level between the FHS and the consultants for the regional studies, in particular between the respective hydrologists and hydrodynamic modellers. Therefore, working sessions will be held on a monthly basis (called by the RMC), where the progress of the FHS and its results will be discussed in-depth. This ensures that the FHS will be fully geared to the needs of the regional studies and that all regional studies adopt the same methodologies concerning the selection of design events, design hydrographs and considerations with respect to the joint probability of extreme rainfalls in the regions and flood hydrographs on the main rivers. Ongoing regional study teams have expressed their support for this proposal and it should therefore be implemented at the earliest.

2. OBJECTIVE OF THE FLOOD HYDROLOGY STUDY

The terms of reference (TOR) for the Flood Hydrology Study (FHS) are contained within the TOR for FAP-25. The objective of the FHS was stated as 'to provide the hydrological basis for establishing unified engineering design events for the FAP', to be achieved by 'analyzing in depth the characteristics of flood hydrology in Bangladesh by taking into consideration among other things the joint probability of the simultaneous occurrence of the individual main causes of floods'. In brief the following tasks were to be undertaken:

- collection and review of existing relevant material and reports concerned with flood hydrology
- a statistical flood hydrology analysis, based on available data considering the major causes of floods in Bangladesh, and their individual and joint probabilities of occurrence
- identification and testing of various methods for producing regionally distributed information on hydrology design events, e.g. a pure statistical approach based on available data, the use of the SWMC models to run through a large number of events as a basis for a statistical analysis, or the use of a particular historic event or

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- combination of events (model simulations to be undertaken by SWMC)
 - preparation of a report of the FHS and recommendations to the FAP Technical Committee on unified design events to be applied throughout the FAP.

In addition to these TOR Prof. Jahir Uddin Chowdhury, a member of the Local consultants, proposed in early April 1991 the following specific issues to be addressed by the FHS:

- a. A unified methodology for estimating flood magnitude (discharge or water level) of given return period, i.e. design flood
- b. A unified methodology for developing a rainfall hyetograph of given depth-duration-return period, i.e. design rainfall
- c. A unified methodology for generating a hydrograph (water level or discharge) of given return period, i.e. design hydrograph
- d. Conditions when joint probability analysis is important require a unified methodology for joint probability analysis. The methodology will indicate how various variables like flows in upstream branches, downstream water levels, time between peaks, duration of floods, tributary flows, backwater effects, tidal influence, etc. will be incorporated in the joint probability analysis according to their importance
- e. Method for incorporating the influence of proposed flood protection schemes (especially embanked rivers) in the estimation of design events
- f. A unified methodology for assessing the reliability of the estimated design event considering data error, hydrologic uncertainties and hydraulic uncertainties.

In addition to the above, consultants for the NW, NC and SE regional studies were requested to indicate their requirements with respect to outputs of the FHS. Apart from design levels and flows a request was made to provide full season flood hydrographs with specific return periods, and to distinguish characteristic design variables for 3 sub-seasonal flow conditions, in particular:

- the pre-monsoon period (April-June): early rise of water levels before harvesting of Boro crops and planting of Kharif I crops
- the monsoon period (July-August): speedy rise of water levels, peak levels and duration of flood inundation
- the post-monsoon period (September-October): too slow drainage to permit timely planting of certain crops

In general the consultants expressed a need to obtain series of historical flood season hydrographs, to which a specific

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return period can be assigned and which can be applied with the associated historical rainfall series.

Finally, it is appropriate to recall the recommendation of the CAT mission of October 1990 to execute the FHS in 3 stages, i.e.:

Stage 1:

Statistical analysis of historical rainfall, flow and water level data for a few selected strategic locations in the system to obtain a first estimate of design flows, levels and rainfalls

Stage 2:

Assuming that a fairly complete set of data may be available for a substantial period, the General Model could be run and the results analyzed statistically. Some sets of boundary conditions could then be selected, which produce flows and levels corresponding to selected return periods.

Stage 3:

Flood protection works may affect the design levels in the main river system, which act as boundary conditions for the regional models. Once the consultants have defined various protection works the effects thereof on design conditions in other areas have to be determined with the General Model.

3. SUMMARY OF PROPOSED METHODOLOGY FOR THE FHS

3.1 General Considerations

The main problem in a joint probability analysis of various causes of floodings is to incorporate the interaction of the physical system with these causes. For example, a certain water level in a backwater zone can be produced by various combinations of tail water levels and rainfall dependant upstream inflows. The physical system of rivers, flood plains and embankments determines for each particular location the interaction of the various causes of floodings. Joint probability analysis can only be undertaken once various combinations of events with the same impact on flood levels are known.

It may well be possible to carry out such analysis for the main system in its present conditions, based on historical water level and flow data. However, such data generally do not exist for the major part of the regions, outside the main

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system. Moreover, results of such analysis for the main river system are also not applicable for potential future situations upon completion of a nation-wide flood protection scheme. Embankments along all the major rivers may change the pattern and amount of spills substantially, and consequently induce significant changes in the probability distributions of water levels and flows, and in the joint probabilities of various flood causing factors.

The conclusion remains that a joint probability analysis as anticipated in the TOR for the FHS is extremely difficult and impracticable, in particular in view of the need to derive design hydrographs for potential future situations with major changes in the conditions of the main river system. Hence, the only practical and feasible option is to use the GM extensively to derive design hydrographs for the main system. A similar reasoning holds for the establishment of design conditions within the regions.

3.2 Proposed Methodology

The proposed methodology for the FHS consists of three main components, i.e:

- a validation of the GM for the full period 1964-1989, statistical analysis of its results, supply of design boundary conditions to the regional consultants and graphic display of return periods for historical selected floods, valid for specific design characteristics (e.g. annual maxima, sub-seasonal flood volumes, etc.); to be completed early September 1991
- base line statistical and joint probability analysis and similar type of studies with the aim to produce required design statistics, to determine the representativeness of the period 1964-1989 for the full century, to assess the quality of available data (i.e. a quality assurance study) and to provide standard errors of estimate for specific design criteria
- runs with the GM for the full period 1964-1989 for potential future situations after the implementation of alternative nation-wide flood protection schemes, including the analysis of results and supply of design boundary conditions to the regional consultants (mainly in 1992)

Regional consultants can use the maps with spatial distributions of return period, c.c. one map for each particular flood season, to select one or more historical flood seasons which produce the required design conditions in

the main rivers near their study regions.

It is the CAT's opinion that this approach, which draws extensively on the use of the GM, is the only feasible option to establish reliable design boundary conditions for the regional studies. The study will mainly use observed water level, derived discharges and rainfall data for the period 1964-1989, by all means the only available consistent set of data for Bangladesh. A very preliminary analysis revealed that this period is adequate to derive design conditions for return periods upto at least 50 years. All efforts must be undertaken to disclose at least some relevant hydrological data of earlier origin, as a check on the representativeness of this rather short period for the full century.

The detailed approach to the FHS is outlined in chapter 4, in a logical sequence of activities as would be adopted in case the study was not constrained by serious time limits. The actual planning as outlined in chapter 5 reflects the need to produce practical and useful results for the regional studies at short notice, at the latest in early September 1991.

4. DETAILED APPROACH TO THE FHS

This chapter presents a detailed description of the approach to be followed for a speedy and efficient completion of the FHS, in the form of a series of well-defined activities to be undertaken as from May 20, 1991. A crucial point in the workplanning is the success or failure of the validation of the General Model for the entire period 1964-1989. So far, the model has only be validated for the last four years in this period. In the event of a substantial failure in terms of a proper simulation of time dependent water levels for various key-stations along the main rivers of Bangladesh, all efforts must be undertaken to solve such problem at the earliest.

4.1 Data Checking and Completion

Annex 2 presents some notes raising some doubt about the reliability of discharge measurements on the Ganges, Brahmaputra and Padma rivers. It is questionable whether it will be feasible to dig-up enough history on discharge measurements, in particular in the Ganges, to shed some light on this problem, but the matter should be looked into, for example by consulting reports of earlier projects in the region. The issue should also be of great concern to MPO and the SWMC and their cooperation in resolving the matter should be sought.

Data on flows in the Brahmaputra, as available in Bangladesh, seem to go back as far as 1956, with a gap in the information between 1959 and 1964 (see MPO report, 1987). An attempt should be made to fill-in this gap for the flood season through correlation with neighbouring stations. This period contains at least one major flood on the Ganges (1961). More flow data for the Brahmaputra river may also be found in the hydrological studies for the FAP-1 project, in the earlier Jamuna Bridge studies and in the study on 'Dependable flows of border rivers' (1986; BWDB and Sir William Halcrow and Partners).

Obviously there should be a lot more information available on Brahmaputra flows and Ganges flows, possibly going back as far as the early part of this century, but this may also very well concern stations located in India. It is known that old records exist for the following stations in India:

- Farakka on the Ganges River, about 20 km upstream of the border between India and Bangladesh
- Pandu on the Brahmaputra River, about 250 km upstream of the border

Some of these data are available in Dhaka within the INDO-BANGLADESH JOINT RIVERS COMMISSION. It is said that data have been exchanged for the near-border stations, for periods for which both India and Bangladesh possess data. This may imply that data on Brahmaputra flows before the sixties are not available within the Joint Commission in Bangladesh. Whatever the precise situation is, it is imperative that FPCO, the POE and FAP-25 should undertake all possible efforts to obtain these earlier flow data on river flows. After all, various FAP multi-billion dollar projects will be designed and implemented on the basis of statistics of the Brahmaputra and Ganges river flows. Retrieving these data, as far back into the past as possible, should therefore be pursued to the maximum.

A serious attempt should be made to bring to the surface the results of earlier work on river flows in the Ganges and Brahmaputra. One would expect old reports, dating back to the time before 1947, to be somewhere available, either in Bangladesh or in the UK. It is known that in London a library exists where reports and other documents concerning surveys in all parts of the former British Empire are kept. From the SE regional Consultant information was received that the Old Indian Office in London possesses a wealth of information in this respect and the CAT investigate how to get hold of this information. Such information on the main rivers in Bangladesh, dating back before 1947, will be of much use for the analyses outlined in the following sections.

Correlation of the data from India with those recorded in Bangladesh will be of great help to check the quality of the data recorded at Hardinge Bridge on the Ganges and at Bahadurabad on the Brahmaputra, to correct these data as far considered appropriate and to extend the series for the two stations in Bangladesh back into history. These updated series will then provide a sound basis for any statistical analysis or simulations with the GM, as required.

A full fledged data screening and validation study cannot be part of the FHS, since these are very time consuming efforts and require many field visits to check on measurement procedures, gauge histories, etc. Such work should actually be done by MPO, but can also well be part of the FAP 24 project. Hence, the FHS should carry out only data screening for about 15 key-stations used for the validation of the GM, as far as this can be done in office and without time consuming field visits.

Obvious errors can easily be removed by plotting observed hydrographs. Most efforts should be put in establishing annual relation curves between water levels observed at pairs of gauging stations, as a basis for detecting errors and obtaining an impression on the reliability of observed water levels at various stations.

Much attention should also be devoted to the establishment of reliable annual rating curves for a few key-stations, in particular for the boundary stations of the GM.

4.2 Joint Probabilities of Main Stream Flows and Rainfall inside Bangladesh

The question of correlations between main stream flows and rainfall in Bangladesh will often arise. It is therefore proposed to establish joint probabilities between rainfall over (part of) Bangladesh and flow on the Ganges river, between rainfall and flow on the Brahmaputra river, and between flows on both rivers. The question comes down to determining for example the rainfall distribution for various values of the river flow, etc. A first simple approach can be to plot all observed values of both variables against each other, to determine the regression line and related correlation coefficient, and to determine the probability distribution of the residues of the dependant variable for various class intervals of the other variable (a normal distribution to be assumed for a first quick analysis).

It is meaningless to determine such joint probabilities for daily values of flows and rainfall over Bangladesh. Most likely hardly any correlation will be found. Instead, it is suggested to correlate first seasonal values of river flow

(flood volumes) and rainfall. Given encouraging results, i.e. rather high correlation coefficients, one could continue with sub-seasonal flood volumes and rainfall.

A correlation between annual maximum water levels or flows with an average 10-day rainfall over (part of) Bangladesh preceding the peaks, or something similar, is unlikely to provide any useful results. If a good correlation does exist, then peak flows on both the Brahmaputra and Ganges rivers should usually coincide, which is not the case.

Although perhaps not of direct benefit for the FAP-studies, the results and graphs from this will at least set the problem of joint probabilities in a proper perspective, and may serve as a guide-line in selecting design events or flood seasons at a later stage. The actual correlation structure of various causes of floodings is embedded in the actual data series for the last 25 years, and is therefore automatically well taken into account.

4.3 Representativeness of Recent Years for the Long Term

Presently available flow data mainly pertain to the period 1964-1989. Most of the statistical analyses have necessarily to be confined to this period. This raises the question whether or not this recent period contains a sufficient range of flow and rainfall conditions to represent the same for a long period. The FHS should provide statistics of maximum levels and river flows, flood volumes (i.e. average flows) and rainfall data for a few rainfall stations in each region on a seasonal and sub-seasonal basis, both for the long term and for the 1964-1989 period. The result of this analysis will serve to assign return periods to the historical floods of specific years in the period 1964-1989, and similar to historical seasonal or sub-seasonal rainfall series.

Homogeneity Analysis Flow and Rainfall Data

Annex 2 also presents a note on a brief statistical analysis of maximum flows on the Ganges river at Hardinge Bridge. It appears that flows in the period 1934 - 1945 have been very low compared to the remainder of the period. On the average peak flows in the former period are 20% less, while the record shows little variation in peak flows from one year to the other. Either the data are completely erroneous, or there has been a long dry spell. It is indeed reported that famines have occurred in 1938 and 1942. It is worth studying the rainfall records for one or two stations in each region in Bangladesh for the entire century, to determine whether this possible dry spell in the Ganges basin can also be discovered from the rainfall data recorded in Bangladesh. A simple analysis will do, for example:

- moving average analysis of annual flood season rainfall data back to the early part of this century (data back to 1964 are available in FAP-25 office for 22 stations)
- sum of residues of rainfall (same as above)
- same as above for Ganges flow data
- try to allocate any earlier study on this issue (FEC, Ganges-Kobadak, Jamuna Bridge study, FAP-1)
- trend analysis on rainfall data? Note that a substantial increase in Ganges flood flows due to developments in its catchment or due to erosion and deforestation, to the extent that it could explain the relatively dry spell at the beginning of the record for Hardinge Bridge, is not very likely.

The result of this study may well be that part of the observed Ganges flows must be disregarded, and statistics are to be based on a shorter period.

Frequency Analysis of Rainfall Data (short/long periods)

A frequency analysis of rainfall (type of distribution?) is to be made for 2 principal stations in each of the regions (in total 12 stations), considering seasonal and 3 sub-seasonal average values or totals (April-May, June-July and August-September) for the periods 1900 - 1989 and 1964 - 1989.

This activity will involve the creation and subsequent statistical analysis of some 100 time series and will put some demand on the availability of a proper data processing system. A comparison of the results for the short and long time periods will reveal the representativeness of the period 1964 - 1989 for the long term hydrometeorological conditions in the regions. It will also support the selection of certain historical seasonal rainfall series for prescribed return periods and provide the regional studies with basic statistical information on rainfall data. Obviously, it may well be possible to reduce the number of series to be analysed substantially on the basis of some preliminary analysis.

Frequency Analysis of Flow Characteristics

Under stage 1 of the FHS a statistical analysis based on the Gumbel distribution has been made for annual maximum water levels and flows at key river stations, mainly for the period 1965 - 1988. This is also to be done for annual flood volumes and sub-seasonal flood volumes, because such flow characteristics may provide better design criteria in certain cases. In the event for some stations more data, further back into history, would become available, the above analysis should be repeated for these longer time series, for reasons as indicated above for the rainfall data.

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Remarks

The above analyses will produce:

- a quantitative impression of the representativeness of the floods observed in the period 1964-1989 for the long term flood conditions
- statistics of annual maximum water levels, discharges, seasonal and sub-seasonal flood volumes, and of seasonal and sub-seasonal rainfall data.
- a proper indication of return periods to be assigned to historical flood hydrographs and seasonal or sub-seasonal rainfall patterns

It is noted that the FHS is not expected to perform a statistical analysis of rainfall data for all the stations in Bangladesh. Moreover, time available for the FHS in terms of manmonths and time to completion is very limited. It should therefore be considered that the rainfall analysis, as indicated above, is to be carried out by the regional consultants in close cooperation with the FHS. Obviously a proper coordination of the adopted methodology and an intercomparison of obtained results is necessary.

The issue of the selection of a suitable distribution to fit observed distributions of annual maximum water levels and discharges for the prevailing conditions in Bangladesh is highly debatable. One may expect that in particular the log-Pearson-III and the Extreme Value type II (Frechet) distribution are not suitable for fitting observed distributions of annual maximum water levels in Bangladesh. These distributions have a lower threshold and tend to overestimate extreme values with very high return periods (for example 1000 years), whereas in nature the rise of water levels tends to slow down with increasing discharges. Hence, one would expect a distribution with an upper threshold to fit better than one with a lower threshold.

The 3 - parameter log-normal distribution with a lower threshold may also be applicable for many stations. In view of some preliminary results produced by the FHS team the best chance is that the 2 - parameter Gumbel distribution and the 3 - parameter log-normal distribution produce quite the same estimates for the 100 year maximum flood levels, while the other above mentioned distributions may tend to overestimate the extreme quantiles.

There is a good chance that within the range of observations with probabilities of non-exceedance in the range of 5 to 95% statistical test, such as the CHI-square test will confirm that any tested distribution will be acceptable, and that it will be hard to discriminate on the basis of such tests. The

ultimate choice of a distribution therefore very much depends on proper judgement and visual inspection of probability plots.

To arrive at a decision on this issue it is proposed to test the above mentioned distributions for curve fitting. The ultimate choice should then be made on for example the following criteria:

- first of all visual inspection of the probability plots
- results of CHI-square tests
- consideration of very extreme events as produced by the various distributions, for example the 1000 year maximum flood level
- confidence intervals of the estimated distributions (note that a 2 - parameter distribution produces smaller confidence intervals than a 3 - parameter model, including a threshold parameter)

It is stressed that there is no particular reason that the same distribution should best applicable throughout the country.

It is observed that the Gumbel distribution does not fit very well the highest observed maximum water levels at quite a few stations. The Hardinge Bridge station is an outspoken example. It can possibly be fitted properly with a combination of two Gumbel distributions. To do this, a routine which allows the fitting of the Gumbel distribution to censored data should be available. The question upon the viability of such approach remains to be addressed.

A combination of two Gumbel distributions is not suitable for the other stations analysed so far. For these stations one should consider for example the General Extreme Value Type III distribution (GEV-III) as an alternative. This distribution has an upper threshold, which will never be exceeded. The rationale is that with increasing discharges and water levels inundations become gradually so massive, that even the very extreme flood volumes are simply not large enough to induce water levels above the threshold. A Gumbel distributed maximum flow may well induce a GEV-III type distributed maximum water level due to the interaction of the flow with the physical system.

It is worth stating the obvious. Statistics of extreme water levels, in particular in the situation of Bangladesh, should only be used for extrapolation with great care because of the above mentioned severe interaction of flows with the natural physical system. Moreover, any substantial alteration in the physical system, e.g. embankments of the main rivers, will

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change such statistics significantly. Therefore, design events can only be based on extreme flows rather than on extreme water levels. The General Model is to be used to calculate extreme water levels for a given design (flow) hydrograph.

In view of the short records generally available, the need to extend the series for Hardinge Bridge on the Ganges and Bahadurabad on the Brahmaputra further back into the past, and to subject such extended series to statistical analysis, is imperative.

4.4 Unified Methodologies for Statistical Analyses

The FHS is expected to provide methodologies for statistical analyses for:

- estimating extreme flows and water levels for given return periods
- developing rainfall hyetographs of given depth-duration-return periods

This requires the FHS to furnish descriptions of the theory, for selected statistical procedures, probably including :

- the maximum likelihood method for fitting of selected probability distributions (method of moments not to be adopted).
- the maximum likelihood method for fitting of a suitable distribution function for extreme point rainfalls for a given duration and the derivation of rainfall depth-duration-frequency curves
- the combination of the above point rainfall d-d-f curves into maps displaying hyetographs of given depth-duration-frequency curves
- to establish reduction coefficients for the transformation of d-d-f curves for point rainfalls to similar curves for larger areas
- statistical tests to determine the goodness-of-fit of theoretical distributions (chi-square)
- algorithms to determine confidence intervals

The FHS is not expected to undertake any statistical analysis of rainfall data other than described under point 4.3, if any. The regional consultants should therefore acquire there own software for deriving depth-duration-frequency curves. The task of FAP-25 in this respect is merely coordination.



Consultants for the regional studies should be requested to submit a description of the methods they propose to use for rainfall analysis and the derivation of design storms, whereas FAP-25 should tune these methods to each other and approve the procedure selected in close consultation with the consultants. Whether the consultants eventually wish to (further) develop their own software and/or share the latter can be left to their consideration. FAP-25 will not provide such software.

4.5 Dedicated Version of the General Model

The General Model contains at present some 800 grid points and is said to take a running time of 50 minutes for the simulation of one month with a time step of one hour (MS-DOS version on a PC-386). Such very small time steps are generally only required for an accurate simulation of events with a characteristic period of about 1 or two days. Running the GM for at least 25 flood seasons (150 months) will under these conditions certainly be impracticable.

A timestep of a half to one day would seem to be more appropriate. This warrants in general an accurate simulation of flood peaks with a characteristic time period of some 25 days, which is sufficiently accurate for the purpose of the FHS. The simulation of overbank spills may however prohibit such time steps. Therefore, steps must be undertaken to increase the time step for running the GM to at least 12 hours. This would reduce the total running time for a sequence of 25 flood seasons to some 10 hours, which can be completed overnight or within one working day.

The main reasons for using at present such small time steps for running the GM are said to be the presence of some steep and relatively small rivers, in particular the Teesta river and the Old Brahmaputra river, and the simulation of overbank spills. The fact that these rivers run dry in the dry season adds to this problem. Hence, the Teesta river should be eliminated and its flow to be introduced as a direct lateral inflow into the Brahmaputra river. Moreover, the dry season is excluded from the simulations for the FHS. Eventual situations with hardly no flow in the Old Brahmaputra river (in the early part of the flood season) can simply be handled by introducing an artificial low base flow as lateral input at its upstream end.

All rivers in the Upper Meghna watershed could be combined as well into one channel and provided with an artificial minimum baseflow, if needed, or eventually be truncated at Bhairab Bazar. Hence, a dedicated version of the GM should be produced at short notice in close cooperation with the SWMC. This dedicated version of the GM will in the remainder of this

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report simply be addressed to as the GM.

During the presence of the CAT team in Dhaka the SWMC has kindly undertaken an exercise to explore the possibilities of increasing the timesteps of the computations, and it was indeed concluded that the GM could at least be run with timesteps in the order of 4 hours, reducing the running time for a full flood season (6 months) on a PC-486 to about one hour. Hence, running of a sequence of 25 flood seasons becomes feasible, be it that it still takes at least 2 working days.

The regional consultants may well wish to use the GM for purposes other than analysing the joint impacts of all sorts of projects implemented in the various regions. The FAP-25 considers only the latter type of applications as its responsibility (see section 4.13). For other purposes, whatever they may be, it may be quite appropriate for the consultants to use the dedicated version of the GM as developed for the FHS. The representation of the main river system will be similar to the one in the original GM. The only difference is to be found in the representation of some smaller streams such as the Teesta river and the Old Brahmaputra. This is of relevance for example for the SE regional study, which anticipates to use of a GM version truncated at Bharaib Bazar and Baruria. Such truncation will only be useful if many runs are to be made with the GM, which require a proper representation of tidal phenomena. Such computations should however only be made for short time periods, where the results can be superimposed on the results of long term computations with non-tidal downstream boundary conditions.

4.6 Boundary Conditions for the GM

The FHS requires the running of the GM for the period 1964-1989 for the present situation, for the ultimate embankment situation and possibly for various intermediate scenarios. This justifies putting a substantial effort in the set-up of a proper set of boundary conditions for this period.

Flow boundary conditions

Daily river flows at the upstream boundaries of the Ganges, Brahmaputra and Upper Meghna watershed are generally available. Missing data on the latter inflows can either be generated from rainfalls in the area (strong correlation) or be filled-in by using average values. Flows at the upstream boundaries of the Upper Meghna rivers are anyhow of minor importance in view of the overall water balance of Bangladesh.

Rainfall boundary conditions

The contribution of rainfall over Bangladesh to the flow in its main river system is determined with the NAM model. The SWMC has used in total 120 stations to derive average daily areal rainfalls as inputs for 55 sub-catchments in the NAM model. The task to collect and process daily rainfall data for all these stations for the entire period 1964-1989 will certainly be too time consuming. On the other hand, FAP-25 already has collected and partly processed rainfall data for this period for 22 stations in the country. It is proposed to use only these stations to derive inputs for the NAM model. A sensitivity analysis should reveal the viability of this approach (see section 4.7). It may even turn out that the application of a monthly average rainfall distribution over Bangladesh provides acceptable results of the GM in terms of its requirements for the FHS, in particular at short notice.

Downstream boundary conditions

Downstream boundary conditions are to be provided for some 6 stations along the coast of Bangladesh. Water levels at a number of these stations, as far as located inland, are significantly affected by the upstream flows. Therefore, possibly available observed water levels for Chittagong, Cox's Bazar and Heron Point, representing the conditions in the Bay of Bengal, are not adequate for use as downstream boundary conditions. Hence, it should be considered to extend the dedicated version of the General Model to the Bay of Bengal, provided sufficient data exist on daily levels in the Bay for the period 1964-1989.

The GM has to be run with average water levels instead of with tidal levels. To eliminate the effects of spring and neap tides it is suggested to use moving average values (15 days)

Data for the extension of the models to the Bay and on levels in the Bay may well be obtained through the ongoing Pusur-Sibsa and Land reclamation Projects.

The normal rate of sea level rise, as detected over the last century should obviously be taken into account for all designs. Hence, the FPCO should indicate a time horizon for the design of flood protection works. Additional sea level rise due to green house effects will not be included in the downstream boundary conditions (see section 4.14).

Evaporation data

Evaporation during the flood season is much less significant for the run-off to the main rivers than rainfall, giving only a marginal contribution to the flow in the main rivers. Hence, it appears adequate to use monthly average values for the period 1986-1989 as input to the NAM model. Any further work on this subject is not necessary.

4.7 Sensitivity Analysis of GM Model Results for Rainfall Input

The earlier work on the GM has revealed that rainfall over Bangladesh contributes only marginally to the flow in the Lower Meghna river (some 5 to 10%). Hence, one may well arrive at acceptable results, at least in view of the short term requirements of the regional studies, by the application of a monthly average rainfall distribution (separate spatial distributions for each month of the flood season) over Bangladesh. This can be checked by running the models with these inputs for the years 1986 to 1989. The results can be compared with the earlier results of the calibration and validation of the GM for the years 1986 to 1989. Eventually this sensitivity analysis can be extended by running the models for the same period with as inputs for the NAM model:

- a spatial rainfall distribution of monthly average values with a return period of 20 years
- the same with a probability of non-exceedance of once in 20 years (low rainfall)
- actual areal average daily rainfalls derived from the above mentioned 22 rainfall stations (only if the earlier results indicate its necessity)

A comparison of the results of all the above simulations should reveal to which level of detail actual rainfall distributions over the country should be used as input into the NAM model.

4.8 Validation of the GM and its flow Boundary Conditions

The GM model has been calibrated and validated for the period 1986-1989 and will be updated annually since then. Discharges measured in these years in the Ganges at Hardinge Bridge as compared to those measured long ago at similar water levels (see Annex 2) raise serious doubts as to either their accuracy or to the stability of the river on the long term. Differences in peak discharges at equivalent water levels up to some 30% have occurred. Hence, either the measurements and the model are accurate and dynamic processes explain these differences,

or the measurements are in serious error and the model has been adjusted to cope with these errors, or the river system has indeed significantly changed. The latter two reasons would seriously reduce the applicability of the GM for the simulation of possible future situations involving a substantial embankment of the main river system in Bangladesh.

Hence, there is an urgent need to validate the model for some years with medium to high floods in the sixties and seventies. Eventual significant differences between observed and simulated water levels for these years (nation wide) may be due to:

- errors in the boundary conditions, in particular in the observed flows on the Ganges and Brahmaputra rivers
- deficiencies in the calibration of the model
- significant changes in the river system
- errors, either systematically or at random, in water levels recorded at the selected key-stations.

Such validation runs will reveal the combined effects or all sorts of errors contained in the observed data on river flows and deficiencies in the calibration of the NAM and GM model, and as such comply with the questions raised by FPCO, the POE and Prof. Chowdhury with respect to the accuracy of hydrological data and the impacts of data errors and hydraulic uncertainties on the reliability of design hydrographs.

Actions to be taken in the event of non-acceptable validation results for the earlier years can not be anticipated at this instant, and should be considered in close communication with the SWMC.

If rainfall on Bangladesh does not affect river flows and water levels in the main system to a great extent, it is suggested to run the GM as soon as possible with the river flow boundary conditions for the full period 1964-1989 and an average rainfall pattern over the country. The results in terms of water levels should be compared with all available observed records for this period. Such analysis will produce at short notice at least a "quick and dirty" impression of the accuracy of observed river flow and water level data along the main streams and of the calibration of the GM. It has to be checked whether or not there is a systematic component in the deviations between the model and nature, which may indicate a gradual change of the river system in certain areas. Standard deviation of differences between observed and simulated water levels should be calculated.

Provided that data indeed become available for the Ganges and Brahmaputra rivers for some years in the first half of the



century, it is advocated to run the GM as well for those years with an average rainfall distribution over the country. This will shed even more light on the applicability of the GM, based on 1990 river conditions, for the evaluation of water levels as they may occur on the long term.

If the above analysis leads to the conclusion that significant changes have occurred in the river system during the last part of the century, one may well choose to add an extra freeboard to the design levels of the river embankments.

It is noted that the FAP-25 is not bound to produce a study of the long term morphological developments of the rivers in Bangladesh. At best some evidence for the existence or absence of such changes will be produced. A more detailed study of such phenomena may be subject of further study under the FAP-24 project (River Survey Project).

4.9 Application of the GM for the period 1964-1989

At short notice FAP-25 should assess in consultation with the regional study consultants which output (levels and flows) is required at which location. Upon completion of the boundary conditions the GM should then be run for the full period 1964-1989, or even further back into history depending upon the availability of boundary conditions for the main rivers. Results of these computations should, after preliminary inspection and analysis, be supplied soonest to the regional studies.

4.10 Analysis of Simulation Results

The results of the simulations for the period 1964-1989 should be subjected to an error analysis as already indicated under section 4.8. Computed flows and water levels should be analysed statistically, in terms of peak flows, seasonal and sub-seasonal flood volumes. This analysis is similar to the analysis mentioned in section 4.3 for observed historical water levels and the reasons of eventual differences between the results of both analyses should be addressed.

Based on the statistical analyses a graphic display of the spatial distribution of return periods for selected historical flood seasons (years), and for specific design characteristics, e.g maximum water levels, seasonal or sub-seasonal flood volumes should be prepared. This may enable regional consultants to select for a specific return period historical years, which produce the required design conditions in the main rivers near their study regions.

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Design events for projects within a region will probably not exceed 25 years, while the design return period for the embankments along the main rivers may well be in the order of 50 years. Therefore, the period 1964-1989 should provide a sound basis for such designs, provided that this period is, as far as rainfall and river flows are concerned, representative for a longer period of time (see section 4.3).

The 1988 flood is likely to be chosen as a design flood season for a return period of some 40 to 60 years, except for the Ganges river. It may well be considered to use a (for example) 10% increase of this flood as a design flood season for a return period of about 100 years, the percentage to be determined on the basis of the slopes of fitted frequency curves. One may wish to use such a return period for the protection of major urban cities. The GM should then be run for these boundary conditions on the main rivers (for example with the rainfall distribution of 1988), for the situation that the main rivers are generally protected against a flood with a return period of for example 50 years.

In view of all the uncertainties and inaccuracies embedded in the historical hydrological data, the relatively short period of records and the possibility of gradual changes in the morphology of the main river system in Bangladesh, one will never be able to determine return periods with a high degree of accuracy. Therefore, one should rather talk in terms of extreme, high and moderate floods than in terms of very specific return periods.

The FHS should at least indicate a spatial distribution of standard errors for specific design floods. Standard errors as determined from the simulations for the period 1964-1989 (observed-simulated) together with standard errors of statistical estimates (quantiles) determine the standard error of the design condition to be taken into account in determining the free board of embankments. Both type of standard errors can be taken as statistically independent variables.

4.11 Acquisition of Software

The activities discussed in this chapter require adequate and user-friendly software for data storage and retrieval, statistical analysis and analysis of results of simulations. It is questionable if the presently available software package TROPHEE provides sufficient facilities to complete the FHS efficiently and as soon as possible. The package is quite limited in its scope and may not provide sufficient options for statistical analysis and the analysis of rainfall data, as anticipated in this study. The need to acquire a better and

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well proven hydrological data base and processing system should therefore be considered at short notice.

4.12 Methodology for Selecting Boundary Conditions for Project Design at the Regional Level

The methodology for the selection of boundary conditions for the design of projects within the regions necessarily should follow the same lines as outlined in this Chapter for the main river system, i.e.:

- baseline statistical analysis of rainfall and possibly other important design parameters, analysis of the representativeness of the period 1964 - 1989 for the century (as far as not achieved under the FHS) and selection of historical rainfall sequences to which a specific return period can be assigned
- development of a dedicated version of the regional model, which allows larger timesteps to be used and makes running of this version practicable for long time periods
- preparation of boundary conditions required to run such a dedicated regional model for the period 1964-1989, or at the minimum for a selection of 10 years which contain both the 5 years with highest floods on the main rivers in the period and the 5 years with the highest rainfalls
- running of the model for the present conditions and 10 to 25 historical flood seasons and statistical analysis of the results, aimed at assigning return periods to selected historical seasonal or sub-seasonal periods, which then can be used for preliminary design purposes
- upon completion of the designs, and perhaps also once as an intermediate stage, it will be necessary to test the performance of proposed protection schemes under all conditions as prevailed in the area in the period 1964-1989 (model runs for 25 years)

In the planning and conceptual design stage the main aim of using the regional model will be to assess the hydraulic efficiency of alternative flood protection schemes or components. For this purpose it will be quite sufficient to run the regional model only for some 3 historical flood seasons, say 1987, 1988 and another year. The need to follow a practical approach is evident.

It is felt that a highly theoretical joint probability analysis is both extremely difficult and quite impracticable. Moreover, the period of 1964-1989 is likely to provide a sound

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basis for design for the regional studies since the return period of their design conditions is not expected to exceed 30 to 50 years.

Obviously, the consultants should make a simple test on the correlation between high river flows and high rainfalls, to put the problem of joint probabilities at the regional level into perspective. The actual correlation structure is however embedded in the actual data series for the last 25 years, and is therefore automatically well taken into account.

4.13 Analysis of Joint Impacts of Projects in Various Regions

From time to time FAP-25 is expected to run the GM with incorporation of various regional projects (development scenario or strategy), to determine joint impacts of all sort of projects and to design conditions for such situations. This may either require running of GM for full period of 25 years or only for selected years to which a specific return period has been assigned. This exercise will be repeated a number of times during the course of the various FAP studies.

It is expected that such activities will start to take place in 1992, when the NW regional study has started its project preparation activities, the NC study has completed its preliminary activities, the SW study may have completed its Inception Report and the SE study has started with its feasibility studies. The position of the NE study is not clear in this respect.

Before that, consultants may wish to have a rough idea of the joint impacts and the consequences thereof for their designs of a few, roughly outlined development schemes. Provided the consultants together can give an outline of such schemes, it will be fairly simple to make at short notice runs with the GM for a number of historical years, or even for the full period of the last 25 years, including eventually a run for an extreme event such as the 1988 flood increased with some 10%. This assumes that the use of a monthly average rainfall pattern over the country is acceptable and that the validation of the GM for the period 1964-1986 does not confront the FHS with major problems. The FAPMCC may be the proper forum to initiate such activities.

Obviously the role of the RMC is crucial in making the arrangements for this sort of activities, where the regional studies should all participate actively in selecting a set of regional plans which should be incorporated in such series of runs with the GM.

4.14 Miscellaneous Issues

Sea Level Rise

World wide ongoing studies indicate that the green house effect and related sea level rise may have considerable impact on flooding in Bangladesh. In some countries it has become practice to design flood protection works in such a way that, if and when a noticeable sea level rise would occur, flood protection works can be adapted without too much destruction of earlier capital investments. Hence, it is recommended to take sea level rise into account in the above sence. The normal rate of sea level rise, as detected over the last century should obviously be taken into account for all designs. Hence, the FPCO should indicate a time horizon for the design of flood protection works.

It may not be adequate to include already at this stage extra freeboard in the design levels of embankments to cope with an eventual sea level rise. Large structures may however be designed in such way that a moderate sea level rise can be dealt with quite easily. The General Model can be used to perform a sensitivity analysis with respect to the impacts of sea level rise on design levels along the main rivers. Regional models can be used to perform similar analysis for the SW, SC and SE regions. The matter is left for consideration and analysis by the regional consultants, although the FAP-25 can upon request assist in some computations with the GM for the purpose of a sensitivity analysis.

Cyclones

Cyclones often occur in the months of April and October/November. A coincidence with extreme flood levels will be rare and cyclones are therefore not considered relevant for the definition of design floods due to high river flows. The issue of protecting the coastal belt against the impacts of cyclones is therefore left to the FAP-4,5 and 7 projects.

Spring Tide

Spring tides are to be taken into account, as well as wind set-up and wave run-up, in establishing design levels for coastal embankments and embankments along the Lower Padma. However, tidal fluctuations will not be taken into account in the boundary conditions for the GM as used for the FHS. It is left to the regional consultants to incorporate tidal levels as boundary conditions in their models, as required.

5. WORKPLAN AND TIME SCHEDULE FOR COMPLETION OF STAGES 1 AND 2

The workplan for the remainder of stages 1 and 2 of the FHS is set-up such as required to provide at short notice, that is before September 1st, 1991, design boundary conditions for the present conditions to the regional studies. Preliminary results, based on a 'quick and dirty' analysis, but which may be quite sufficient for preliminary designs, can possibly be provided earlier. Improved results will gradually become available during the remainder of 1991. The time schedule assumes a reasonable validation of the GM for historic flood seasons back into the sixties. If and when it turns out that the GM does not reproduce properly such past observed water levels, it may take quite some time to resolve the matter, if it can be resolved at all.

The workschedule is based on the cooperation of Dr. Guna Paudyal, working at the SWMC for the FHS, and a new hydrologist to be appointed soonest for the study. Dr. Paudyal will be primarily responsible for the development of the dedicated GM, guidance of data preparation for the model and the running of the model, whereas the Hydrologist will be responsible for the baseline statistical and related studies and for the analysis of the results obtained with the GM.

All efforts should be undertaken to complete soonest the validation runs for the GM back to the early sixties, in the first instance with actual observed flow data on the Ganges and Brahmaputra and with an average rainfall pattern over the country.

Activities and Timing for Completion Stages 1 and 2

June - early September 1991:

1. Initiate further data collection
2. Develop dedicated version of the GM
3. Extend the GM to the Bay of Bengal, if feasible
4. Study and establish downstream boundary conditions for the GM
5. Prepare upstream boundary conditions, including filling-in of missing data
6. Run the GM for 25 years with an average rainfall pattern
7. Sensitivity analysis of GM results for rainfall data input
8. Analyse validation of the GM and improve the model, if needed
9. Prepare rainfall data input the NAM model for 1964-1989 and run the NAM model, if needed
10. Run the GM with actual rainfall data for 25 years and perform error analysis

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11. Prepare statistics and return period maps for present conditions and specific floods and supply data and results to regional consultants

September 1991 - January 1992:

12. Run the GM for selected years and a potential country-wide protection scheme: sensitivity analysis and pilot study to establish proper procedures for similar activities under stage 3 in 1992
13. Data checking, correction and completion (section 4.1)
14. Run the GM for selected years before 1964 and monthly average rainfall pattern, provided data become available, and adjust return period of specific floods accordingly, if appropriate
15. Determine joint probabilities of main stream flows and rainfall (section 4.2)
16. Analyse the representativeness for the century of hydrometeorological conditions in the last 25 years (section 4.3):
 - moving average and sum of residues analysis
 - frequency analysis of rainfall data
 - statistical analysis of various flood
17. Describe unified methodologies for statistical analysis and selecting boundary conditions for design of regional projects (sections 4.4 and 4.12)
18. Perform additional runs with the GM, if adequate, taking into account the results of the above analyses
19. Provide standard errors of estimate for specific design criteria (due to measurement and model errors and due to statistical uncertainties)
20. Prepare report on stages 1 and 2

Stage 3 (as of February 1992):

21. Perform GM runs to provide boundary conditions and statics for potential future nation-wide protection schemes analyse results, reporting and supply of results to the regional consultants

6. INPUT IN MANPOWER FOR COMPLETION OF FHS

The Flood Hydrology Study is expected to require an additional input of an expatriate Hydrologist for a period of 6 months, at the latest to start as from August 1st, 1991, but preferably as from July 15th. The Hydrologist should be available at the latest upon completion of the activities mentioned under point 10 of the above time schedule. Part-time

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input of a modeller (Dr. Paudyal, working at the SWMC) is required for the remainder of 1991, and occasionally also during 1992. The input of the two hydrological assistants presently working for the FHS has to be extended to the end of 1991. It should be anticipated to provide some input of an hydrological assistant during 1992 for the activities mentioned under stage 3.

The newly to be appointed Hydrologist should have post-graduate qualifications and experience of 7 to 10 years, be experienced with data processing and to some extent also with the use of hydrodynamic models, and should above all be able to communicate easily on a professional level with hydrologists, hydrodynamic modellers and design engineers of the regional consultants.

Annex 1: Overview of achievements of stage 1 of FHS

The following activities have been completed under stage 1 of the FHS, as per May 15th, 1991:

- Data collection for the period 1964-1988 for:
 - 77 water level stations
 - 22 discharge stations
 - 21 rainfall stations
 - 13 evaporation studies
- Frequency analysis of flooded areas for divisions and districts
- Completion of data base for selected strategic stations:
 - 22 water level stations
 - 14 discharge stations
 - 21 rainfall stations
- Frequency analysis of annual maximum water levels and discharges for the selected strategic water level and discharge stations, including confidence intervals; comparative study of distributions
- Rainfall intensity-duration-frequency analysis for 21 stations
- Multi-correlation analysis between maximum water levels at Bahadurabad, Hardinge Bridge and Baruria
- Conceptualization of alternative methodologies for generating reference floods with specific return periods
- Preparation of an Interim Report (April 1991)

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Annex 2: Some notes on observed discharge data and extreme flow statistics for the Ganges at Hardinge Bridge

The accuracy of the design conditions, as derived through the FHS, depends on various factors, one of them being the accuracy of the discharges used as upstream boundary conditions for the Ganges, Brahmaputra and Meghna rivers. Discharges are occasionally measured and most of the time derived from rating curves. Hence, the reliability of such curves is of great significance for the reliability of design levels. Figures 1 - 3 show the relation between annual maximum water levels and discharges for Hardinge Bridge, Bahadurabad and Baruria.

Deviations from a unique relationship as displayed may be caused by inaccuracies of measurements, wrong extrapolation of rating curves for extreme floods, dynamic flow effects and changes in the river morphology which have caused shifts in the rating curve. An example of such river dynamics is shown in figure 4, showing cross-sections of the Ganges river at Paksey (Hardinge Bridge) as surveyed between July and October 1965. This example illustrates the substantial morphological changes which may take place from one year to the other.

The above raises the question whether the General Model (GM), representing a particular morphological bed feature pertaining to a particular year, is fit to generate reliable hydrographs over a sequence of years under a fixed schematization of the river cross-sections. Figure 5 and 6 present some information on the subject for the Brahmaputra river. Variations in discharge for the same level can be significantly and should well be taken into account in setting the standard error of estimate for of design levels derived from the GM.

Since the GM has only been calibrated and validated for the period 1986-1989, it is of utmost importance to test its performance over a longer period (1964-1989). A comparison of observed and simulated water levels will allow proper estimation of the standard error of estimate of calculated water levels.

Figures 7 - 9 show the fit of the Gumbel distribution to observed annual maximum discharges on the Brahmaputra and Ganges rivers, the latter for the periods 1964-1989 and 1934-1989. Extreme events estimated from the data for the short period seem to overestimate peak flows with a specific return period slightly, but some doubts on the accuracy and consistency of the discharge measurements over the full period remains. The first impression is however that the period 1964-1989 is quite well representative for the full period 1934-

1989, and therefore may provide a sound basis for the estimation of design floods for specific return periods.

It is striking that the return period of the 1988 flood has a return period of some 20 years for the Ganges and some 50 years for the Brahmaputra, while its return period for locations further downstreams on the Padma may well have exceeded 50 years. This illustrates in a nutshell the problem of joint probabilities of flood events, originating from various sources.

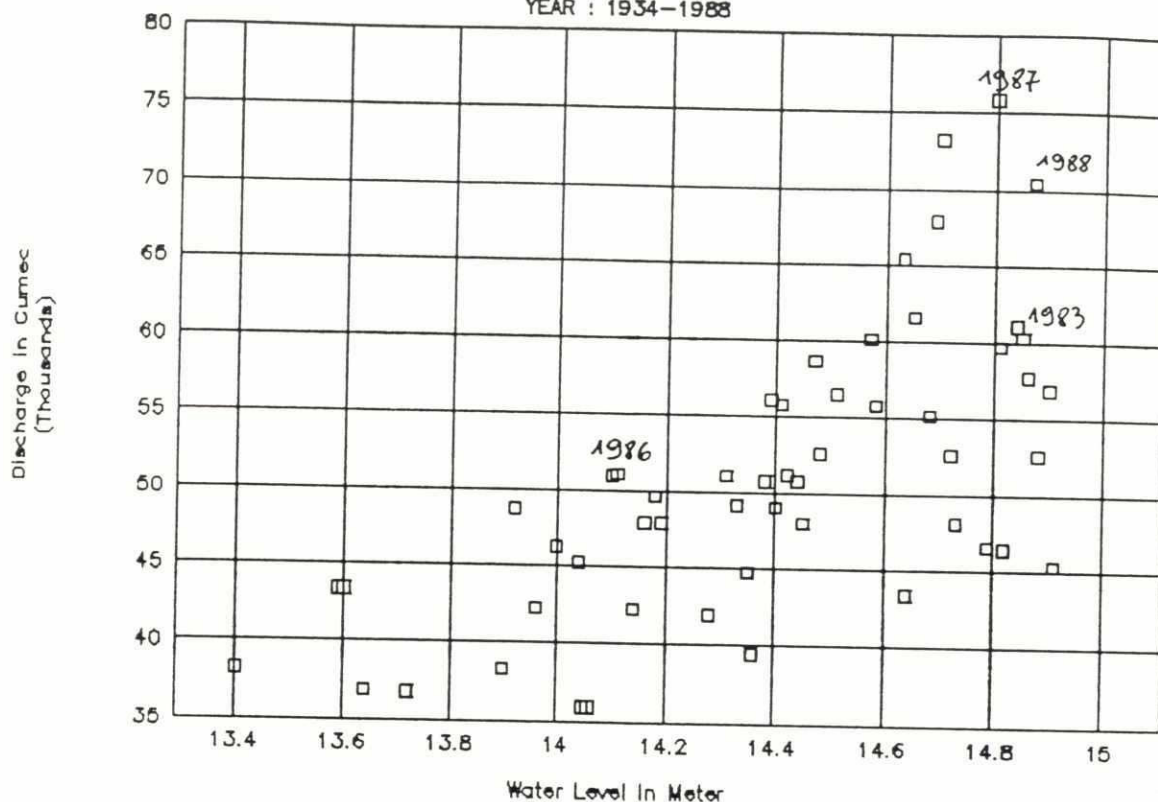
Finally, it is noted that an increase in maximum discharges with only 10% means a shift in return period from 40 to 100 years on both rivers. The corresponding increase in water levels is probably only some decimeters. Hence, the actual choice of the design return period seems to have only limited impact on the design levels of the river embankments. The rather large freeboards to be adopted due to significant standard errors of estimate and for various other reasons, seem to be of more importance. However, this picture may change in case all rivers are embanked and the fluctuations of water levels with discharges may become more pronounced.

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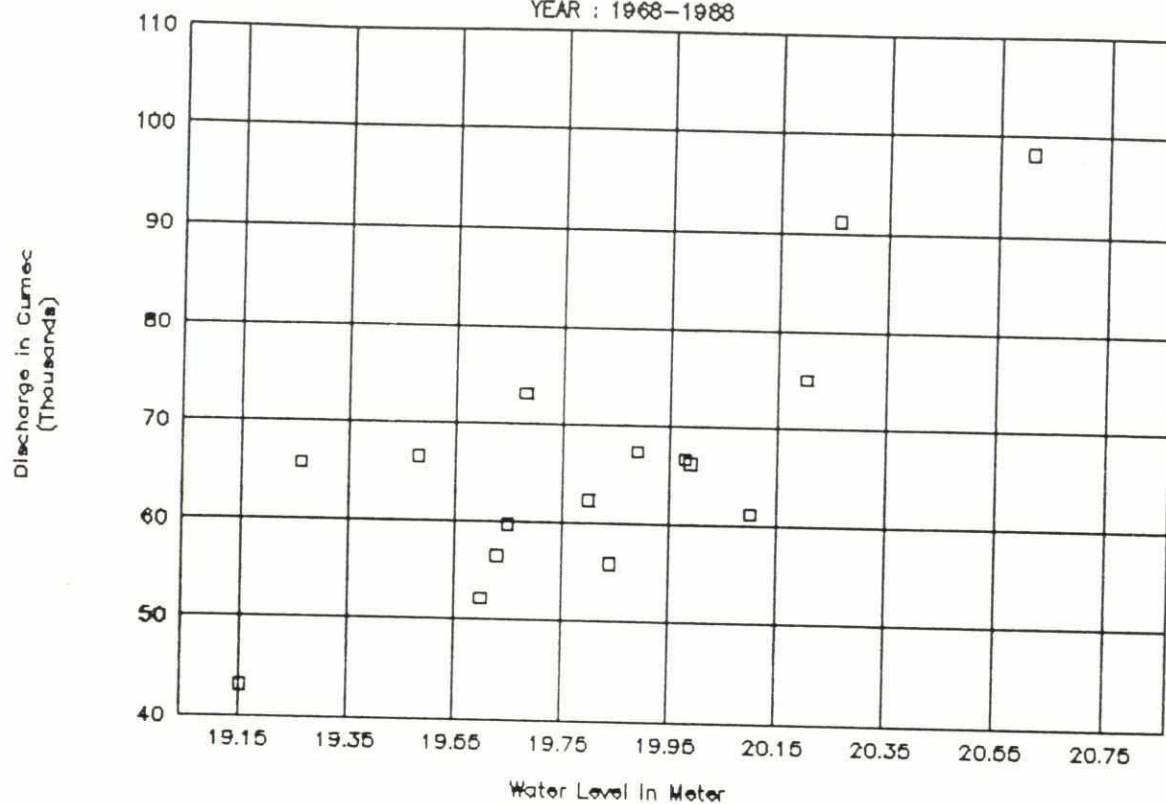
HARDINGE BRIDGE WL VS Q

YEAR : 1934-1988



BAHADURABAD WL VS Q

YEAR : 1968-1988

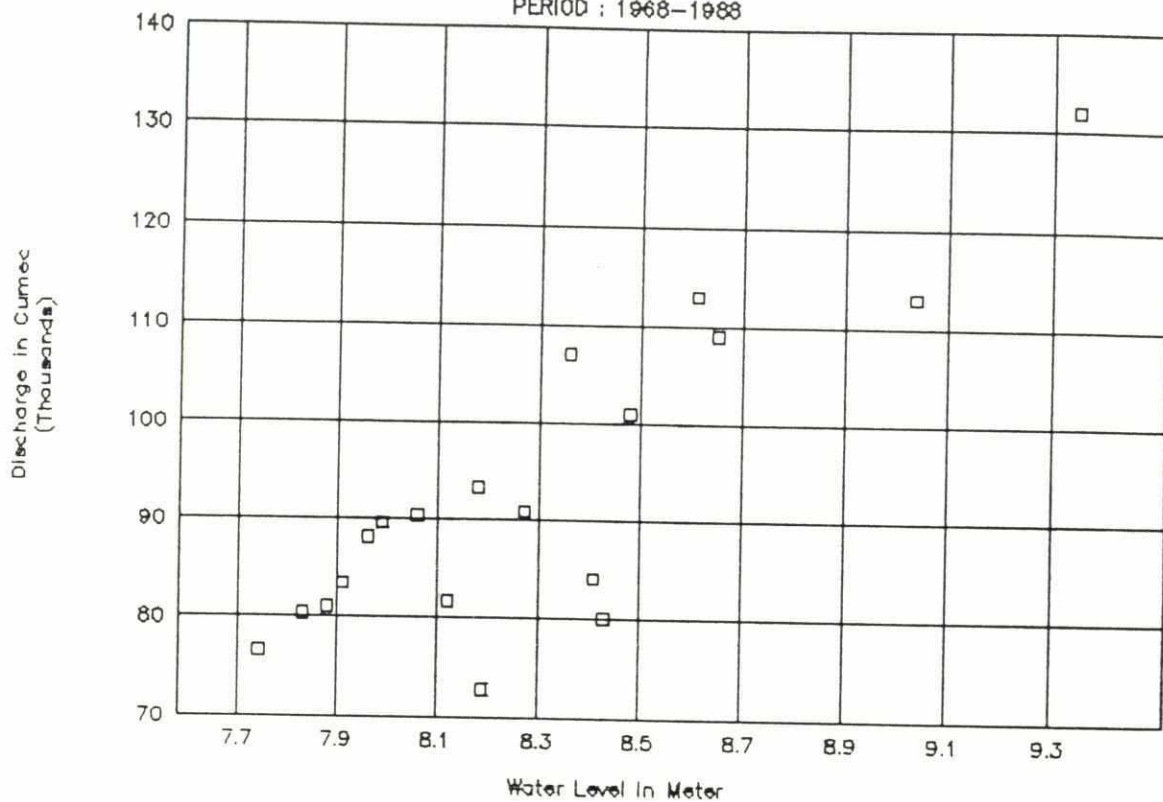


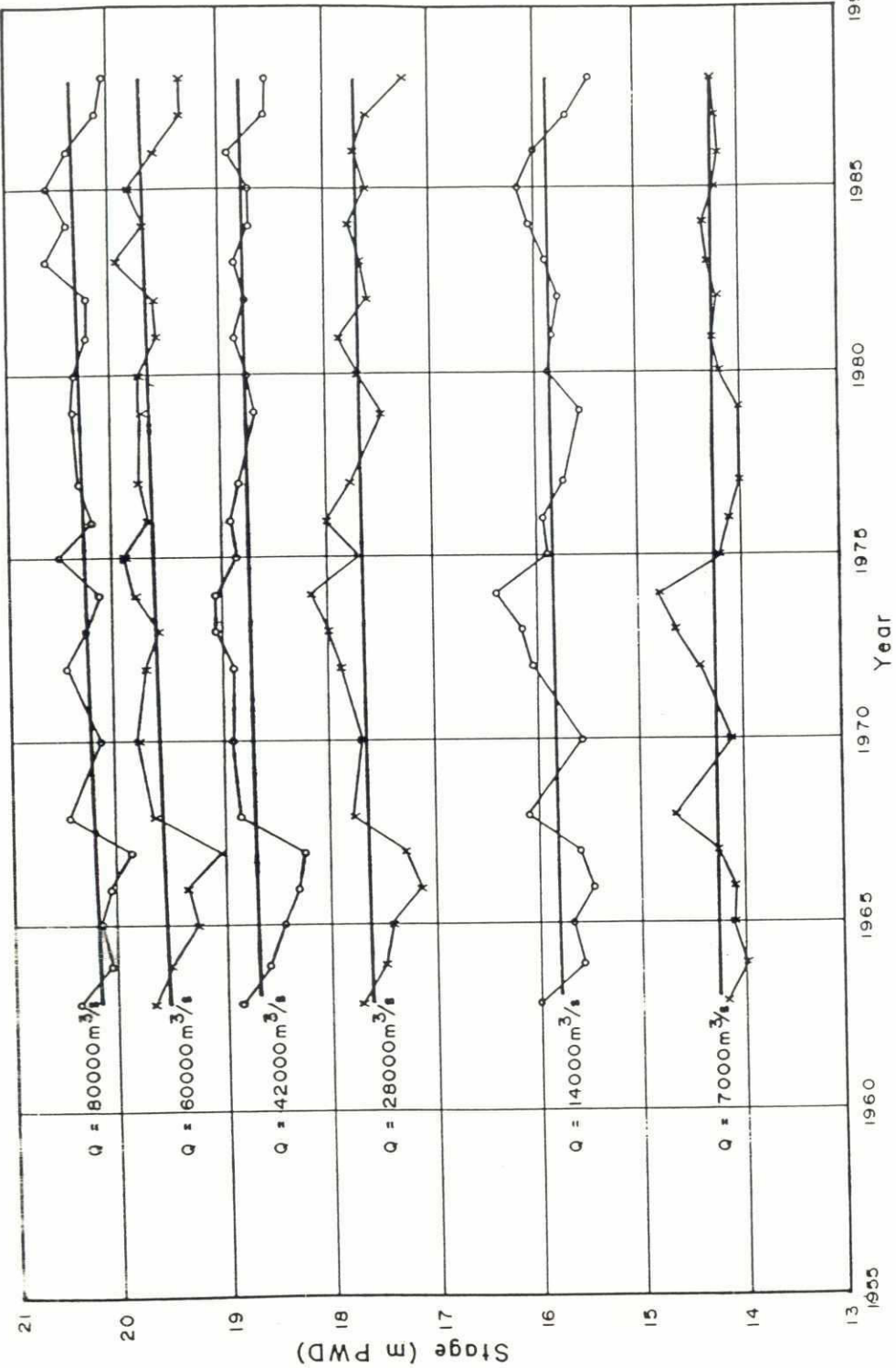
III

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BARURIA W.L VS Q

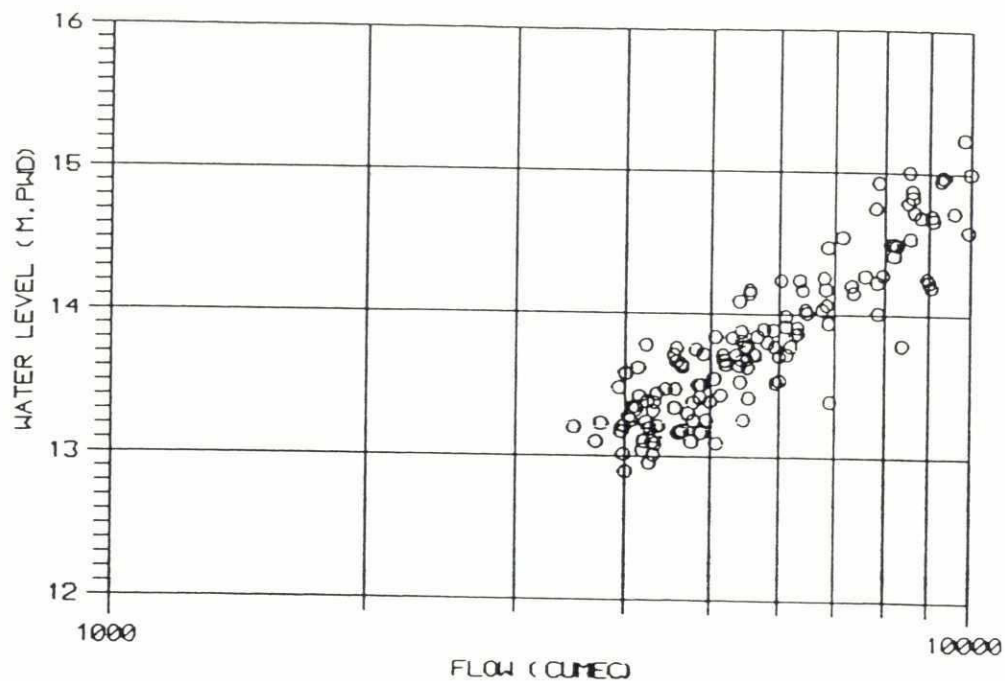
PERIOD : 1968-1988



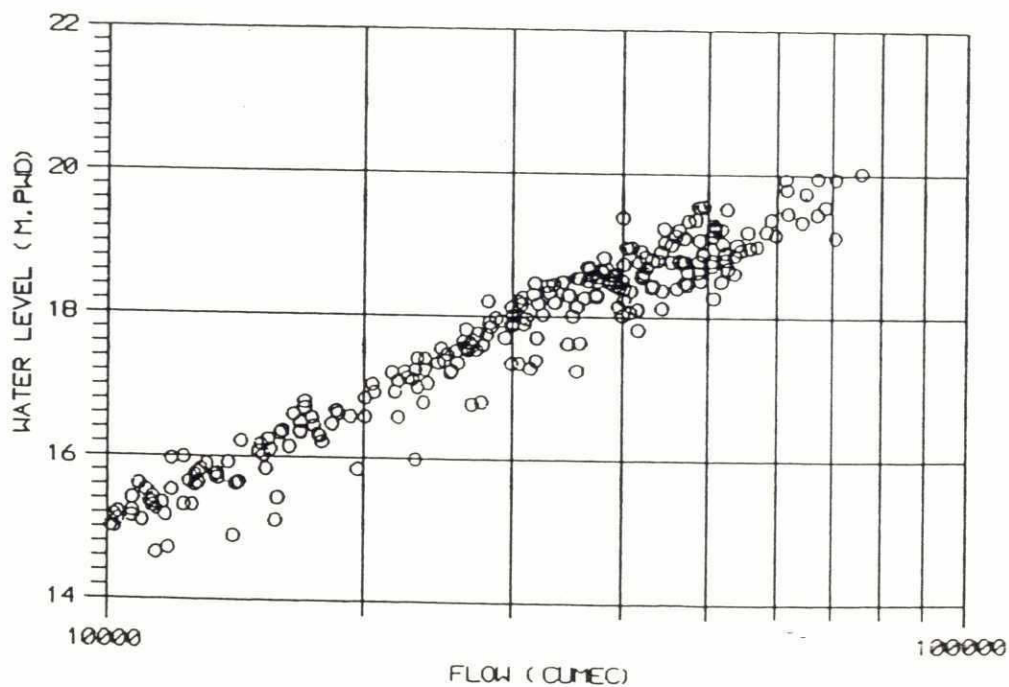


WATER LEVEL VARIATION FOR SIX RELEVANT DISCHARGES AT
BAHADURABAD - BRAHMAPUTRA RIVER (1963-'89)

FIGURE : ~~28~~ 6



(a) Observed discharge in the range of 1,000 - 10,000 m³/s



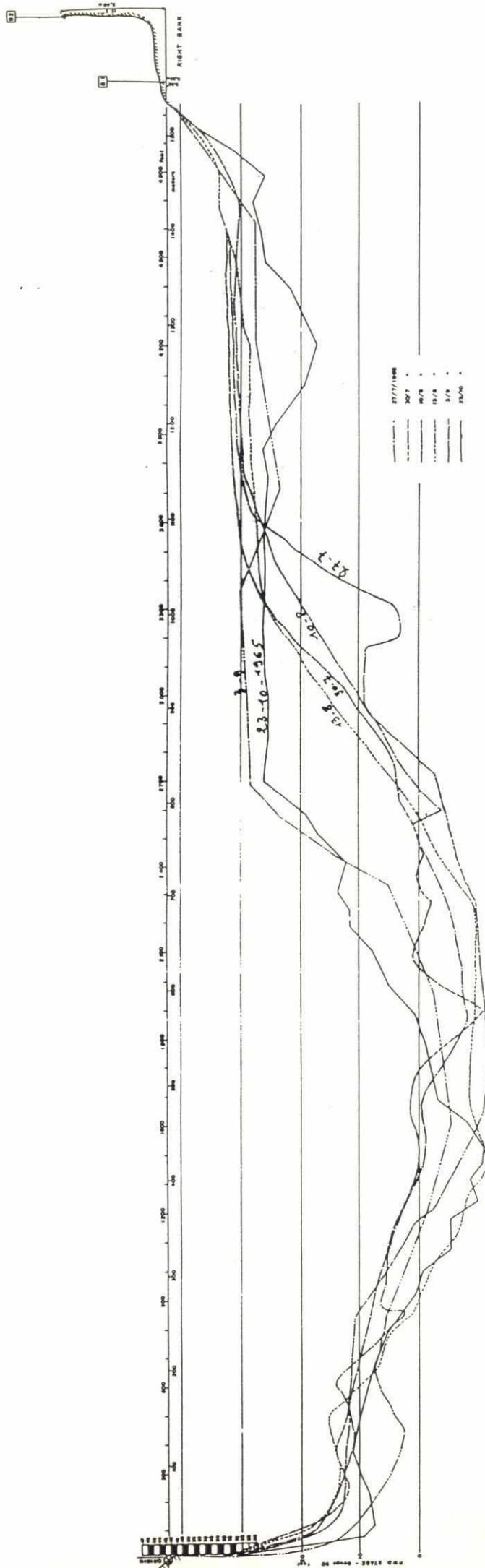
(b) Observed discharge in the range of 10,000 - 100,000 m³/s

CHARACTERISTICS OF OBSERVED DISCHARGE MEASUREMENTS OF
THE BRAHMAPUTRA AT BAHADURABAD TRANSIT (1976 - 89)

Fig. 4

IV

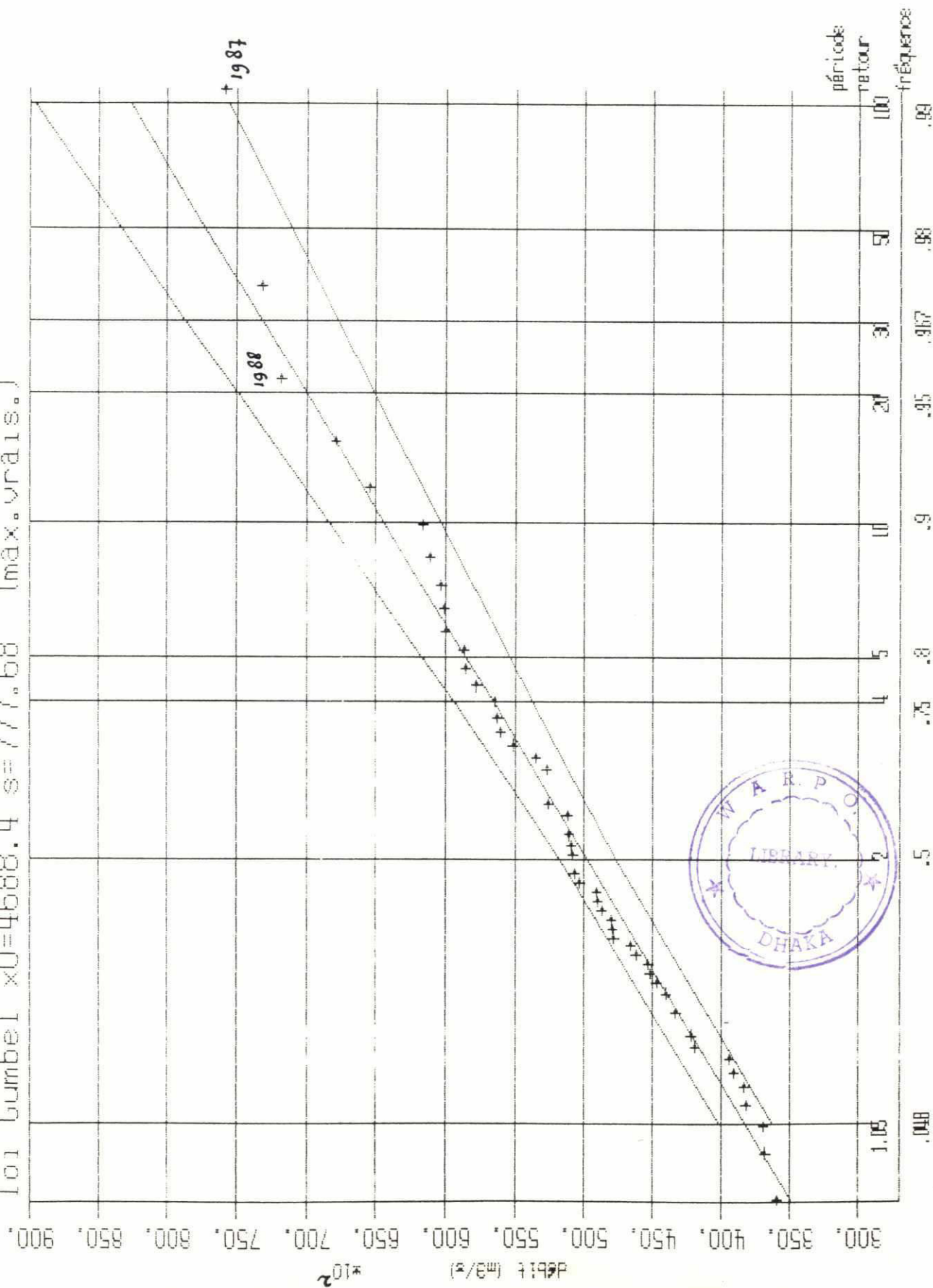
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PRADA
Station: PAKSEY
River: GANGES
Designation: VARIATION OF WETTED CROSS-SECTION — EVOLUTION OF BED PROFILE —

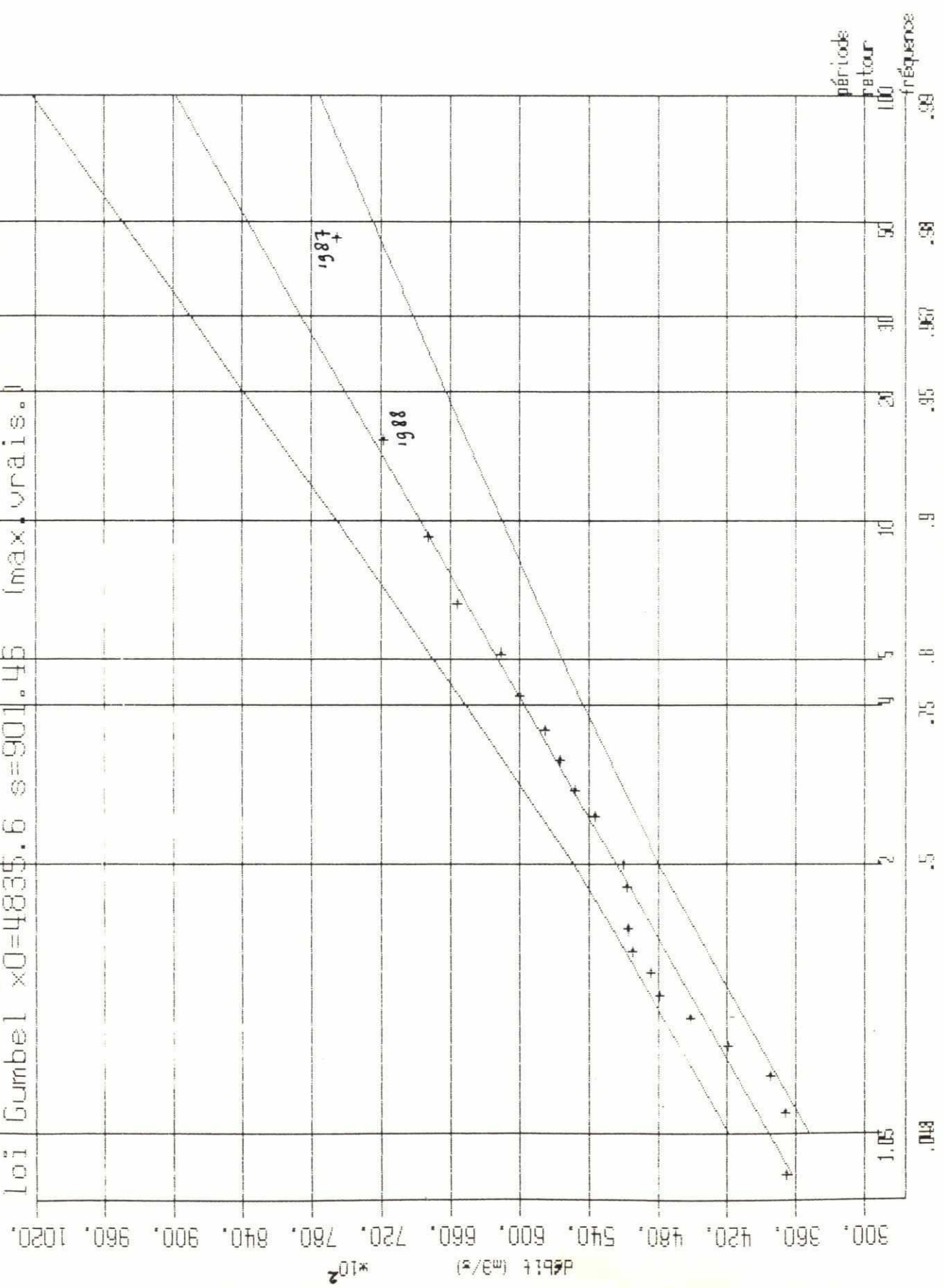
IV

Discharge HARDINGE BR. (54) période: 1934-1988
 débits de pointe maximaux annuels (m³/s)
 loi Gumbel $\alpha=4688.4$ $s=777.68$ (max.vrais.)

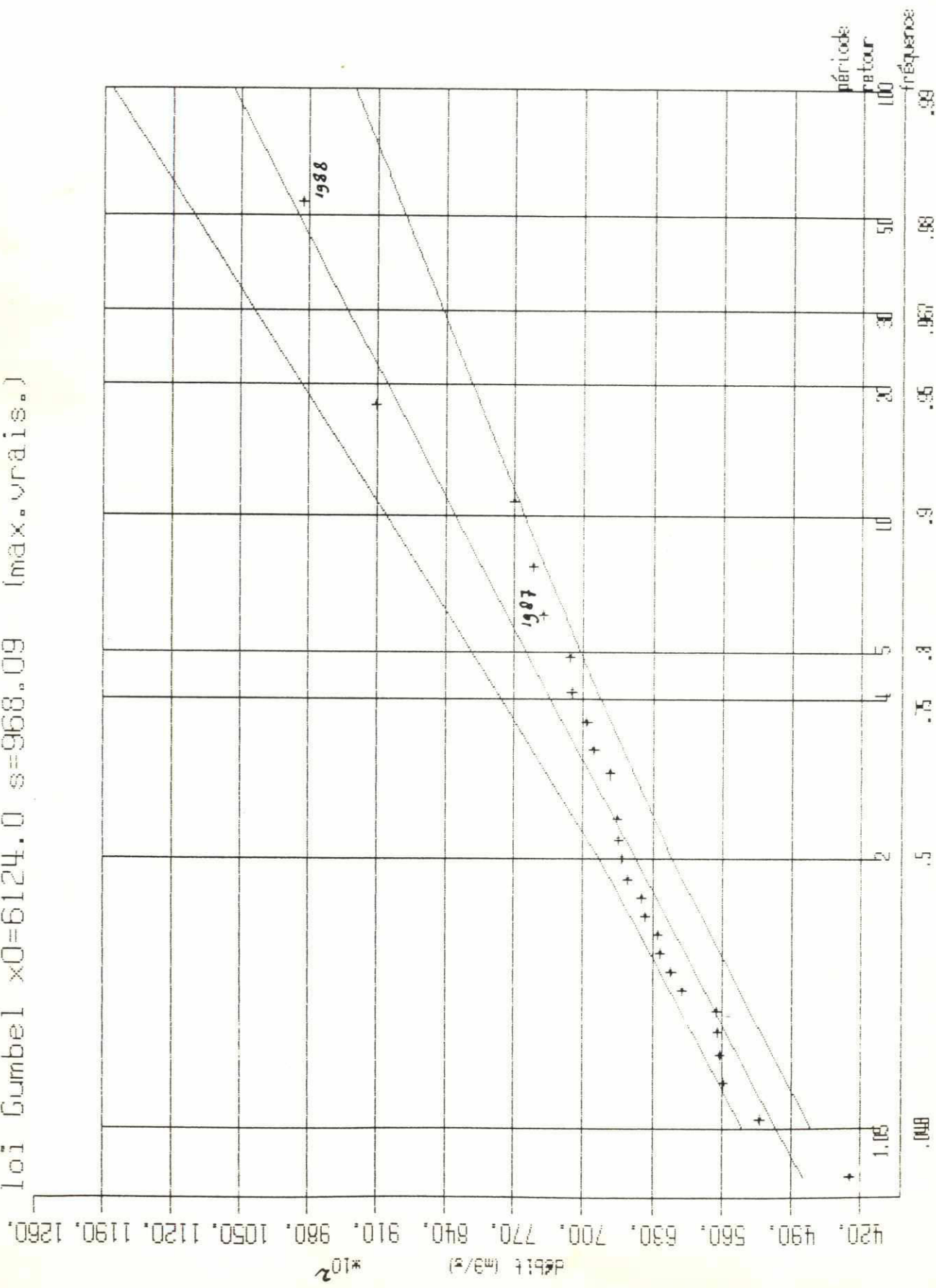


Discharge HARDINGE BR. (23) période: 1965-1988

débits de pointe maximaux annuels (m³/s)
 loi Gumbel x0=4835.6 s=901.45 (max. vrais.)



Discharge BAHADOURABAD (27) période: 1956-1989
 débits de pointe maximaux annuels (m³/s)
 loi Gumbel $x_0=6124.0$ $s=968.09$ (max.vrais.)



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Appendix 7 : Proposed TOR for FMM Detailed Project Formulation Mission.

The CAT considers that the need for, and the detailed specification of, the FMM are not well defined at the present time. In particular discussions with the Regional Study consultants have yet to take place concerning flood protection measures which are likely to be recommended within FAP. Hence the CAT proposes an Formulation Mission to firm up the justification, uses and detailed specification for FMM's.

Activities to be included in the mission are :

- determination of the views and requirements of potential users within GOB
- determination of the flood control measures which are being evaluated, and possibly recommended by the Regional Study consultants.
- determination of the precise features to be included in the FMM.
- determination of the uses of FMMs locally, regionally and possibly nationally.
- determination of the online data requirements of local, regional and national FMMs.
- determination of how /whether such data requirements can be achieved.
- determination of hardware and software requirements for local, regional and national FMMs plus their data collection systems.
- determination of user requirements in terms of FMM output
- preparation of detailed Terms of Reference for the FMM, including staffing requirements, project organisation and lines of communication, relations to other FAP components and detailed budget.

The Formulation Mission will be carried out by one or two senior experts who combine the following qualifications :

- experience of water management projects in Bangladesh (preferably flood control and drainage projects)
- background in hydraulic engineering and some experience with mathematical modelling

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- at least 10 years of experience

The input of the senior experts will be a total of approx 2 man-months.

The experts will work very closely with the Resident Model Coordinator of FAP 25

The Formulation Mission will be carried out in close coordination with the donor agencies of Denmark and France who have indicated interest in funding the project, and with the Netherlands who has indicated interest in supporting the FMM through additional manpower input to FAP 20 (Compartmentalization Project). The proposed manpower requirements and budgets should be discussed with the donor agencies prior to finalization of the TOR and PLOP.

