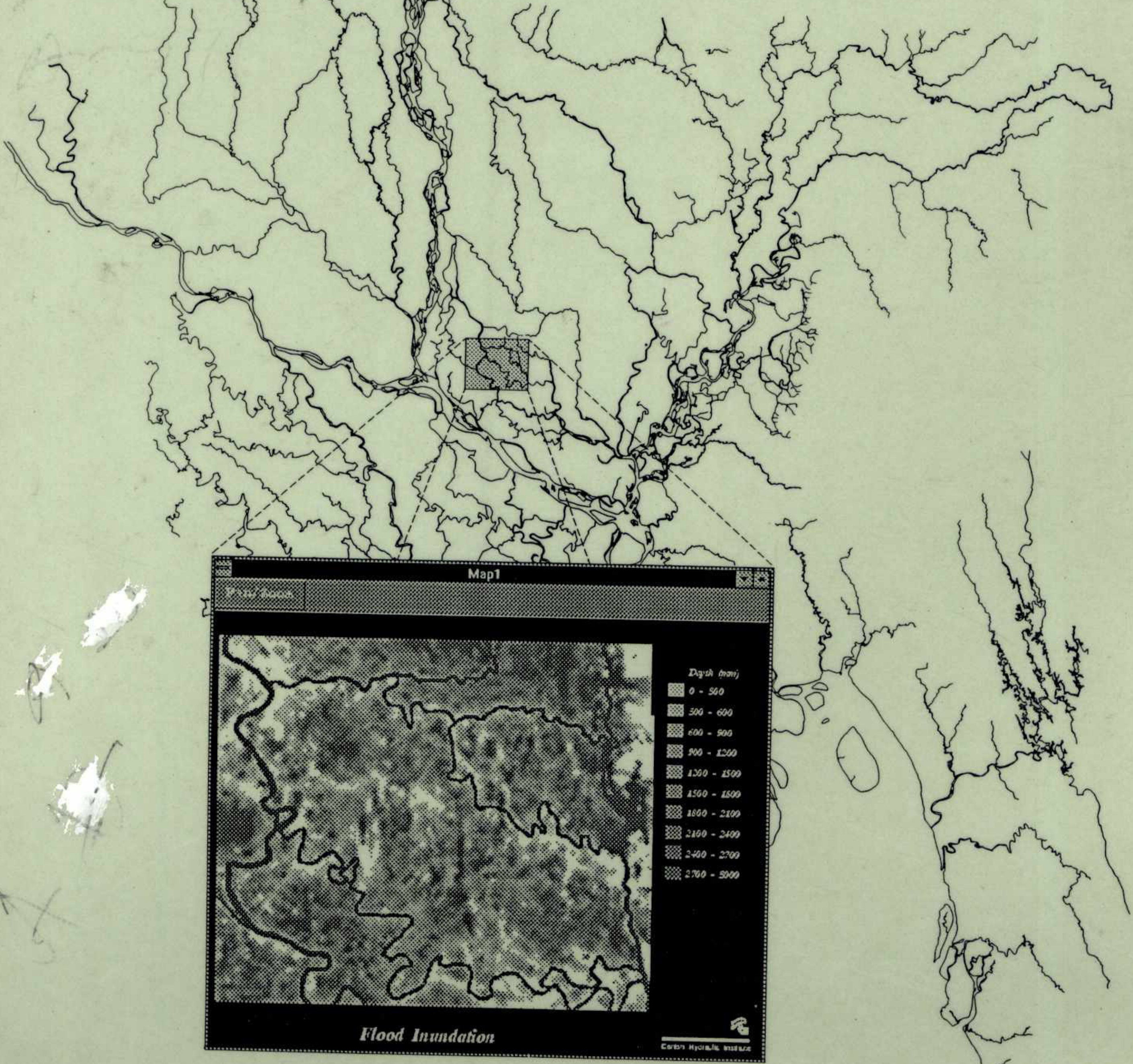
Government of the People's Republic of Bangladesh
Flood Plan Coordination Organization
FAP25: Flood Modelling & Management

Flood Management Model

Interim Report - I

January 1994



Consultants: **Danish Hydraulic Institute**
in association with
EUROCONSULT
BCEOM

Donors: Denmark France The Netherlands

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ACRONYMS / ABBREVIATIONS

AML	ARC/INFO Macro Language
ARC/INFO	Geographic Information System Package
BADC	Bangladesh Agricultural Development Corporation
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BIWTA	Bangladesh Inland Water Transport Authority
BRDB	Bangladesh Rural development Board
BRRI	Bangladesh Rice Research Institute
BWDB	Bangladesh Water Development Board
CAT	Coordination Advisory Team.
CFD	Caisse Francaise Developpement
CHE	Computational Hydraulic Engineer
CIDA	Canadian International Development Agency
CPP	Compartmentalization Pilot Project.
DAE	Department of Agricultural Extension
DANIDA	Danish International Development Assistance
DEM	Digital Elevation Model
DHI	Danish Hydraulic Institute
DOE	Department of Environment
DOF	Directorate of Fisheries
EIP	Early Implementation Project (Dutch-assisted FCD Project)
FAP	Flood Action Plan
FCD	Flood Control and Drainage
FCDI	Flood Control, Drainage, and Irrigation
FF&WC	Flood Forecasting & Warning Centre
FFW	Food-For-Work
FHS	Flood Hydrology Study
FMM	Flood Management Model
FPCO	Flood Plan Coordination Organization (under MIWDFC)
GIS	Geographic Information System
GM	General Model
GOB	Government of Bangladesh
GPS	Geopositional Satellite
HD	Hydrodynamic
HYV	High Yielding Variety
HP	Hewlett Packard
ISPAN	Irrigation Support Project for Asia and the Near East
JPPS	Jamalpur Priority Pilot Study
LGEB	Local Government Engineering Bureau
LGED	Local Government Engineering Directorate
MIKE11-GIS	River Modelling - Geographic Information System Interface
MIWDFC	Ministry of Irrigation, Water Development and Flood Control
MOA	Ministry of Agriculture
MPO	Master Plan Organisation (under MIWDFC) now WARPO

NAM	Rainfall Runoff Model (Danish Abbreviation)
NCRM	North Central Regional Model
NCRS	North Central Regional Study
NGO	Non-Governmental Organization
O&M	Operation and Maintenance
POE	Panel of Experts
R&H	Roads and Highways
RRI	River Research Institute
SPARRSO	Space Research and Remote Sensing Organization
SSWCSIII	Small Scale Water Control Structures III Project
SRP	Systems Rehabilitation Project
SWH	Surface Water Hydrology
SWMC	Surface Water Modelling Centre
SWSMP	Surface Water Simulation Modelling Program
TCM	Tangail Compartment Model
TL	Team Leader
TIN	Triangular Irregular Network
TOR	Terms of Reference
UNDP	United Nations Development Program
USAID	United States Agency for International Development
UX	UNIX
WARPO	Water Resources Planing Organization
WBS	Work Breakdown Structure
WMO	World Meteorological Organisation
WS	Work Station

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1. INTRODUCTION

1.1 Background

In the past, floods in Bangladesh have hampered the national economic progress by causing widespread damage to physical infrastructure and national resources. The resulting international concern led to the formulation of the Flood Action Plan (FAP). Donors from Denmark, France, the Netherlands and the United Kingdom responded positively by participating in the execution of the FAP Component No 25: Flood Modelling and Management. The Danish International Development Assistance (DANIDA) has supported FAP 25 as the lead donor.

The FAP 25 - Flood Modelling and Management Project commenced in October 1990 and has three components. The Flood Hydrology Study (FHS) is designed to establish the hydrological basis for engineering design criteria along the major rivers and to develop common modelling standards and techniques for the FAP studies. A Coordination Advisory Team (CAT) has been set up to ensure consistency and compatibility in modelling, and to coordinate development of models for FAP at the Surface Water Modelling Center (SWMC). The third component is the development of a Flood Management Model (FMM) and demonstration of its applicability.

The Flood Plan Coordination Organization (FPCO) under the Ministry of Irrigation, Water Development and Flood Control (MIWDFC) is the implementing agency of the FMM component. DANIDA is the coordinating donor agency on behalf of the contributing donors, Denmark, France and the Netherlands. The Dutch support to the project is being provided through FAP 20 - the Compartmentalization Pilot Project (CPP). The Danish Hydraulic Institute (DHI) in association with EUROCONSULT and BCEOM are undertaking the FMM study.

The general concept of FMM and methodologies are guided by the Terms of Reference (Ref. 1). The Inception Report (Ref. 2), submitted in April 1993, describes the detailed workplan for the present study.

1.2 Introduction to FMM

FMM is conceived as a decision support tool which integrates the MIKE11 based flood modelling system with advanced graphical displays and analysis using a Geographic Information System (GIS). FMM assists in flood management planning and design and operation of flood control and drainage (FCD) systems. It facilitates examination of a wider range of alternative structural and non-structural flood management options than would be possible using standard methods, and also forms a basis for real time inundation forecasting and warning.

1.3 Objectives

The overall objective of the FMM is to provide a tool which, through prediction and analysis of the behaviour of floods, assists in the management of mitigation measures to minimize flood damage.

The MIKE11 based simulation models developed at SWMC provide the basis for such tools, although additional features are required to make them operational for flood management purposes. The objectives of the present study should be seen in conjunction with other on-going modelling activities in Bangladesh, in particular those under the FAP. The specific objectives of the present study are laid out as follows.

- To develop a MIKE11-GIS interface as the main FMM tool to assist in flood modelling and management in Bangladesh.
- To integrate the developed technology with other activities, and apply it on a test basis at National, Regional and Compartment levels.
- To present the developed technology to GOB authorities and other potential users, and identify and implement required modifications.

The overall long term objective is to achieve an on-line mathematical model linked to the flood forecasting model of FAP 10, which would provide information to assist in the management and control of floods in real-time with parallel simulation of a range of possible scenarios. The model would indicate river water levels, areas and depths of inundation and ideally the impacts in terms of potential crop losses, displacees, infrastructural disruption etc., all in clear graphical or tabular form which could be easily and rapidly assimilated. The information would be used for disaster preparedness / management as well as for the operation flood control measures.

FMM TOR (Ref. 2)

The FMM study is being carried out in two stages. The main activity of Stage 1, the Development Phase, is to develop the MIKE11-GIS interface. This will permit improved river and floodplain modelling and the generation of flood maps. Stage 2, the Application Phase, concentrates on the development of dedicated FMM models at national, regional and compartment levels.

1.4 The Interim Report

The general concepts and methodology of FMM and a detailed work plan for the study were presented in the FMM Inception Report (Ref. 1). This First Interim Report presents the status of project progress and presents the FMM features developed to date by the study team. The report is presented in six chapters, with a supporting appendix on data collection.

Chapter 2 is designed to allow the user to understand the concept of flood management and the possible benefits of FMM in flood management. A brief introduction to the software is also provided in this chapter.

Chpater 3 presents the progress on the development of FMM and particularly the MIKE11-GIS interface.

Chapter 4 presents the status of the activities related to the development of the dedicated models and their application to national, regional and compartment levels.

Chapter 5 presents the activities of training and workshops. A program of activities for the remaining part of the project is presented in Chapter 6. Also presented is the schedule of staff input.

Appendix A presents a summary of the data collection activities during the last year.

1.5 Supplementary Documentation

This report is aimed at providing a brief description of the FMM concept while the technical documentation is available from:

- MIKE11 Reference Manual (Ref. 3)
- MIKE11 User's Guide (Ref. 4)
- MIKE11-GIS Reference Manual (prepared as a part of this project)
- ARC/INFO Manuals and Documentation
- MIKE11-NAM Dynamic Interface (prepared as a part of this project)

2. FLOOD MANAGEMENT

2.1 Introduction

FMM incorporates the technologies of flood modelling and Geographic Information Systems (GIS). Consequently, FMM incorporates a number of different terminologies and methods, not easily or clearly understood by those not associated with the various specialities.

This chapter aims to clarify FMM concepts, terminology and methodology.

2.1.1 Terminology

Terminologies of the different FMM components are defined below. Terms are underlined in the definitions for cross-referencing.

Software — Computer program(s)

Hardware — Computer(s) plus any additional devices for data storage and display.

Flood Modelling — Mathematically simulating a flood wave based on the physical laws of fluid flow. The output is flood levels and discharges (flows) over time at locations along rivers and floodplains.

MIKE11 — Flood modelling software which is generic (ie. can be universally applied to any river system).

MIKE11 Model — A dedicated, site specific MIKE11 application.

GIS — Geographic Information System. Many definitions of GIS can be found. Below are two taken from an ARC/INFO training course.

1. A computer system capable of holding and using data describing places on the earth's surface.
2. An organised collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information.

ARC/INFO — GIS software.

MIKE11-GIS — Software interfacing MIKE11 and ARC/INFO running under ARC/INFO.

FMM Flood Modelling and Management concepts and methodologies developed by FAP25 and designed for application as a general Bangladesh flood management tool. It uses the MIKE11, ARC/INFO and MIKE11-GIS software.

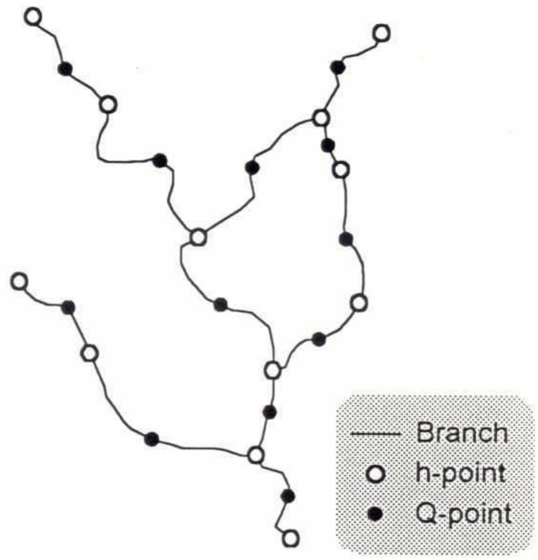
FMM Model A dedicated, site specific application of FMM. A FMM Model is composed of MIKE11 Model(s) and MIKE11-GIS applications.

SWMC Model A MIKE11 Model developed by the Surface Water Modelling Centre. A FMM MIKE11 Model may differ from a SWMC Model for the same study area, because it may require more detail over the floodplains.

DEM Digital Elevation Model (or Digital Terrain Model - DTM). XYZ data representing the terrain topography of an area on the earth's surface.

2.1.2 *MIKE11 - Flood Modelling Software*

The MIKE11 software package models flows and water levels in rivers and estuaries. It is used as a flood management tool to simulate flooding behaviour of rivers and floodplains. Models which numerically represent the river and floodplain topography are developed and calibrated. Once a base case is established, flood impacts from artificial or natural causes are quantified as changes in flood level and discharge.



MIKE11 Network

MIKE11 is based on an efficient numerical solution of the complete non-linear equations for 1-D flows. A network configuration symbolises the rivers and floodplains as a system of connected branches. At discrete points along the branches flood levels (at h-points) and discharges (at Q-points) are calculated as a function of time.

The menu based user interface is used for data capture and display, and carrying out simulations. For details refer to the MIKE11 Reference Manual (Ref. 3) and MIKE11 User's Guide (Ref. 4).

2.1.3 DEM

A Digital Elevation Model (DEM) models the elevations over an area of the earth's surface at discrete (digital) points. Each elevation is geographically referenced to the earth's surface by an XY coordinate (eg. latitude longitude).

A DEM is only a representation or approximation of the real terrain surface elevations. The ability of a DEM to accurately model the real terrain is dependent on:

1. The resolution (spacing) of elevation points.
2. The accuracy of the elevations.
3. The accuracy of the XY coordinates.

For flood mapping the elevation accuracy is of the utmost importance. If the accuracy is only +/- 1.0m, accurate flood mapping will not be possible.

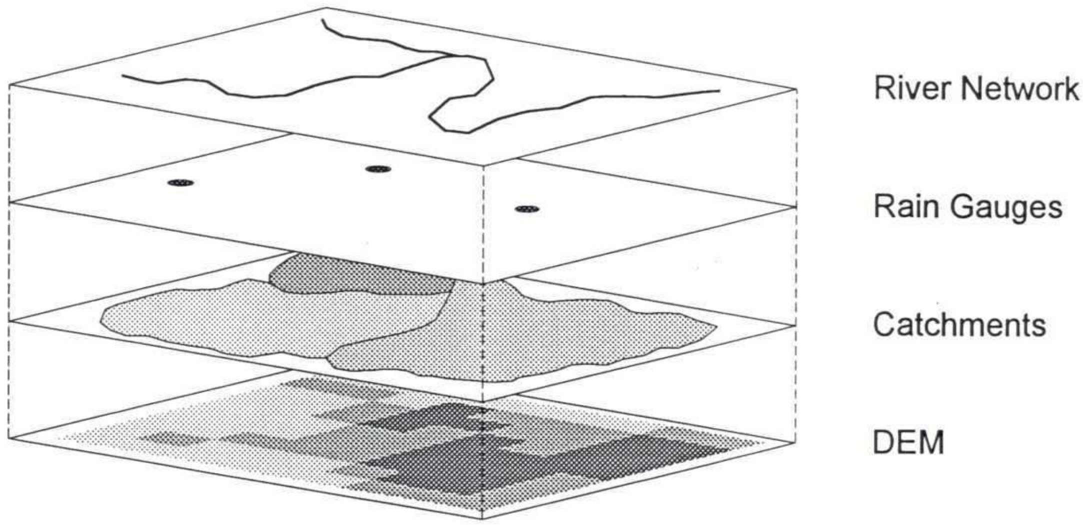
The resolution or spacing of points is also important for modelling river banks, embankments, villages - especially at the compartment or sub-regional level. Where sudden changes in elevation occur over the floodplain, a closer spacing of elevation points are required.

A DEM developed for purposes other than flood management may not be suitable. A flood management DEM requires accuracy over the floodplain, with little or no elevation data in flood-free areas - most DEMs do not fall into this category and must be enhanced in flood-prone areas before they are of practical use.

2.1.4 ARC/INFO - GIS Software

ARC/INFO is an established and powerful GIS for manipulating, analysing and displaying geographically referenced data.

GIS data is best visualised as layers, where each layer has a theme. A theme may be a river network, rain gauge locations, a DEM or a water level surface.



GIS Data Layers

If each GIS data layer has been geo-referenced, layers can be analysed and displayed with each other. For example, displaying the river network and rain gauges on the DEM, or extracting the DEM elevation of each rain gauge.

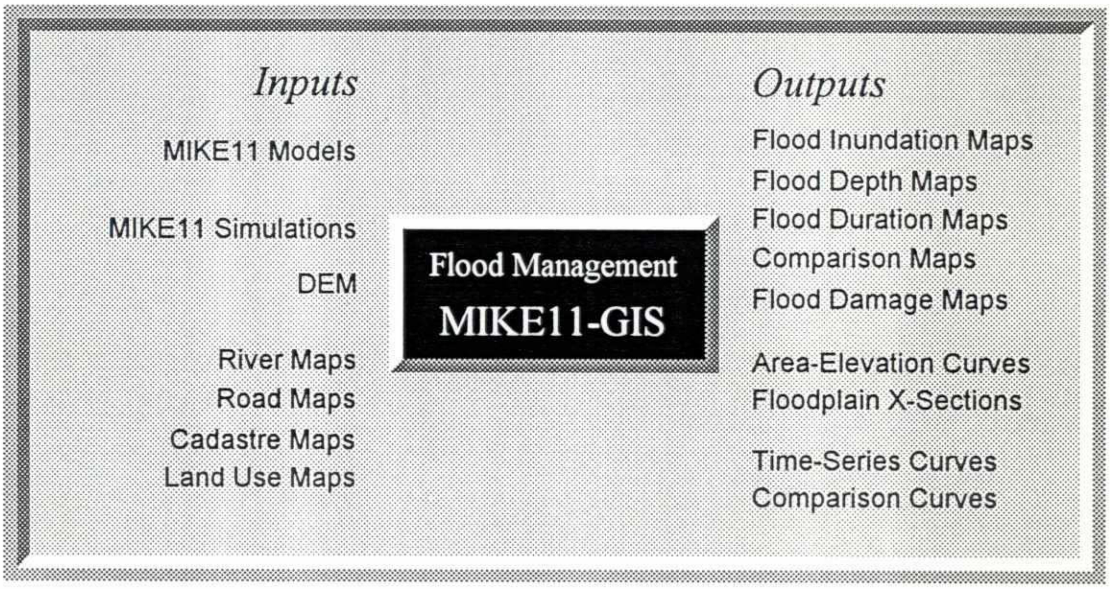
GIS represents complex flood management inputs as one or more layers, for example: flood depths; land use; crop types; fish yield; urbanisation; roads. It geographically analyses and displays data layers making it a powerful spatial decision support tool. GIS has the potential to make flood management decision making easier.

2.1.5 MIKE11-GIS

MIKE11-GIS is the key FMM software component. It is a flood modelling - GIS interface merging the two worlds of flood modelling and GIS as an engineering and planning spatial decision support tool for river and floodplain management.

MIKE11-GIS more clearly clarifies and disseminates impacts of flood management proposals on flood hydraulics, urbanisation, agriculture, fisheries and the environment.

Also, flood modelling benefits from a GIS by extracting MIKE11 floodplain topographic data from a DEM - traditionally a time consuming and laborious task.



MIKE11-GIS requires input from MIKE11 models and a DEM and optionally GIS data such as river, road, land use maps, satellite images, etc. It outputs floodplain topographic data for MIKE11 models, and produces flood maps and other graphic displays.

Inputs

MIKE11-GIS imports MIKE11 flood model details, and flood simulation output for flood mapping and analyses. Calibrated MIKE11 models must be developed before or during MIKE11-GIS application.

The DEM is an important MIKE11-GIS input and critical to flood mapping accuracy. DEM floodplain elevations must be sufficiently accurate to yield reliable flood maps. The DEM should also be representative by including linear features such as rivers, levees, embankments and roads.

The accuracy of MIKE11-GIS output is dependent on the main input data: the MIKE11 flood model and the DEM.

Remember: *Garbage In, Garbage Out*.

Optional MIKE11-GIS inputs are maps of rivers, infrastructure, cadastre, land use, agricultural use, satellite imagery or other project specific data.

Outputs

MIKE11-GIS's main outputs are flood maps and comparative flood maps. Flood maps show in graphic detail inundation depths, flood durations and flood extent.

Comparative flood maps illustrate differences in flood depths resulting from proposed works, structure failure, embankment breaching and other artificial or natural causes. They also show areas which would become flooded and which would become flood free. Two MIKE11 simulations are needed for these maps, ie. "before" and "after" scenario simulations.

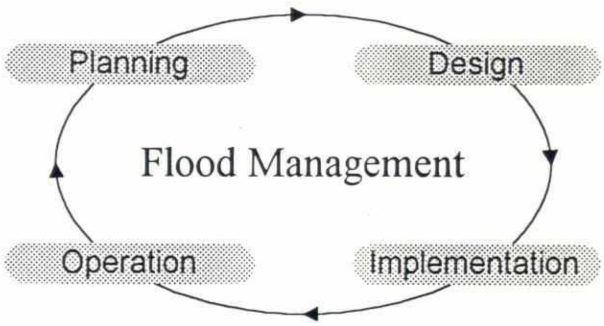
The flood maps may also be used for flood damage assessments on infrastructure, agriculture, fisheries.

MIKE11-GIS extracts floodplain topographic data (cross-section profiles and flooded area versus elevation curves) from a DEM for output to MIKE11.

2.2 Use of FMM in Flood Management

2.2.1 Flood Management Cycle

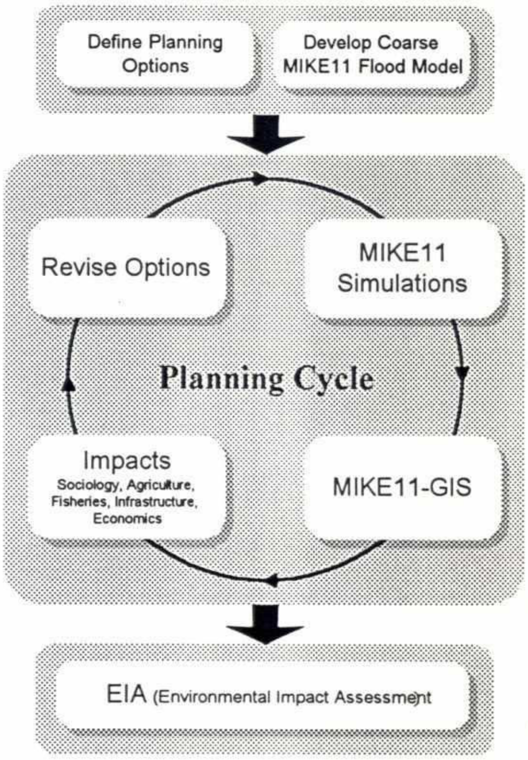
Flood management follows a cyclic pattern linking ideas, proposals, consultations, adopting proposals, preparing guidelines, designing proposals, constructing and implementing proposals, operating and maintaining finished schemes. This is the flood management planning, design, implementation and operation cycle, in which, FMM plays an active and useful role.



2.2.2 Planning

At the planning level FMM helps assess proposed flood mitigation options and prepare environmental impact assessments.

Flood management planning activities may range from flood preparedness programmes to major civil works.

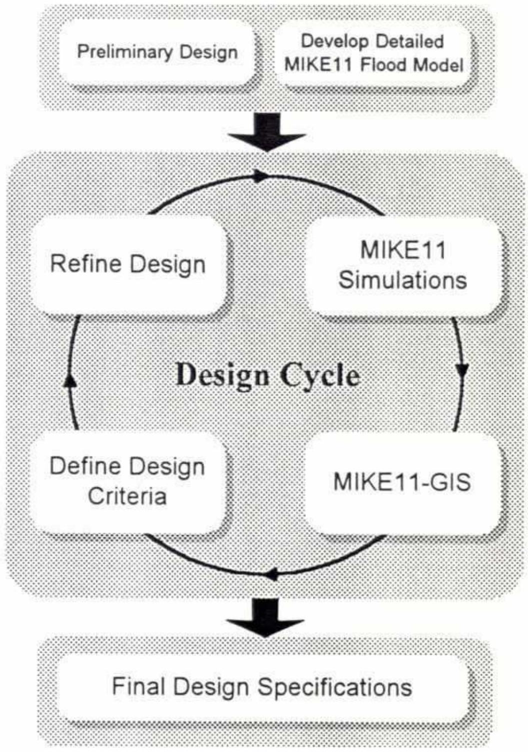


Planning options must be identified, a calibrated coarse (preliminary) MIKE11 model must be developed, and other preparations made. The planning cycle then commences: MIKE11 flood model simulations; MIKE11-GIS analysis and display; assessing impacts; revising options. Finally, an EIA and other documents are prepared for distribution to receive feedback, and to outline design, implementation and operation recommendations.

MIKE11-GIS is a useful flood management planning tool. Output from MIKE11 model simulations can be displayed as flood maps showing depths, inundation duration and differences in flood levels. These maps in turn can be used for impact assessments on socio-economics, agriculture, fisheries and infrastructure. They are also excellent media for communicating options during consultations, and for receiving feedback.

2.2.3 *Design*

Preparations for the design stage requires a preliminary design based on planning recommendations, and detailed MIKE11 model development and calibration to define existing flood conditions.

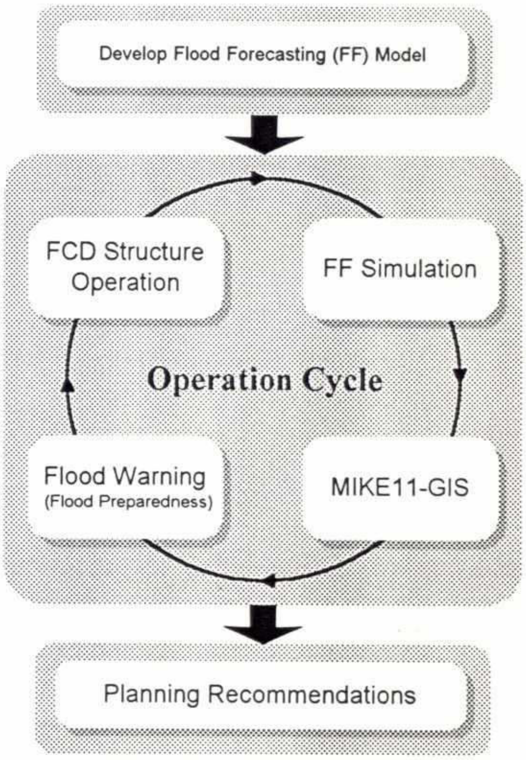


The design cycle carries out more accurate MIKE11 flood model simulations, uses MIKE11-GIS to display and define design flood levels and to ensure impacts are within planning guidelines, and finally refines the design. When not all planning criteria are attainable they may need to be reviewed. The iterations of modelling and design refinement culminate in final design specifications.

Output from flood model simulations can be displayed as flood maps showing design depths and to verify impacts are within planning guidelines.

2.2.4 *Operation*

MIKE11-GIS combined with a MIKE11 flood forecasting (FF) model can aid distribution of flood warnings for FCD structure operations and flood preparedness programmes. Real-time flood predictions presented as flood inundation maps allow rapid interpretation and dissemination of potential danger areas to field operators and emergency relief organisations.



FMM is presently set up as an off-line flood management tool. However, it is feasible in the forseeable future that FMM technology could be extended to on-line operation. For example, FAP10 may be the first application of FMM as an on-line flood forecasting tool.

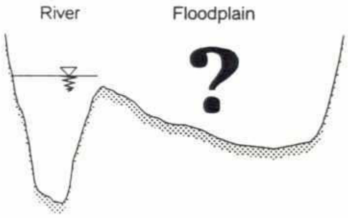
2.3 Floodplain Modelling

Floodplains support intensive agriculture, industrial sites, urban and rural communities, and environmentally sensitive areas. During periods of flooding, most damage and disruption will occur on the floodplains - not in the rivers. Modelling the interaction between river and floodplain is therefore an important aspect of flood management.

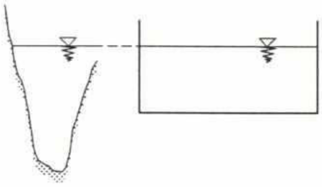
Unfortunately, there is usually a scarcity of floodplain calibration data and inadequate topographic data, thus making calibration and detailed model development difficult. Detailed modelling also requires greater human and computer resources which encourages use of simpler but less accurate methods.

Reliable flood mapping, however, depends on having an accurate DEM, and accurate floodplain water levels. Efforts toward developing a flood model with well represented floodplains will result in better flood maps.

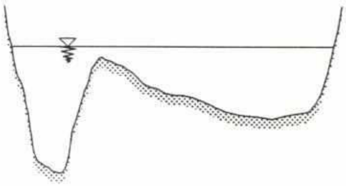
FP1
Floodplain ignored.



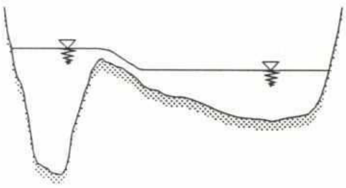
FP2
Floodplain modelled only as storage. Same water level in river and floodplain.



FP3
Floodplain modelled as part of river cross-section. Same water level in river and floodplain.



FP4
Floodplain modelled separately to river. Connected by spill channel.



There are several methods for modelling floodplains. The simplest ones assume the river and floodplain water levels are always the same, however, in some areas this may not be appropriate and a quasi 2-D methodology needs to be adopted.

2.3.1 Methodology

Floodplains are generally modelled by a 1-D scheme such as MIKE11 in four different ways:

FP1 They are ignored. This may be satisfactory for a pilot model, preliminary investigation or in areas well removed from a study interest area.

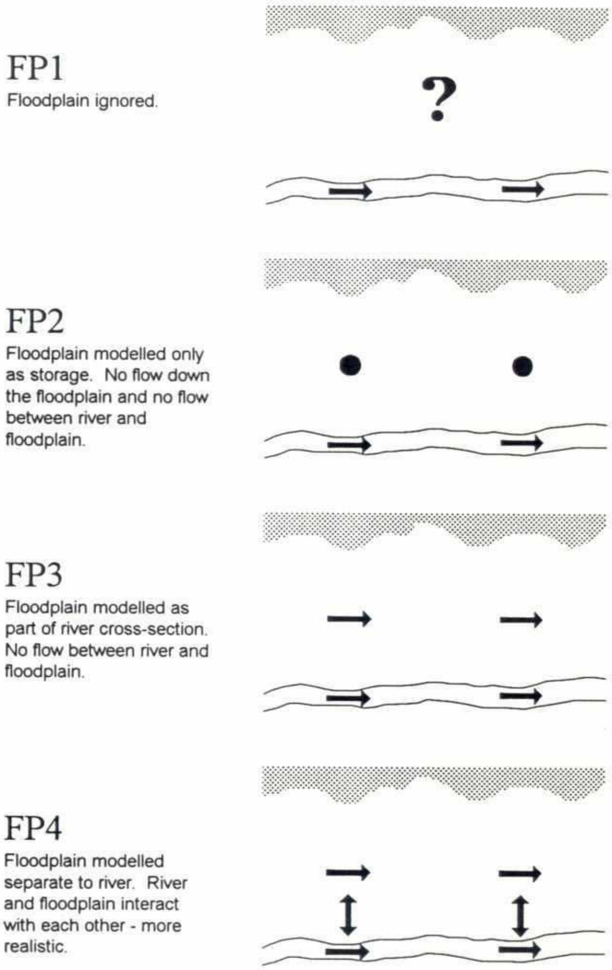
FP2 River cross-section profile plus additional flooded area curve (AE curve) to model the floodplain storage. Limitations: floodplain conveyance is not modelled, and the river and floodplain water levels are always the same.

FP3 Cross-section profiles include both river and floodplain(s). The roughness coefficient can be varied across the river bed and floodplain. Limitations: river and floodplain water levels are always the same.

FP4 The river and floodplains are modelled separately and are linked by spill-channels (often referred to as quasi 2-D modelling). This is the most detailed and accurate methodology but requires more computer and professional resources.

The four basic methods for modelling floodplains each have advantages and disadvantages. A mixture of methods should be adopted according to resources and constraints; size and type of floodplain and project objectives.

Deciding which method to use is a function of available resources, study objectives, data and the interaction between river and floodplain. All four methods may be used throughout a model - it is not wise to adopt a single method. For example, for floodplains remote to an area of interest, FP1 may be suitable, however, in the area of interest, FP4 may be necessary.

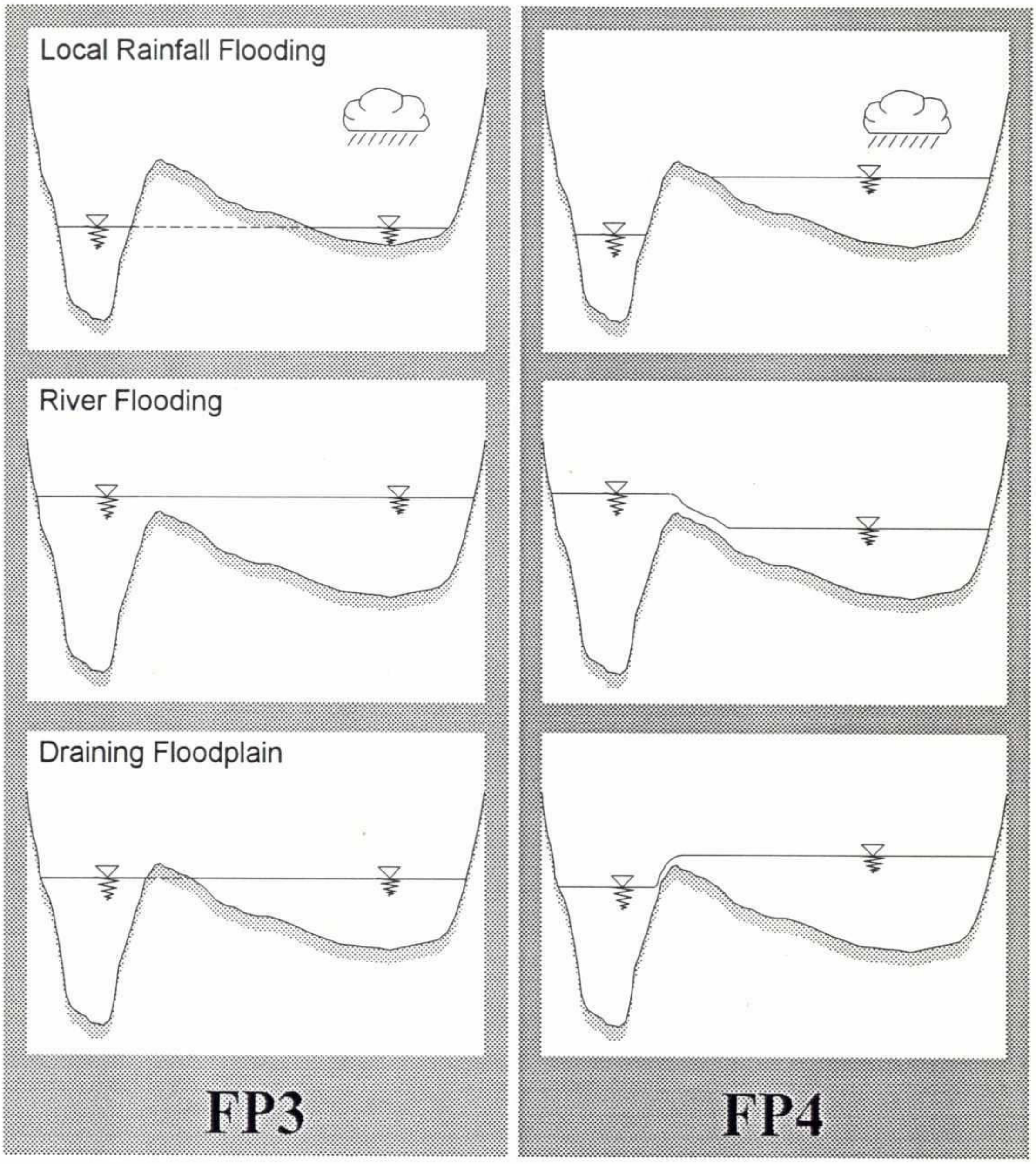


2.3.2 *Local Rainfall Flooding*

Differentiating between river and local rainfall flooding is particularly important for designing FCD schemes which plan not only to prevent or control flooding, but to also drain flood waters. The time duration to drain flood waters is particularly important for assessing agricultural impacts and other flood damages. To correctly model river and local rainfall flooding the river and floodplain must be modelled separately.

Methods FP2 and FP3 are not designed for this purpose because the river and floodplain are represented as one cross-section with one water level - local rainfall will directly drain to the river irrespective of any natural or artificial controls.

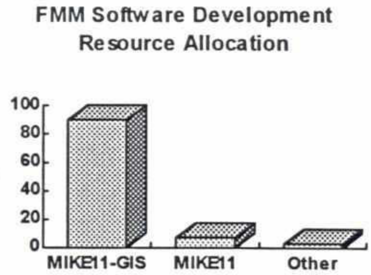
FP4, however, models the river and floodplain as two separate branches connected by link channels. The link channels' geometries and the river and floodplain water levels control the discharge between river and floodplain. Local rainfall directly flows to the floodplain, then to the river via link channels. River water will only start flooding the floodplain once a link channel is overtopped. FP4 differentiates between river and rainfall inundation by modelling the dynamic interaction between river and floodplain.



Methods FP2, FP3 and FP4 yield different results when modelling floodplains. Being aware of the differences is an important part of flood modelling and management. Illustrated above are examples comparing FP3 and FP4.

3. FMM DEVELOPMENT

The FMM development phase has produced an integrated package of methodologies, software and detailed documentation.



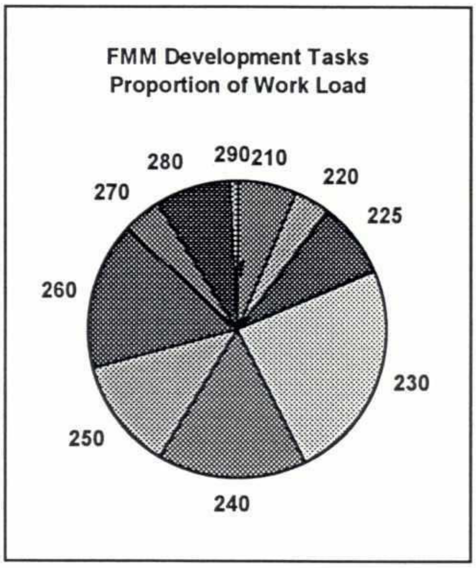
Most resources were directed towards researching and developing methods for interfacing MIKE11 and the ARC/INFO GIS. The methods were then coded into MIKE11-GIS.

Modifications to the MIKE11 software were also made to provide data links with MIKE11-GIS and to improve the modelling of complex FCD structures.

Development closely followed the tasks defined in the FMM Inception Report.

FMM Development Tasks

No	Task
210	Software Design and Resource Management
220	MIKE11/NAM Interface
225	Relational Database
230	Graphic Editor
240	Topographic Data
250	Surface Generation
260	Analysis and Display
270	Impact Assessment
280	Structures Operation
290	Flood Forecasting



3.1 Work Programme

Progress summaries of each development task are:

Task 210 - Software Design and Resource Management

Design activities concentrated on laying down guidelines for producing a functional, user-friendly interface for MIKE11-GIS.

A Software Development Manual was written as an internal document to establish guidelines for developing MIKE11-GIS. This is an important document which, if adhered to, should maintain continuity and easy maintenance of FMM software into the future.

Management activities were regularly carried out to ensure coordination between professionals working on design, software programming, testing and documentation. Liaison with other professionals to refine software functionality and for testing for practical application was also regularly carried out, along with documentation of the MIKE11-GIS Reference Manual and other technical reports.

For details see the MIKE11-GIS chapter in the MIKE11-GIS Reference Manual.

Task 220 - MIKE11 / NAM Interface

A dynamic interface to couple the NAM and MIKE11 computations was developed. The dynamic interface between the NAM and the Hydrodynamic (HD) modules of MIKE11 is able to address such cases, where calculations in the catchments and the rivers are required simultaneously. This approach will give a better description of the following situations:

- Setup with overlap between the river network and the catchment with interaction between rivers and catchment.
- Areas with flooding where the catchment is inundated for a longer period.
- Areas with spilling from the rivers to the catchment.

The new dynamic interface is based on the existing NAM irrigation/infiltration approach with a coupling procedure between NAM and HD. The calculation and coupling is performed for each NAM time-step.

The details of the interface with an example application to the North Central Region is presented in separate documentation called "MIKE11-NAM Dynamic Interface Documentation and Users Guide". The basic principles of this coupling are presented in this section.

Task 225 - Relational Database

A relational database for exchanging data between MIKE11 and MIKE11-GIS was designed and developed using the ARC/INFO database software.

The MIKE11-GIS relational database imports MIKE11 model setup and simulation output data, and exports floodplain topographic data to MIKE11 models. The database design offers flexibility and easy maintenance which are important factors for assessing flood modelling results and impacts.

All data is exported using ASCII (text) files because of incompatibility between MIKE11 and ARC/INFO file formats, and to allow portability across different hardware platforms. Binary transfer methods, which will be much faster, will be explored (see 3.4 Remaining Development Activities).

For details see the DATA EXCHANGE chapter in the MIKE11-GIS Reference Manual.

Task 230 - Graphic Editor

The MIKE11-GIS graphic edit environment for creating and editing MIKE11-GIS data layers was developed. The edit environment has been designed as a Graphical User Interface (GUI), thus making it highly user-friendly, simple and making the complexity of ARC/INFO's editing environment transparent to the user.

Modifications in MIKE11 were made to export MIKE11 model data via the MIKE11-GIS database for use in the graphic editor. MIKE11 model setups can be graphically displayed alongwith other GIS data layers as a background to the edit environment.

For details see the COVERAGE EDITING chapter in the MIKE11-GIS Reference Manual.

Task 240 - Topographic Data

A DEM has a wealth of floodplain topographic data which, once extracted in suitable formats, is of significant value in developing a MIKE11 model. Traditionally, extracting floodplain topographic data is laborious and time-consuming, however, the developed technology reduces such activity to one of minimal effort.

In MIKE11-GIS, floodplain cross-section profiles and storage volumes can be extracted, displayed and exported to MIKE11. New MIKE11 import facilities were developed to read the MIKE11-GIS files. The topographic data transfer to MIKE11 is direct with minimal effort required from the user.

For details see the CROSS-SECTION PROFILES and AREA ELEVATION CURVES chapters in the MIKE11-GIS Reference Manual.

Task 250 - Surface Generation

A method for generating flood maps using MIKE11 output and a DEM was developed. The method generates 3-D surfaces of the flood wave which is then compared to the DEM ground elevations determining areas which are flooded and flood-free. Flood depths are also calculated.

A data management system was developed to handle the generation of a large number of flood surfaces from many MIKE11 simulations.

Generating surfaces for flood duration mapping was not developed, but will be addressed during the application phase.

For details see the FLOOD MAPS chapter in the MIKE11-GIS Reference Manual.

Task 260 - Analysis and Display

An analysis and display graphic environment was developed. Flood maps and time-series graphs of flood levels and discharges are displayed through a system of menus and graphic windows. The environment, like the edit environment, is a fully interactive GUI making the complexity of ARC/INFO transparent to the user.

For details see the FLOOD MAPS, GRAPHS and DISPLAY COMPOSITIONS chapters in the MIKE11-GIS Reference Manual.

Task 270 - Impact Assessment

The impact or changes in flood levels can be mapped or graphed to graphically illustrate the impact of man-made interventions or natural causes. The change in flooding over a period can also be displayed.

Crop and fisheries damage mapping methods were not developed, but will be addressed in a limited context during the application phase.

For details see the FLOOD MAPS and GRAPHS chapters in the MIKE11-GIS Reference Manual.

Task 280 - Structures Operation

MIKE11 was modified to model complex FCD structures. The facility, named multiple or composite structures, allows two or more structures to be placed at the same location in a MIKE11 model - previously a separate branch had to be made for each structure which is cumbersome especially when a structure is composed of several structures operating independently.

The feature was tested on the Tangail Compartment MIKE11 model, where FCD structures often consist of several gated structures. Each gated structure was modelled as a separate structure in MIKE11 but without the necessity of creating extra branches and "dummy" cross-sections.

Other applications are envisaged such as overtopped roadways on a floodplain - in this case the bridges would be modelled as one type of structure (eg. large culvert) and the overtopping of the bridge and roadway as a broad-crested weir.

Development of embankment breaching, on-line structure operation and optimisation routines were not developed. After further investigation and discussions it was concluded that embankment breaching could be adequately modelled using the MIKE11 Dambreak Module, and the on-line structure operation and optimisation methodologies needed to be more clearly clarified during the application stage before useful development could proceed.

Task 290 - Flood Forecasting

Logic and methodology for applying FMM for flood forecasting will be carried out in collaboration with FAP10 when it commences its next phase.

3.2 Software/Hardware

ARC/INFO in general has proved to be an excellent GIS for prototyping FMM concepts and methods. Several faults were discovered, limiting initial development, however, either alternative methods have been found, or the faults were fixed with the release of Version 6.1.1. Remaining faults have been reported to and acknowledged by ARC/INFO developers, ESRI.

The main limitation is the speed of operation. Because the programming language is compiled as it is run, some processes can be slow to the experienced user. Given that MIKE11-GIS consists of over 30,000 lines of code, this is of some concern. The large size of the ARC/INFO programs and the need to sometimes switch between them is also a limitation because of the "slowness" in loading them.

MIKE11-GIS can only be used with ARC/INFO workstation versions, as opposed to PC based systems. ARC/INFO for workstations, and workstations themselves are more expensive than PC based GISs and PCs, but more powerful. This gap, however, has closed in recent years and is expected to continue to close.

To model the complex river and floodplain systems of Bangladesh to a detail appropriate for using GIS for flood management requires computers at the workstation level. The FMM MIKE11 models also need to be workstation based because of their greater detail and size. However, to disseminate FMM output it will be important to provide facilities for exporting data to cheaper PC based systems.

3.3 MIKE11-GIS

3.3.1 Coverages

MIKE11-GIS coverages represent MIKE11 model networks; create and analyse 3-D water surfaces and define lines and boundaries to generate topographic data.

The MIKE11-GIS coverages are:

BRS	Branch Route System
XSC	Cross-Section Coverage
SCC	Storage Cell Coverage
WSC	Water Surface Coverage
CAC	Catchment Coverage
RGC	Rain Gauge Coverage

The BRS geo-references MIKE11 models and features such as cross-sections and structures. Most MIKE11-GIS analysis and display functions depend on the BRS. The same BRS can be used for any number of MIKE11 models (it is not dependent on a single MIKE11 model).

XSC and SCC coverages are used for extracting MIKE11 model topographic data. A XSC is a line coverage used for extracting cross-section profiles (XSP) from a DEM, while a SCC is a polygon coverage used for calculating flooded area versus elevation (AE) curves. XSPs and AE curves are exported to a MIKE11 cross-section database.

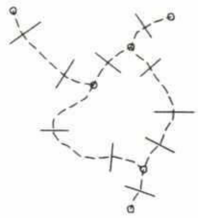
A WSC helps construct 3-D water surfaces from MIKE11 simulation outputs. Relating 3-D water surfaces to a DEM produces flood extent, flood depth and flood duration maps.

A CAC is a polygon coverage delineating catchment boundaries to calculate catchment areas.

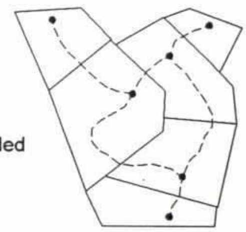
A RGC is a point coverage of rain gauge locations and associated data.

BRS
Branch Route System
Geographically locates MIKE11 model branches, cross-sections, structures, h-points, Q-points, etc. based on their branch name and chainage.

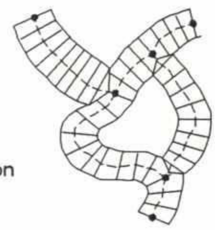
XSC
Cross-Section Coverage
Used for extracting cross-section profiles from a DEM.



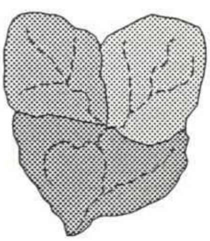
SCC
Storage Cell Coverage
Used for generating flooded area vs elevation curves from a DEM.



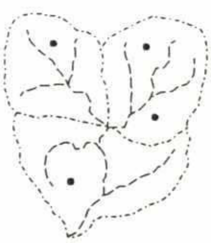
WSC
Water Surface Coverage
Used to create 3-D water surfaces for flood inundation mapping over a DEM.



CAC
Catchment Coverage
delineates catchment boundaries for hydrologic models such as NAM.



RGC
Rain Gauge Coverage
geographically locates rain gauges and information on each rain gauge.



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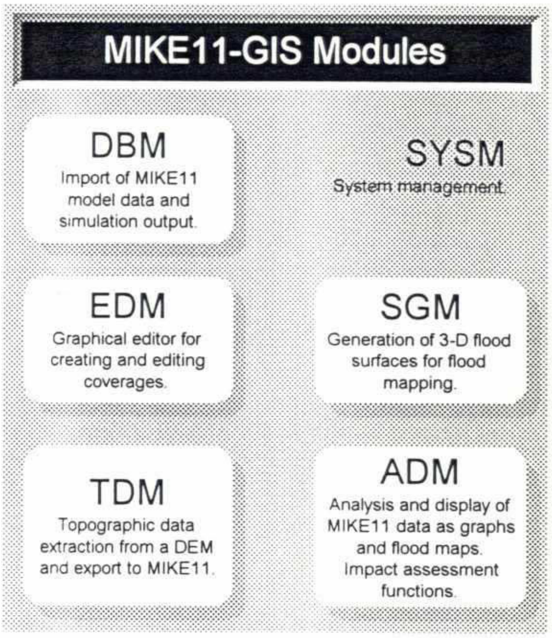
3.3.2 *Modules*

MIKE11-GIS uses a modular structure, partly because of ARC/INFO's separate ARCEDIT and ARCPLOT programs, and also to logically separate processes.



MIKE11-GIS has six modules:

SYSMSystem Module
DBMDatabase Module
EDMEdit Module
TDMTopographic Data Module
SGMSurface Generation Module
ADMAnalysis and Display Module

System Module (SYSM)

SYSM controls the operation of other modules and edits general setup parameters.

Functions:

1. Launching other modules.

2. Defining parameters common to all modules.

Database Module (DBM)

DBM imports and manages MIKE11 model data and simulation outputs using ARC/INFO's relational database program, INFO.

Functions:

1. Importing MIKE11 data.

2. Managing imported MIKE11 data on a relational basis.

3. Displaying tables of imported data.

Edit Module (EDM)

EDM creates and edits MIKE11-GIS coverages (BRS, XSC, SCC, WSC, CAC and RGC) using ARC/INFO's graphical editor, ARCEDIT. Editing operations are made using customized menu systems.

Functions:

1. Real-world registration (for transforming coverages to a real-world coordinate system).

2. Creating and editing MIKE11-GIS coverages.

3. Background display of coverages, DEM, MIKE11 model features.

4. Joining coverage sheets.

Topographic Data Module (TDM)

TDM extracts and exports cross-section profiles (XSP) and flooded area versus elevation (AE) curves from a DEM to a MIKE11 cross-section database. XSPs are extracted from lines in a XSC and AE curves are generated from SCC cells. The graphical environment displays DEM, XSC, SCC, XSPs and AE curves. TDM also exports catchment areas of a CAC.

Functions:

1. Display DEM, XSC and SCC.

2. Generate XSPs, AE curves and CAC catchment areas.

3. Graphically display XS profiles and AE curves.

4. Export XS profiles, AE curves and catchment areas.

Surface Generation Module (SGM)

SGM generates 3-D water surfaces using a WSC and MIKE11 model simulation results. Water surface levels and DEM ground levels are related to give a flood depth surface. Surfaces are generated at instants in time or as peak values.

Functions:

1. Generate flood level and flood depth surfaces.

2. System management of surfaces - many surfaces may be generated using the data management utility.

Analysis and Display Module (ADM)

ADM, a graphical viewing environment, displays flood maps, graphs, and composes displays for hardcopy output. The flood mapping sub-module maps inundated areas and water depths, and displays comparison maps. The graphing sub-module displays time-series graphs of water levels and discharges, and stage-discharge curves. The display composer creates compositions of flood maps, graphs and other data for screen display or hardcopy output.

Functions:

1. Manage viewing environment.

2. Flood map displays.

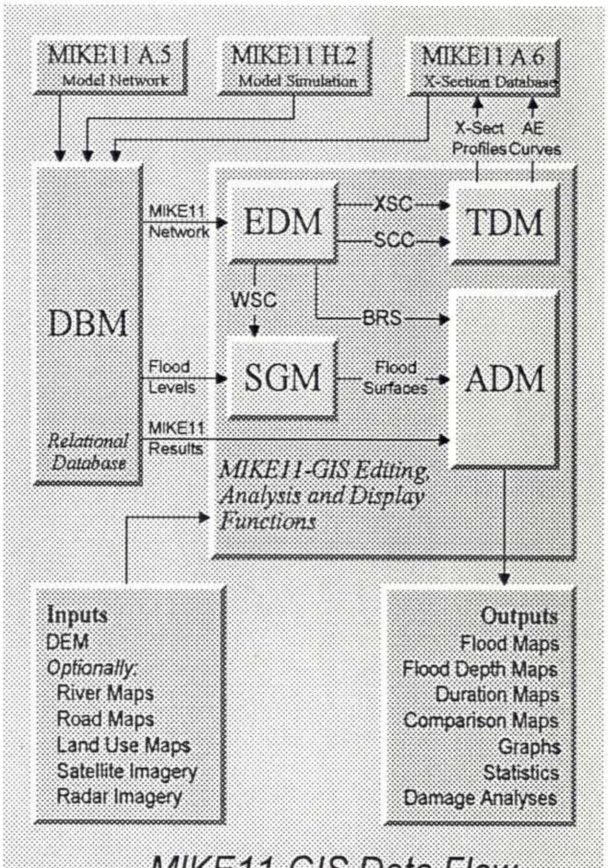
3. Graph displays.

4. Display compositions.

3.3.3 Data Flow

The MIKE11-GIS data flow starts with MIKE11 model inputs to DBM, and digitising and acquiring a DEM and other useful GIS data. It ends with either DEM topographic data for MIKE11 models or graphic displays of flood maps, graphs, etc.

The diagram below illustrates the MIKE11-GIS data inputs, the flow of data between MIKE11 and MIKE11-GIS and the data outputs.



MIKE11-GIS Data Flow

3.4 Remaining Development Tasks

FMM development will continue into the FMM application phase to complete tasks which are either unfinished or have been identified as sufficiently useful to warrant their implementation based on the application thus far. The tasks are:

(a) Binary data exchange between MIKE11 and MIKE11-GIS to speed up the data exchange process.

(b) Import of MIKE11 river cross-section profiles into the MIKE11-GIS database, a MIKE11-GIS facility to graphically merge MIKE11 profiles with DEM floodplain profiles and finally, export back to MIKE11.

(c) Embankment breaching, on-line structure operation and optimisation methods.

(d) Improved shading of a DEM in MIKE11-GIS to facilitate better on-screen digitising.

(e) A simpler and more easier method for modelling links between river and floodplains in MIKE11.

(f) Water surface polygons (areas of horizontal water surface) in the MIKE11-GIS Water Surface Coverage to represent areas modelled as a single flood cell in a MIKE11 model.

(g) Better method for digitising lines in a MIKE11-GIS Water Surface Coverage.

(h) Flood duration mapping.

(i) Tabular output with statistical information in the MIKE11-GIS Analysis and Display Module.

(j) Prototyping techniques or making recommendations for flood damage assessments in other sectors such as agriculture and fisheries.

Other development tasks emerging during the FMM application phase will be recorded and, if feasible, implemented.

3.5 Future Implementation

The sustainability of FMM is largely dependent on its future implementation in other projects. Because MIKE11-GIS is closely tied to and dependent on MIKE11 models, the custodian of MIKE11 models, SWMC, would be the most logical place to maintain and develop FMM models.

However, GIS for floodplain management extends beyond flood modelling and into other sectors such as agriculture and fisheries. These sectors are not particularly interested in the MIKE11 models, but in their output, especially flood maps. They may also not want to use an expensive GIS such as ARC/INFO alongwith the cost of a workstation, but prefer to use cheaper and simpler PC based systems.

The most logical process would be for flood modelling experts to use MIKE11 and MIKE11-GIS to produce flood maps and export these maps to other sectors for their own analysis. The export media can be in formats readable by other GISs or, if requested, just as hardcopy maps. Flood maps would be available in several forms, such as flood extent, flood depths, flood duration and the change or impact on flood extent, depths and duration because of man-made or natural causes.

The future custodian of FMM software will need to consider a practical arrangement for transfer of MIKE11-GIS output for use by other sectors.

4. APPLICATION OF THE FMM

4.1 Introduction

The application of the FMM technology centres on the development of a system of dedicated models on various scales (national, regional and compartment). These will be based on the General Model, (GM), North Central Regional Model (NCRM) and the Tangail Compartmental Model (TCM). The system of models will be operated at different levels - central, regional and compartmental and applied to different purposes, such as:

off-line flood management, i.e. planning, design and training, purposes;

on-line flood management, i.e. real-time flood forecasting and management.

Table 4.1 summarises the model basis, the level of operation, the main drainage features which may be accommodated at the various model scales and the main application areas. The dedicated FMM developments will be carried out in stages, the first stage involving a coarse model to test the concepts and logic for demonstration and training and identifying additional data collection and the second stage developing full integration with the DEM and the GIS.

As clearly indicated in the TOR (Ref. 2), the present study aims to demonstrate the uses of FMM and will develop a sound foundation for achieving the long-term objectives. To this end, the applications will be carried out on a pilot scale at different levels. The following outputs are envisaged:

- o **National Level:** A course FMM using the updated General Model for off-line prediction of flood plain inundation for various scenarios of river floods, rainfall and embankment and structure configurations. Linked to BWDB-FFWC's (FAP 10) flood forecasting model, it may be used for inundation forecasting (but at a coarse level).

- o **Regional Level:** A detailed pilot FMM for the North Central Region using the verified NCRM of SWMC, (eventually allowing for some additional details in selected areas), for prediction of flood plain inundations as for the General Model above. However, as described in Section 5.3, the difference would be in detail; extent and depths of inundation would be less coarse, ideally giving more accurate forecasts at Upazila level; and simulating different configurations and operational models for compartments and polders.

- o **Compartment Level:** A detailed FMM at compartment level using the existing model for Tangail Compartmentalization Pilot Project (CPP) developed by FAP 20 for predicting inundation depths and durations for various management strategies, but with greater accuracy. It would test out the effects of operation of hydraulic structures and, as a pilot for a more comprehensive management model, would introduce flood impact assessment on agriculture, fisheries etc by coupling with GIS.

Status of the development of the application models are provided in the following sections.

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Table 4.1 Flood Management Model - Basic Characteristics and Applications

		FMM Basis	
Characteristic Applications	General Model	Regional/sub-regional model	Compartmental Model
Possible Model Operation Level	Central level	Central or Regional level	Central,Regional or District Level
Potential Model Users	BWDB, WARPO, RRI DoE, BIWTA,BUET, consultants	BWDB, WARPO,RRI, DoE, RHD, MoA, BIWTA, BUET, consultants	BWDB, FPCO, LGEB, MoA, Project Committees, BUET. consultants, NGO's
Typical Drainage Features in the Model	*Major river drainage network	*Regional river drainage network *Compartments as controlled hydrological units *Subcompartments (1,000-2,500 ha) as uncontrolled hydrological units	*Compartment with major drainage network *Subcompartments (1,000-2,500 ha) as controlled hydrological units *Subcompartment units (100-250ha) as uncontrolled hydrological units
Main Types of Model Application	Off-line: Development of flood management strategies. Planning, design, training and demonstr-ation. On-line: Real-time flood forecasting and management.	Off-line: As for GM On-line: Real-time flood forecasting and management, but only on central level	Off-line: As for the GM On-line: Flood management, structure operation.

Source: FMM TOR (Ref. 2)

4.2 General Model Based FMM

4.2.1 Data Collection

No specific data collection programme for the General Model was undertaken but information gathered for the North Central Region may be incorporated if relevant. The level of detail and the large areal scope of the General Model precludes any major data collection activity under this project.

4.2.2 *Model Application Progress*

A coarse DEM of Bangladesh covering the entire country except the Sundarbans and some area of the Chittagong Hill Tracts has been developed by FAP 19. This is based on the MPO 1 km grid elevations. This is being used by FAP 25 for a course national level flood mapping, i.e. for planning and flood forecasting applications. The planning applications will allow modellers to edit the DEM to reflect proposed embankments. The location and height of the embankments will be determined by the modeller. The application will not determine optimal embankment locations, but will allow comparison among proposed embankment configurations.

4.3 North Central Regional Model Based FMM

4.3.1 *Data Collection*

A programme of hydrometric and topographic survey has been carried out during the months of May to October, 1993. Part of the hydrometric survey was initiated in support of the future feasibility and final design level studies that are to take place within the region.

The topographic survey was designed to obtain more specific information on the heights of selected river embankments and the degree of linkage between the river and adjacent floodplain through the intersecting khal network. Some 1000 km. of embankment were surveyed and the results will be used to support the hydraulic model restructuring.

Hydrometric stations were established at 40 locations in the river system with 24 discharge measuring sites. The main purpose of these studies was to improve the understanding of the river behaviour in areas which are uncertain at present in the existing model. In addition to this programme, FAP 25 installed a total of 11 gauges at 10 floodplain locations to monitor the behaviour of the water level on the floodplain.

Further details of survey are given in Appendix A.

4.3.2 *Model Application Progress*

Major structural revision to the existing NCRM will be needed if meaningful representation of flooding patterns within the region is to be reproduced. Emphasis has been initially placed on obtaining better floodplain representation and river/floodplain interaction through additional surveys and study of existing aerial photographs and DEMs.

The programme of activities outlined in the project Inception Report, (April 1993), proposed that work on the model restructuring precede any application of the FMM. Such application runs of the regional FMM would be scheduled to take place in early 1994.

FMM development has required the development of computerised routines for the interactive identification and construction of flood cells or pathways, to be included in the hydraulic model. The hydraulic model development is being phased in conjunction with the development of these computer tools in order that maximum benefit may be derived for both activities. In this way, the hydraulic model development would be simplified and software routines could be tested and refined in a realistic environment. Consequently, model development has been conditional on the development programme of the software.

To simplify the development and testing of both the MIKE11-GIS interface and the NCRM restructuring, a limited sub-model was constructed, (called the Manikganj Model). In this sub-model, the floodplains were represented in a different way to that of the existing NCRM. Individual flood cells and flood pathways were identified, where the water level could behave largely independently of the adjacent river level. Coarse delineations of flood cells and flood pathways were made, considering available topographic information from surveys, DEM and aerial photographs. MIKE11-GIS tools were used to define area/elevation curves of flood cells, floodplain cross-sections and fundamental branch route systems. No major calibration effort was made at this stage.

Experience gained in the production of this sub-model has indicated that fewer flood cells and a coarser grid of levels will be needed in the regional model. The sub-model was constructed with 51 flood cells, of average area 20 sq. kms. over ther total area of approximately 1000 sq. kms. Reproducing this resolution at regional scale, however, will not be practical and further model refinement will be carried out in the coming months. Valuable insight has been gained through working on this sub-model which will enhance the efficiency of the regional model development.

Following on from the restructuring of the North Central Region Model, which is anticipated to be completed by February 1994, development will commence of the dedicated Regional Flood Management Model. At this stage of the project, however, little direct work has been done on the production of the integrated MIKE11-GIS based North Central Model, as this is contingent on the finalisation of the MIKE11 based hydrodynamic model. This approach accords with the programme of activities defined in the Inception Report.

4.4 Tangail Compartment Model Based FMM

4.4.1 Data Collection

The Tangail compartment model has been continually supported and obtained from FAP-20. All new survey of khals and beels has been incorporated.

The existing DEM, based on BWDB data, has been updated with the 1993 1:10,000 scale photomaps. This has greatly enhanced the validity of floodplain data extracted for use in the model.

The predominant source of data for the FMM of Tangail area is FAP 20 and available water level, rainfall and groundwater level data of 1992 have been collected. Details are given in Appendix A.

4.4.2 Model Application Progress

Some initial incompatibility problems were experienced during transfer of the model from

Tangail to FAP-25 and then on to the UNIX operating system platform. These have now been resolved and all models give similar results.

The 'with-project' model has been run under the UNIX operating system, which has removed the constraint on the number of structures permitted.

The model has been verified for the period May - September 1992, although the wet season of 1992 was very dry and significantly different from that of 1991. It was found that the present model needs further work done in order that it might better represent "dry" wet seasons because the floodplain is presently included in the cross-section profiles. This had little effect on the calibration results of 1991 because of the high water levels experienced in that year. Part of the floodplain has to be schematized as flood cells while that part of the floodplain included in the cross-section profiles should be assigned a higher relative bed resistance. The best results which could be achieved without adapting the schematization are shown in Figure 4.3.

Better results for the NAM model have been achieved by re-calibrating with ground water levels and using the irrigation module.

It was decided to postpone the verification run for 1992 until the model has been refined, as indicated, and re-calibrated for 1991.

The network layout for the current situation has been checked and the connections between Korda Jugini structure and the Binnafair / Gaizabari Khal, the connections between Garinda and the Lohajang through Garinda Khal, (called Jalfai in the model), to Jalfai and Bathkura Khal to Bathkura will be re-schematized.

The floodplain representation in the model has been checked. Major beels which cannot be included in the cross-section because they are not directly connected to the khals, will be schematized as flood-cells while the remainder of the floodplain will be included in the cross-sections but assigned a high relative resistance, (a start has been made with the area East of the road Tangail - Karatia).

The rainfall-runoff catchments (NAM catchments) have been checked but will be adjusted to accord with the modifications in the network layout. Due to greater detail in the model, some catchments will require sub-division and adjusting for embankment locations.

It is not anticipated that any changes will be required in the number and location of boundary conditions.

Tests have been carried out to extract floodplain cross-section profiles from the DEM and to export them to MIKE11, using the Topographic Data Module of the newly developed MIKE11-GIS Interface software. The resulting MIKE11 input files have also been used to plot cross-section profiles at various locations to show the shape of the floodplain.

The MIKE11-GIS interface software has been used to produce flood maps and flood-difference maps of available MIKE11 results of the Tangail Compartment Model (see Figure 4.4). The Surface Generation and Analysis & Display Modules, together with flood maps, also produced discharge and water level hydrographs.

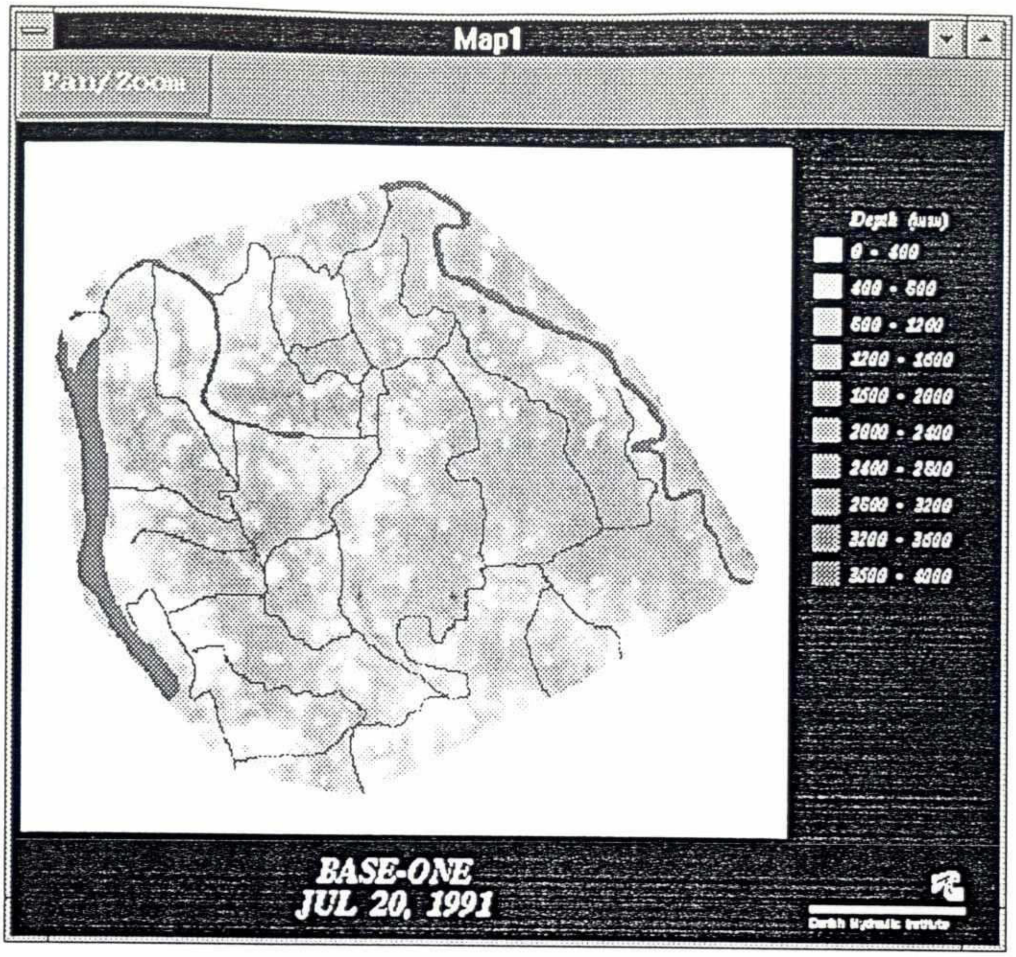
4.5 Impact Assessment

The main objective of a flood control project is to reduce flood damages. It is almost inevitable that such projects will have consequences on agriculture, fisheries, environment, social values and infrastructure, among many others. The Flood Management Model has an important role to play in the assessment of the impacts of projects through the production of comparison maps.

It is not the intention of this project to produce detailed impact assessment maps. The outputs of the FMM will centre around the production of basic flood extent, depth and duration mapping. To consider the more detailed impact of the changes in these phenomena on other sectoral interests, (fisheries, agriculture, environment, etc.), requires specialist inputs.

It is after the basic flood maps have been produced that the user interface becomes specialised. Each sector will interact with the basic FMM output with additional data, probably in the form of data on GIS "layers". The number and complexity of these "layers" would be limited only by user data availability and computer hardware capacity.

As a demonstration, simple dummy layers could be incorporated in the GIS during the application stage of this project, but no "in-depth" specialist impact assessment will be attempted.



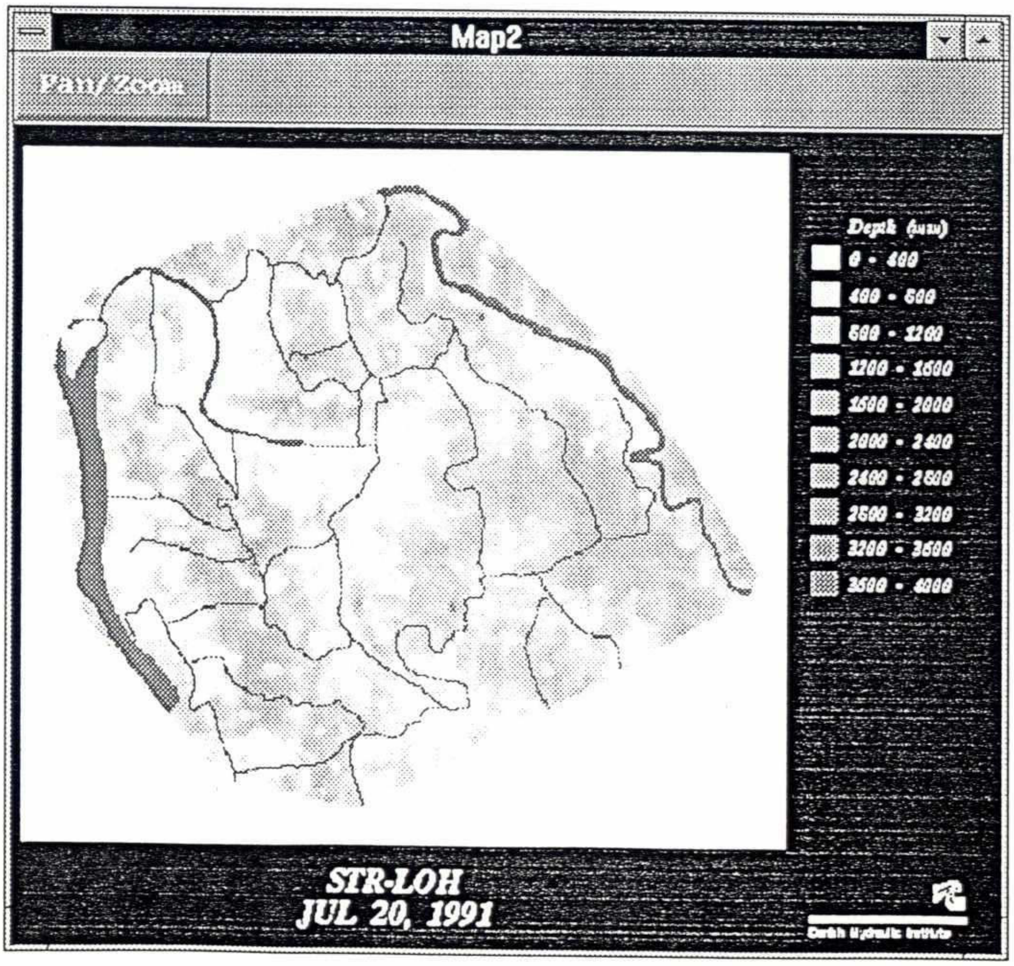


Figure 4.1 Sample Flood Mapping in The CPP

5. WORKSHOPS, TRAINING AND DEMONSTRATIONS

5.1 Workshops

5.1.1 First Workshop

The First Workshop was organised during 9-10 February at the end of the Inception Phase of the FMM study.

The objectives of the First Workshop were to:

- Develop an understanding of the present modelling capabilities and identify the needs and targets of FMM in relation to flood management decisions in Bangladesh.
- Present the FMM concepts and logic developed by FAP 25 project team, review the draft inception report and obtain feedback.
- Provide an opportunity for dialogue between the modellers, model users, decision makers and individuals affiliated to governmental, non-govermental and research institutions.

Participants

A total of 61 participants from various organisations such as MIWD&FC, SPARRSO, BMD, LGED, RHD, DOE, BARC, DAE, IFCDR, RRI, WARPO, SWMC, BWDB, FPCO, POE/FPCO, CAT members, FAP consultants, NGO Representatives and FAP 25 officials participated the First Workshop.

Programme

The programme on the first day introduced existing planning process of BWDB and FAPs and various models used with the data availability.

The features of FMM as developed up to the time of the workshop were demonstrated on the second day.

On the concluding day, the Inception Report of FMM was presented and discussions were held under four working groups on River Modelling, Planning and Design, FCD Structure Operation and Flood Forecasting. Notes from the discussion were placed in the closing session and the Team leader responded to various issues.

Summary of the Group Recommendations

Important observations and recommendations from the meeting are summarised below:

Why Model?

Planners and designers should be educated about how, when and if the FMM can be used in their jobs. This led to discussion of planning and planning organizations in Bangladesh.

User Needs

This was seen as the fundamental purpose of the working group. The challenge was seen as identifying who would use the FMM so that it could be designed to assist them in their activities. The interests of the public was assumed to be the basis for planning. It was felt the FMM should provide mechanisms so that the interests of the public are incorporated into the planning process.

Scenario Management

Different levels of modelling were defined: General, Regional and Sub-regional. The scenarios at these different levels would be managed and used by different user groups. No "local" level planning & design models will be addressed by the FMM. The connections between the different levels of models will require institutional coordination, for example between BWDB and LGED. Flood maps should differentiate between agriculture and non agriculture lands through proper structure operation. Better understanding of rain induced flood is necessary. Forecast with respect to a local reference at sub compartment level (100 sq km) would be required.

Planning Hierarchy

There are differing views on the structure of the planning activities in Bangladesh. Maybe it is more like a network than a hierarchy? Some felt that plans were proposed at the local level, while others felt centralized planners dictated.

Training

The type of training necessary depends on the type of user. Different levels of training would be needed according to the level and purpose of the user. The analogy was drawn to the concept of mechanic, driver and passenger of a vehicle:a mechanic needed to know how a car worked;a driver needed to know what the car could do and the passenger determined where the car was to go.

Sustainability

What happens to the FMM when FAP25 ends? The demand for the FMM must be driven by the user. Regular contacts will be maintained with potential users from the working group to clarify some of the issues and concerns identified during the meeting.

Software and Hardware

Simplified GIS software on PC to manage the likely scenario at site would be needed.

Institution

There are a few institutions as BWDB (FF&WC), SWMC with the potential to take over and develop FMM on completion of FAP 25. These may be reviewed during the development of FMM and based upon the outcome of FAP 26(if any), the final recommendation can be made.

5.1.2 *Second Workshop on FMM*

Objectives

The main objectives of the Second Workshop are:

- to present the FMM features developed so far to relevant GOB authorities, consultants and other potential users, and
- to obtain feedback for improvement

Programme

14 November 1993: (Sunday)

08:30	- Registration
09:00 - 10:00	- **Opening Ceremony** - Welcome by Emadudin Ahmed - Speech by CE FPCO - Speech by Representative of DANIDA - Introduction to FMM Development by Guna Paudyal
10:00 - 11:00	- Coffee break and computer demonstration
11:00 - 13:00	- **Presentation of FMM Development** - Development of MIKE11-GIS Interface by Bill Syme - Editors and Branch Route System by M.A. Shaheed - Topographic Data Module by N. S. Noman - Flood Mapping by Bill Syme, M. A. Shaheed and M. Kamal - Graphs and display composition by N. S. Noman
13:00 - 14:00	- Lunch
14:00 - 14:30	Land Classification & Flood Mapping in Atrai Basin by FAP 19
14:30 - 15:00	MIKE11-NAM Dynamic Interface by Gregers Jørgensen
15:00 - 16:00	- Coffee break and computer demonstration
16:00 - 17:00	Institutional Issues of FMM
17:00 - 17:30	Wrap up

Participants

A total of 72 participants from the following organisations joined the Second Workshop:

MIWD&FC,
SPARRSO,
BMD,
LGED,
RHD,
BARC,
DAE,
IFCDR,
RRI,
WARPO,
SWMC,
BWDB,
FPCO,
POE/FPCO,
CAT members,
FAP consultants,
NGO Representatives and
FAP 25 officials.

Summary Findings

Purpose of Flood Maps

The flood maps are impressive graphic representation of extent and depth of flooding. Impact maps developed from flood maps are more interesting and useful for the decision makers. Presently, FMM is being developed as an off line tool but it will be potentially useful in on-line flood management in future.

Improvement in Floodplain Modelling

The FP4 (Floodplains are modelled separately from river but they interact) type floodplain modelling represents a relistic situation of flooding in Bangladesh. To meet this reality, the project has been improving the model in the NC region. The existing MIKE11 - NAM can represent the flooding but the new MIKE11 - NAM dynamic interface is an improvement over the previous in simulating the attenuation in NAM and would be suitable for detailed modelling (sub regional or local level). Normally, model development is the task of SWMC. However, at the application level, additional improvement is done by the users and so FAP 25 is improving the NCR model by restructuring the floodplain representation at places in the western part of NCR.

Quality of Flood Management Model

The accuracy of a FMM is dependent upon the quality of MIKE11 model and that of the DEM developed from SOB maps. In both the areas of input, errors are likely and as such, the confidence level of FMM output would depend on the quality of these inputs.

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Observations

Modelling a compartment with 50m grid provides a fine output but this resolution is not necessary for a regional model.

Flood duration maps are important for project planning.

For regional flood mapping, existing level of data and information are sufficient but for sub regional or local area modelling, additional data are needed.

Use of radar images to verify the output of FAP 25 is in its infancy and nothing clearly can be stated about its output. Once it is developed, it may have many uses.

Training

Training is an important aspect of FMM. It is expected that selected SWMC officials will be fully trained during the hand over.

Institution of FMM on completion of FAP 25

MIKE11 based surface water models are being developed and used in Bangladesh for quite some time. As such, the MIKE11 based FMM development needs to be continued. Fund and expatriate support for some more time would be needed. FMM therefore should rest with an institution where the required facility and working environment prevails.

SWMC activities have a great linkage with FMM. SWMC in the near future would take the shape of a permanent and self sustaining institution by the end of the 3rd phase in 1996. SWMC is the logical place for FMM and can be well accommodated under SWMC but it will need necessary funds and expertise at the initial stage.

5.1.3 Third and Final Wrokshop

The Third and Final Workshop will be conducted during the last week of September 1994. The main objectives of the Final Workshop will be to present the FMM applications to relevant GOB authorities, consultants and other potential users and obtain comments on the draft final report.

5.2 Training

5.2.1 FPCO Training Course on Flood Modelling & Management

In accordance with the Terms of Reference, the first workshop was held from 9-11 February, 1993, at which the concepts of FMM were outlined, user needs and targets discussed and the Draft Inception Report was presented.

One of the major observations of the workshop was the identification of the need for training of personnel during the development stages of FMM. This training was to be targetted at those staff of GOB who would be in a position of either running the models in the future or who would require a full understanding of model capabilities in order to make management decisions.

In response to requests from FPCO and BWDB, DANIDA agreed to support a suitable training programme to be administered by FAP 25. FPCO and BWDB have nominated their senior and junior/mid-level staff for the training.

FPCO Training Course on Flood Modelling Management

Module I: Flood Modelling (19 July - 4 August 1993)

Module II: Geographic Information Systems (GIS) (2 - 14 October 1993)

Module III: Flood Management Model (FMM) (16 - 30 November 1993)

Module IV: FMM Applications (2 weeks in 1994)

5.2.2 Course Modules

A training course on Flood Modelling and Management consisting of 4 modules has been designed and is presently on-going. The course consists of 4 modules and is being conducted by the expatriate experts of FAP25 assisted by the local professional staff.

The course outline is presented below:

Module I: Flood Modelling (2 weeks):

1. Overview of Mathematical Modelling
2. Mike 11 Modelling system
3. Hands on training on various modules of Mike11
   NAM, HD, AD, ST, Structure Operation
4. Flood Forecasting
5. Data Management
6. Hydrological Analysis

Module II: Geographic Information System (GIS) (2 weeks):

1. Concepts of GIS and applications in Flood Modelling and Management
2. Points, Lines, Polygons, Raster data concepts....
3. Representating surfaces with GIS, Digital Elevation Models (DEM's), water levels, non-geographic surfaces, preparation of contour map of DEMs.
4. Various GIS software, capability and and limitationss
5. Hands-on practice with Arc/Info
6. ArcView concepts and applications
7. Digitizing, GPS.
8. Radar satellite data, processing requirements

Module III: Flood Management Model (FMM) (2 weeks):

1. Introduction to FMM and Mike11 - GIS
2. Databases, Topographic and hydrological data, Import and Export
3. FMM Relational Database
4. Editors for FMM
5. Branch route systems, storage cells
6. Analysis and Display, Flood Mapping, factor surfaces
7. Impact Assessment, overlaying flood extents with land use.
8. Hands-on-practice on various FMM modules and exercises.

Module IV: Applications of FMM

1. Advanced features of FMM
2. Applications at national, regional and compartmental levels.
3. Impacts of alternative embankment design and FCD structures.
4. Further practices on modelling and use of FMM

To make the training more effective, individual and group exercises are given to the participants who are required to submit their work as and when required. The participants will also be required to submit a final training report.

5.2.3 Participants

A total of 11 participants (6 from FPCO, 2 from BWDB's FF&WC and 3 from SWMC) are participating in the training course. Most of the participants are senior officers (Superintending Engineers, Executive Engineers and Sub-Divisional Engineers.

The officials nominated for the training are either using the models or are aware of the model results in their present profession. The trainees have shown a keen interest in the course and their performances have been very satisfactory.

5.2.4 *SWMC Training for Transfer of FMM*

It is proposed to carry out an intensive training program for selected SWMC staff after the end of the present project period. The main objective of the training will be to prepare SWMC in using the FMM technology in general and the MIKE11-GIS tool in particular in the future.

The major part of the training will be carried out while developing FMM for selected case studies. A detailed program of such a training course will be prepared and included in the Second Interim Report. Additional resources will be requested for this extension of the project (19 October to 31 December 1993).

5.2.5 *On-The-Job Training*

All local staff of the project are being trained in-house through on-the-job training. While two local staff members (Software Specialist and GIS Engineer), are directly involved in developing the MIKE11-GIS software, others are regularly exposed to the FMM development process. It is expected that during the application phase of the project all the local engineers will become expert users of FMM. They will also learn the details of the MIKE11-GIS interface and data exchange mechanism between MIKE11 and ARC/INFO.

In addition to the in-house training, hands-on demonstrations are presented from time to time to interested GOB officials and consultants from SWMC and other FAP studies. It is also planned to organize special presentations in the future.

5.3 Demonstration

The tools developed at the FAP25 Project have been demonstrated from time to time to GOB officers, FAP consultants, CAT Members, POE/FPCO, faculty and students from BUET and other visitors to the project office. It is also planned to organize similar demonstrations in the future to selected groups from SWMC, FAP consultants, GOB engineers etc.

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6. WORK PROGRAMME - YEAR 2

6.1 Progress and Revision of Activities and Schedules

Stage 1 of the project is largely complete. The development tools have been successfully formulated and are now ready for rigorous testing in the application environment. It is expected that there will be significant feed-back from the application developers which will necessitate some changes to the work done in Stage 1. However, these changes should be limited to improving the user interface, rather than major code revisions.

During the Development Stage it became even more clear that the project was developing a basic product that would have significant impact on a wide spectrum of sectoral interests. Ad-hoc, informal discussions with other sectoral specialists taking part in studies related to all aspects of water management, watershed management or environmental aspects, have illustrated the potential of FMM. It is of utmost importance that the benefits of FMM be realised by as wide a range of potential users as possible, either in the form which will result from this project, or in sectoral-specific variants to be developed later.

6.2 Future Activities

Future efforts of the project will be focussed on fulfilling the TOR requirements during the Stage 2 - Application and Demonstration Phase. The activities include development of three bespoke flood management models to be applied to the national, regional and compartmental levels. The activities related to knowledge transfer through demonstrations, and on-the-job trainings will continue. Recommendations for future training requirements and training materials will be prepared.

In addition to the above, the future activities for the remainder of the project will include the following:-

- **Development of guidelines for the on-line operation of FCD structures.** This will be based on compilation of historical simulation results to generate a long-term operational policy with a provision for "switching" to a short-term operation rule using a real-time forecast of flooding and its impacts.

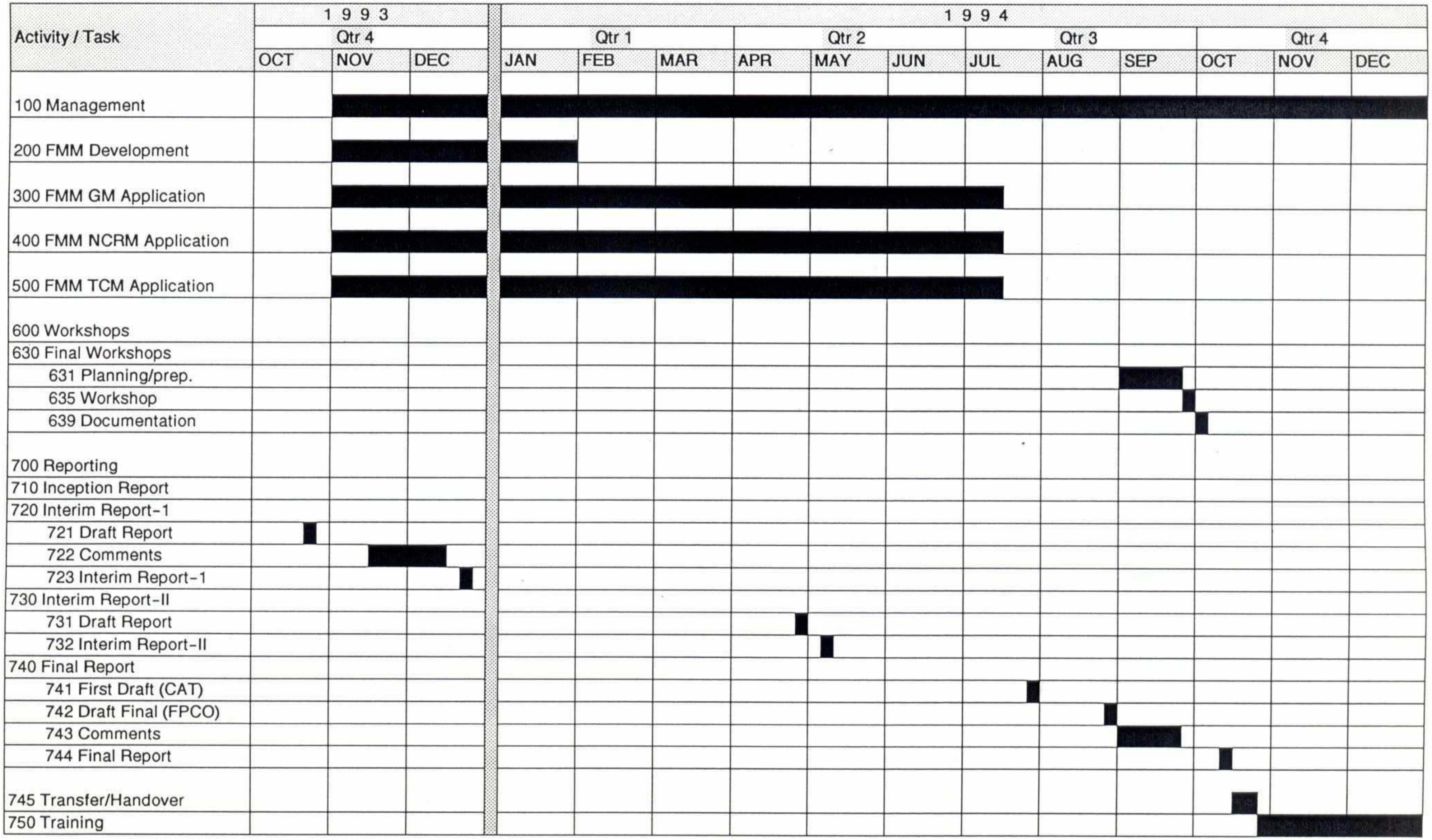
- **Application of MIKE11-GIS flood mapping in impact assessment.** This activity will demonstrate the use of FMM as a spacial decision support tool, (SDSS), which will integrate the spacial outputs, (flood mapping), from MIKE11-GIS into a multiple criteria-oriented SDSS. Recommendations will be made on data and modelling requirements for quantitative impact assessments needed for project appraisal.

- **Institutionalisation of FMM.** Recommendations will be drawn up on the possible future institutional responsibilities associated with the operation, maintenance and further development of FMM.

There has been a slight modification on the activities and schedules reported in the Inception Report. Figure 6.1 shows the revised schedule of the main activities. Figures 6.2 and 6.3 respectively, present the expatriate and local staff schedules.

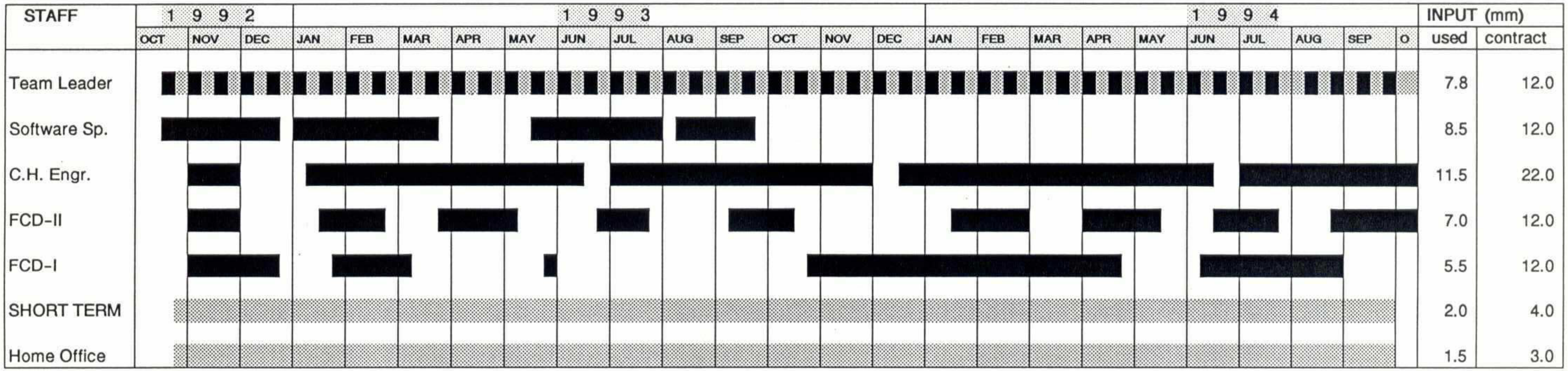
Figure 6.1: Work Program Year 2

Project: FMM
Date: 20/12/93



DATE ==> 31/ 12/ 93

EXPATRIATE STAFF INPUT



Full Time Input

Part Time Input

Figure 6.2: Schedule of Expat. Staff Input

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LOCAL STAFF INPUT

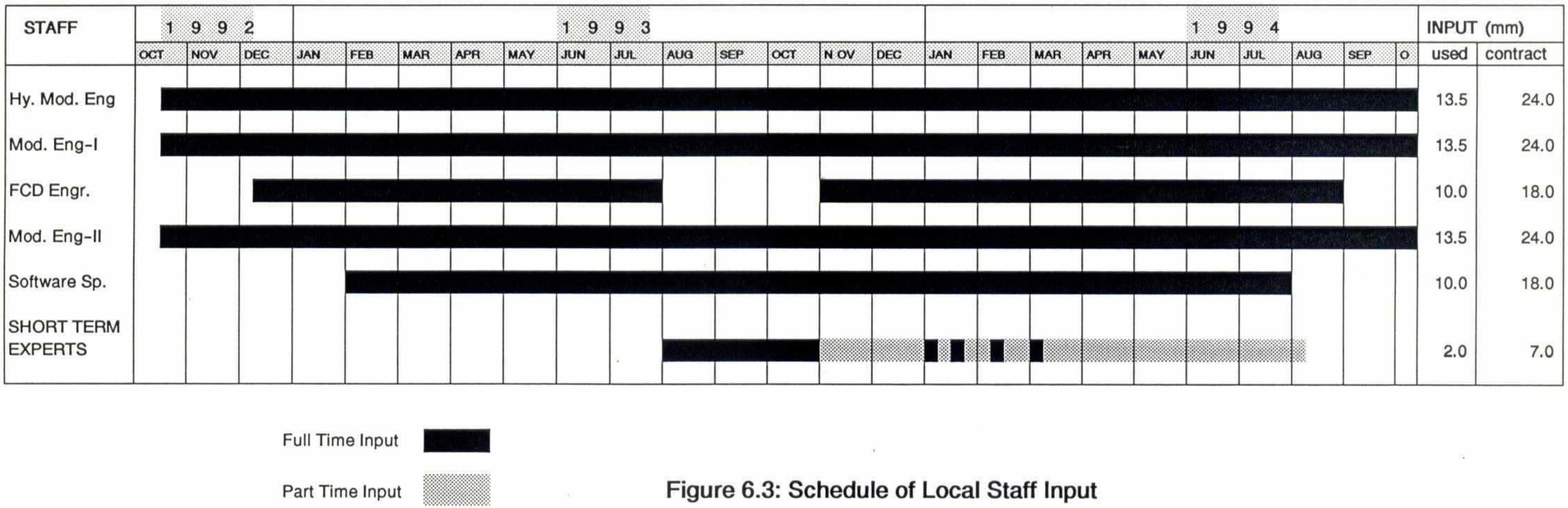

Figure 6.3: Schedule of Local Staff Input

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APPENDIX A

APPENDIX A

DATA COLLECTION

A.1 Introduction

The challenge in developing the FMM is largely a problem of data integration. Flooding is a "complex" problem typically addressed by a variety of experts who tend to specialize in some aspect of the problem, e.g. hydraulics, hydrology, modelling, fisheries, agriculture, socio-economics. Usually these experts have their own special models that use data created by another expert. The effort spent on acquiring and loading this data must be minimized. Hence it has been the intention to take full advantage of the existing data with various organizations and studies being carried out under the auspices of FAP. Existing data with the various organizations plays a key role in the successful application of FMM. In order to establish a smooth data exchange both the technical and institutional aspects must be considered.

Different modelling systems typically use "proprietary" data structures that are unreadable by other modelling systems. By defining exchange formats for different types of data it becomes easier to exchange data. Standardized exchange formats decrease the complexity of moving data from one modelling system to another.

Another aspect of data integration is addressed by relational database technology. Relational databases store all information in tables that consist of rows and columns, where each row has the same number and type of columns. ARC/INFO uses files with fixed length records for tables; MIKE11 uses variable length records, which are very difficult to manage using relational database techniques. Through a process called normalization it is possible to design a relational database so that information from variable length files may be exported to relational tables. FAP25 has normalized the information in the MIKE11 files so that ARC/INFO, or any other relational database system, can more easily use the information.

A.2 Data Sources

The Surface Water Modelling Center is seen as a key data source for the MIKE11 models which form the basis of FMM. Several models developed by the SWMC have been transferred to FAP25. The data consists of model topography, topology and the hydrometeorological time series.

Topographic data related to the DEMs have been obtained from FAP19. Recently, spot elevations from the 1:10000 orthomaps produced by FINNMAP for FAP20 were digitized and a DEM grid produced.

The Local Government Engineering Department (LGED) is another potential source of map based data. LGED has embarked upon a project to digitize the thana maps used in planning local engineering projects. These data collection and mapping activities are also based on Arc/Info. The information being collected by the LGED will eventually be useful to the FMM, while the results of the FMM would also be of use to LGED in developing minor structural design specifications (culvert requirements, roadway heights, etc).

Other sources of GIS data for future applications of FMM, particularly for agricultural and fisheries impact assessment studies, are the Crop Diversification Project (CDP), and FAP17: Riverine Floodplain Fisheries Study and Pilot Project.

The first Earth Resources Satellite (ERS-1) launched by ESA last year is able to collect RADAR images of potential use to the FMM. There are two types of RADAR imagery of interest, each collected with a special detector. The first type, Side Aperature Radar (SAR), might allow areas of inundation to be determined. The second type, radar altimetry, might allow very precise measurement of water surface elevation. RADAR can penetrate the clouds that block conventional satellite operational bandwidths. The possible acquisition of RADAR imagery for the flood season in Bangladesh is being coordinated by FAP 19.

FAP25 has participated in a RADAR ground truthing exercise coordinated by FAP19. The purpose of this exercise is to collect data on ground conditions at the time the satellite passes over so that later the image may be analyzed to see if "signatures" for different types of land/water cover can be determined. Once a signature is found, an entire image may be classified. It is hoped that the classification will distinguish flood extent, but this technology is in its infancy and some caution must be exercised if anticipating definitive results in the short term.

Application of FMM to realtime inundation forecasting will be based on the realtime data from the BWDB's Flood Forecasting and Warning Centre. SPARRSO is the source of satellite imageries.

A.3 Field Data Collection

A.3.1 Additional Survey in the North Central Region

The North Central Regional Model needs considerable restructuring in certain areas so as to realistically represent the hydraulic connection between the river channel and flood plain to meet the requirements of Flood Management Model. Representation of hydraulic connection of the conveyance channel and the flood plain storage cell is a key element in modelling flood flows in certain areas of the north central region. Quasi 2-dimensional modelling was considered appropriate and a limited programme of embankment survey was undertaken to those rivers having significant influence on the regional hydraulic behaviour. The survey work concentrated on establishing the locations of water interchange between river and flood cell.

To further improve understanding of the river/floodplain interaction, additional water level gauges were set up in selected flood plains of the region. The purpose of this was to study fluctuations of flood plain water level with respect to adjacent river level variations and to establish the degree of connectivity between them.

Topographic Survey

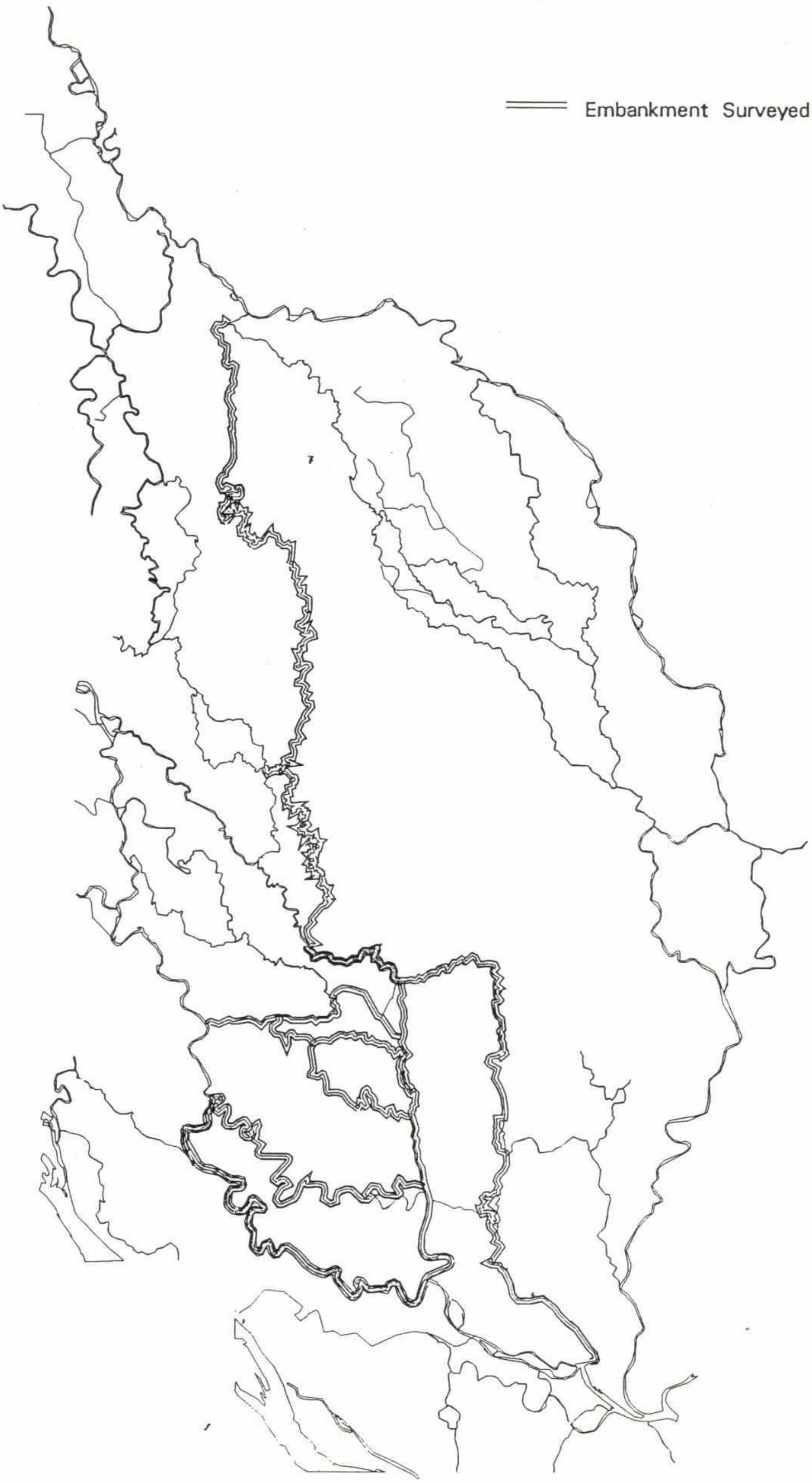
Embankment survey was carried out by contract with SWMC. The specifications called for the establishment of levels of embankment or natural levee, together with the location of intersecting rivers and khals. In addition, the surveyors were required to make 200 metre long transects into the adjacent flood plain at approximately 1 km. intervals.

The SWMC surveyors attempted to make a survey of the location and size of hydraulic structures encountered, but were only partially successful owing to the prevailing high water levels.

Both banks of the following rivers were included in the overall survey programme:-

River	**Contractor**
Futikjani	SWMC
Bangshi	SWMC, Hydroland
Dhaleswari	SWMC, Hydroland
Turag	SWMC
Tongi Khal	SWMC
Buriganga	SWMC
Barinda	Hydroland
Dhantara Khal	Hydroland
Bangshi South	Hydroland
Kaliganga	Hydroland

Figure A.1 shows the location of the embankment surveys.



Location of Additional Embankment Survey

Figure A.1 **NORTH CENTRAL REGION**

Survey Programme - I

Area Surveyed: Embankment survey along both banks of the rivers Futikjani (partly), Bangshi and Dhaleswari (partly).

Duration: March 14 to June 19, 1993 (84 working days)

Distance: Total distance covered 277 km.

The survey work started on 14th March, 1993, with carrying of BM from FINNMAP BM No. 5803 in front of Chamraria Free Primary School at Kalihati. A total of 277 km were covered on both the banks of Futikjani, Bangshi and Dhaleswari river from Charan, Kalihati to Dhalikandi (Kalatia) Keraniganj. The work was suffered several times due to heavy rainfall. Representative ground levels on the embankment or on natural levee along both banks of the river were taken at around 200 m interval. Three representative spot levels at 30 m interval were taken laterally to the country side flood plain at an interval of around 1 km along the bank survey. The survey party took cross-sections of a number intersecting channels across the survey route. The work has been completed in June 19, 1993.

Hydraulic Structures

The party noted down informations on hydraulic structures during the survey work. However, they could not collect informations on many structures as they were under water during the survey. The informations are listed in Table A.1.

Table A.1 Information on Hydraulic Structures.

Sl.No	Location	Size of vent	Sill level	No. of vent	Connecting River
1.	Charan R/B	1.56x1.22m	6.376 m	1	Futikjani
2.	Salim Nagar L/B	...	...	2	Bangshi
3.	Bullah's Khal L/B	Fully upset	..		Bangshi

<u>Cross-sections on Bangshi River</u>

The party surveyed three river cross-section on Bangshi river. The cross-sections would be used in NCR FMM. The location of cross-sections surveyed are given in Table A.2.

Table A.2 Location of the Cross-sections Surveyed on Bangshi River.

Sl.No.	River/Canal	Location	Remarks
1.	Bangshi	Boalia, P.S.Kaliakoir, BH1 # 22R.	200 m d/s from Kalimajang & Bangshi confluence.
2.	Bangshi	Gohalbari,P.S.Savar BH1 # 23R	
2.	Bangshi	Nalam, P.S. Savar Cross-section No.BH1 # 24R	

<u>**Cross-sections of intersecting channels across the Survey Route**</u>

The party also surveyed cross-sections of canals and rivers that falls into the river surveyed. The party found 23 nos. of intersecting channels on the left bank of the river Bangshi from Ratanganj to Dhalikandi, P.S. Keraniganj. The width and the bottom level of the channels are given in Table A.3. The party surveyed 3 intersecting channels on the right bank of the river Futikjani from Charan, P.S. Kalihati to Ratanganj Bazar and 25 intersecting channels on the right bank of the river Bangshi from Ratanganj bazar to Dhalikandi, P.S. Keraniganj. The width and the bottom level of the channels are given in Table A.4 and A.5 respectively.

Table A.3 Width and Bottom Level of Channels on Left Bank of Bangshi

Sl.No.	Name of Intersecting Channels	Width (Metre)	RL.of deepest point(mPWD)	Chainage from Charan (km)
1.	Bangshi river	90	3.44	7.285
2.	Toonkigang	60	4.566	11.331
3.	Khal	56	6.25	17.623
4.	Khal	40	6.25	20.803
5(a).	Khal	40	6.06	32.784
5(b)	Khal	80	6.14	40.092
6.	Khal	160	5.03	43.302
7.	Khal	20	6.18	49.943
8.	Khal	20	5.65	50.716
9.	Kamailarjore at Patharghata	47	0.81	55.716
10.	Pathakhaligang	110	(-)2.392	63.853
11(a).	Bhullah's khal	73	2.85	73.945
11(b)	Khal	30	3.09	80.687
11(c)	Khal	33	2.95	82.509
12.	Turag river	112	(-)1.127	85.007
13.	Khal	17	2.101	93.459
14.	Gang	190	2.101	97.024
15.	Dallai Bill	195	3.698	103.375
16.	Khal	30	1.09	105.991
17.	Khal	35	0.58	118.142
18.	Khal	85	1.65	123.752
19.	Karnatali khal	137	(-)1.11	124.164
20.	Santirbazar to Boilapur river.	290	(-)0.91	135.107

Table A.4 Width and Bottom Level of Channels on Right Bank of Futikjani

Sl.No	Name of Intersecting Channels	Width (Meter)	Rl. of Bottom point (m PWD)	Chainage from Charan (km)
1.	Charan Khal(East para)	30	9.72	0.174
2.	Langulia Gang at Ballah	48	6.30	2.704
3.	Maragangy (Haora river) at Gonabari, Kalihati	42	7.10	4.435

Table A.5 Width and Bottom Level of Channels on Right Bank of Bangshi

Sl.No	Name of Intersecting Channels	Width (Meter)	Rl. of Bottom point (m PWD)	Chainage from Charan (km)
1.	Dafadarbari Khal at Jorebari,Kalihati	20	7.37	7.545
2.	Darbarshi Khal at Dulshimul,Kalihati	20	5.88	9.312
3.	Johang river	80	8.32	11.038
4.	Langlai south	196	4.44	12.953
5.	Bangrar Khal south site of Sunnah Bazar.	50	4.97	25.056
6.	Khal	18	5.92	38.496
7.	Mirikpur Khal	66	-0.12	39.144
8.	Khal	25	5.49	42.300
9.	Khal	61	3.95	46.925
10.	Old Bangshi	117	2.17	57.213
11.	Pungli river at Chak Laskar, Mirzapur	95	2.92	62.735
12.	Khal at Mirzapur	120	5.78	65.143
13.	Talipara Khal, P.S.Mirzapur	56	3.06	68.519
14.	Kodalia Khal, Mirzapur	95	3.14	71.017
15.	Khal	58	2.53	78.791
16.	Khal	45	2.41	80.412
17.	X-section BH1 # 21 R at Kaliakoir	72	2.88	82.714

18.	Khal	185	2.25	91.104
19.	Dhantara Khal(Low land area)	120	0.98	95.079
20.	Khal (Low land area)	160	1.99	96.404
21.	Khal (Low land area)	117	1.85	99.953
22.	Kaklajani River	182	0.11	105.520
23.	Gazikhali River	195	-0.89	115.976
24.	Dhaleswari River (1)	203	0.73	116.599
25.	Dhaleswari River (2)	82	1.02	117.691

BM/TBM Connection for Checking

The survey party cross checked five BWDB gauge TBM and seven FINNMAP BM values during their embankment survey to verify the accuracy of the survey. The findings are given in Table A.6.

Table A.6 BWDB TBM, FINNMAP BM & the Survey Values

Location	Type of TBM/BM	TBM/BM values in m PWD	Survey values in m PWD	Difference in m
Kawaljani	BWDB Gauge TBM FINNMAP BM 6105	11.390 11.836	10.947 11.820	+ 0.443 + 0.016
Mirzapur	BWDB Gauge TBM FINNMAP BM 6112	10.690 11.065	10.895 11.101	- 0.205 - 0.036
Kaliakoir	BWDB Gauge TBM FINNMAP BM 7912	8.990 9.901	8.954 9.926	+ 0.036 - 0.025
Nayerhat	BWDB Gauge TBM	9.543	9.214	+ 0.329
Savar	BWDB Gauge TBM FINNMAP BM 6313 FINNMAP BM 6312	8.358 7.981 7.699	8.037 8.041 7.749	+ 0.321 - 0.060 - 0.050
Keraniganj	FINNMAP BM 6309 FINNMAP BM 6308	6.923 6.985	6.915 6.883	+ 0.008 + 0.102

Survey Programme - II

Area Surveyed: Embankment survey along both bank of the rivers Turag, Tongi khal (partly), and Buriganga.

Duration: April 10 to May 28, 1993 (42 Working days).

Distance : Total distance covered 129 km.

The survey started on 10th April, 1993, with carrying of BM from FINNMAP BM No. 7912 at Kaliakoir. It covered 48 kilometers on both the banks of Turag river from Kaliakoir to Asulia. The survey party could not proceed with the work on the right bank of the river Turag after Asulia as the area was submerged and need to abandon 3 kms from chainage 48 to 51 km. The survey party continued work on the Greater Dhaka City Flood Protection Embankment from Tongi Highway Bridge to Keller More in Dhaka.

The survey work disrupted frequently due to heavy rainfall and early monsoon flooding. The field condition did not allow always to follow strictly the work guidelines. Finally, the work was completed on 28th May, 1993.

Hydraulic structures

The party found some hydraulic structures during the survey work and noted down the ventage of regulator, but could not take the size of vents and sill levels since they were partly under water. The informations are listed in Table A.7.

Table A.7 Informations on Hydraulic Structures.

Sl.No.	Location	No. of Vents	Connecting River
1.	Tyebpur R/B	3	Turag
2.	Rustampur R/B	2	Tongi Khal
3.	Tongi R/B	2	Tongi Khal
4.	Near Botanical Garden L/B	8	Turag
5.	Diabari L/B	1	Turag
6.	Kallyanpur L/B	4	Turag
7.	Rayer bazar L/B	2	Turag
8.	Nawabgonj L/B	1	Turag
9.	Nawabgonj L/B	2	Turag

Cross-sections on Tongi Khal & Turag River

The party took two cross-sections on Turag river and one on Tongi khal. These cross-sections would be used in NCR FMM. Locations of the cross sections are shown in Table A.8.

Table A.8 Cross-sections Surveyed on Tongi Khal and Turag River

Sl.No.	River	Location	Remarks
1.	Tongi Khal	Nayanehala (ATT4)	
2.	Turag	Rustampur	100 m d/s to Turag-Tongi Khal confluence
3.	Turag	Gabtali	100 m d/s to Mirpur Bridge.

Cross-sections on Intersecting Channels along the Survey Route

The party surveyed some cross-sections on different rivres and channels those fall into the river surveyed. On the way of their survey route the party found eight intersecting channels on left bank of the river Turag from Kaliakoir to Asulia bazar. Informations on those cross-section are listed in Table A.9

Table A.9 Width and bottom level of channels on left bank of Turag

Sl.No.	Name of Intersecting Channels	Width (meter)	RL of Deepest point (m PWD)	Chainage from Kaliakoir (km)
1.	Niknakhali Khal	22	2.486	6.200
2.	Narakhali Khal	30	2.083	11.170
3.	Goallar Khal	25	1.918	11.770
4.	Saldah Nadi(1)	25	1.098	15.000
5.	Saldah Nadi(2)	26	1.201	15.500
6.	Nynni Khal	30	2.678	16.950
7.	Kata Khal	38	1.543	18.410
8.	Kata Khal	18	1.087	25.900

Table A.10 Additional Hydrometric Stations in NCR

Station Number	Station Name	River	Station Number	Station Name	River
1 (Q)	Belamari	Kalu Mondal Daha	21	Baniapara	Dahitoka
2 (Q)	Char Atiapara	Datbhanga	22 (Q)	Ganjana	Bangshi
3	Dhaluabari	Lohajong	23 (Q)	Pach charan	Jhenai
4	Hat Gobindah	Nangla Khal	24	Ratangonj	Jhenai
5 (Q)	Gobindapur	Nangla Khal	25 (Q)	Nakasim	Nangila
6 (Q)	Poyla Bridge	Madar Daha	26 (Q)	Patharghata	Bangshi
7	Khashimara	Madar Daha	27 (Q)	Latifpur	Bangshi
8 (Q)	Islampur	Old Brahmaputra	28 (Q)	Kalampur	Bangshi
9 (Q)	Delirpar	Dali	29	Mallabari	Bangshi
10 (Q)	Madhyachar	Bhabki Khal	30	Kaitkai	Bangshi
11	Hazipur	Jhenai	31 (Q)	Teki chandpur	Barinda
12 (Q)	Benjail Rampur	Chatal/Jhenai	32	Dhantara	Dhantara
13 (Q)	Jhalopara	Branch of Jamuna	33	Saforta	Warshi
14	Digpaith	Bangshi	34	Gopalpur	Bairan
15	Rashidpur	Kairar Khal	35	Kuturia	Sapa
16	Rubshanti	Kuchiamara	36 (Q)	Pungli Bridge	Pungli
17 (Q)	Koyra	Jhenai	37	Bill palima	Borni
18	Bhengula	Jhenai	38	Kalihati	Jhenai
19	Dhopa Kandi	Katakhali Khal	39	Nolsafa	Jhenai/Lohajang
20 (Q)	Belua	Jhenai	40 (Q)	Mitara Bridge	Mitara Khal

Note: (Q) indicates location of discharge measurement

Source: North Central Region Feasibility Studies - Preparatory Studies

A.3.2 *Floodplain Water Level Data*

Work Description and Area Coverage.

Hydrological data are collected by BWDB on the important water courses and MIKE 11 models of SWMC are based on this data and represent the flood plain equally to the nearest h point of the river in the model. This representation, though approximate, is considered suitable for planning since the hydrodynamic modelling of the flood plain is complicated, time consuming and simulation would be difficult for want of observed data. FMM has the mandate to look more closely in the modelling of flood plain and with that understanding capturing of water level data in a sample area of North Central region got priority. The Inception Report of Flood Management Model therefore proposed for monsoon data collection (water level) in the flood plain on a priority area under the North Central region (Ref. 1). The purpose of this data collection would be to verify the FMM output with the observed data for subsequent improvement of FMM.

A total of 12 water level gauges were installed, 5 along the Dhaka-Aricha road, 4 along the Dhaka-Tangail road, 1 on Savar-Kaliakair road and 2 along the Dhaka-Mawa road. The location of the gauges are shown in Figures A.2 to A.3. Local people, mainly school/college students living near the gauge stations were engaged on contract basis for the monsoon period (1st June to 31st October, 1993) to record water level data twice a day (0900 and 1800 hours) on a format supplied by FAP 25. They also record qualitative intensity (in terms of High, Low or Medium) and duration of local rainfall on the same format. A preliminary training was offfered to the gauge readers by the project staff on how to read and record data on a prescribed format.

Bench Mark Connection and Monitoring of Data Collection.

Bench Mark connection to the gauge was made from the nearby FINNMAP B.M. except for 2 gauges along the Dhaka-Mawa road. These were connected from the BWDB B.M. at Mawa. Adjustment to elevation of the FINNMAP is made according to

PWD datum = GTS (FINNMAP) + 0.46 m

Therefore, the zero value of the gauges connected from FINNMAP B.M. were increased by 0.46 m. List of water level gauges and the reference B.M. is given in Table A.11. In case of shifting of gauges, reading from both the gauges were recorded simultaneously for a few days. In addition survey was carried out to recheck the B.M. connection after gauge shifting and very little differences were observed from the earlier value. However, results from the second survey (recheck) were finally adopted.

Table A.11 Information on Water Level Gauges

Area Coverage	ID No. of Gauges	Name of Place	FINNMAP B.M. No.	Elevation
Dhaka-Tangail road	FMM-01	Kurni	FM-7907	9.8251
	FMM-02A	Sohagpur	FM-7909	9.6103
	FMM-02B	Sohagpur	FM-7909	9.6103
	FMM-03	Sutrapur	FM-7911	10.8706
Savar-Kaliakoir road	FMM-04	Sripur	FM-8139	9.2095
Dhaka-Aricha road	FMM-05	Dhulivita	FM-8136	7.0476
	FMM-06	Srirampur	FM-8133	7.6607
	FMM-07	Krishnapara	FM-8131	7.8534
	FMM-08	Bhatbaur	FM-8128	7.5359
	FMM-09	Uthali	FM-6230	9.1212
Dhaka-Mawa road	FMM-10	Kuchiamora	BWDB-Mawa	
	FMM-11	Srinagar	BWDB-Mawa	

Data Plots and Analysis

Sample plots of water level hydrograph on the flood plain data captured in the FMM gauges are shown in Figures A.2a-d. In general, the hydrographs are similar in shape in the flood period i.e. they maintain similar trend. However, in the early monsoon (in this case up to about the third week of June) the features of hydrographs are not uniform. These may be explained as follows:

- In the monsoon, links among the channels, major rivers and flood plains are established. The channel slopes in the flood plain being very gentle, most of the links are established simultaneously. One can therefore conclude that the gauges are all installed in a single basin though at different locations;

- The rise and fall of the flood plain hydrographs match very nicely with that of major rivers/channels;

- Before the establishment of any connection with the channels, the water level gauges are independent and depend on the local rainfall or independent sources;

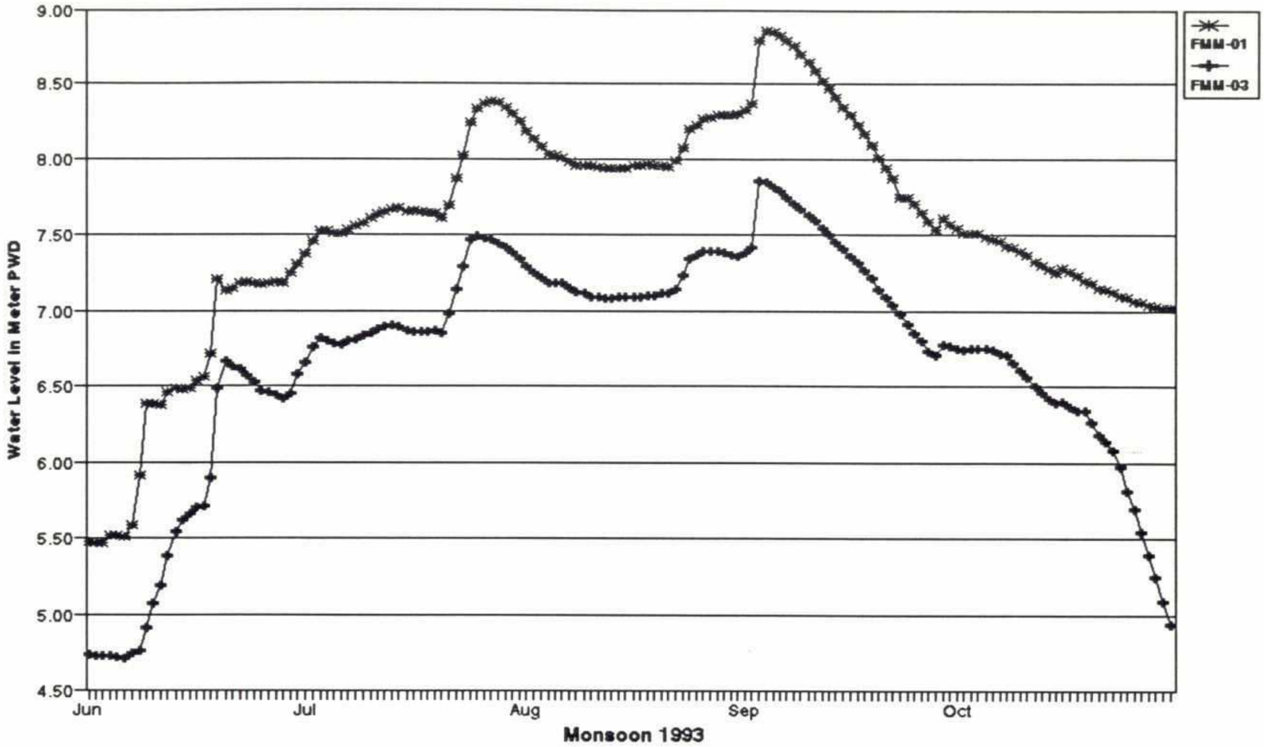


Figure A.2a : Water Level Hydrographs for the Gauges on Tangail Road

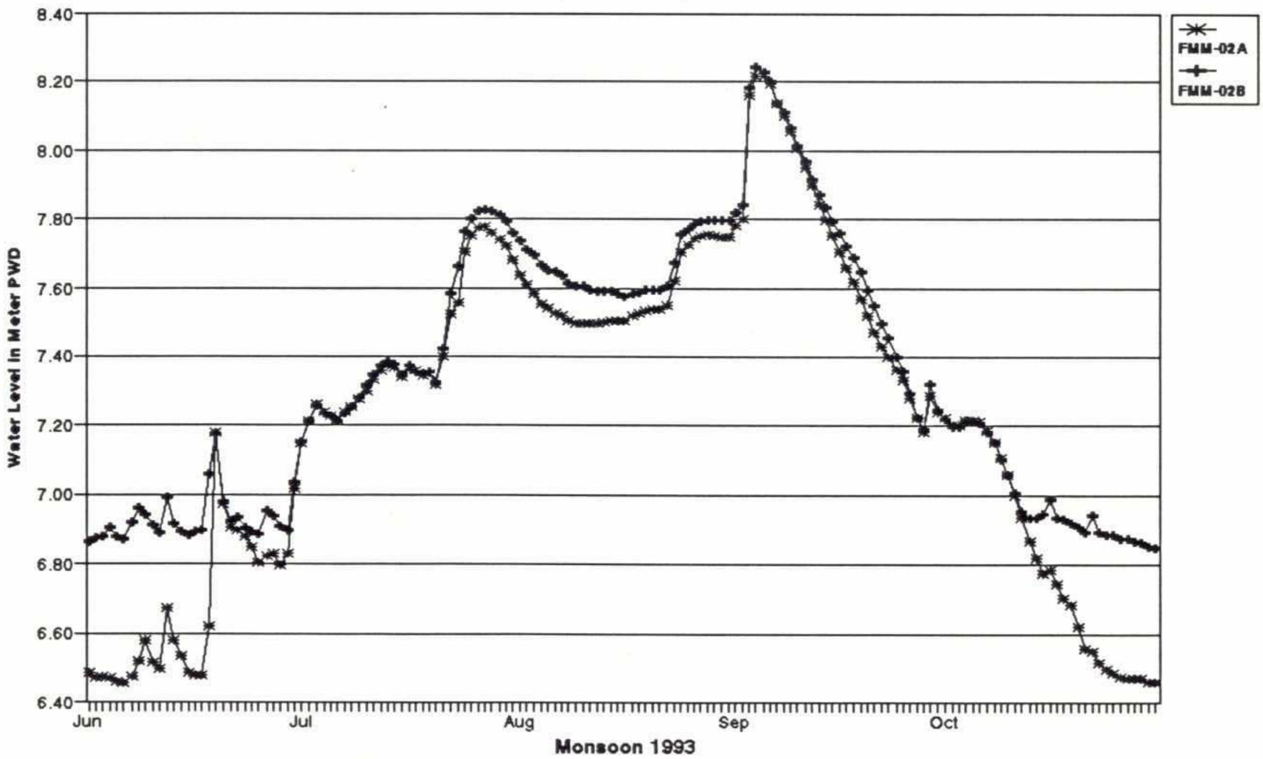


Figure A.2b : Water Level Hydrographs for the Gauges on Tangail Road

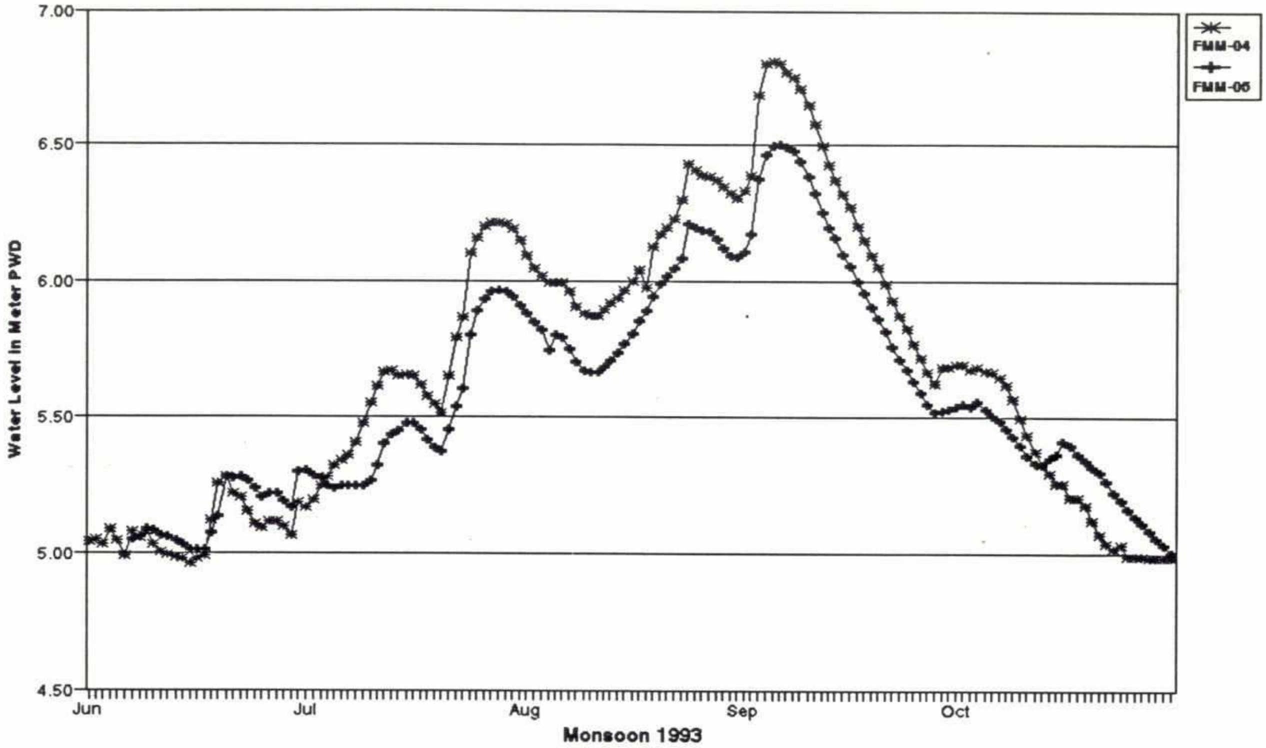


Figure A.2c : Water Level Hydrographs for the Gauges on Savar-Kaliakoir Road

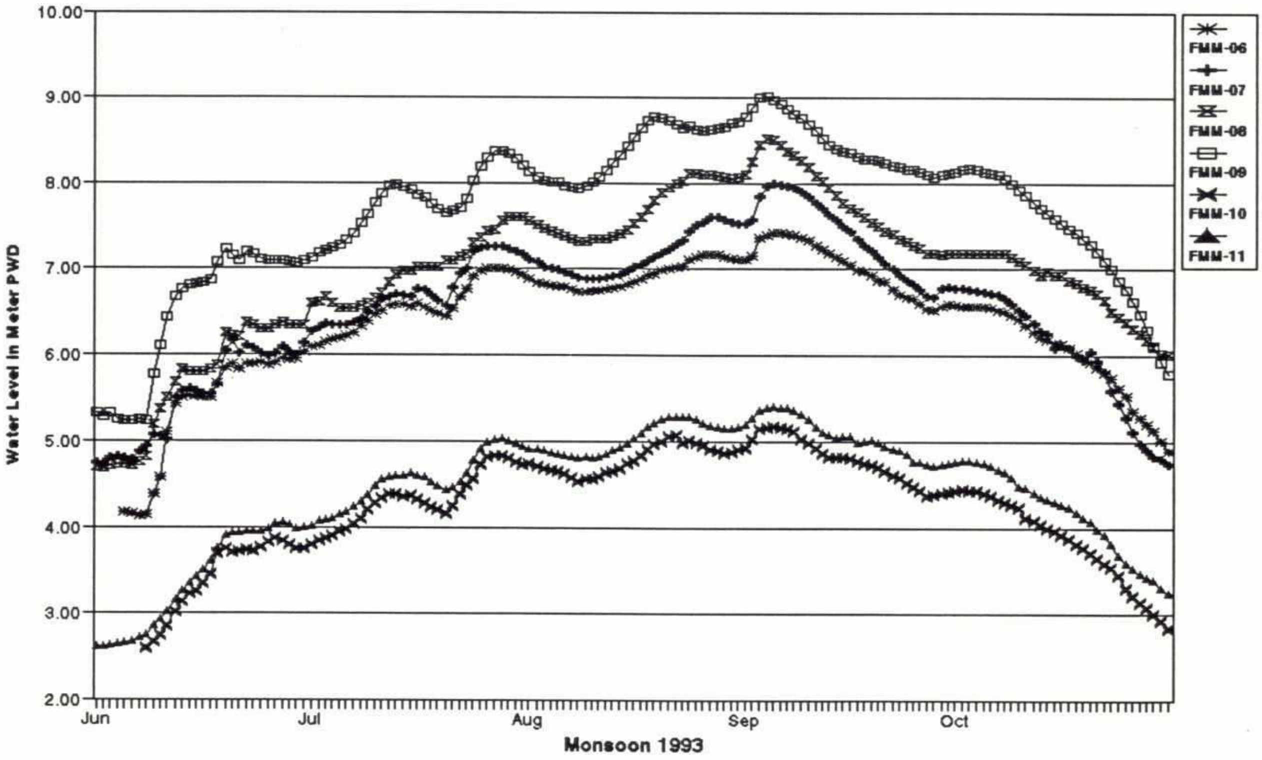


Figure A.2d : Water Level Hydrographs for the Gauges on Aricha and Mawa Road

- The fluctuations in the hydrograph are sharp in the flood plain over the major rivers due to the influence of local rainfall;

- Gauge 2A and 2B are located on two sides of the same road at one site. The hydrographs have separation and rejoining (see Figure A.2b). A clear explanation could not be developed as yet except 2A is located at the downstream and 2B is near the river;

- The rate of rise and fall of water ranges from 0.02 - 0.05 m/day with the highest in one day by about 0.36 m. As such, gauging twice a day in the flood plain appears sufficient to represent the flooding.

Hydrometric Survey

In support of the proposed feasibility level studies in the Bhuapur region and final design stage of the Jamalpur Prority Area, the Caisse Française de Developpement, (CFD), have funded a preparatory data collection programme. Since all the hydrometric stations established in this programme, (40 in all), are located within the NCR, the regional FMM may derive benefit from the monitoring of these stations.

A number of the stations are re-installations, since the previous gauge was missing or damaged, but the majority are new locations which were chosen to best assist in the simulation of fluvial behaviour in critical areas. This particularly refers to the Bangshi River, which serves as the main drainage "spine" for the region, but which, up to now, has not been fully understood in the middle and upper reaches.

Monitoring commenced during the month of June, 1993 on all 40 stations and is due to continue until the end of October, 1993. Water levels are recorded every 3 hours on a routine basis, but with provision for additional monitoring during periods of high flows. BWDB Hydrology Division are also carrying out a programme of fortnightly discharge measurements at 20 of the above 40 stations with a further 4 additional locations at existing BWDB water level stations.

Figures A.2 to A.8 show the location of all these gauges and have been consolidated to include the locations of other major gauging stations in the North Central Region. Refer to Appendix B1 for details of the water level and discharge gauging stations

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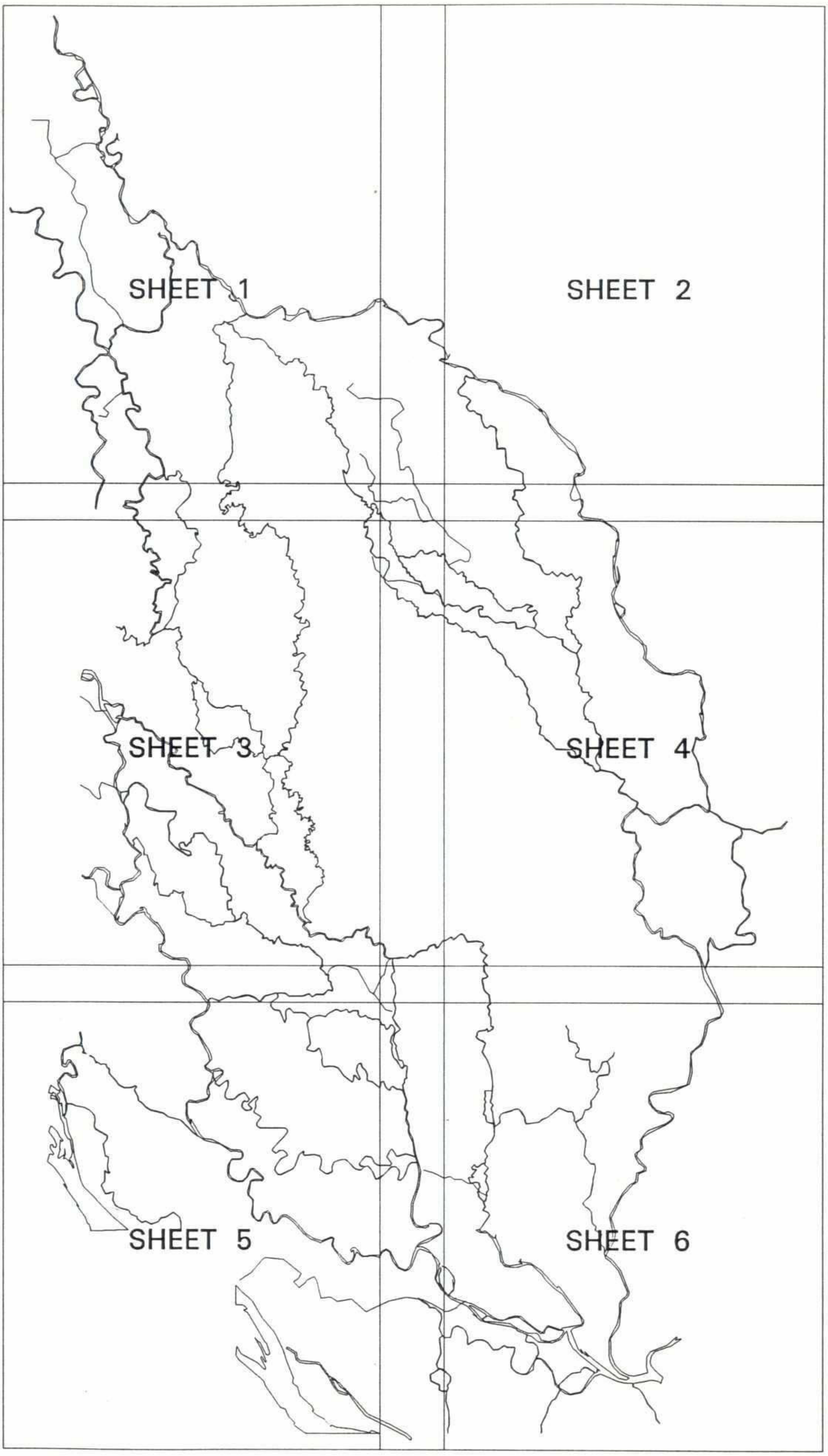
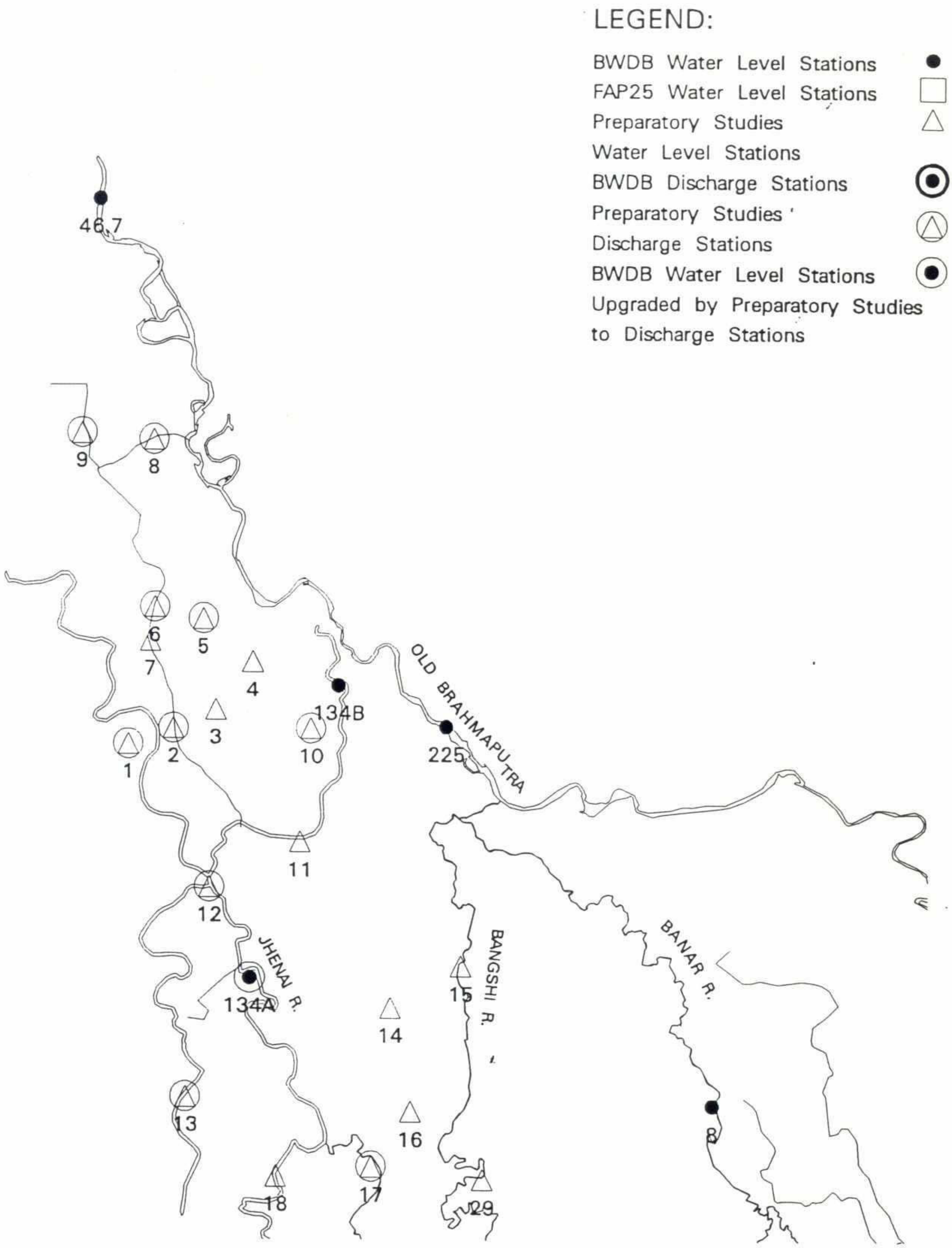


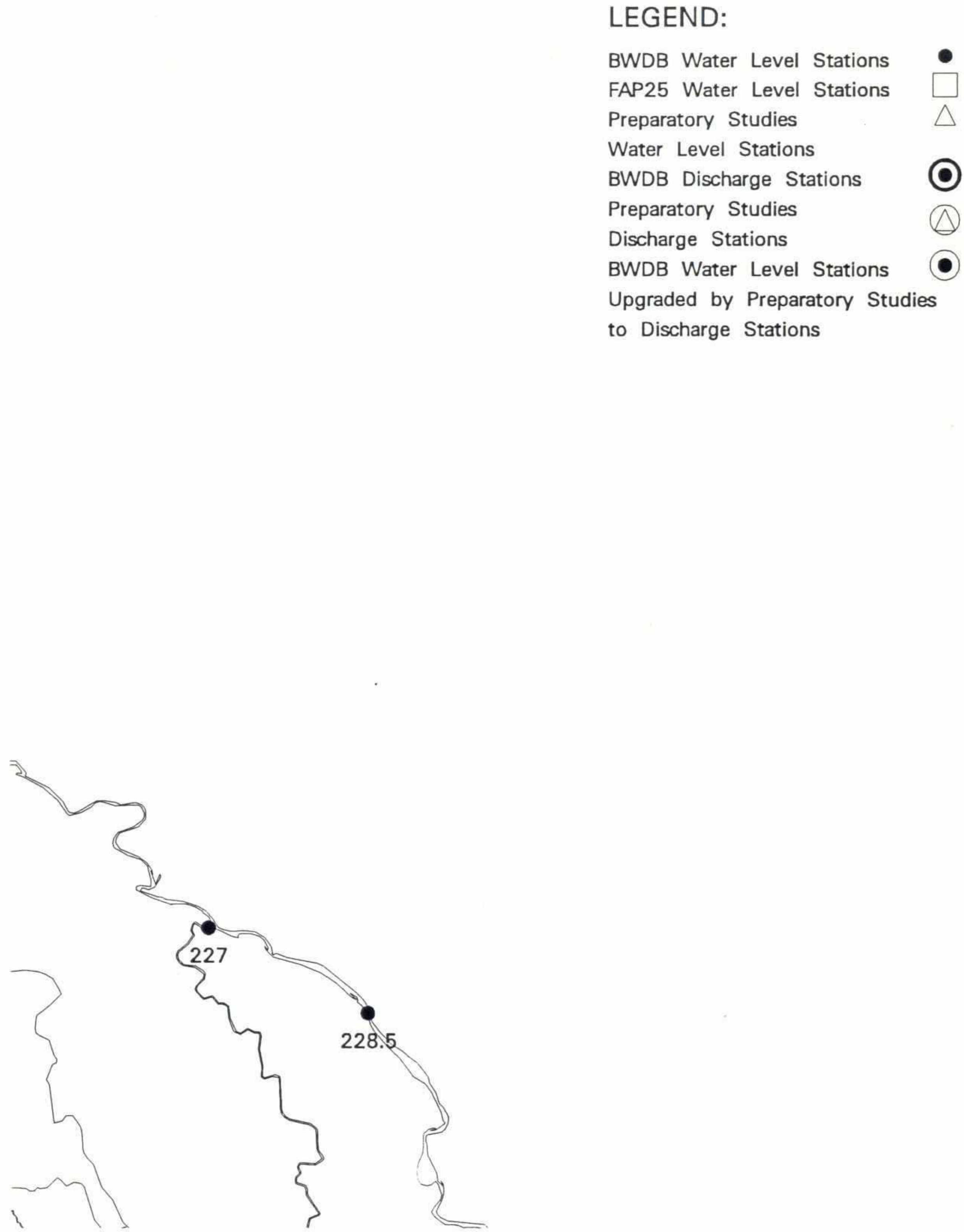
NORTH CENTRAL REGION

Figure A.3 MAP SHEET INDEX



MAP SHEET 1

Figure A.4 **NORTH CENTRAL REGION**



MAP SHEET 2

Figure A.5 **NORTH CENTRAL REGION**

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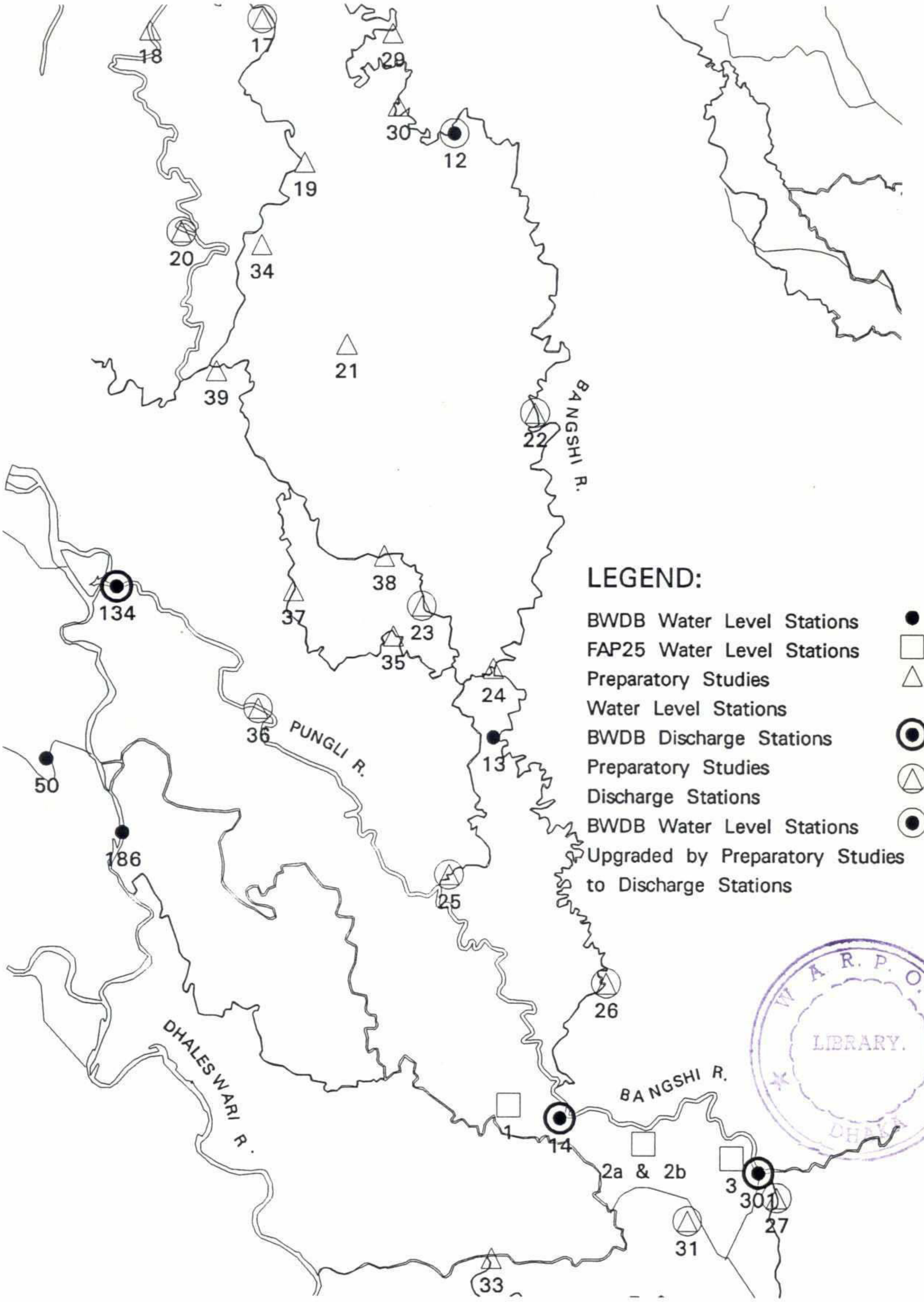

MAP SHEET 3

Figure A.6 **NORTH CENTRAL REGION**

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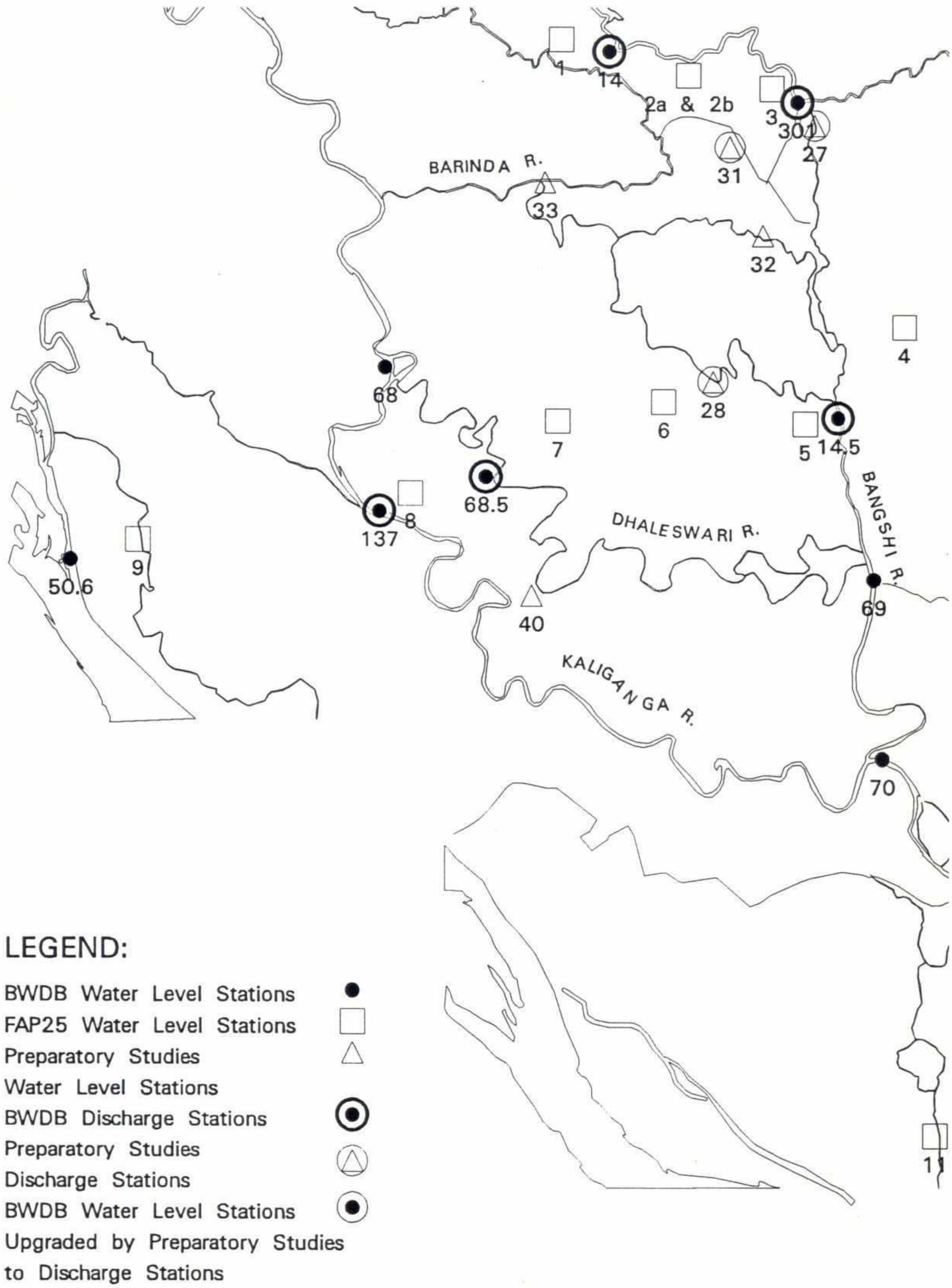
MAP SHEET 4

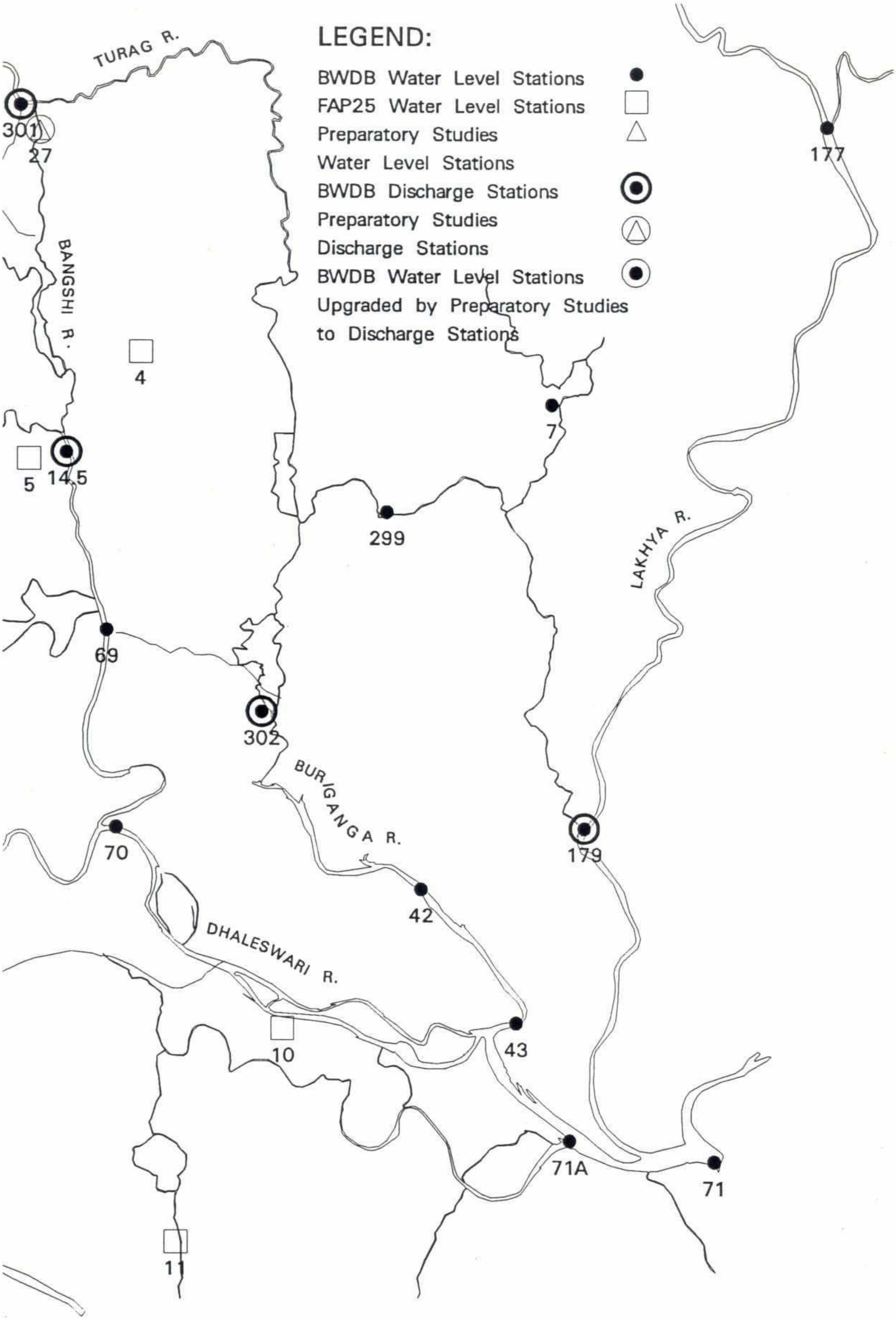
Figure A.7 **NORTH CENTRAL REGION**



MAP SHEET 5

Figure A.8 **NORTH CENTRAL REGION**

97



MAP SHEET 6

Figure 2.8 **NORTH CENTRAL REGION**

A.3.3 Data Collection by CPP, Tangail

Topographic Data

All the cross-section profiles of khals surveyed in 1991 and after have been checked and included in the 1993 MIKE11 model.

Prior to the wet season of 1993, excavation was carried out of 3.575 km of the Binyafair Khal, starting at Santosh, of the Gaizabari Khal (2.402 km) and the Chilabari Khal (3.322 km). The changes resulting from these excavations have been included in the cross-section profiles of the 1993-model.

In accordance with the FMM methodology, the flood plain cross-section profiles will be derived from a DEM. A test has already been performed using the FAP 19 DEM which was derived from BWDB mapping. In July, 1993, owing to the availability of 1991 FINNMAP 1:10,000 scale photomaps, a new DEM was digitised and has subsequently replaced the previous version. It is now possible to extract up-to-date flood plain cross-section profiles.

The main embankment elevation data (except SC-E1) are available.

For the SC 9, 10 and 11 road locations and beel location, depth and extent data are available. Additional measurements will be carried out in these and other sub-compartments by FAP 20 commencing in the 1993 wet season.

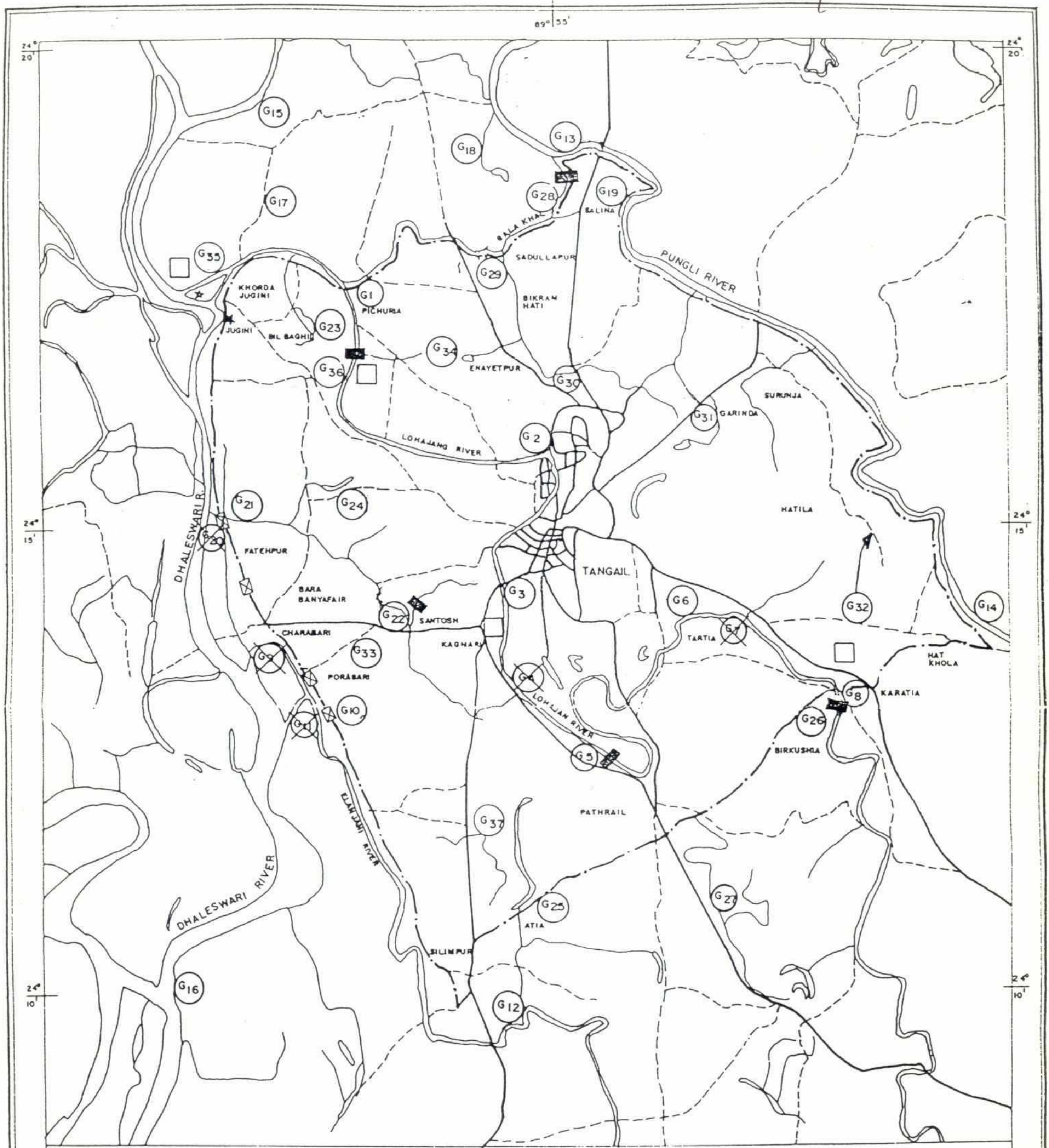
Hydrometric Data

The predominant source of data for the FMM of Tangail area is FAP 20 and available water level, rainfall and groundwater level data of 1992 have been collected. (Figure A.10).

During the wet season of 1993 the water level has been observed at 32 locations in- and outside the Tangail Compartment (Table A.14). Presslogs have been installed at G35, G36, G3 and G8. The water level data of the months May (partly), June, July and August of these locations and the rainfall data of station R2, Atia, already have been made available and have been checked. The monthly availability and checking of the data improves the quality significantly. (Figure A.11).

During the months July, August and September of 1993 discharge measurements have been carried out every week at 5 locations.

Groundwater levels are measured at 5 locations in the Tangail Compartment.



LEGEND:-

PROJECT BOUNDARY

HIGHWAYS

LOCAL ROAD

RIVER & KHAL

GAUGE LOCATION G_{21}

DISCHARGE MEASUREMENT LOCATION

NEW MEASURING STAFFGAUGE– G_{35} G_{36} G_{37}

1993 PROGRAMME

JUGINI ★

NEW PRESSLOG POSITION– □

GAUGE LOCATION DISCONTINUED AFTER 1992 ⊗

MINISTRY OF IRRIGATION, WATER DEVELOPMENT AND FLOOD CONTROL
BANGLADESH WATER DEVELOPMENT BOARD
FLOOD PLAN COORDINATION ORGANIZATION

COMPARTMENTALIZATION PILOT PROJECT
FAP 20

LOCATION OF WATER LEVEL MEASURING STATIONS, DISCHARGE MEASUREMENTS AND PRESSLOGS, 1993

Consultants: Euroconsult, Lahmeyer Int, Bets Ltd, HCL.

Drawn by: K. Rahman	Checked by:	Fig/Drg No. A.10
Date:	Date: Jan. 1994	

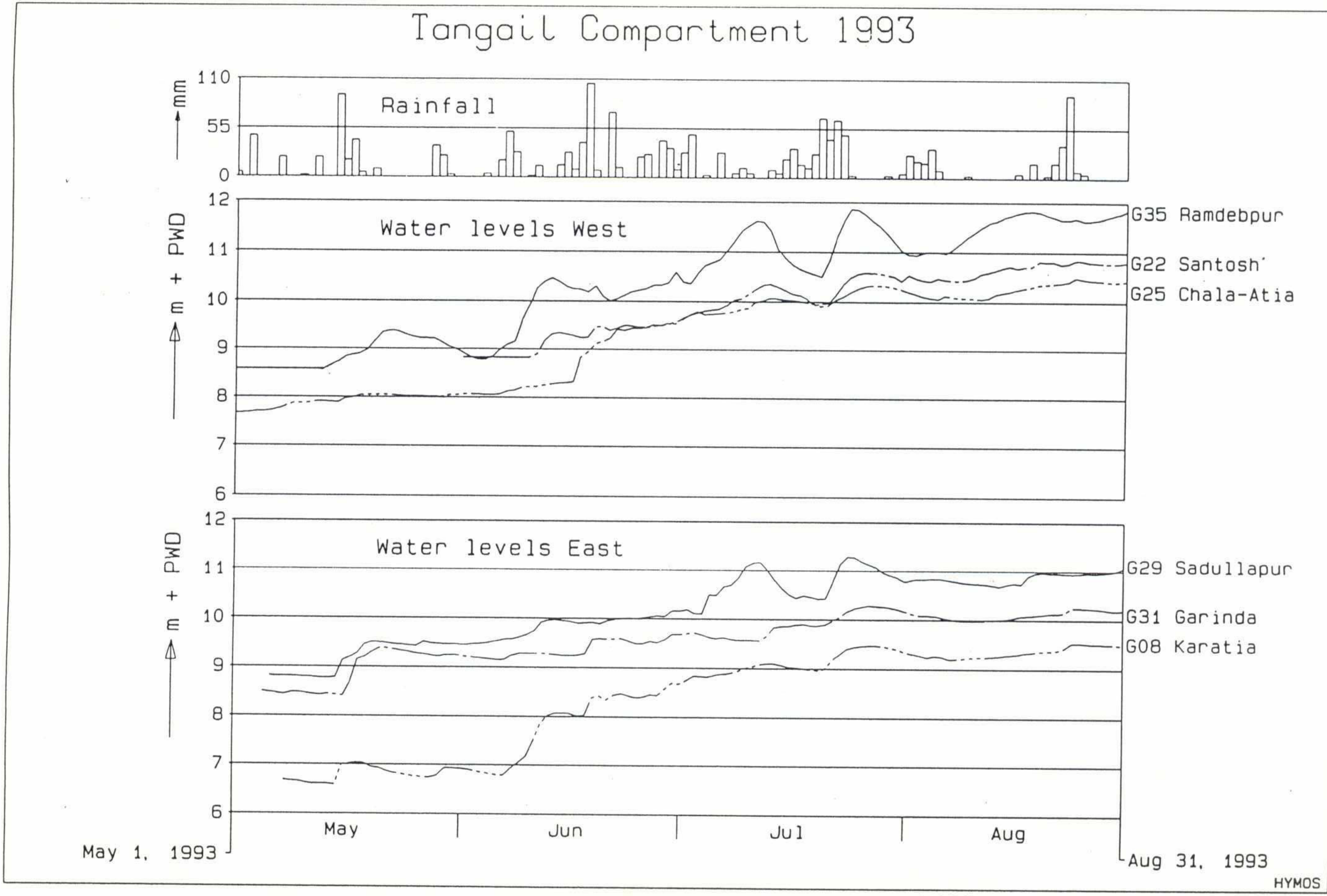


Figure A.11 CPP Rainfall and WL Data (1993)

A.4 Data on CPP

Table A.12 CPP Discharge measurement locations 1993

No.	River/Khal	Location
1	Gala Khal	N. of Rasulpur (gauge station G28)
2	Lohajang River	Dithpur (gauge station G36)
3	Lohajang River	Deojan (gauge station G5)
4	Lohajang River	Karatia (gauge station G8)
5	Gaziabari Khal	Santosh (gauge station G22)

Table A.13 CPP Groundwater level stations

No.	Name	Data Collected
TA03	Fatehpur	1987-92
TA08	Panchelachine	1987-92
TA09	Aditangail	1987-92
TA35	Akurtakur	1987-92
TA39	Suruj	1987-92

Table A.14 CPP water level gauge stations in the Tangail Compartment and adjacent areas.

Gauge 92/3	91	River/kahl/beel	Place	Zero value (m+PWD)	Years
G1		Lohajang River	Pichuria	8.36	91/2/3
G2		Lohajang River	Tangail Town	7.69	92/3
G3*/	G2	Lohajang River	Kagmeri bridge	7.24	91/2/3
G4		Lohajang River			92
G5		Lohajang River	Deojan	7.86	92/3
G6		Lohajang River	Nagar Jalfai	6.81	92/3
G7	G3	Lohajang River			91/2
G8*/	G4	Lohajang River	Karatia	5.78	91/2/3
G9		Elanjani River	Charabari		92
G10		Barabelta Canal	Barabelta	9.48	91/2/3
G11		Elanjani River	Barabelta		92
G12	G8	Elanjani River	Goziabari	5.74	91/2/3
G13	G10	Pungli River	Pauli	7.11	91/2/3
G14	G11	Pungli River	Nothkola	6.41	91/2/3
G15		Chowdury Maloncho Khal	Chowdury Maloncho	10.11	92/3
G16		Dhaleswari River	Shubarnotholi	7.32	92/3
G17		Beel Ghaghorjan	Ghaghorjan	8.69	92/3
G18		Floodplain	Bara Basalia	9.82	92/3
G19		Beel E1	Salina	8.96	92/3
G20		Old Dhalaswari River	Fatehpur		91/2
G21		Binyafair Khal	Fatehpur	10.24	92/3
G22	G5	Binyafair Khal	Santosh	9.00	91/2/3
G23		Beel Baghil	Baghil	9.28	92/3
G24		Panch(Ghatakbari) Beel	Dinya Shibram	8.49	92/3
G25	G7	Beel Atia	Chala Atia	7.65	91/2/3
G26	G8	Birkushia Canal	Birkushia	7.43	91/2/3
G27		Beel Rupshi	Sheoratoil, Rupshi	8.28	92/3
G28	G14	Gala Khal	Rasulpur	8.62	91/2/3
G29		Sadullapur Khal	Sadullapur	8.21	92/3
G30		Sadullapur Khal	Enayetpur	8.02	92/3
G31	G9	Gharinda Khal	Gharinda	7.87	91/2/3
G32		Beel Garasin	Namdar Pungli	9.62	92/3
G33		Floodplain	Rakhitbelta	9.79	92/3
G34		Enayetpur Beel	Magur Ata	9.31	92/3
G35*/		Lohajang River	Shibpur (Ramdebpur)	8.55	93
G36*/		Lohajang River	Dithpur	9.12	93
G37		Baruha Khal	Bhurbhuria	9.09	93

bto

A.4.1 Ground Survey for Radar Images

FAP 25 has participated in the field campaigns for ground truthing of satellite radar imagery coordinated by FAP 19. FAP 25 were responsible for the field campaigns in two areas in the North Central Region, on 31 July and 28 August, 1993 to coincide with the passage of ERS - 1 over the region.

Two survey teams were constituted from FAP 25 to record the information relevant for ground truthing. One of the teams moved along the Dhaka - Aricha highway and the other team worked along the Dhaka - Tangail road. The sites were selected on the basis of diversity of land use, covering such variations as paddy fields, jute plants and sugarcane, bridges, major buildings, forest coverage etc.

After selection of a site, coordinates were recorded from a GPS and the site was marked on SPOT images. Photographs were taken of the area and information on canopy coverage, percentage of area under cultivation, length of crops above water and depth of water with colour of water, (if sediment-laden), were recorded in a specified format. Details of weather conditions, height of trees, road width, side slope, roofing of the houses etc. were noted. This information, together with photographs were handed over to FAP 19 for use in the "calibration" process.

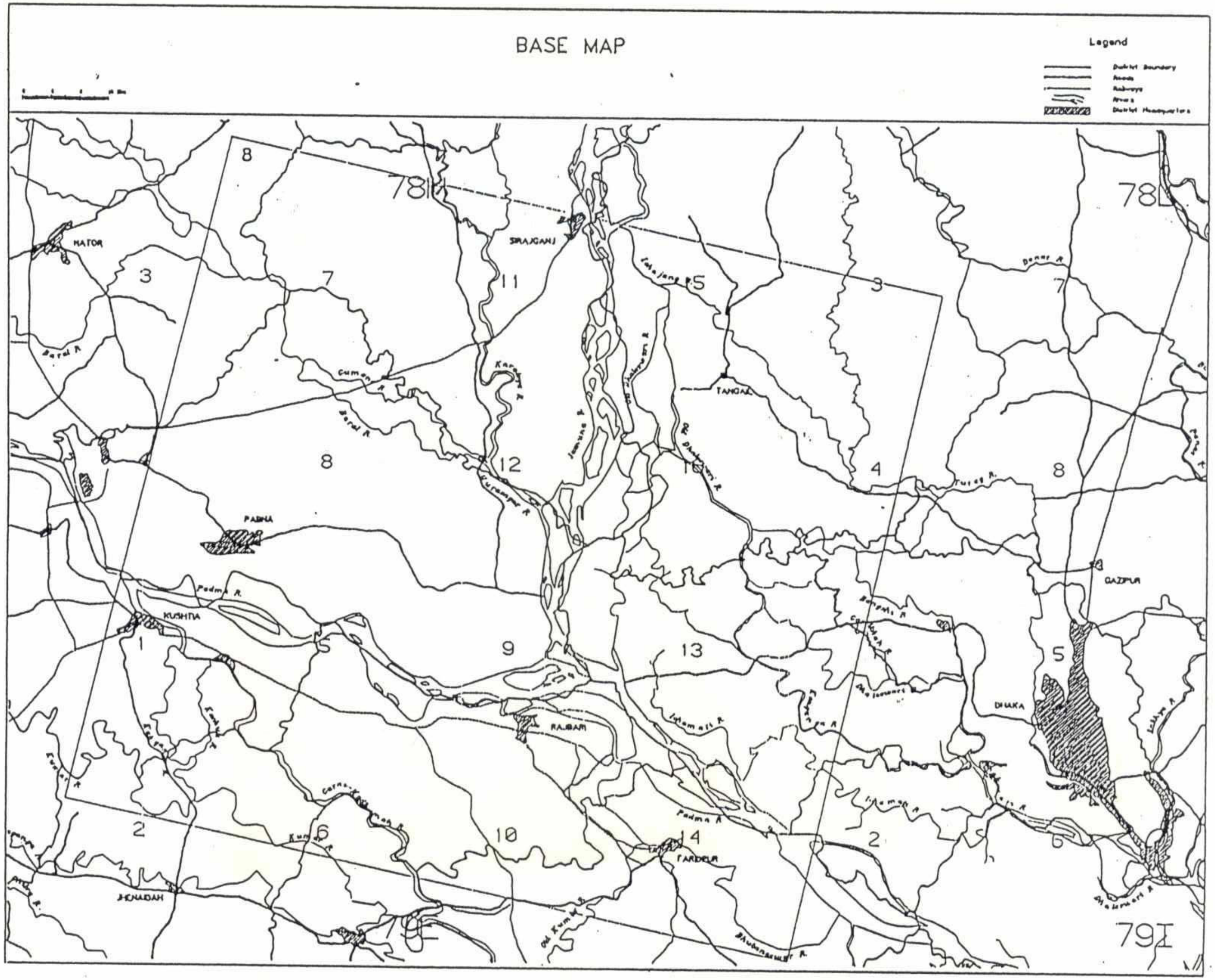


Figure A.12 Ground Coverage for Radar Satellite