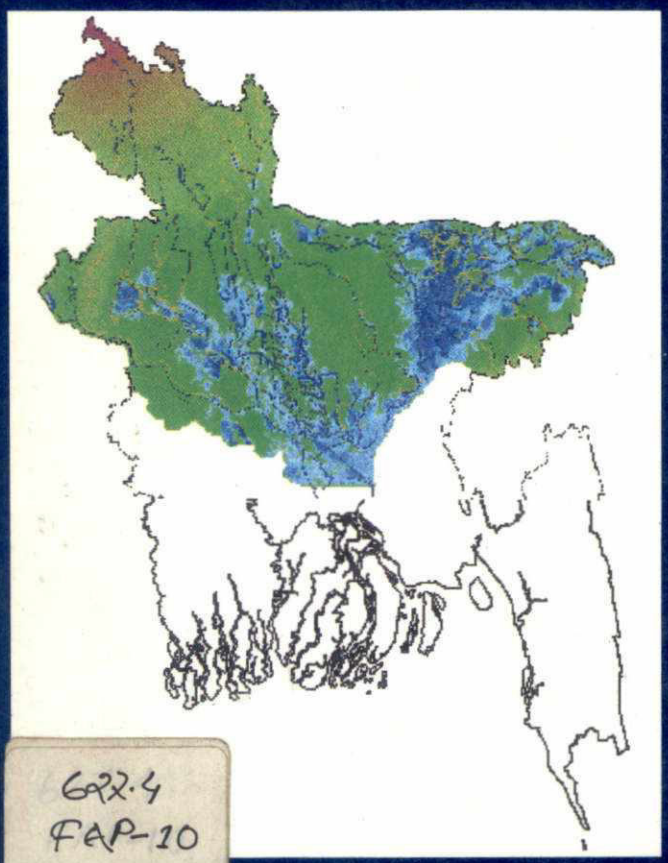
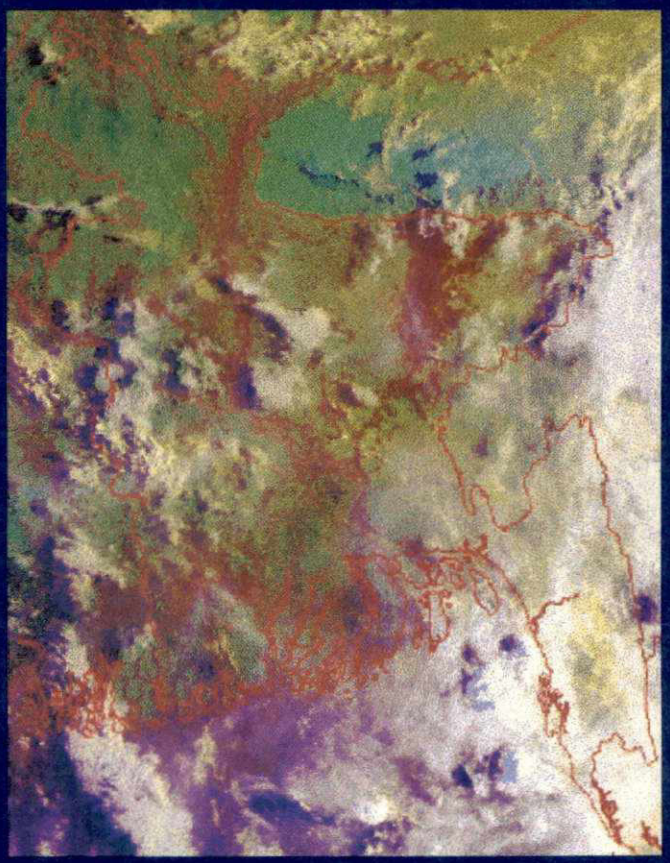
EXPANSION OF FLOOD FORECASTING AND WARNING SERVICES

Final Report

December 1997





BANGLADESH WATER DEVELOPMENT BOARD

FLOOD FORECASTING AND WARNING CENTRE

Consultants: Danish Hydraulic Institute
Surface Water Modelling Centre

EXPANSION OF FLOOD FORECASTING AND WARNING SERVICES (FAP10)

List of Contents

APPENDICES

List of Figures

Abbreviations and Acronyms

ANN	Artificial Neural Networks
ArcView	proprietory GIS software package
BMD	Bangladesh Meteorological Department
BTT	Bangladesh Telephone and Telegraph
BTV	Bangladesh Television
BWDB	Bangladesh Water Development Board
C&I	Construction and Instrumentation Division of SWH
Danida	Danish International Development Assistance
DEM	Digital Elevation Model
DHI	Danish Hydraulic Institute
DMB	Disaster Management Bureau
FAP	Flood Action Plan
FAP10	Flood Forecasting and Warning Component of FAP
FAP11	Disaster Management Component of FAP
FAP19	Geographical Information System Component of FAP
FAP25	Flood Modelling and Management Component of FAP
FF	Flood Forecasting
FFWC	Flood Forecasting and Warning Centre
FFWRS	Flood Forecasting, Warning and Response System
GIS	Geographical Information System
GMS	Geostationary Meteorological Satellite
GoB	Government of Bangladesh
JICA	Japanese International Cooperation Agency
JRC	Joint River Commission
MIKE11	River Modelling System Developed by DHI
NAM	Precipitation Runoff Model
NASA	United States National Aeronautical and Space Administration
NGO	Non Government Organization
NOAA	
NPD	National Project Director
PC	Personal Computer
SAARC	South Asian Association for Regional Cooperation
SPARSSO	Space Research and Remote Sensing Organization
SSB	Single Side Band radio
SWH	Surface Water Hydrology Directorates of BWDB
SWMC	Surface Water Modelling Centre
UNDP	United Nations Development Programme
WAPDA	Water and Power Development Authority
WMO	World Meteorological Organization

Glossary

Magic Box a semi-automatic device with simple manual operation designed to improve the transmission of real time data from the gauging stations to FFWC (also referred to as a **data box**)

Flood Watch an ArcView project containing the sequential procedures for real time stations status display, flood forecasting, and thana status mapping; as an alternative, the procedures may be executed from the icons in the Flood Watch group

real time a process that it is completed in real time is a process whose time of completion from start to finish is completely predictable, and is generally completed in a short time

SuperModel an integration of the General Model and the North West, North Central and North East Regional Models (from SWMC) prepared and adapted for flood forecasting purposes

telemetry the transmission of data in real time from the gauging station to the central operations office; in the context of flood forecasting in Bangladesh, it is used to describe the transmission of data by microwave link

updating procedure whereby the model forecasts are amended to make maximum use of the latest available real time data from the field to produce the most accurate forecasts

Cover Page The front cover shows the predicted area of inundation forecast in Bangladesh (left) alongside the satellite image (right) taken at the time for which the forecast was made (0600, 23rd July 1997). The flooded areas in the prediction are shown in different shades of blue, indicating depth. The flooded areas in the satellite photograph are shown in red.

SUMMARY

Introduction

Bangladesh is at the downstream end of one of the world's largest river systems, with 90% of the catchment lying upstream of its international borders. The country has vast flood plains which are both fertile and densely populated. Flooding is an annual event with both beneficial and adverse effects. Comprehensive large scale flood protection is neither economical nor environmental. Non-structural measures to mitigate the damaging effects such as flood forecasting and flood preparedness assume major importance.

Flood forecasting is the prediction of water levels, areas and depths of flooding in rivers and flood plains either qualitatively or quantitatively. Flood warning is the preparation of the forecasts in a meaningful format which can be numerical or visual. In order to be effective, the warning has to be disseminated: to the media for broadcast, to concerned organisation who are prepared to provide relief, and to the vulnerable communities.

The Flood Forecasting and Warning Centre (FFWC) under BWDB was established in 1972 and is located in the WAPDA building in Motijheel, Dhaka. In cooperation with the BWDB Hydrology Directorates, and with support from UNDP/WMO and Danida, it prepares status reports and flood forecasts for 16 locations in Bangladesh. There is a network of 60 stations reporting rainfall and water levels in real time to the Centre; the forecasts are based on the results of an advanced mathematical model.

At the outset of the present project, there was a perceived need for improved and expanded capability to provide more detailed and meaningful information, and better dissemination. The three year project with the objective of improved information to aid national preparedness for floods and to mitigate flood impacts commenced in January 1995 with assistance from Danida.

The Danish Hydraulic Institute (DHI) were the main consultants. The Surface Water Modelling Centre (SWMC) provided support to the modelling activities, while the World Meteorological Organisation (WMO) was subconsulted for the dissemination activities (taken over directly by DHI in 1997), in particular liaison and coordination with the Disaster Management Bureau (DMB) under the Ministry of Relief and Rehabilitation. A separate component to install a microwave based telemetry system was funded by the Japanese International Cooperation Agency.

Flood Forecasting and Warning Operations

The preparation of flood forecasts and the issue of flood warnings follows a sequence of operations:

- data transmission and reception
- satellite image reception and processing
- flood forecasting
- preparation and issue of flood warnings

The procedure is computer based, and has been highly automated ensuring each operation is correctly executed. This also leaves the staff of FFWC with more time to concentrate on the components that still require their judgement and experience. Each of the activities is described in the following sections.

A Flood Forecasting and Warning Action Plan sets out the basic operations of FFWC, consolidating the new procedures developed in the course of the project. The project has also prepared a Flood Warning Manual containing the framework for a comprehensive and integrated approach to flood preparedness, warning and response, and is intended to inform and guide those working in this area.

Institutional Aspects

Considering the importance of its operations, FFWC has a relatively lowly position within BWDB. It was part of the agreement between Government of Bangladesh and Danida that its status would be raised, having its own budget, greater recognition of its services, more effective liaison with outside bodies and an increased sense of value among the staff who work in the Centre.

While the Centre's activities would be less during the dry period from October to March compared with the intensive monsoon period, there is a number of review, maintenance and training tasks which should be carried out. To this could be added low flow forecasting.

Data Transmission and Reception

Clear and dependable real time data transmission and reception are a vital component of the flood forecasting process. At the start of the project, 60 stations reported real time rainfall and water level by voice radio to FFWC. Readings are taken manually from the gauges, and hand carried the one to five kilometres to the radio station.

The various types of radios were outdated and spare parts not available. The stations operate from 1st April to 30th September transmitting the daily rainfall and three hourly water levels to FFWC between 0800 and 0900 hours. The single frequency used is congested and communication is not clear.

Several means were considered to improve the transmission using: satellites, public telephone and traditional short wave radios with a modem. A satellite based system would be economical, reliable and easy to maintain, but was dismissed as apparently Bangladesh Telephone and Telegraph are not ready to handle satellites for domestic communication. The existing telephone system is not reliable for use in emergencies; the near advent of global satellite communication will change this, and must be the favoured option for the future.

As a result the traditional short wave radio was selected: a new digitally capable unit was chosen to operate in conjunction with a modem for direct digital transmission of the real time data to FFWC. The system operates in conjunction with a data box, dubbed a Magic Box, which functions both as a notebook for the gauge reader and an intelligent modem for the radio.

In 1996 and 1997, 35 new radios and Magic Boxes were deployed in the field, with two in FFWC and one in BWDB, Green Road where monitoring and maintenance is based. Twenty-two radios are available as spares and for further installation. Training was provided to staff at all levels: gauge readers, radio operators and maintenance staff, the later in Dhaka, in the field, in the UK (where the radios are manufactured) and in Denmark.

While the established system works well technically, there are numerous administrative problems related to the uncertain status of field staff and non-payment of salaries, replacement of field staff, lack of power supply to stations, and failure to maintain and charge batteries. The most serious is the transfer of the trained maintenance technicians in June 1997: there are now no trained staff available to maintain the radios and the transmission system.

Data Exchange with India

The major constraint to further improvement in the accuracy and lead time of the forecasts is availability of real time water level data from stations on the major rivers upstream. While significant improvement in the receipt of data from nearby stations in India came about in1997, real improvements require the receipt of continuous real time data from stations as far upstream as Alahabad on the Ganges and Gowahati on the Brahmaputra. The speed and ease of transmission could be improved with e-mail, direct from the monitoring station to Dhaka.

Satellite Image Processing

Remote sensing information for flood forecasting comprises satellite images in various spectra and ground based radar images. They are used to provide rainfall forecasts, and images of flood inundation. New satellite equipment was installed to receive data from NOAA satellites. Using information downloaded from the Internet, the satellite antenna on the roof of the WAPDA building is steered by a PC, which automatically receives the images as each satellite passes overhead.

Two satellites are presently active: each passes overhead twice a day, and four real time images are available. The satellite images cover visible light, infrared and thermal spectra. Software programs process the acquired images to provide information for rainfall forecasting and inundation areas. The staff of FFWC have been fully trained, both in Dhaka and in Denmark, and are fully conversant with the operation of the system. There is potential for more development work to improve the processing and obtain quantitative rainfall and inundation information.

SuperModel Forecasting

The need for improvement to the mathematical forecasting model has been primarily driven by more forecast locations and area inundation forecasting. The initial plan was to set up local inundation area forecasting at two or three pilot areas; GoB requested inundation forecasting for the entire northern area of Bangladesh, at a coarse level.

The MIKE 11 flood forecasting model is the largest hydrologic/hydrodynamic model ever constructed. It is termed the SuperModel and covers the entire northern half of

Bangladesh, an area of 82,000m^2 with 7,270km of rivers and flood plain. The hydrologic component extends into India.

The forecast is made running the model for a period starting around five days before the time of forecast, and three days into the future. An updating procedure ensures the maximum information available from the real time observations is utilised. The basic results are water levels and discharges throughout the model area up to 72 hours ahead.

A visual presentation of the results showing the forecast area and depth of flooding is made through the medium of Geographic Information Systems, incorporating a digital model of the terrain. The topographic data with a 1.0km resolution are relatively coarse. The picture presented, while not highly accurate, gives a good overall impression of the state of flooding in the country,

Mathematical modelling is the most technically demanding of all the tasks carried out by the staff of FFWC. They have received comprehensive training in Dhaka and Denmark. Despite its necessary complexity, the staff are fully capable of operating the model. While the model is robust, it can and does occasionally fail. Usually the problem is incorrect data input which have not been trapped by the quality control procedure. The problem has to be recognised and dealt with promptly. The FFWC staff need to acquire more experience in this area.

The rivers of Bangladesh are morphologically dynamic. Every three years or so the model should be updated with the most recent cross section and topographic surveys. FFWC staff will need assistance in this area; SWMC would be in the best position to provide this service.

Preparation of Flood Warnings

The preparation of flood warnings has been enhanced through the automatic generation of simple textual flood warning messages for broadcast over radio and television, and forecasts in a visual format. The latter are forecast area inundation maps, and thana level flood maps based on the forecast percentage of area flooded. A special thana map has been prepared for broadcast on Bangladesh Television.

The Internet is growing as a medium for communication. An outline design has been prepared for a FFWC Internet site to publish the daily forecasts, with emphasis on the visual presentations, and provide general information. While access to the Internet is presently limited in Bangladesh, potential users are: the Prime Minister's Office,

government departments, district offices, NGOs and international donor and funding agencies both inside and outside Bangladesh. The site could also receive feedback and comments from interested parties.

Dissemination of Flood Warnings

FFWC has developed a strong capability in flood forecasting, producing a range of textual and visual information daily during the monsoon period. None of the new message formats has been approved by the Steering Committee, and is consequently not been tested outside FFWC. The special thana maps prepared for BTV were similarly not broadcast.

In 1992, the Disaster Management Board was established with a mandate including flood warning dissemination. Despite attempts by the project, no effective liaison has been established between FFWC and DMB.

To complement the new warning messages, flood marker posts were set up in four villages in 1996. The marker posts relate to the warning messages, and give villagers an impression of the degree of flooding they can expect in coming days. As the new warning messages were not actually broadcast, the tests which included education and publicity material were compromised, but yielded some useful results for future studies.

Flash Flood Forecasting

Whereas normal flooding in Bangladesh develops over a number of days or even weeks, flash floods are more dynamic and occur in a matter of hours following a rainstorm. They occur typically along the border with India in the east and in the north west.

A new procedure was developed, based on the collection and transmission of more frequent real time rainfall and water levels, and the application of pattern recognition techniques to boundary estimates. Two river systems with different characteristics were selected for testing: the Karatoya-Atrai in the north west, and the Manu in the north east.

Owing to difficulties obtaining up to hourly data from the new stations (see Data Transmission and Reception), only limited testing was carried out. While the basic

procedure has been shown to work, considerable more work is required in the area of boundary estimation.

Conclusions and Recommendations

The activities of FFWC have been appropriately expanded. The forecasting information prepared is vastly improved. The duties and responsibilities of FFWC are crucial to the ability of Bangladesh to prepare and cope with flooding. The status of the Centre and its staff should be raised to increase staff moral and to increase the importance accorded to its output. The Action Plan aimed at maintaining and enhancing the quality of the existing services, including a comprehensive annual review, should be brought into use.

The data transmission and reception facility installed makes best use of appropriate technology for Bangladesh. Further developments should make use of satellite technology, specifically the global communication network which will be established in the next few years. There are severe administrative problems within BWDB which seriously handicap the present data collection and transmission system.

FFWC has the capability to receive satellite images which among other things show rain clouds over and areas of inundation in Bangladesh and the neighbouring region. Further work on processing can extend the information which can be extracted.

The SuperModel is used by FFWC to forecast floods with acceptable accuracy up to 72 hours ahead. Owing to the dynamic morphology of the rivers of Bangladesh, the model should be updated with new survey information. FFWC will need assistance from eg SWMC in this. The model can occasionally break down, usually owing to invalid data which have escaped the quality controls. FFWC need training in model troubleshooting.

The Flood Warning Manual incorporating the new warning messages should be (provisionally) approved by GoB, and brought into operation alongside distribution of the new visual flood forecasts: area inundation maps and thana flood severity maps.

Dissemination activities have only reached a preparatory stage. Cooperation with concerned agencies is required to gain acceptance of the more informative and meaningful warnings, eg with BTV, DMB and NGOs. FFWC should set up an Internet Site to complement other dissemination activities. The proposal giving extensive testing to the Flood Marker Posts should be implemented.

1. BACKGROUND

1.1 Flood Forecasting and Warning

Flood forecasting is the prediction of water levels and possibly also areas and depths of flooding in rivers and flood plains following heavy rainfall or snow melt in the catchment upstream. The forecasts may be qualitative, eg moderate flooding, severe flooding, catastrophic flooding, or quantitative providing actual levels, depths and areas of flooding.

Flood warning is the preparation of the forecasts in formats that are meaningful and useful to those organisations and individuals who will take action as a result of the forecast. The warnings may take the form of tables of locations and forecast levels, or map based showing the area and depth of inundation.

The concerned organisations will generally be the media for general broadcasting, and government departments and non-government organisations engaged in the provision of relief to the affected populace, and the protection of the basic infrastructure. Individuals are the people living in the towns and villages of Bangladesh which are vulnerable to flooding.

Dissemination of the Flood Warnings to concerned organisations can be accomplished by normal means of communication, ie telephone and telefax, and radio, though these are generally under stress during severe climatic conditions or widespread disaster. The Internet is also a useful medium, particularly for international funding agencies and news agencies. The vulnerable populace can be informed rapidly and directly by television and radio.

In Bangladesh the people most severely affected are those in the towns and villages vulnerable to flooding. As the basic infrastructure of Bangladesh is weak, and the flooding is frequently widespread, it is often the affected people themselves who will be the only ones taking action to mitigate the damaging effects of flooding. It is therefore important that the Flood Warning information reaches them in good time, and in a meaningful format.

1.2 Need for Present Project

1.2.1 Background

Bangladesh is at the downstream end of two of the world's largest rivers, the Ganges and the Brahmaputra, both with their origins in the Himalayan mountain range. More than

90% of the catchment area of these rivers lies outside Bangladesh, mainly in India (see figure 1.1). The topography of Bangladesh is formed by the rivers, and is primarily a delta with extensive flood plains, which are fertile and densely populated.

Bangladesh experiences an intensive monsoon from May to September, and flooding is an annual occurrence. In extreme events, the flooding covers up to one third of the land area. While embankments have been constructed along certain river reaches to alleviate flooding, comprehensive protection is not practical: confining the flood waters raises levels within the river channels, the rivers are morphologically active, and are liable to undercut embankments. Breaches of the embankments are frequent, often causing more damage and personal injury than if there were no embankment.

Non-structural measures can be particularly effective in mitigating the damaging effects of flooding in Bangladesh, and flood forecasting and warning are primary means to achieve this in a highly cost effective manner.

1.2.2 Flood Forecasting and Warning Centre

The Flood Forecasting and Warning Centre (FFWC) of the Bangladesh Water Development Board (BWDB) was established in 1972. The FFWC is a division of the Directorate of Surface Water Hydrology-II, which is in turn under the control of the Chief Engineer, Hydrology.

The centre has received more or less continuous support from UNDP in the period from 1981 to 1992 through projects executed by the World Meteorological Organisation (WMO). The outputs in this period have included:

- an improved and extended real time data collection system
- a flood forecasting model installed and operational
- improved communication facilities
- staff training

In the course of the UNDP/Danida funded project (1990 to 1994), training was given to FFWC staff on the principles and operation of MIKE11 in Denmark, and MIKE11 was installed in FFWC and set up for operational testing for 24 hour flood forecasts in Bangladesh.

1.2.3 Future Development

Given the importance of non-structural measures in mitigating flooding in Bangladesh, and in particular flood forecasting and warning, the following requirements were identified to improve the service provided by FFWC:

- improved and expanded capabilities for the centre to function as an effective flood information centre
- extend the coverage of the flood monitoring and forecasting to a wider area, providing more detailed and meaningful information
- improved dissemination of the flood warnings, developing institutional and public awareness, particularly at the grass roots level

1.3 Project Implementation

Terms of Reference for the present project as a component of the Bangladesh Flood Action Plan (FAP10) were first prepared at the end of 1992. An appraisal was conducted by Danida in November 1993, and the project finally got underway in January 1997. The linkage to the Disaster Preparedness Programme (FAP11) of the Disaster Management Bureau in the Ministry of Relief and Rehabilitation was considered important for the widespread dissemination of the flood warnings to the grass roots level.

The project is organised in four modules:

Module 1: Coordination and monitoring, integration of outputs from other activities, improved real time data collection and transmission, staff training.
Module 2: Updated and improved modelling tools.
Module 3: Support to the (executing agency for FAP11) for improved warnings and public dissemination, especially to the grass roots level in Bangladesh society.
Module 4: Installation of telemetry system for real time data transmission.

Modules 1 to 3 comprise a three year project, which commenced in January 1995, under the direction of a National Project Director from BWDB. The modules have been executed by the Danish Hydraulic Institute (DHI), with financial assistance from Danida. DHI subcontracted the Surface Water Modelling Centre (SWMC) for local consultant support on module 2, and WMO was subcontracted to execute module 3.

Module 4 is executed independently with financial assistance from JICA.

1.4 Objectives

The development objective is the provision of improved information to aid national preparedness for floods and to mitigate flood impacts.

The immediate objective of the project is support to the Flood Forecasting and Warning Centre in order to improve performance, with regard to increased mobilization of local resources and efficient utilisation of resources available.

1.5 Outputs

In line with the project objectives the anticipated outputs are:

- real time flood forecasts at regional level and provision of real time coarse area-inundation forecasts for the major part of the Northern Regions
- a pilot forecast system for two flashy rivers
- improved data exchange with countries in the Ganges-Brahmaputra-Meghna basins
- a public awareness programme on the availability and understanding of flood warning and forecast information
- trained staff in all areas of forecasting and warning activities
- improved institutional structure within FFWC to provide and sustain the established services

The project objectives, outputs, activities and inputs are incorporated in a logical framework matrix (see Appendix I). The logical framework matrix provides a structured approach to project planning, execution and monitoring. It is based on the Plan of Operations, prepared in November 1996.

1.6 Structure of Report

The following Chapter 2 of the report contains a review of the project based on the Logical Framework Matrix. Chapter 3 provides an overview of the entire flood forecasting, warning and dissemination process. The following Chapters 4 to 10 describe the various components in the process from real time data collection through to dissemination of the warnings.

These chapters are structure similarly, starting with the procedure in use before the project started, the process of development under the project, the present procedure now in operation, and finally conclusions and recommendations for further development.

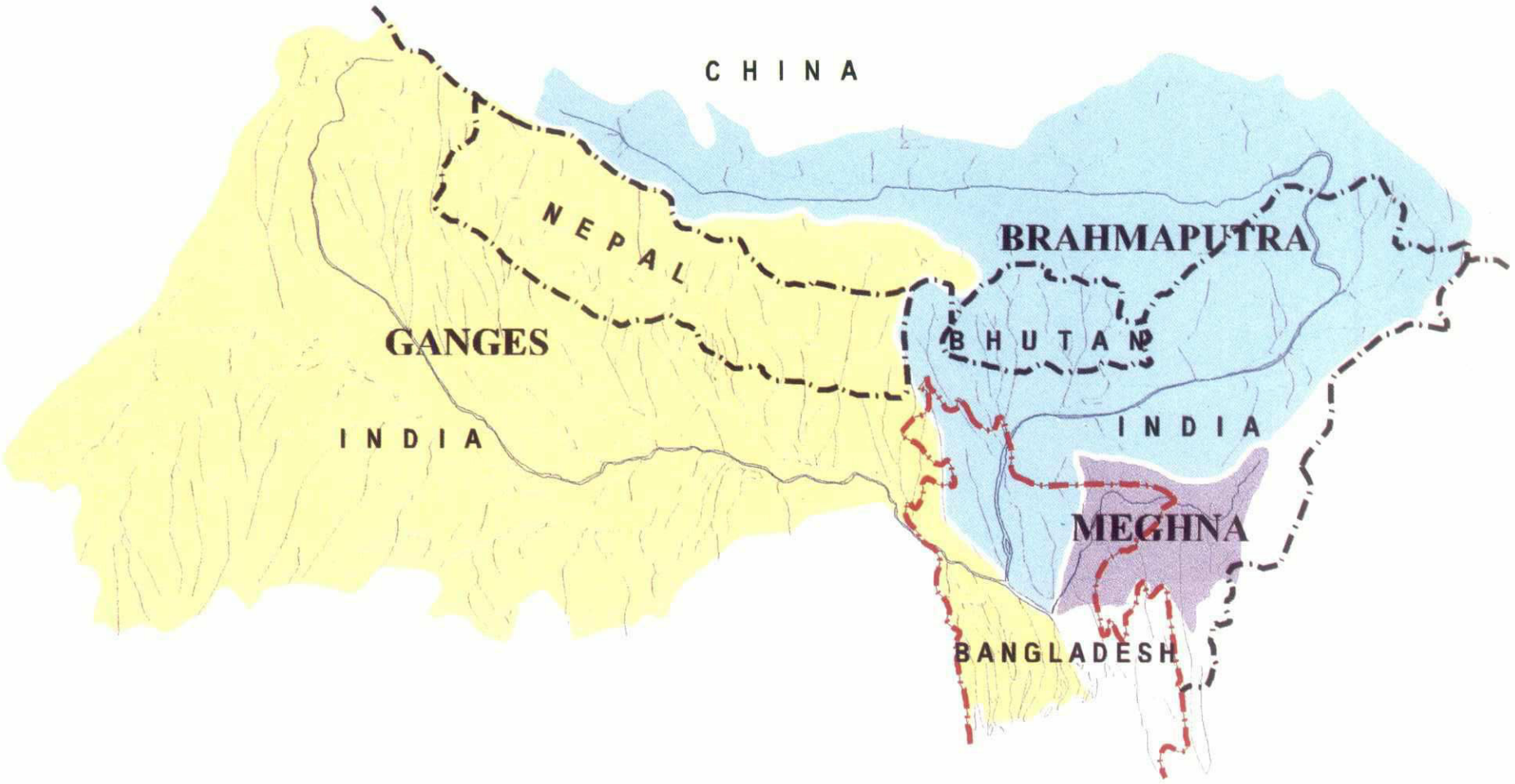
Chapter 11 presents the overall conclusions and recommendations for the future flood forecasting and warning operations.

1.7 Additional Documents

In addition to the Inception and Quarterly Progress Reports, the project has prepared a Flood Warning Manual for Bangladesh, reports on the Public Awareness Programme, and manuals for the operation of the entire system and its components. The full list of documents is presented in Appendix II.

CATCHMENT MAP

FIGURE 1.1



Ganges, Brahmaputra and Meghna River Basins

2. PROJECT REVIEW

2.1 Introduction

The following sections presents a summary of the planned outputs and actual achievements of the project, based on the Logical Framework Assessment Matrix (Appendix I), in terms of the planned output, assumptions, verification, difficulties encountered and programme changes. A summary of the project's achievements is presented in the table on page 2-7.

2.2 Real Time Flood Forecasting

Planned Output

Real time flood forecasting has been carried out using the SuperModel (based on regional level models), including the provision of coarse area inundation forecasts for the entire forecasting area. New powerful PCS have been procured and a network established linking all computers in FFWC.

The real time station network has been equipped with a total of 38 data boxes and Orion 7000 radios installed in the field, in FFWC and in C&I Division. Twelve are available as spares.

A satellite receiver has been installed in FFWC with the capability to download images of Bangladesh and the near basin from the presently active NOAA12 and NOAA14 satellites every 6 hours. The FFWC are trained to process and interpret the images to give qualitative rainfall forecasts, to identify the flooded areas and to add additional satellites as they become active.

Assumptions

Data would be available from new real time stations, and good topographic data would be available.

Verification

The number of locations for which forecasts are issued would be increased from 16 to 30, including forecasts on secondary rivers.

Difficulties Encountered

Changes in staffing both in the field and in the C&I Dhaka based technicians have necessitated retraining. There are several unoccupied posts among the gauge readers and radio operators. Transfers have meant that none of the current C&I technicians are trained in maintaining the data transmission network. Several radio stations do not have a power supply, and batteries are not maintained charged.

The total number of forecasting points is 25. Irregular transmissions from five stations meant these locations could not be included as forecasting points.

Teething problems with the flood inundation mapping at the beginning of the 1997 monsoon meant that the maps were not produced until August.

The satellite receiver can presently receive images from NOAA12 only, and parts of the steering mechanism have corroded. Replacement parts will be supplied under guarantee by the manufacturer.

Programme Changes

The original output was detailed inundation mapping for selected areas for which detailed topographic data were available, eg Tangail. This was changed to coarse mapping for the entire forecasting region at the request of the steering committee in August 1995.

The satelllite reception equipment replaced assistance to BMD in maintaining their Dhaka meteorological radar station. Time spent identifying problems with the receiver meant that it was not possible to calibrate the received images to provide quantitative rainfall forecasts.

2.3 Flashy River Forecasting

Planned Output

The flash flood forecasting system for two flashy rivers has been established on a pilot basis. Only limited testing was possible for the north west flash flood model, and none for the north east.

Assumptions

Frequent real time rainfall and water level data would be available from the flashy river catchments.

Verification An established forecasting system on two flashy rivers.

Difficulties Encountered The difficulties with the real time data transmission discussed in the previous sections proved more serious on the flashy catchments. These are more remote and have heavier demands in respect of more frequent data collection and transmission, up to hourly.

The batch of radios for installation in the new flash flood forecasting stations were delivered several months late by the manufacturer, and not installed until August 1997. There were no significant flash flood events following this.

2.4 Improved Data Exchange with India

Planned Output Improved data exchange with countries in the Ganges-Brahmaputra-Meghna basin was planned. Significant improvements in the data exchange with India occurred in the course of the 1997 monsoon, with India fulfilling the agreement. The means of transmission, ie telex from Delhi via BMD, and the spacial and temporal variation in data transmitted, remain unchanged.

Assumptions India agrees to improve the data transfer to Bangladesh.

Verification Comparison between the data received now and the data received at the start of the project.

Difficulties Encountered The expatriate consultant made two trips to India visiting the Central Water Commission and the Ministry of Water Resources. Discussions showed a willingness on the Indian side to improve the transmission, possibly by e-mail. The matter would have to be agreed at the JRC. The project informed the JRC of developments, and requested that the matter be raised in June 1996 and again in June 1997.

The project was not informed whether the matter was raised in the JRC, or what the outcome was.

2.5 Public Awareness Programme

Planned Output

A Flood Warning Manual (including phased warning messages) and a Flood Forecasting and Warning Action Plan (incorporating formal Annual Review procedures) have been prepared, and given provisional acceptance by the Steering Committee (though this is not recorded in the minutes).

Education and publicity materials have been prepared and tested in conjunction with Marker Posts in the field at the grass roots level. Many useful lessons have been learned in this respect. A proposal is prepared for testing the dissemination through NGOs, intended for direct funding by donor(s) to NGO(s).

Additional flood warning information is conveyed visually as maps showing the forecast severity of flooding in individual thanas (also for television presentation), and flood inundation maps for the entire forecast area.

Assumptions

Good cooperation with the Disaster Management Bureau, approval of the Flood Warning Manual by GoB and cooperation among government agencies.

Verification

Increased awareness and participation by all stakeholders, in particular government agencies and NGOs; documented procedures introduced; phased level warnings introduced.

Difficulties Encountered

The UNDP financed Support to Disaster Management (FAP11) in DMB was curtailed and is currently being reformulated. The consultants had several discussions with DMB, but no formal cooperation was initiated.

The phased warning messages, and the new visual flood forecasts in the form of maps were not approved by the Steering Committee. The new warnings were not issued outside FFWC. Given that many of the existing developments are not formally approved, it has not been possible to carry out detailed long term planning for FFWC.

Programme Changes

As no action was being taken in any other quarter, the project proceeded to conduct its own dissemination testing. While the scope of the tests were limited, and the warning messages were not approved and not disseminated, some useful results were obtained which could be used to guide future work in this area.

2.6 Staff Training

Planned Output

Eight staff member in FFWC routinely work on the expanded flood forecasting and warning services. They have been comprehensively trained in all the tasks undertaken, and are fully capable to operate the system, both in Bangladesh and overseas. External support may be required for software maintenance.

Three officers of C&I Division received overseas training in the operation and maintenance of the data transmission and reception equipment. Gauge readers and radio operators, and in some cases guards, have received training in the operation and basic maintenance of the data box and Orion 7000 radios.

Assumptions

Trained staff do not leave FFWC or C&I.

Verification

Review of the data reception at FFWC, the condition of the real time field stations, the forecasts and the warnings produced in the course of the monsoon.

Difficulties Encountered

Many field stations do not receive the required support in respect of funds to carry out even very minor repairs, and staff salaries and electricity bills are not paid, resulting in a terminated power supply.

The three C&I Division technicians who received comprehensive training in the UK and Denmark were transferred at the beginning of the 1997 monsoon. There are many unfilled posts among the field staff, and trained field staff are frequently replaced.

Programme Changes

In 1997, additional training was provided to the gauge readers and radio operators who replaced the previous trained staff after the 1996 monsoon.

2.7 Improved Institutional Structure

Planned Output

The status of FFWC has not changed, and there is no improved institutional structure. FFWC has the trained human resources to provide and maintain the established forecasting services, though staff transfers remain a threat. Owing to transfer of trained staff, there are no technicians in C&I Division to maintain the data transmission.

Assumptions

The political support and will to expand the flood forecasting and warning services exists.

Verification

Comparison of the setup of FFWC now with that when the project commenced.

Difficulties Encountered

The deputy director still reports and applies for funds for individual items to the Director of SWH-II. The gauge readers are managed by SWH-I.

The C&I technicians who have been trained in the operation and maintenance of the data transmission and reception equipment were transferred at the beginning of the 1997 monsoon.

2.8 Review Summary

The project has met with mixed success in fulfilling its outputs and achieving its objectives. In a broad appraisal, improved information regarding the extent and accuracy of the forecasts is available in a variety of formats designed to be of value to the end users, ie concerned organisations and affected individuals. The actual dissemination of this improved information has improved little to that at the start of the project.

OBJECTIVES	ACHIEVEMENTS	COMMENTS
Development Objective Improved information to aid national preparedness for floods and to mitigate flood impacts.	Flood forecast information is available in a variety of formats directed at different media.	Recipients do not fully utilise the available information, owing to insufficient liaison with FFWC.
Immediate Objective Support to FFWC to improve performance with regard to increased mobilisation of local resources and efficient utilisation of resources available.	Support to FFWC has been provided in terms of enhancing human resources through training and joint development with DHI, and the provision of advanced yet appropriate technology.	FFWC staff are fully capable of operating the sophisticated system established. Assistance with maintenance will be required in future years. The consequence of present staff leaving the Centre for better prospects could be serious for continued operation.
Real time forecasting at regional level and coarse area inundation forecast for northern Bangladesh.	FFWC utilise the SuperModel daily to forecast water levels for 25 locations throughout the northern half of Bangladesh. Flood inundation maps are prepared showing areas and depths of flooding.	The complex process has been successfully highly automated, reducing the risk of error and enabling the staff to concentrate on areas such as boundary estimation where human judgement is still required.
Forecast system for two flashy rivers on a pilot basis.	Flash flood models have been set up for two river systems in the north west and north east. Only limited testing was made due to problems receiving the more intensive real time data.	Problems with real time data transmission are largely owing to a lack of basic support in the field from BWDB.
Improved data exchange with countries in the river basins.	The consultant's visits to India have revealed that there is a general willingness to improve the transmission of data from the upstream basins in India by, for example e-mail. Further action is required by the JRC at government to government level.	In practice, data exchange by the traditional methods has improved in 1997. Considerable scope for improvement in transmission times, dependability and regions covered remains.
Public Awareness programme of the availability and understanding of flood warning information.	The limited implementation of FAP11 in DMB, and lack of effective liaison with DMB and other organisations, has meant that the projects limited resources had little impact in this area.	A solid basis for proceding avoiding the difficulties of communicating within the government system has been put forward, and has found major support in many quarters.
Trained staff in FFWC.	The staff of FFWC have received comprehensive training throughout the three year project area in all areas of activities. They are able to perform all the forecasting tasks independently, and to judge critically the results of their efforts.	Significant developments were still being made in the forecasting procedures in the course of the 1997 monsoon. The 1998 monsoon should not require any further development, and should see the consolidation of the forecasting activities.
Improved institutional structure within FFWC.	Major changes are being implemented in the entire BWDB Hydrology Department.	Assessment of the outcome can only be made after the new structure settles into place.

3. FLOOD FORECASTING AND WARNING OPERATIONS

3.1 Flood Forecasting and Warning Centre

The Flood Forecasting and Warning Centre (FFWC) is part of the Surface Water Hydrology-II Directorate of BWDB. Its position in the structure of BWDB is shown in figure 3.1. It is located on the eighth floor of the WAPDA Building in Motijheel, in the commercial district of the capital Dhaka. The centre occupies a floor area of 260m^2.

The centre is staffed by employees of BWDB, with the organogram shown in figure 3.2. The office of the Director is located in Green Road, Dhaka. The main operations are centred on the Computer Room of FFWC, the layout of which is shown in figure 3.3. The project has provided radio transceivers, satellite reception and computer equipment in the centre, as well as a general upgrading of the furnishings.

During the dry season from October to March, the centre operates normal government office hours. During the monsoon season from April to September, the centre operates seven days a week, and round the clock during major flood periods. The operations are detailed in the Flood Forecasting and Warning Action Plan.

3.2 Construction and Instrumentation Division

The Construction and Instrumentation (C&I) Division also comes under the Surface Water Hydrology-II Directorate, as shown in figure 3.1. While the office of the Executive Engineer in charge of the Division is located next to the WAPDA Building, the Division's staff and workshop are in Green Road.

The Division has the responsibility to maintain the real time data transmission and reception equipment of FFWC, including the data boxes and radios deployed by this project, and the telemetry system installed by JICA (Module 4). The project has provided the Division with a workshop for the maintenance of the data boxes and radios.

3.3 Sequence of Operations

The preparation of the flood forecasts and issuing the flood warnings follows a defined sequence of operations, illustrated in figure 3.4:

Data Transmission and Reception	the transmission of rainfall and water level to the centre immediately after the measurements are taken in the field

Satellite Image Reception and Processing	the reception of images from two NOAA satellites, and the processing of these images to produce rainfall forecasts
Flash Flood Forecasting	the forecasting of flash floods on rivers in the northern and eastern borders of Bangladesh (presently for two rivers on an experimental basis)
SuperModel Forecasting	the forecasts of water levels for a total of 40 locations on the rivers in the three northern regions of Bangladesh, and the production of GIS maps showing the areas inundated; the accuracy of the forecasts are monitored and a statistical summary prepared at the end of the monsoon
Issue of Flood Warnings	the issue of flood warnings in visual images and textual messages to concerned organisations, including BTV and radio

The operations are described fully in the following chapters of this report. Documentation of the entire process and the individual components has also been provided (see section 1.7).

3.4 Institutional Aspects

3.4.1 Introduction

The project is implemented under the Flood Action Plan (FAP). The project is headed by the National Project Director (NPD), who is the director of SWH-II. The NPD reports on project matters to the Director General of the Water Resources Planning Organisation, under which the FAP is implemented.

The Danida funded component of the project is separated into three modules (see section 1.3). The first two modules are concerned with project coordination, training, data transmission and flood forecasting, and the direct concern of the FFWC. The third module is concerned with dissemination and public awareness.

In addition to informal on-the-job training, a range of formal training activities have been conducted under the project in all aspects of flood forecasting and warning. The training has been conducted in Bangladesh in FFWC and C&I Division in Dhaka, and in the real time field stations; and overseas in Denmark, the United Kingdom and Australia. The training has encompassed staff from FFWC, C&I Division, and the gauge readers and radio operators of SWH-I and II respectively in the real time field stations. A complete list of the training undertaken is given in Appendix III.

There are two further institutional aspects:

- the establishment of the FFWC as a full directorate under the Chief Engineer, Hydrology, with a general raising of the status of the centre, its staff and its output
- the roles and potential of FFWC, DMB and NGOs in warning dissemination in Bangladesh

Each aspect is discussed in the following two sections.

3.4.2 Status of Flood Forecasting and Warning Centre

As shown in the organogram in figure 3.1, the FFWC has a relatively lowly position in BWDB, headed by a deputy director reporting to the second of the two Surface Water Hydrology Directors. It has been part of the project agreement between the Governments of Bangladesh and Denmark that alongside the general upgrading and extension of the scope of the centre's services, the status of the FFWC would be raised to that of a directorate, headed by a director reporting directly to the Chief Engineer, Hydrology.

In conjunction with raising the standard and quality of FFWC's output in terms of forecasts and warnings, this would have numerous advantages, among which are:

- the centre would receive greater recognition for its efforts
- the sense of value of the staff of the centre, who at times of major flood work round the clock to produce forecasts, would be enhanced
- the centre would be given its own budget to meet necessary expenses, without having to apply to the director for funding on an item by item basis
- the head of FFWC would have the authority to undertake liaison with other organisations at a senior level, and to be effective in implementing necessary changes in systems and procedures

Given the responsibilities of FFWC and its dependancy on the reliable transmission of timely and accurate real time data from the field, the gauge readers, radio operators, and equipment maintenance technicians should be under the direct authority of the head of FFWC.

One argument against raising the status of the centre is that its activities are minimal during the dry season, from October to March, and as a directorate would be more or less idle in this period. In fact there are a number of duties which have to be performed in the dry season, among which are (a full list is given in the Flood Forecasting and Warning Action Plan):

- prepare and issue flood reports
- test, service and maintain all equipment and communication links
- review model forecast performance, and incorporate new hydrographic and topographic survey data as available
- review and revise dissemination procedures on the basis of feedback from the recipients of the warnings
- carry out training programmes for staff development

To this list could be added low flow forecasting, to which the model could be readily adapted, using a subset of the real time flood data transmission stations.

3.4.3 Dissemination of Flood Warnings

It has been the intention of the third module of the project to expand public awareness of the services offered by FFWC, and conduct liaison with and provide support to the project Support to Disaster Management (FAP11). This project did not materialise as expected, and the present project conducted some testing and evaluation of dissemination through the 1996 monsoon.

These modest efforts were compromised by a failure to gain approval of the warning messages prepared, nationwide political disruption and relatively little severe flooding. Nonetheless some useful conclusion were reached. These are discussed in section 10, with a details in the Development and Training Report.

BWDB considers it outside its responsibility and scope to conduct trials of the dissemination to the grass roots or village level. BWDB neither has a mandate, the appropriate skills base, nor a socially oriented administrative structure in the country. The new draft Standing Orders for Disaster are not yet available, but the project has been advised they indicate that the responsibility for dissemination lies with DMB. At this stage, DMB's role in this respect is not well developed.

It was a further intention to utilise NGOs, with their grass roots knowledge and links, to conduct the dissemination at the village level. In the run up to the monsoon, it was decided that the test areas were on too small a scale to be useful, and different messages to the test areas could cause confusion. Thus no further work on dissemination was carried out in 1997.

Under the proposals developed in FAP10, the stand alone flood warning messages prepared by FFWC are disseminated to the Disaster Management Bureau (DMB) and Bangladesh Radio and Television. DMB are to disseminate this further to the District Offices, but arrangements for further dissemination from that level is uncertain. The arrangements with the radio and television is that the flood warning information will be broadcast over radio and television. This includes message texts as well as maps

showing degrees of flood inundation down to the thana level. The FFWC also use their radio network to disseminate flood forecast information to a single contact in most districts.

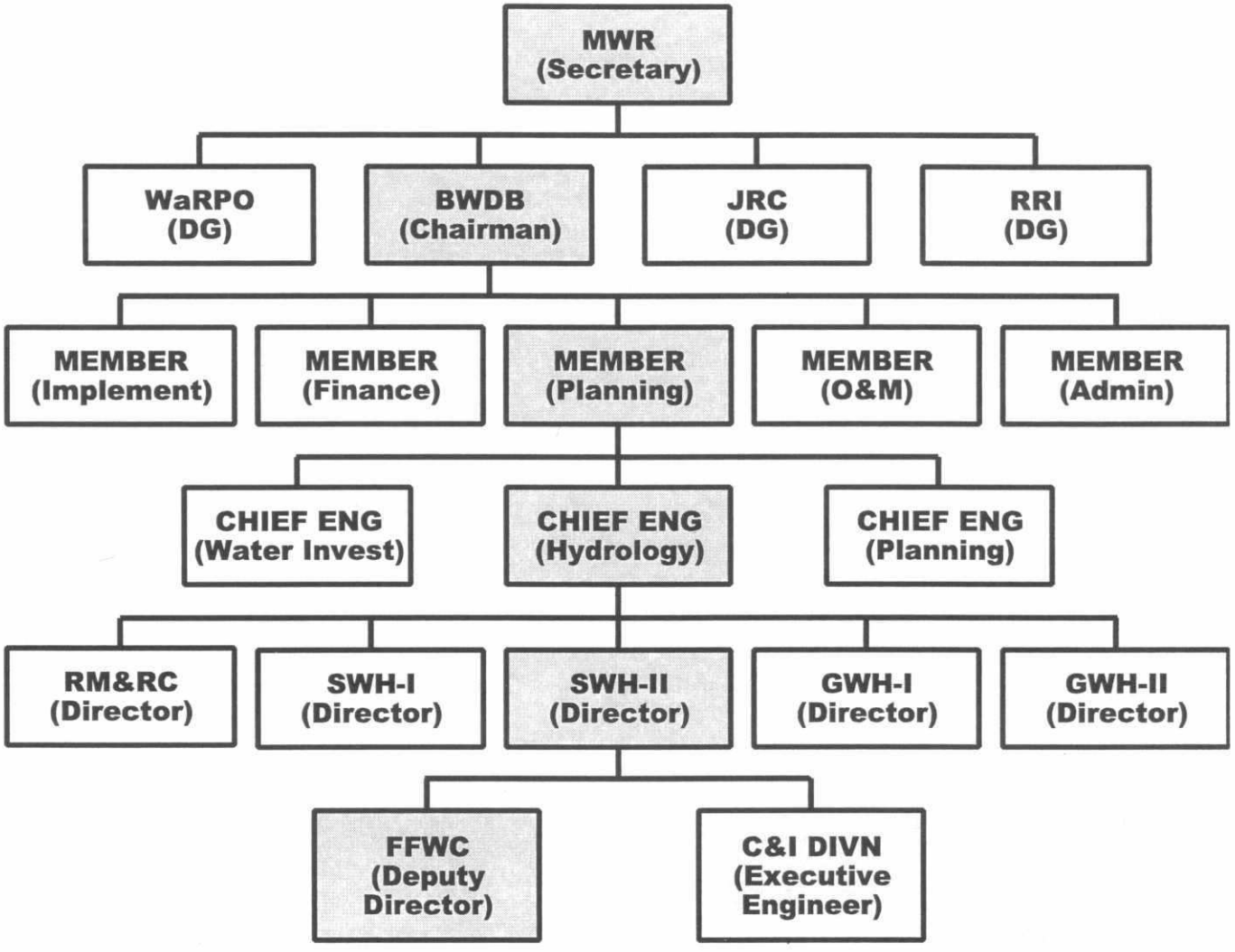
A proposal has been prepared involving NGOs to fill this gap in the dissemination system between the District Office (or in some cases Thana) level and the villagers. Although the broadcast of the information over radio and television reaches these levels there is still a need for the message to arrive by other channels to provide the all important opportunity to confirm the message. This is an essential component of warning effectiveness.

Dissemination to the District (or Thana) level would be achieved through three means:

- through the wireless network of FFWC
- broadcast over radio and television, and through the DMB (most NGOs have a representative at these levels and good communication systems to get information right down to the village level)
- some NGOs may be able to disseminate effectively messages received at their national office.

A proposal has been prepared to test this approach (see Appendix IV), in the context of the possible eventual development of a more locally based flood warning dissemination system built around the flood marker post concept, and involving a local administrative structure centred around local government.

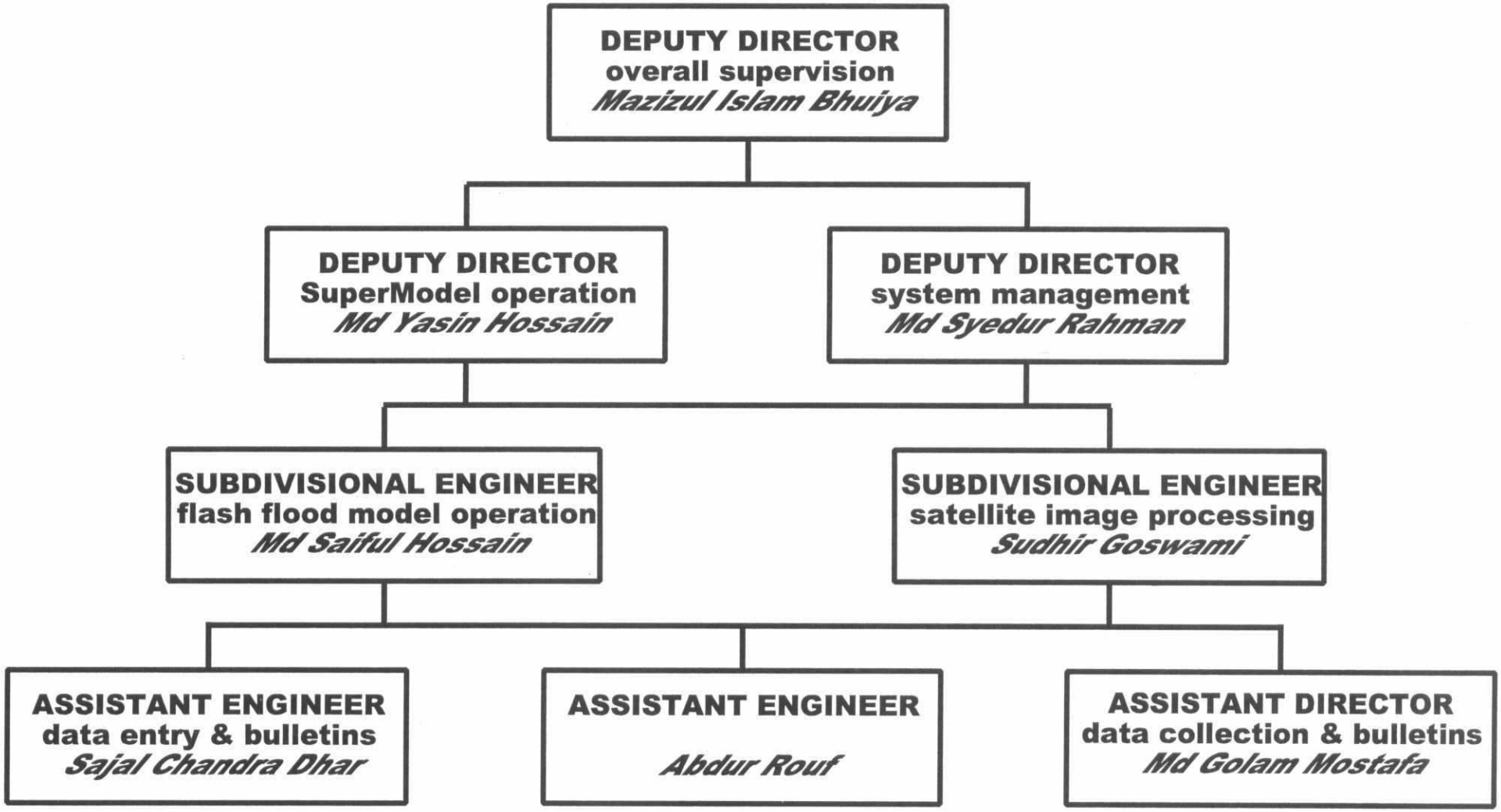
The proposal outlined above involves inputs from BWDB in the form of close links with FFWC to streamline the flow of information to and from the field to coordinate the dissemination and local warning system activities. Input from BWDB would also be needed for establishing the threshold flood levels on the marker posts and any surveying required for the installation of the post. BWDB's role in dissemination should not go beyond this role as it does not have the necessary facilities nor expertise to do more.

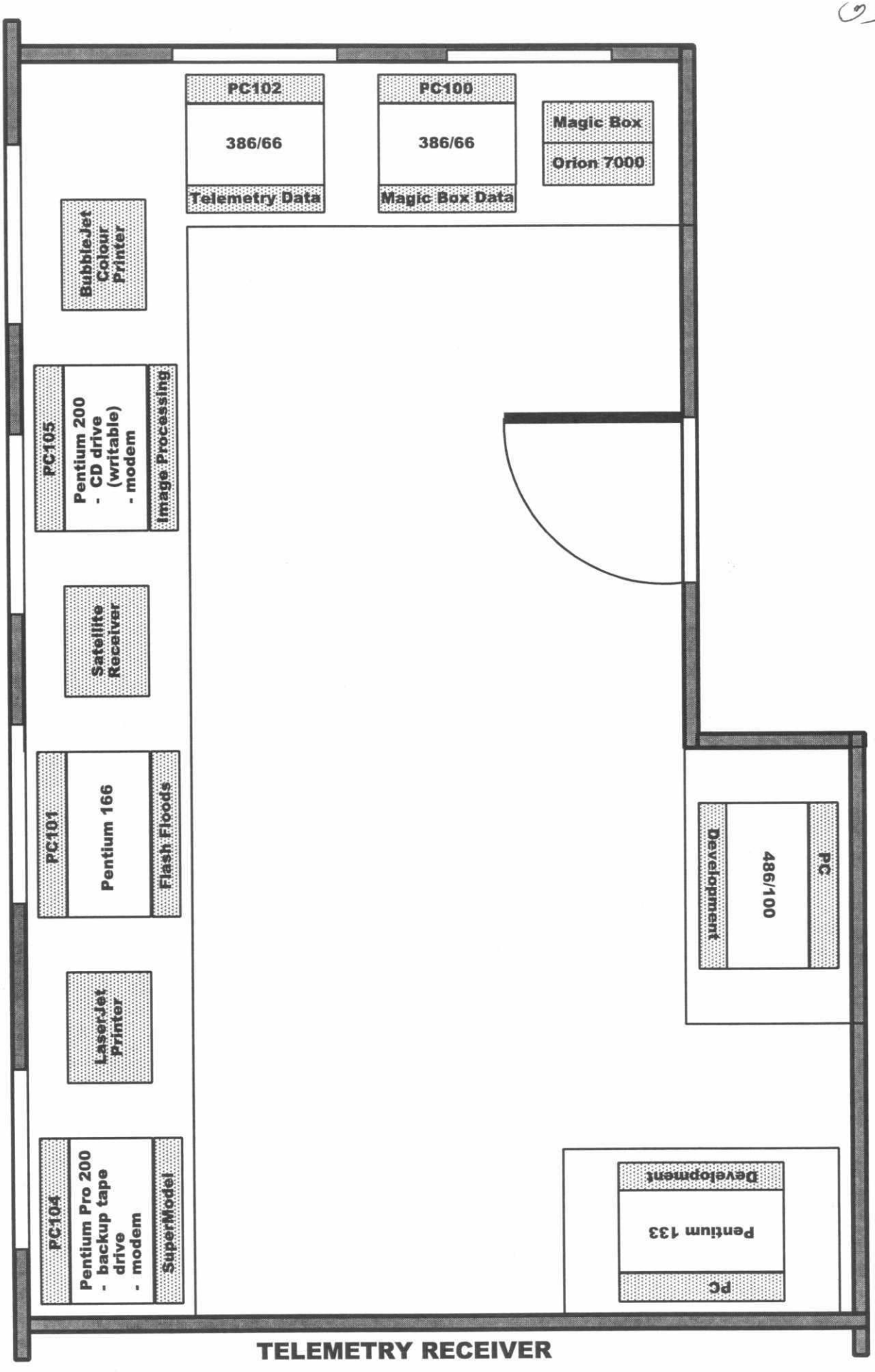


INSTITUTIONAL POSITION OF FFWC | **FIGURE 3.1**

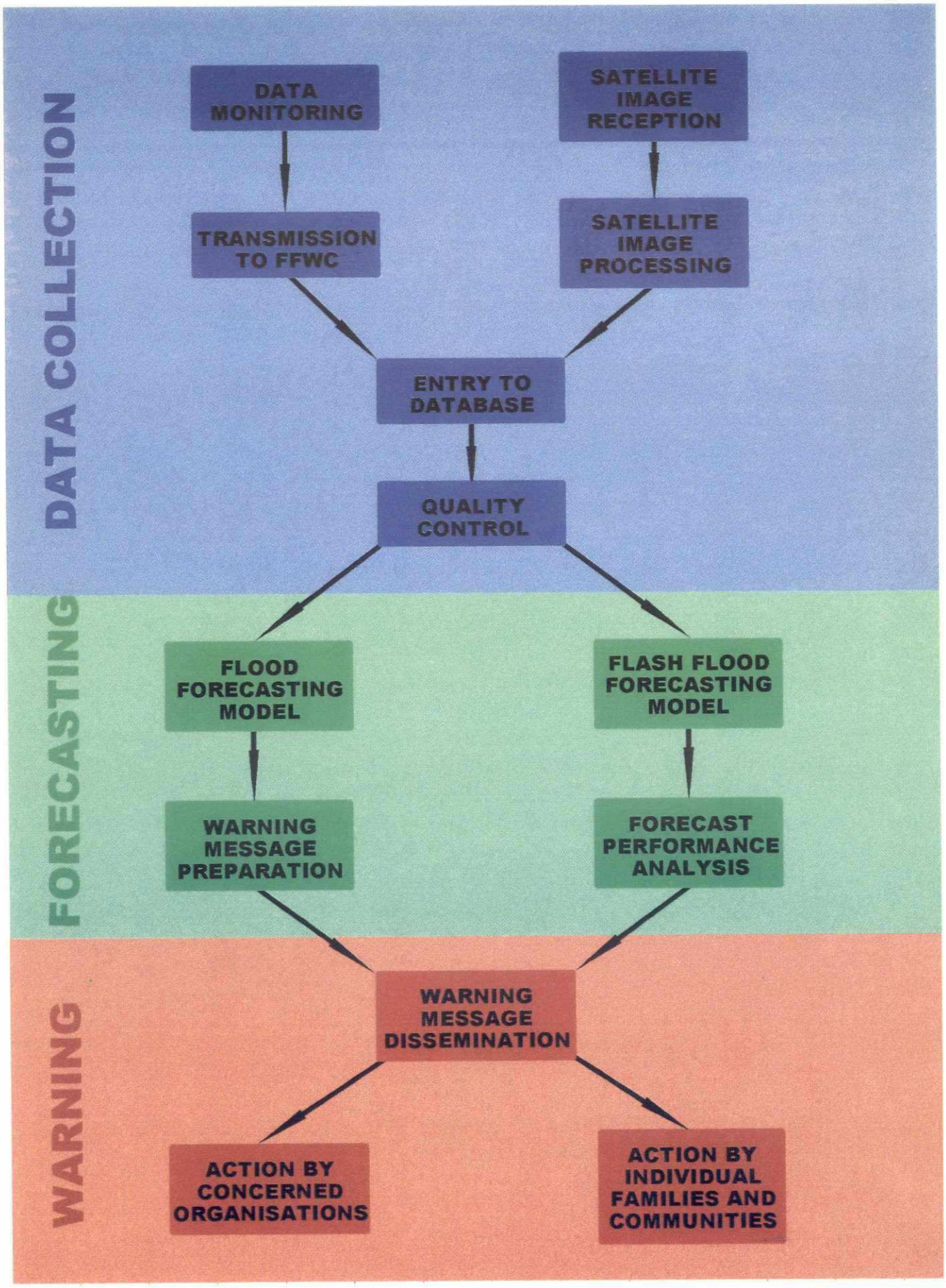
ORGANISATION OF FFWC

FIGURE 3.2





LAYOUT OF FFWC COMPUTER ROOM | **FIGURE 3.3**



SEQUENCE OF OPERATIONS	FIGURE 3.4

4. DATA TRANSMISSION AND RECEPTION

4.1 Previous Procedure

In the system operating prior to FAP10, real time data were transmitted from a total of 60 stations reporting rainfall and water level to FFWC in Dhaka by voice using wireless radios. The stations are mostly located in the northern half of the country, above Dhaka. There are a few rainfall stations south of Dhaka, and both rainfall and water level stations in the Chittagong and Hill Tracts areas.

The gauges are operated and maintained by field staff from the Surface Water Hydrology-I directorate. The various SSB (single side band) radios are operated and maintained by staff from the Surface Water Hydrology-II directorate, under which also comes FFWC. FFWC has permission from Bangladesh Telephone and Telegraph (BTT) to use six frequencies for wireless communication. Normally only 8,157kHz is used. The hand written gauge readings are conveyed on foot, bicycle or rickshaw from the gauge to the radio, a distance of between one and five kilometres.

The pool of available SSB radios comprises five different brands, most of which are out of production, and spare parts are not available. Given in addition the conditions of high temperature and humidity in Bangladesh, operating rooms without air conditioning or sometimes even a fan, most of the radios were past their useful life.

Additional problems with the transmission are owing to lack of battery maintenance, poor electrical connections, lack of transport for C&I maintenance staff, lack of spare parts and instruments for maintenance, poor workshop facilities, continued replacement of qualified and experienced staff, trees disturbing antennae, termites and a general lack of cleanliness, unpaid staff salaries and electricity bills, disagreement between the gauge readers (from SWH-I) and the radio operators (from SWH-II).

The stations are generally operational from 1st April to 30th September, and report the readings between 0800 and 0900 hours, maintaining a set time for transmission if possible. The 0600 reading of rainfall and water level, and the water level readings from 0900, 1200, 1500, and 1800 the previous day, are transmitted vocally. Only 39 of the 60 stations are manned by qualified radio operators, the remainder being operated by the guard.

The frequency becomes very congested during the transmission period, and during the morning around 0900 communications are not clear, especially at higher frequencies. Nonetheless, generally most of the data are reported successfully. In May 1997, the government changed the office hours from 0800 to 1430 Saturday to Thursday, to from 0900 to 1700 Sunday to Thursday. The data are now transmitted between 0900 and 0945, where conditions permit.

After the data are received in FFWC, they are entered manually into the database. The system is vulnerable to errors both human and as a result of poor reception conditions.

4.2 Development Process

4.2.1 Communication System

Clear and dependable real time data transmission and reception are an essential component of the flood forecasting process. As a first step towards improving the data transmission and reception in FFWC, the antenna on the roof of the WAPDA (BWDB) building in Mothijeel was repaired.

The wireless system was analysed, and a new data collection methods using digital communication considered:

- satellite based
- via the public telephone system
- traditional short wave SSB radio with a modem

4.2.2 Satellites

A simple and reliable way to transmit real time data would be solar powered satellite terminals. An obvious choice would be to use the INMARSAT C system, designed specifically for digital communication to remote areas. The system is reliable and independent of atmospheric conditions, repeater stations are not required, the antenna is simple and can be (re)located anywhere, and capital costs are moderate.

The cost of operation is around US$2 for the transmission of six rainfall and water level readings. With 40 stations making one call each day, the annual cost would be around US$15,000. Apparently the Bangladesh Telegraph and Telephone (BTT) authority are not yet ready to handle satellite communication equipment, despite its widespread international use.

4.2.3 Public Telephone System

The telephone system is frequently discarded even in developed countries for use in an emergency situation. It is vulnerable in severe climatic conditions, with the possible general failure of infrastructure. Even in normal conditions, outside Dhaka, the system is too unreliable for use in an emergency situation.

When the satellite based world wide cellular telephone system is implemented, in the near future, this should be reconsidered.

4.2.4 Short Wave SSB Radio

The C&I Division of SWH-II has permission to use six different radio frequencies. Only the 8,157kHz frequency is suitable, and this is always used,. A local consulting company was commissioned to investigate and report. A frequency in the range 6,900 to 7,000kHz was recommended for optimal reception, and an application to BTT was made in March 1996. It is still being processed: in the meantime 6,996kHz is employed by the real time stations.

Experienced has shown that the Orion 5000 radios have given good performance in Bangladesh. The radios have been produced by Eddystone, UK since the second World War, and recently a new model the Orion 7000 has been brought into production. This has the following attractive features:

- a fully enclosed cabinet proof against dust and humidity
- prepared for digital data transmission
- technicians can change the frequency
- built in diagnostics for fault location
- only three easily replaceable modules

This means of communication was selected. The first ten radios were delivered in February 1996 and installed in May. The second batch of 30 radios was delivered and installed during 1996 and 1997.

The installation was carried out by the project, with the assistance of C&I technicians for on-the-job training. A third batch of 20 radios was delivered in July 1997, bringing the total up to 60. Owing to the transfer of experienced C&I staff, none of the last batch of radios has been installed. Ten of the last batch are intended to serve as spares, a complete radio being cheaper than the sum of its component parts.

At the same time as installation of the new radios, the electrical connections were inspected and repaired or replaced where required. The stations were also equipped with new batteries and chargers. Where transmission conditions were poor, a new Delta Loop antenna was installed.

4.2.5 Magic Box

As stated, the radios are capable of transmitting digital data. This would normally require coupling to a PC, not a realistic option for Bangladesh field stations. A simple low cost solution was implemented using a data box, dubbed a Magic Box. The Magic Box (see figure 4.1) is a small hermetically sealed weather proof plastic box powered by batteries which are charged when the box is connected to the radio.

The box serves two purposes:

- a notebook for the gauge reader
- an intelligent modem for the SSB radio

The gauge reading and transmission process is as follows:

Step	Action	Process
1	at the time for the reading, the gauge reader takes the Magic Box to the gauge, switches the box on, and is guided by messages displayed by the box to enter correctly the water level and rainfall	the reading is stored, along with earlier readings, in the Magic Box together with the time and date from the internal clock (the box switches itself off to conserve the battery)
2	at the time for transmission, the gauge reader goes to the radio station, connects the Magic Box to the radio, and waits while the data are automatically transmitted to FFWC	the PC in FFWC automatically calls each station in sequence and transfers the data entered since the last transmission (duration around 15 seconds for each station)
3	none	the data are checked for errors on the PC; if there is an error, the data transfer will be repeated; once data are received correctly, the data in the Magic Box are automatically erased

Human error is reduced to reading the staff gauge, and to minimise this the same reading has to be entered by the gauge reader twice.

The Magic Box was successfully tested in Chandpur and Manikganj during the 1995 monsoon, with a much improved reliability and speed of data collection in FFWC. Forty new Orion 7000 radios with digital capability were procured; by September 1996, 20 were installed at real time stations around the country, plus one each for central digital and analogue (voice) reception in FFWC, and one as a "listening station" to monitor the transmission and reception in the refurbished Construction and Instrumentation Division workshop in SWH-II in Green Road, Dhaka. Fifteen of the stations were also equipped with Magic Boxes.

The technicians of the C&I Division have been fully trained in basic electronic workmanship. This has been neglected in the past, and is the reason behind the frequent breakdown of equipment. The staff have also been trained in the establishment and maintenance of the stations. A new fully equipped electronic workshop has been set up in the Green Road office of BWDB for servicing and maintaining the new equipment. Documentation on the operation and maintenance has been prepared and distributed as part of the training. The importance of good workmanship and cleanliness have been emphasised throughout.

Accompanied by the DHI instrumentation engineer, three staff of the C&I Division participated in a one week theoretical and practical training course at the Eddystone factory in Birmingham. The following week the staff went to DHI in Denmark for further training. All three participants in the foreign training were transferred from the

C&I Division in 1997, and are no longer involved in the maintenance of the flood forecasting data transmission equipment.

The radio operators (and the guards where there is no operator) have been trained in receiving, collection and transmission of data and messages, and in maintenance of the radios. The operators have been trained in minor repair work and replacement of parts.

4.2.6 Other Communication Systems

In August 1995, a microwave link between the WAPDA building and BTV was established by the project enabling the independent transmission of forecasts as text messages and visual images to Bangladesh Television. The system broke down in 1996 and attempts to locate the fault in 1997 failed. It was replace by a modem telephone connection which functions satisfactorily.

FFWC has a dedicated telephone connection with the Bangladesh Meteorological Department for the transmission of radar images and data from India. In 1997, the link was cut by BTT owing to non-payment of the bill by BWDB. Although the bill was subsequently paid, the direct link was not reestablished. The normal telephone network is now employed, which has worked satisfactorily.

A total number of five new telephone lines was installed in FFWC by the project, including one telefax machine. A computer and modem installed in the Prime Minister's Office enables direct communication with the computer system at FFWC.

4.3 Present Status

An overview of the sources of flood forecasting data arriving at FFWC is shown in figure 4.2. By the end of the 1997 monsoon, 35 stations have been equipped with Orion 7000 radios and Magic Boxes. Numerous problems were experienced during the monsoon period mainly owing to:

- the uncertain status of many gauge readers and operators with regard to their employment by BWDB, and the departure of many trained staff
- the transfer of key trained technicians from C&I Division
- lack of power supply to certain stations, and failure to maintain and charge the batteries supplied
- problems with the computer program in FFWC controlling the reception of the data

The problems were addressed in the course of the monsoon, including an on site retraining programme in July 1997. By September the system was functioning satisfactorily, with successful reception of around ...% of the total potential for digital

transfer data. Ten Magic Boxes and Orion 7000 radios are available with C&I Division for the replacement of faulty equipment while repairs are undertaken.

The performance of the radio transmission and reception can be monitored from FFWC and the C&I Division executive engineer's office. In both locations a PC is set up with an Orion 7000 and Magic Box to receive and store the data. A software program monitors the data received. If data from a particular station are not received, the C&I Division, who have responsibility to maintain and operate the stations, have immediate knowledge and can take prompt action to rectify the problem.

The voice transfer system is still operating parallel to the digital system. This is expected to continue until the digital system has proved itself over some years, and FFWC and C&I staff have full confidence in it.

Maintenance of the system is crucial for its continued successful operation. Ten sets of Orion 7000 radios and Magic Boxes are available for spares and replacement. The radios comprise three basic modules. The trained C&I technicians are capable of identifying the faulty module, and of replacing it. The faulty module has to be sent to the UK for repair; a budget from the Board is required for this. The life of wet batteries is around three to four years, after which time they will require replacement.

4.4 Telemetric System

Under the JICA financed module 4 of FAP10, a telemetric network has been installed with 14 stations transmitting water level data, of which 6 also transmit rainfall, hourly by microwave to FFWC. The microwave link is based on the national communication network, extended to connect the automatic monitoring stations and FFWC. The data are transmitted, received and stored without manual intervention. The computer system installed in FFWC also provides graphic display of the data. It is proposed to extend the system to 39 stations.

A serial connection has been established between the FFWC forecasting computer network and the telemetry computers. This has proved temperamental in operation, and the telemetry data are currently entered manually to the database.

4.5 Data Exchange with India

The major constraint to the further improvement in longer term forecasts is the availability of basic real time rainfall and water level data from stations such as Patna and Gowahati. The present mode of transmission is by outmoded communication, ie telex, and passes to Dhaka via Dehli; the delay renders the data of limited value.

The expatriate consultant has made two visits to India: to the Central Water Commission in New Dehli and Patna, and to the Ministry of Water Resources Commissioner for Eastern Rivers. Discussions have shown a willingness on the Indian side to improve the transmission, using the modern but simple and reliable e-mail on the Internet, now

installed in the FFWC. The matter has to be discussed and agreed at the government to government level, in the forum of the Joint Rivers Commission.

In the meantime, the receipt of data from India has improved considerably in the 1997 monsoon. Data are received regularly and on time according to the existing arrangements: from Patna on the Ganges, the Brahmaputra at Pandu, Goalpara and Dubrighar, and other stations on the Teesta, Khowai, Manu and Gumti.

There still remains considerable scope for forecast improvements if additional data could be received from stations up to say 100km upstream on the Ganges, eg at Alahabad. Data should be transferred throughout the monsoon period, not just when a warning level is exceeded. The use of e-mail would enable the data to be transferred in near real time for a nominal expenditure. The availability of such data on a regular basis could enable forecasts to be made up to seven days in advance compared to the present maximum of three days.

4.6 Conclusions and Recommendations

The receipt of accurate and timely real time data from the field is crucial to successful flood forecasting. The use of Magic Boxes to transmit data semi-automatically and digitally has proved a good compromise between manual and automatic operation, and between simple and advanced technology.

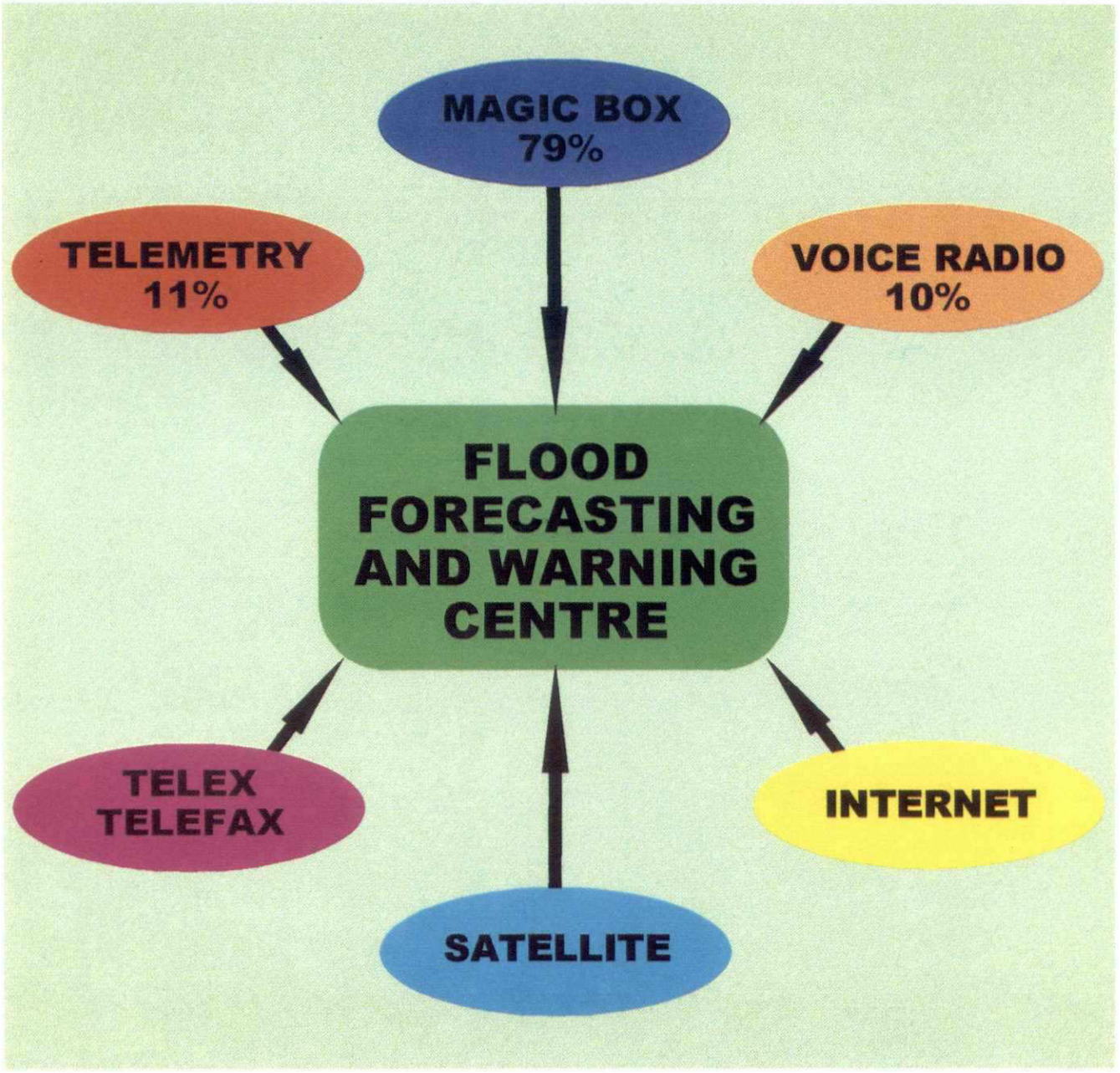
The dependability of the Orion 7000 radios has been proved in the field. Over 1996 and 1997, only two have broken down, probably owing to lightning strikes. They have been repaired in the UK under warranty.

There is nonetheless still a need for the gauge readers and radio operators to be properly motived and rewarded in their work. While many are, there remain serious problems with support from BWDB:

- many of the field stations do not receive the necessary support in respect of funds to carry out very minor repairs
- many of the field staff have not received their salary for more than one year
- electricity bills are not paid, and the power supply is cut off.

Installation was only completed in August 1997, numerous staff changes were made from the 1996 monsoon, and some difficulties were still being experienced operating the system during the monsoon. A further year of operation is required to allow the readers and operators to become fully familiar and settled with the new technology.

TOP : Transmission from Field BOTTOM: Reception at FFWC	FFWC
DATA TRANSMISSION AND RECEPTION	**FIGURE 4.1**



DATA RECEPTION IN FFWC	FIGURE 4.2

5. SATELLITE IMAGE PROCESSING

5.1 Previous Procedure

Remote sensing information for flood forecasting comprises radar and satellite images. They are used to provide rainfall forecasts covering Bangladesh, and images of actual flood inundation. The information requires interpretation and judgement based on experience, and the forecasts are necessarily qualitative.

At the start of the project, the Bangladesh Meteorological Department (BMD) radar in Dhaka was not operational, and considered obsolete. The microwave communication link established between FFWC and BMD for the transmission of radar images was blocked by a recently constructed tall building. A dedicated telephone line was installed in 1994 and disconnected in 1995. The FFWC satellite receiving station was not functioning, probably owing to both software and hardware problems.

Satellite images are received daily from the Space Research and Remote Sensing Organisation from the Western Pacific Geostationary Meteorological Satellite (GMS), via BMD, together with isobar charts and the official weather forecast. On the basis of judgement and experience, the FFWC officers use the images to forecast the rainfall over Bangladesh and the near basins, and to estimate the rainfall and discharge boundary conditions for the forecasting model. There are no formal procedures.

There are plans to install two new radars with assistance from JICA, one in Dhaka and the other in Rangpur in the north west. There are no plans for a radar installation in the north east. The Dhaka radar covers part of the state of Tripura in India, the source of much of the rapid and heavy runoff to the east of Bangladesh.

5.2 Development Process

A study testing the applicability of satellite images in flood forecast mapping was initiated in cooperation with the Geographical Information System project (FAP19). High resolution radar satellite images showing the extent of flooding would be compared with the flood inundation maps. The radar images were not received and FAP19, now the Environmental Geographical Information System project has dropped the cooperation.

In June 1996, a proposal was prepared to purchase new satellite receiving equipment for the project. The installation shown in figure 5.1 would fulfil two functions:

- improve the rainfall forecasts over Bangladesh and the near basins upstream, and thereby the accuracy of the model forecasts, particularly with respect to flash flooding
- improve the accuracy of the flood inundation mapping through comparison of the model generated area with the satellite images

The receiver would receive data from the NOAA satellites, which are operated by NASA. The satellites are in polar sun synchronous orbits and as the earth rotates each satellite covers the whole globe twice in 24 hours. As the satellite advances it builds up a continuous image around 3,000km wide, with a maximum resolution in the centre of its path of 1.1km.

Information on the precise position of the satellites is downloaded from an address on the Internet. This should be updated every two weeks. A software program running on a PC in FFWC displays the positions and orbits of the satellites on a world map (see figure 5.2).

Functioning in conjunction with a GPS receiver, the program uses the position information to steer the antenna mounted on the roof of the WAPDA building towards the satellites as they pass over Bangladesh. The program also displays and stores the images as they are downloaded. As each of the two satellites passes over Bangladesh twice each day, four images at around six hour intervals can be received every 24 hours.

The satellite scans five separate parts of the electromagnetic spectrum, covering visible light, infrared and thermal. There are no charges or copyrights on the received images.

The staff of FFWC have received comprehensive training on the reception and processing of satellite images, firstly as part of an intensive course at DHI in Denmark, then on location in FFWC. The present staff are fully capable of operating the system, storing the images, carrying out limited image processing and interpretation, and adding additional satellites to the reception program when they become active.

5.3 Present Procedure

5.3.1 Introduction

The complete satellite receiving system is installed in FFWC, running on a PC on the centre's computer network. Software programs perform two main functions:

- tracking the location of the NOAA satellites, displaying their location, and downloading the images from the satellites
- processing the acquired images to provide information for rainfall forecasting and inundation areas

5.3.2 Image Reception

Of the two NOAA satellites currently active, NOAA12 passes over Bangladesh in the morning between 0500 and 0800 hours, and in the evening between 1700 and 2000 hours; NOAA14 passes between 1300 and 1500 hours, and between 0100 and 0300 hours (see figure 5.2).

At present, the signal received from NOAA14 is too weak to be of use. Following lengthy correspondence with the manufacturer and tests for interfering signals in the vicinity of the receiver on the roof of the WAPDA building, a new antenna and filter will be supplied by the manufacturer.

5.3.3 Image Processing

Owing to relative movements between the earth and the satellites, the raw images downloaded from the satellites are to a certain degree distorted. This is automatically removed in the processing software by georeferencing the images to a known map projection.

The next step is to run a batch program which carries out the following as it's primary tasks:

- convert the corrected images to the required format for image processing, and if necessary joined to provide a single image covering Bangladesh with a 1km resolution
- convert the thermal channels to degrees Kelvin, and the visual and near infrared channels to reflectance values based on the elevation of the sun
- prepare images covering Bangladesh and the surrounding region at a 2km resolution

The established image processing procedures carry out the following tasks:

(1) the temperature images are used to monitor the weather situation in the region of Bangladesh: the cloud surface temperature is linked by an empirical relationship to the expected rainfall intensity, which is displayed with graduated colours and a legend (see figure 5.3)

(2) a combination of the visual, near infrared and thermal channels shows for example the optical thickness of the clouds which can improve estimates of the rainfall intensity (see figure 5.4)

(3) the same image can also be used to delineate the actual inundated areas, and to compute the inundated areas.

5.3.4 Meteorological Information on Internet

There is great potential to obtain satellite images and weather forecasts on the Internet, and these are continually developing. The present status as described here will soon need to be updated in respect of the latest and best information available. Many weather sites give information on temperature and whether rain is expected tomorrow. Detailed forecasts with precise information over the next 12 or 24 hours are few at present.

An Internet connection has been established in FFWC, additionally to obtain satellite tracking information as described in section 5.2.

The Japanese Geostationary Meteorological Satellite (GMS) is a one of a well established range of equatorial and geostationary weather satellites. It is owned and operated by the Japanese Meteorological Agency. Geostationary weather satellites have three roles: firstly to obtain images of earth for meteorological purposes, secondly to disseminate these images to the world's weather services and thirdly to relay data from Data Collection Platforms.

The GMS Internet sites receive new images every two hours, with a delay around two hours behind the actual image time. The image shows the surface and cloud temperature over India, Bangladesh and neighbouring countries (see figure 5.5). They are not as informative as the NOAA satellite images, but can fill in the gap between NOAA satellite passes.

The Centre for Ocean-Land-Atmosphere Studies and the Centre for Application of Research on the Environment provide forecasts on the Internet based on global numerical models which are not reviewed by meteorologists. Major errors can result from defective input data. Among other sites providing weather forecasts including precipitation is the Programme for Climate Model Diagnosis and Intercomparison, shown in figure 5.5, and gives 3 day forecasts at 12 hour intervals. The resolution is rather coarse.

A complete list of potentially useful sites (as at August 1997) is given in the Documentation on Image Processing.

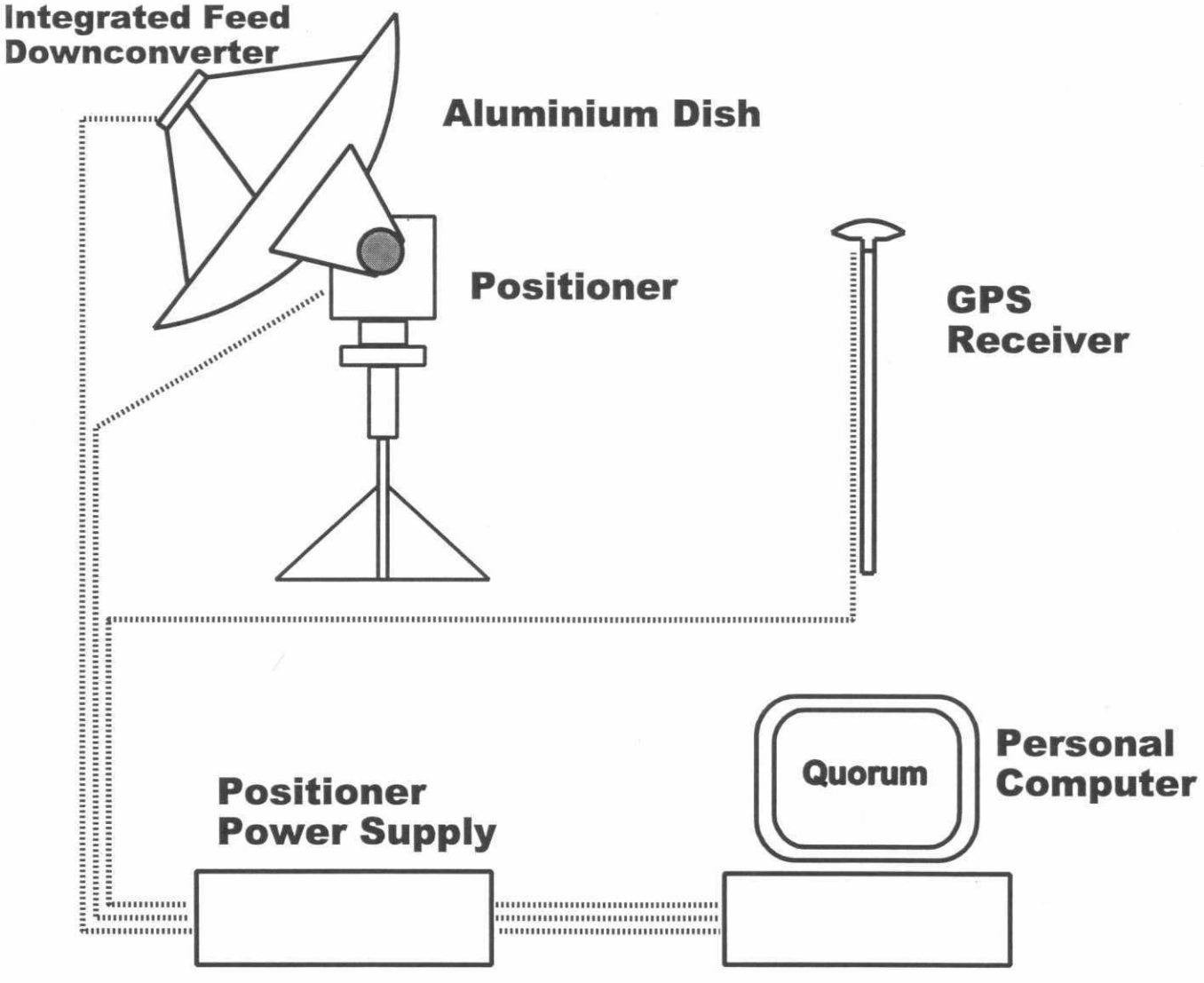
5.4 Conclusions and Recommendations

The satellite image receiving and processing equipment has been installed in FFWC and tested in the course of the 1997 monsoon. Certain hardware components supplied by the manufacturer have been found faulty and will be replaced under the guarantee.

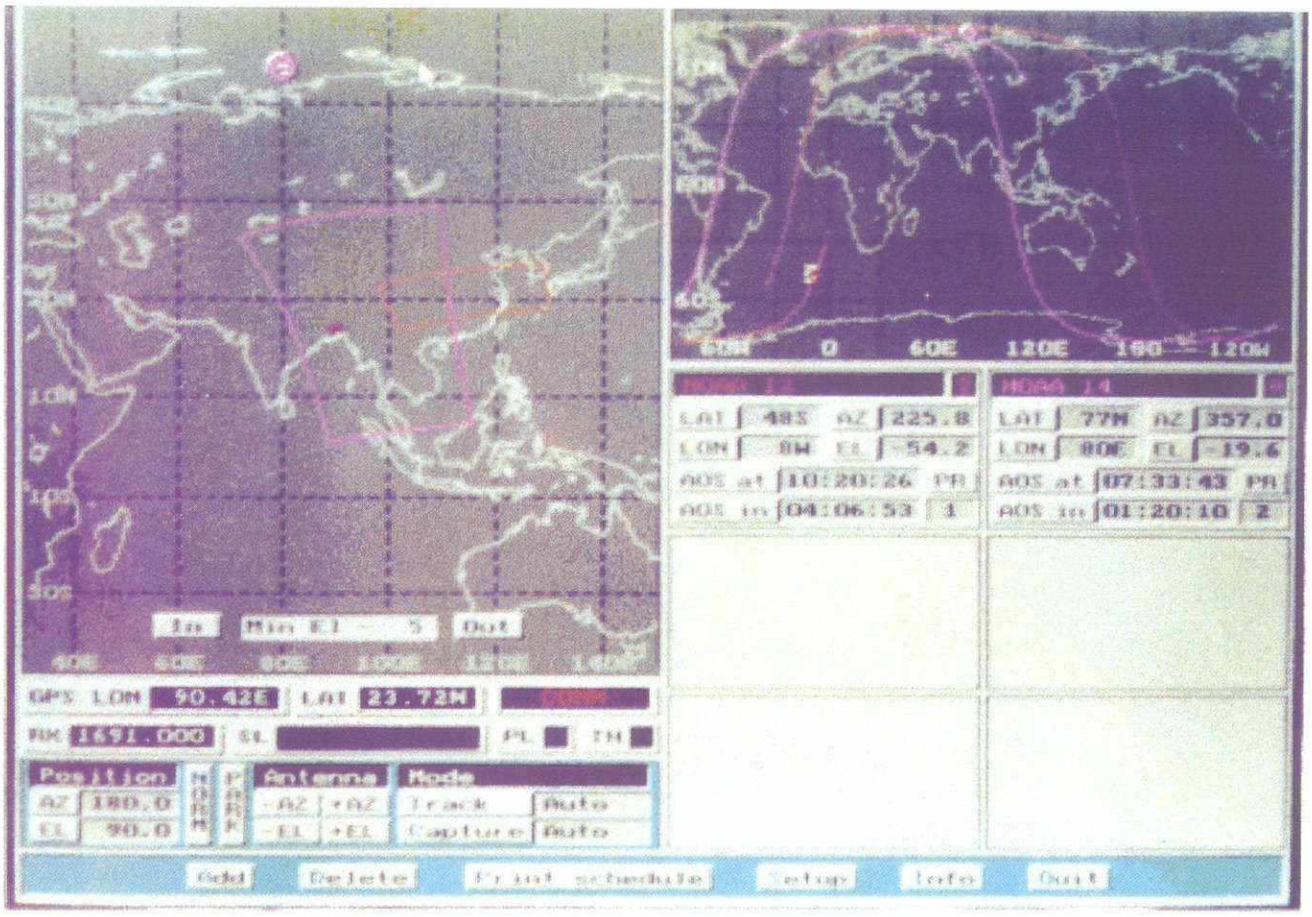
It has been possible to download two images regularly nearly every day. These have been stored for future reference, and subjected to preliminary analysis. This indicates that information can be extracted from the real time images not available from any other source in Bangladesh, specifically:

- the surface temperature of the clouds and thereby improved estimates of the intensity, and spatial and temporal variation of rainfall over Bangladesh and the region
- the actual area of flood water inundation

Despite the constraints of hardware problems and time, the equipment installed has demonstrated its usefulness in the preparation of flood forecasts and warnings in FFWC, and exhibits great potential for further development.



SATELLITE IMAGE RECEPTION	FIGURE 5.1



Screen Shot Showing Online Satellite Data Download Capability at FFWC	FFWC
SATELLITE IMAGE REVEIVER	FIGURE 5.2

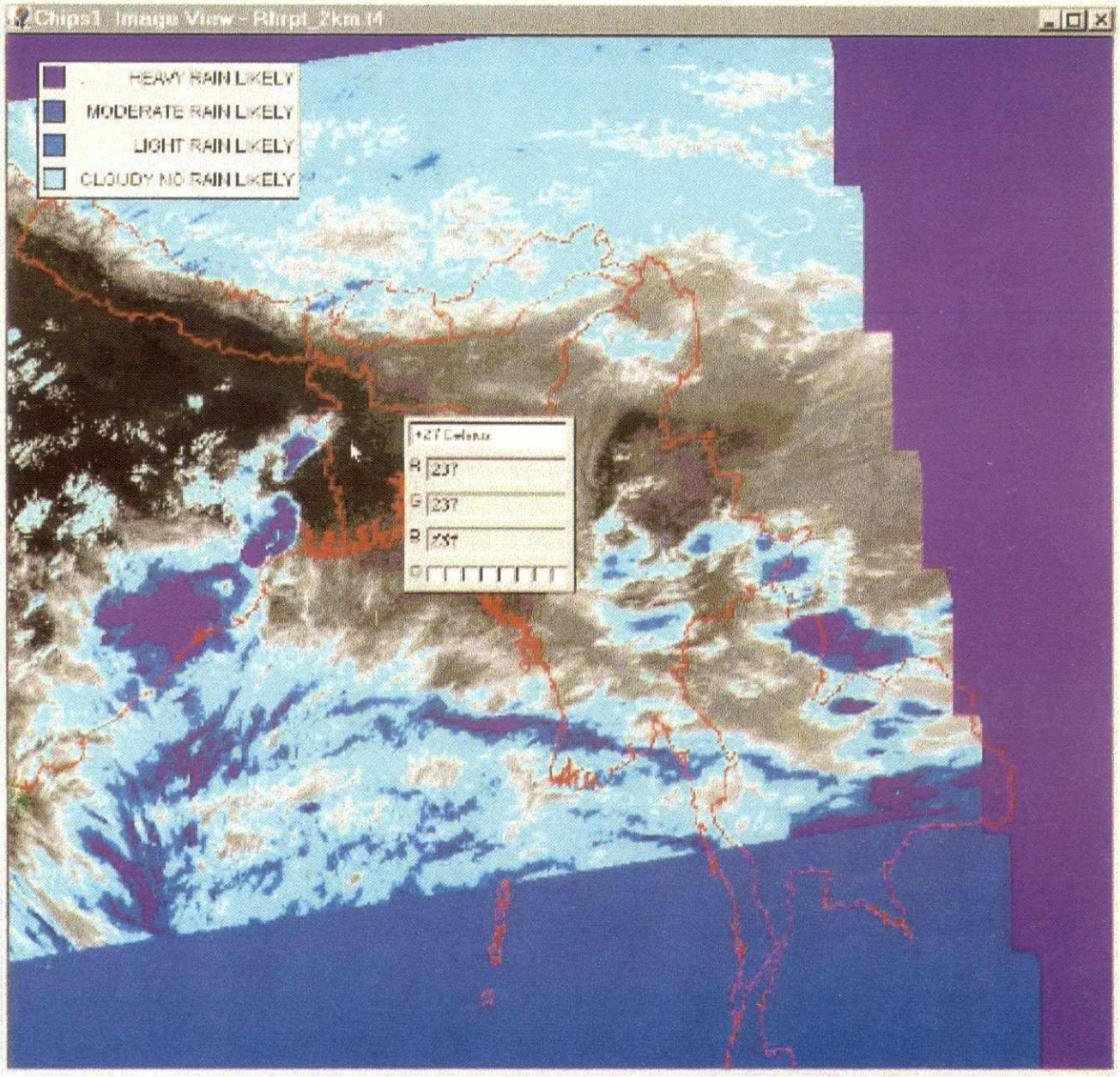
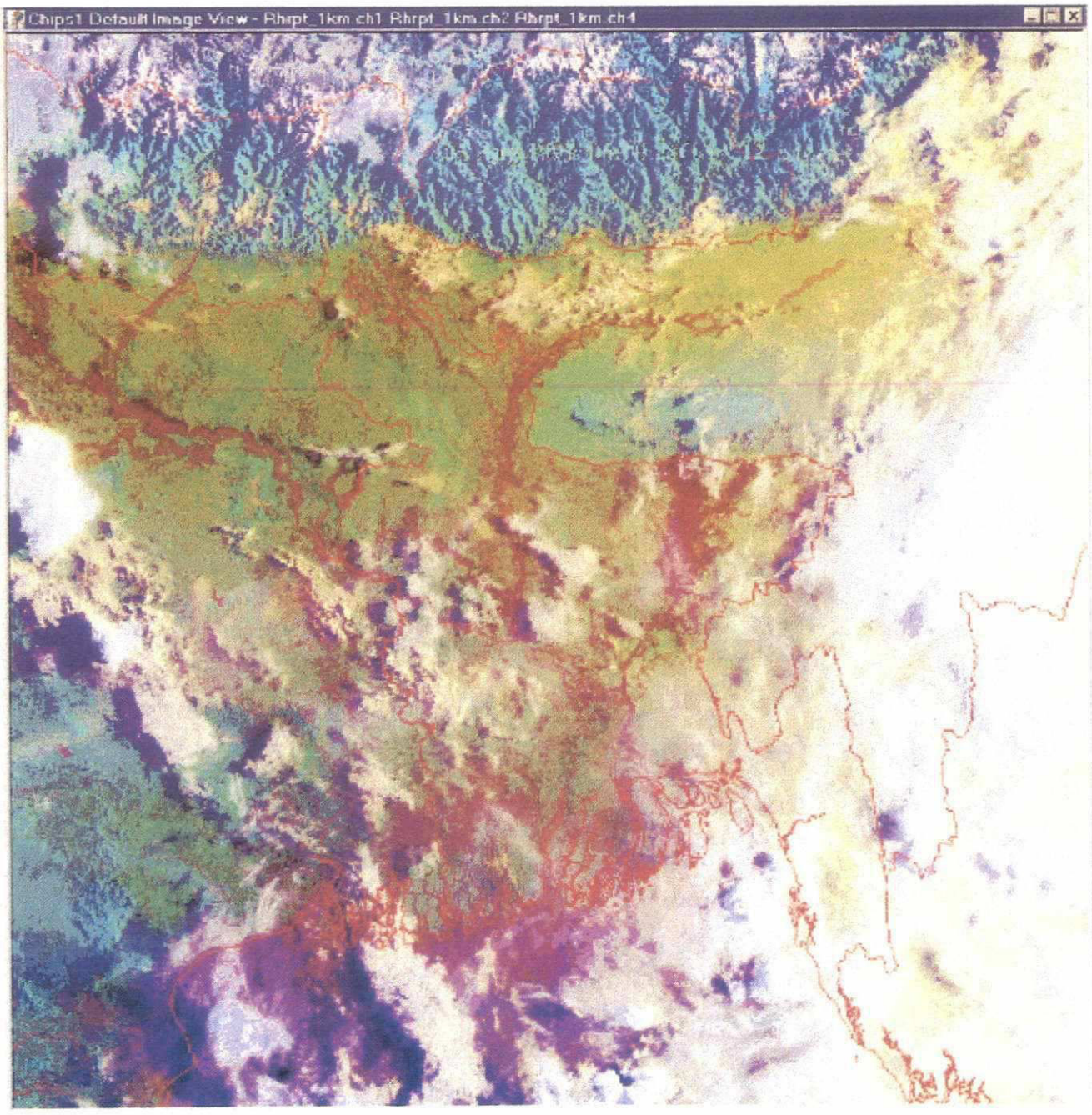
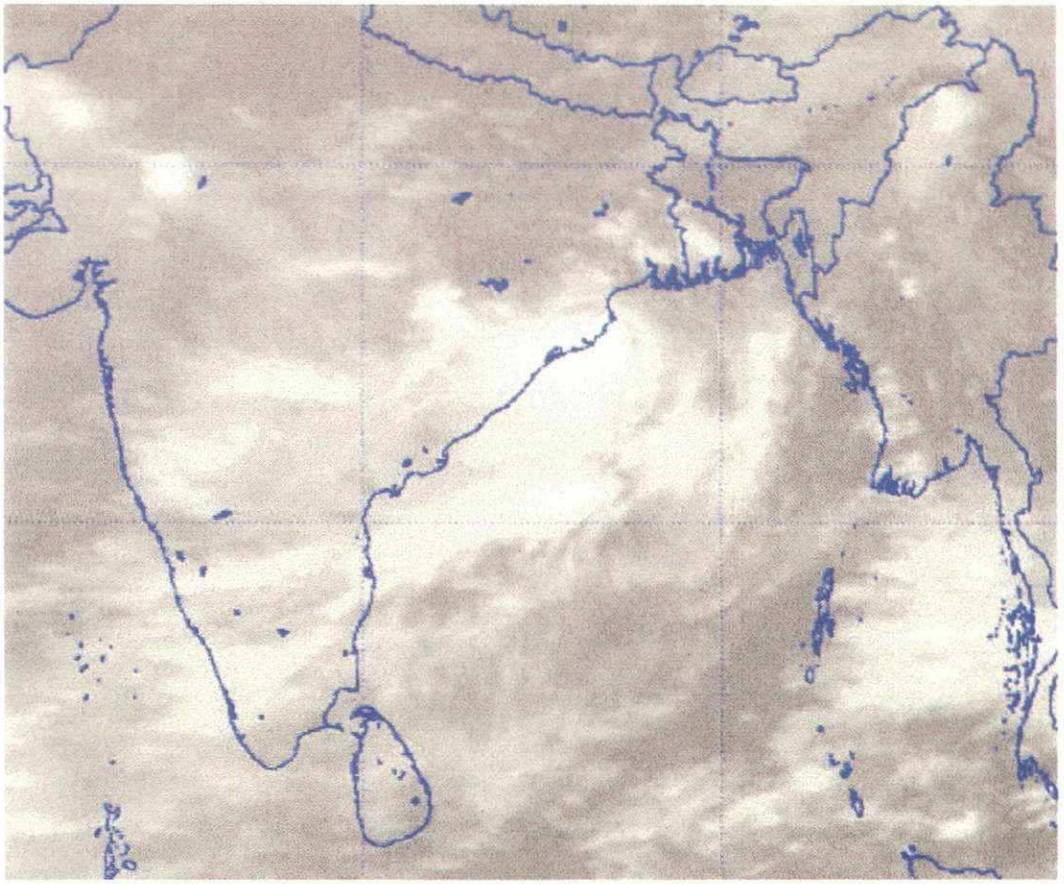
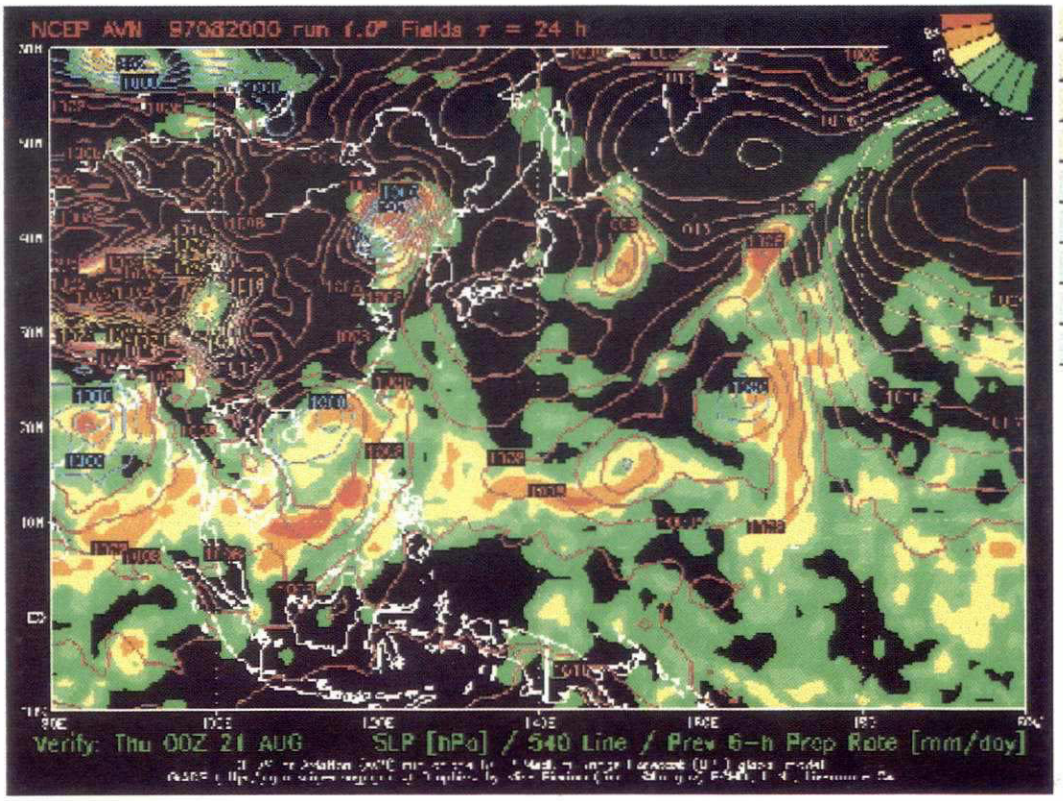


Image Interpretation Showing Cloud Temperature	FFWC
SATELLITE IMAGE OF RAIN CLOUD	**FIGURE 5.3**



NOAA 12 Satellite Image received on 25th August 1997 showing Inundated Areas	FFWC
SATELLITE IMAGE OF INUNDATED AREAS	**FIGURE 5.4**





TOP : GMS Satellite Image **BOTTOM : Internet Site Providing Rain Forecasts**	**FFWC**
GMS IMAGE and PCMDI INTERNET SITE	**FIGURE 5.5**

6. FLOOD FORECASTING AND WARNING PROCEDURE

6.1 Introduction

The present procedure for flood forecasting at FFWC is highly automated. Flood forecasting using the SuperModel involves a number of key tasks which must be carried out in a specific order. Automating the flood forecasting procedure ensures that all operations are carried out in their correct order without unnecessary complexity.

The primary activities carried out as part of the flood forecasting procedure are:

- Magic Box - conversion of digitally transmitted data to the Flood Watch database
- Flood Watch - the entire procedure from data entry and checking through model simulation to the issue of forecasts in various formats

In the following sections of this chapter, each activity is briefly outlined to provide an overview of the procedure. The specific components of the process are described in chapters 7 to 10. Full documentation is available in the System Operation Manual.

6.2 Magic Box

Digitally transmitted data are downloaded from the main FFWC data box to the Flood Watch database. The data are preprocessed before entry into the Flood Watch database. A series of activities automating the necessary preprocessing is executed by clicking each icon in a series of steps illustrated in figure 6.1.

Each activity is represented by an icon within the Magic Box folder. Each icon is selected following the order lying in the folder. Full details of the function of each step are given in the documentation on System Operation.

6.3 Flood Watch

6.3.1 Introduction

Flood Watch is an ArcView GIS project. Three principle mapping activities are carried out within Flood Watch:

- Flood Forecasting
- Real Time Stations Display
- Thana Status Mapping

The various activities may be carried out within the Flood Watch ArcView interface, or executed by clicking with the mouse on the sequence of icons in the Flood Watch group, shown in figure 6.1.

6.3.2 Flood Forecasting

The activities involved in the flood forecasting procedure and carried out within Flood Watch are as follows.

Rainfall and Water Level Data Entry Rainfall and water levels for stations from which digitally transmitted data are not available are entered manually in the data entry form. The icon opens the data entry form and plots are taken to check for input errors. The form and plots are shown in figure 6.2.

Issue of Flood Observation Bulletin The production of the flood observation bulletin is created automatically on selecting the flood status bulletin icon. An example of the observation bulletin is given in Appendix V.

Data Processing and Visual Checking This icon starts the data processing. During processing, the following actions are carried out:

- water level bench mark corrections
- real discharges for the boundaries calculated
- scaled discharges provide discharge boundary conditions for numerous ungauged inflows in the north east
- all data for boundary stations are copied into temporary sensors in the database

Boundary Estimation and Visual Checking All the real time data up to 0600 hours of the current day are now in the database. Boundary information estimates for the period of the forecast are made 72 hours into the future at 24 hour intervals. Estimates are based on real time satellite images, real time water level and rainfall data from Bangladesh and India, and the FFWC officer's experience.

Update Stations Visual Check An automatic plotting facility is made from 4 to 8 days before the time of forecast to the time of forecast to check that all data are available at the updating stations (see figure 6.3). If data are missing they must be estimated and stored as processed water levels.

Data Conversion from FFWC Database to MIKE11 FF Database All data for MIKE11 simulations is written to the MIKE11 dedicated databases.

SuperModel Simulation The SuperModel has now the necessary data to perform a forecast simulation. The model is generally run from between 4 to 8 days before the time of forecast until 3 days into the forecast.

Backup of SuperModel Results The model results are copied to a backed up directory in order to ensure that the results are not lost.

Transfer of Model Results to the Flood Watch Database After a model simulation, the results are transferred to the Flood Watch database.

Issue of Forecast Bulletins Two forecast bulletins are produced automatically (examples given in Appendix V):

- Forecast Bulletin of forecast water levels for 30 stations over the next 72 hours at 24 hour interval
- Rise and Fall Bulletin for the forecast at 30 stations for the next 24 and 48 hours

6.3.3 Real Time Stations Display

An ArcView view displays the status of real time stations (water level and rainfall) for any day. Water level and rainfall stations are displayed as point themes on the view. The user selects the icon which updates the status of these stations to the user specified day according to assigned categories. An example of the station status is shown in figure 6.4.

6.3.4 Thana Status Mapping

An ArcView view displays the flood status of thanas for any day associated with the MIKE11 forecast simulation. The user selects the icon which updates the status of the thanas to the user specified date. The thana averaged water levels (relative to Danger Level) are categorised into one of three categories and displayed. The same thana map can also be created in black and white using shading instead of colours for transmission by telefax.

Following close interaction between the project staff and BTV technicians, and numerous trials with different formats, a special thana status map was produced for display on television. It has a black background and bright colours are used for better display on television (see figure 9.3).

An automated procedure has been established in FFWC to produce the map, which is directly sent via modem to a computer set up by the project in BTV, from where it can be transferred directly to the editing room for display and broadcast.

6.3.5 Flood Inundation Mapping

A flood inundation map is a plan map of an area showing the flood extent and depth, from which the areas inundated can be readily identified. Areas which are inundated to a shallow depth can be easily distinguished from areas deeply inundated. Features of flood inundation maps include:

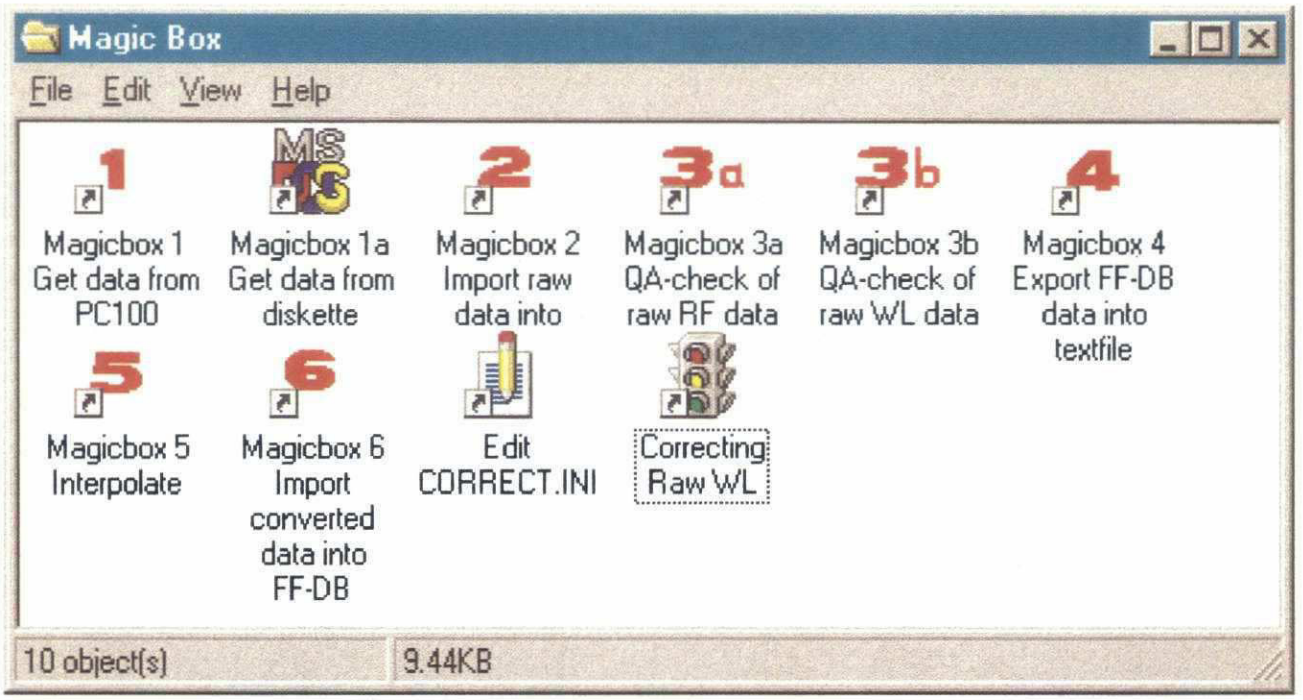
- different shades of blue for different depths of inundation
- significant hydrological features such as water level measurement stations

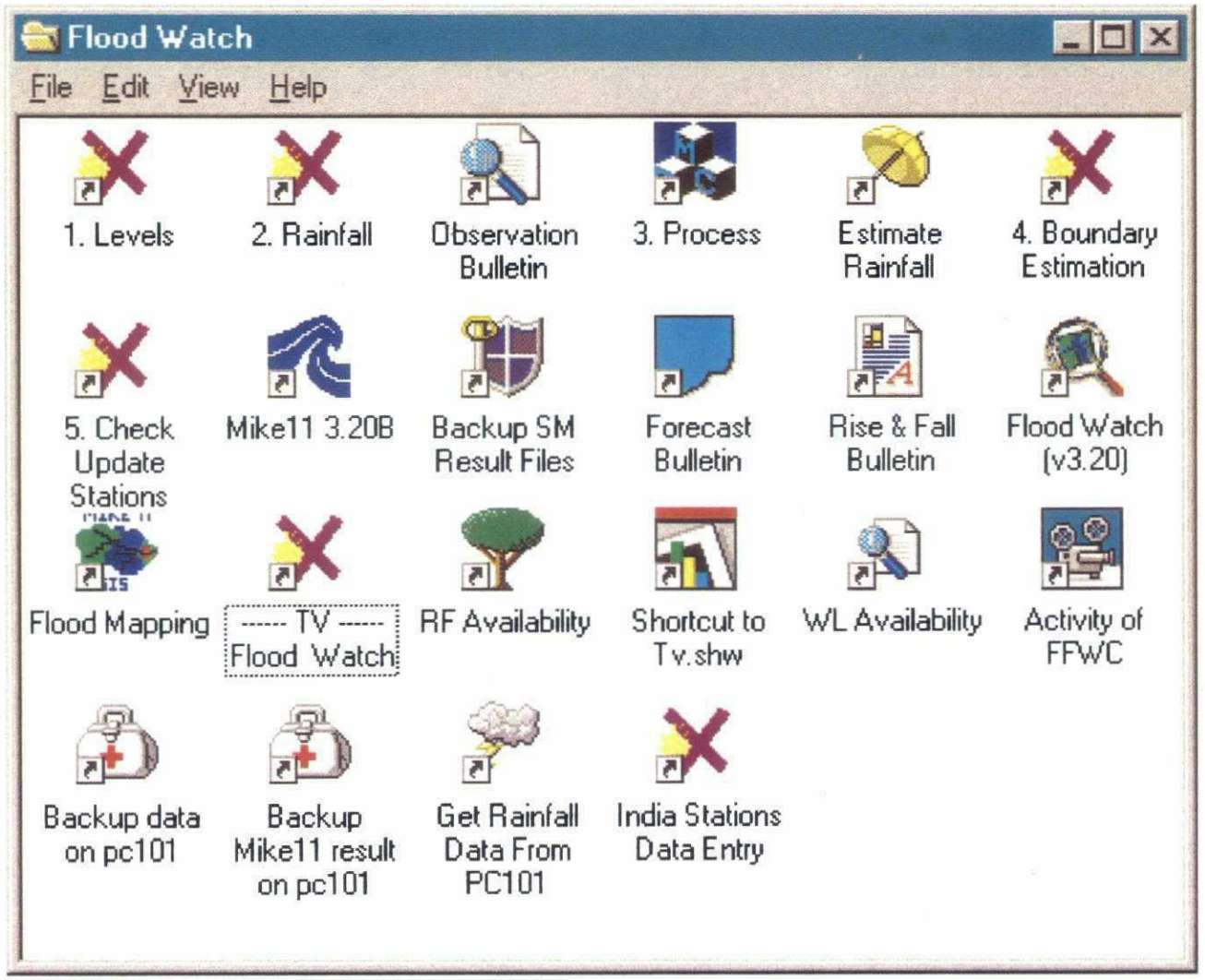
- other useful features such as thana boundaries, rivers, coastline, roads and railways

An example of a flood inundation map is given in figure 8.4.

Thana Mapping Based on Area Inundation

After the flood map has been generated the thana map based on the area inundated can be carried out. In the thana mapping based on area inundation the percentage of area inundated is shown (see figure 9.2).





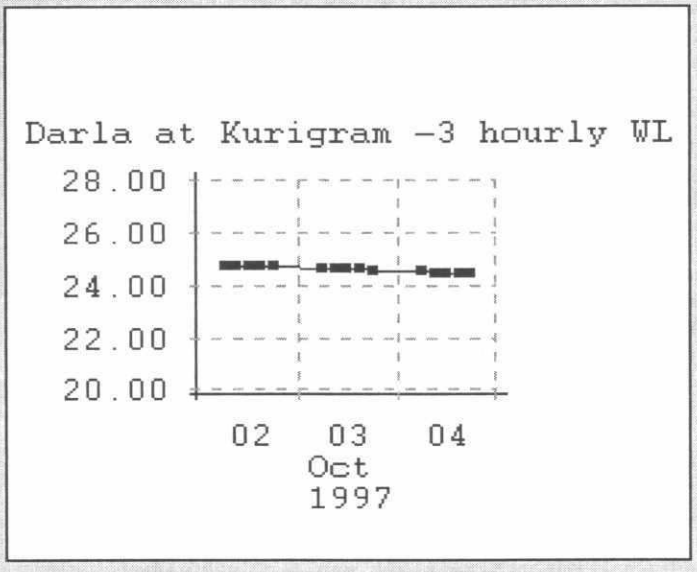
TOP : Databox Processing **BOTTOM : Forecasting and Warning**	**FFWC**
DAILY PROCEDURES	**FIGURE 6.1**

form - [levels.rls]

File View Window Help

	1997/10/04 06:00:00	1997/10/04 09:00:00	1997/10/04 12:00:00	1997/10/04 15:00:00	1997/10/04 18:00:00
Kurigram (\fap10\data\0	24.57	24.49	24.48	24.46	24.43
Dalia (\fap10\data\0016'	51.14	51.13	51.12	51.11	51.11
Kaunia (\fap10\data\003	28.27	28.29	28.28	28.28	28.25
Noonkhawa (\fap10\data	24.65	24.64	24.63	24.62	24.61
Chilmari (\fap10\data\0(	22.14	22.12	22.09	22.05	22.01
Bahadurabad (\fap10\da	18.39	18.37	18.36	18.34	18.32
Serajganj (\fap10\data\0	12.37	12.35	12.33	12.32	12.29
Aricha (\fap10\data\0002	8	7.99	7.97	7.97	7.95
Jamalpur (\fap10\data\0I					
Mymensingh (\fap10\dat	10.27	10.27	10.26	10.25	10.23
Dhaka -3h (\fap10\data\(	4.51	4.48	4.52	4.51	4.46
Dhaka -daily (\fap10\dat	4.51				
Narayanganj -3h (\fap10	4.6	4.66	4.71	4.64	4.55
Mirpur -3h (\					
Mirpur-daily					
Tongi (\fap1					
Taraghat (\fa					
Panchagarh					
Dinajpur (\fa					
Chapai-Naw					
Naogaon (\f					
Pankha (\fap					
Rajshahi (\fa					
Hardinge Bri					
Goalondo (\f					
Bhagyakul-3I					
Bhagyakul-d:					
Gorai Rly Bridge (\fap10\	10	9.97	9.93	9.91	9.9

Quick graph



CLOSE
< DAY
> DAY
+ DAY <
+ DAY >
NEXT
PREVIOUS

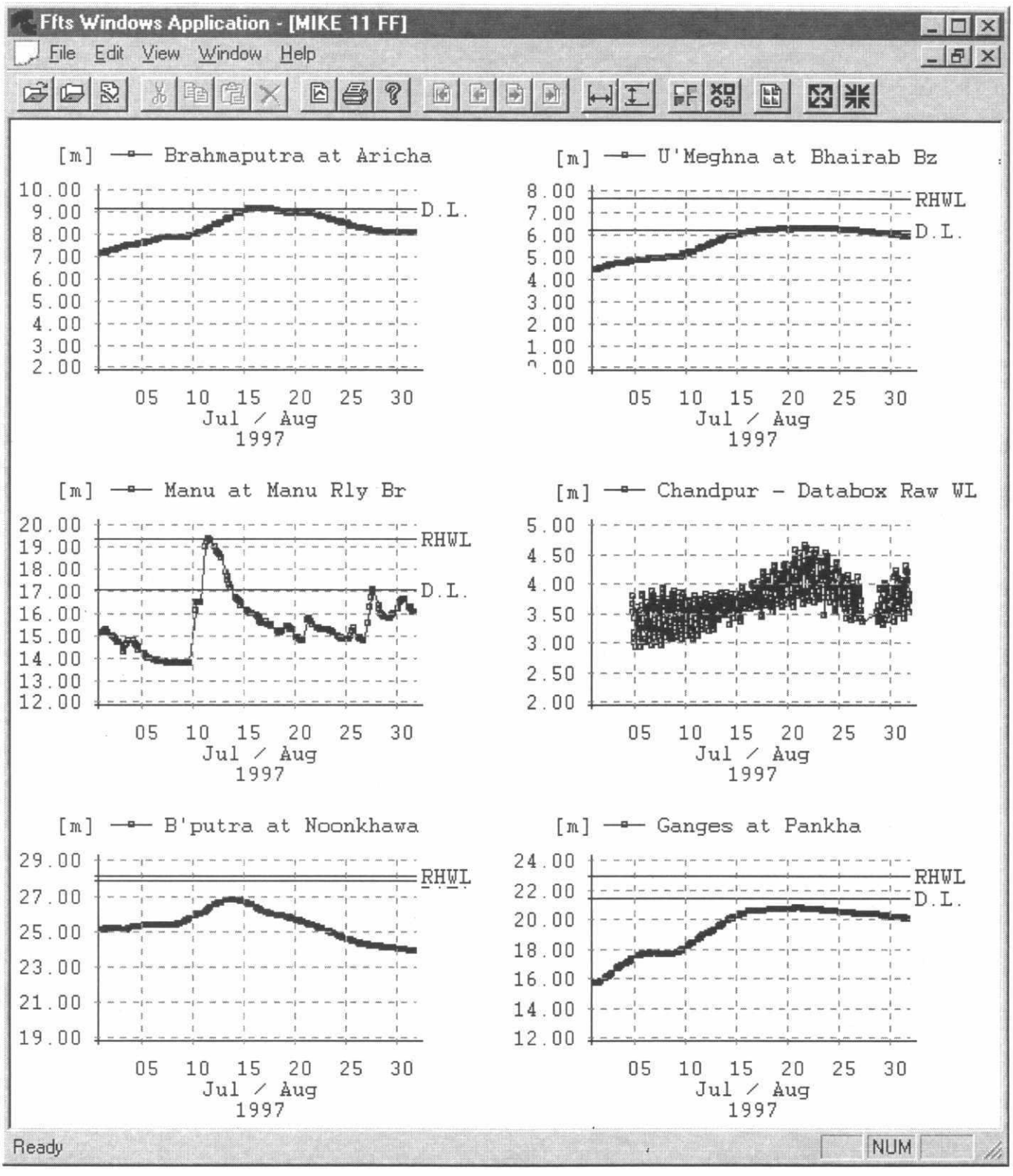
Ready NUM

Entry screen showing online data checking capability

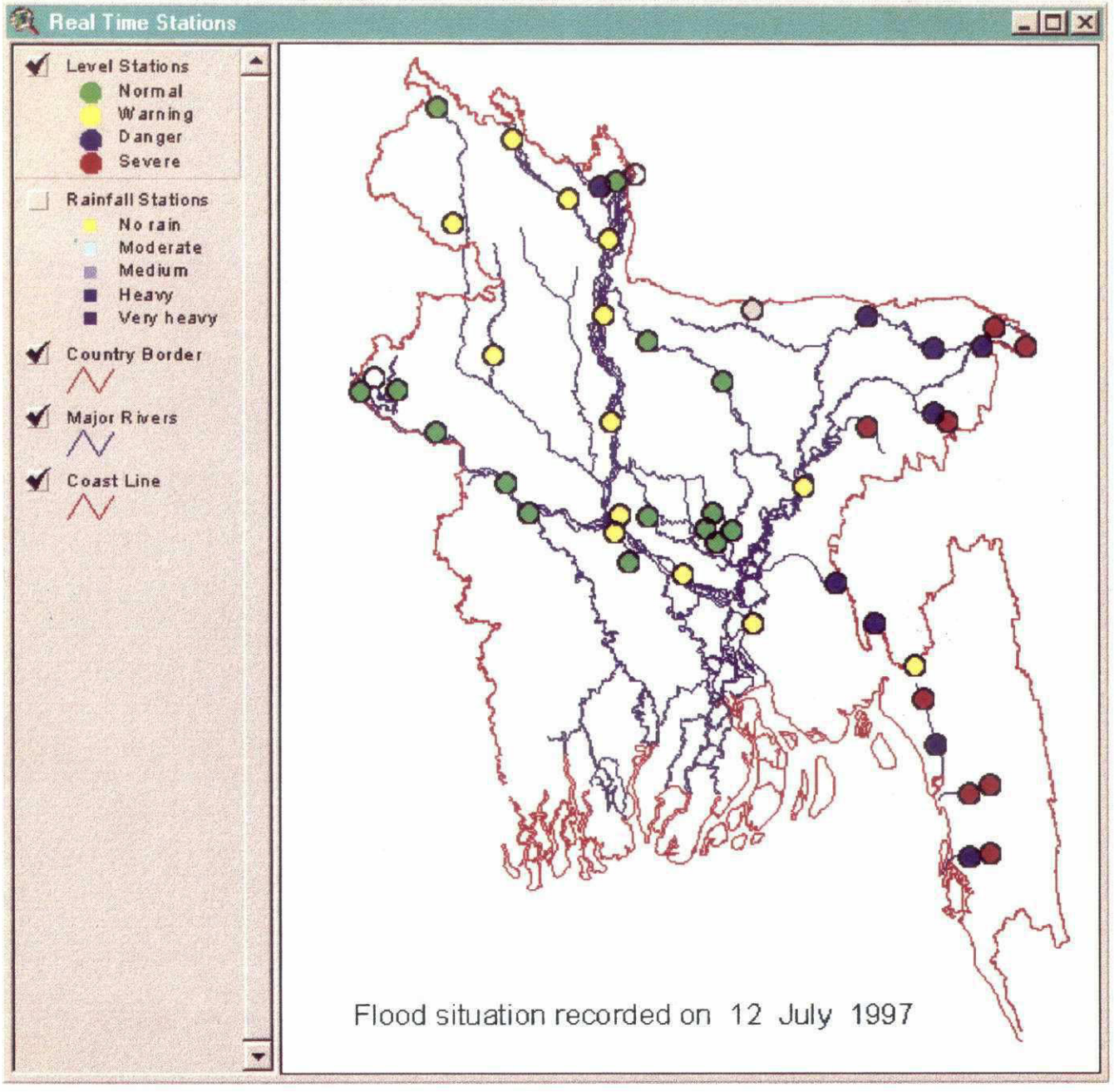
FFWC

DATABASE ENTRY

FIGURE 6.2



Flood Forecasting Time Series utility displaying time series plot, Danger Level and Recorded Highest Water Level	FFWC
DATABASE TIME SERIES PLOTS	**FIGURE 6.3**



Utility displaying status of real time water level stations	**FFWC**
REAL TIME WATER LEVEL STATIONS	**FIGURE 6.4**

7. FLASH FLOOD FORECASTING

7.1 Introduction

Flash floods differ from normal floods in the rapid rate at which the catchment runoff enters the rivers, and the rate at which the flood wave travels downstream. Normal flooding in Bangladesh develops gradually over a number of days or even weeks. Flash floods are much more dynamic and occur in a matter of hours following the rainstorm.

The nature of the floods leaves little time for vulnerable people to protect themselves and their property. The result is injury and loss of life, damage to property, and considerable loss of livestock and crops.

7.2 Previous Procedure

Prior to FAP 10, there was no methodology developed to carry out flash flood forecasting. As the SuperModel covered the flash flood areas, forecasts were made for these regions.

The single most important factor in flash flood forecasting is quantification of the spatial and temporal variation of the rainfall in the catchment, transmitted in real time to the forecasting centre. Sparse data arriving hours after the rainfall is recorded are inadequate for any sort of forecast. The level of accuracy was low, and it was considered that a separate flash flood model would provide more accurate forecasts for these regions.

7.3 Development Process

7.3.1 Introduction

The first stage of development was to determine whether the present software (MIKE11) would perform satisfactorily when modelling flash floods. Tests were carried out on historical data to determine the applicability of MIKE11. It was ascertained that MIKE11 was capable of simulating these events. It was then decided to develop flash flood forecasting for two flashy catchments on a pilot basis.

One of the main difficulties in flash flood forecasting is the estimation of boundaries, ie upstream inflows and rainfall over the catchment downstream. Conventional procedures do not yield very accurate estimates. One alternative methodology is through the use of artificial neural networks (ANN). ANN is an area of artificial intelligence based on pattern recognition. Research into use of various algorithms of ANNs is being carried out worldwide for application to pattern recognition problems.

During this project the use of ANN was investigated to give an indication of whether this methodology could be used to develop a decision aid tool for upstream boundary

estimation. After testing two algorithms, it was concluded that ANNs could be used to improve boundary estimates not only in the flash flood region but for nearly all boundaries.

Primarily, flash floods occur in the north east and the north west regions of the country. In the north east, flash floods are triggered by rainfall in neighbouring Indian catchments and its associated runoff into Bangladesh. In the north west, rainfall is predominantly within Bangladesh, although there is also substantial cross border runoff into Bangladesh causing flash floods.

As the spatial events are slightly different in the two regions, it was decided to select one study from each region. The north west flash flood model comprises the Karatoya-Atrai system, and the north east the Manu system. The locations are shown in Figure 7.1.

7.3.2 North West Flash Flood Model

The north west region experiences flash floods due to high intensity rainfall within the country as well as cross boundary runoff into the catchment. Floods are forecast for Dinajpur and Bhushirbandar. Dinajpur is a boundary station for the SuperModel and lies close to the international border. The river flowing through Dinajpur, the Punarbhaba, continues into India and re-enters Bangladesh just north of Rohanpur on the Mohananda. There is no data available for the reach within India. Cross sections were derived for this reach from the hydraulic characteristics of the flow, and a good calibration was achieved.

Five real time rainfall and water level stations were installed in the catchment, as shown in figure 7.1. Data transmission from Rohanpur proved erratic and could not be used as intended as a boundary station. The model was extended downstream to Chapai Nawabganj which has a more reliable real time water level station.

7.3.3 North East Flash Flood Model

The north east flash flood model was developed along the same lines, based on the availability of real time data and a limited area covered to allow very fast computation times. In case of a flash flood the model would be run several times a day to update the forecast.

The Manu catchment was selected for this study (see figure 7.1). Manu Railway Bridge is located some eight kilometres within Bangladesh from the Indo-Bangla border. Manu, and subsequently Moulvi Bazar, experience flash floods due to rainfall across the border and by rainfall within the Manu catchment. The model was set up as shown in figure 7.1 with four real time rainfall and water level stations.

During development the Dhalai river proved to contribute as much as 30% of the flow in the Manu catchment. This is a scaled boundary, ie the flow at Dhalai is taken as 33% of the flow at Manu Railway bridge. As Moulvi Bazar is an updating point, it is not of major importance to have a real time boundary at Dhalai.

Data for the remaining stations, with the exception of Sherpur, are transmitted via Orion 7000 radio and Magic Box. Sherpur is a telemetric station capable of automatic unmanned reporting every hour round the clock. Frequent reliable measurements of water level and rainfall are of great value in flash flood forecasting. The data received from Sherpur are not reliable and the station is often not functioning. It was not possible to extend the boundary downstream as this would involve the addition of numerous rivers and flood plain channels in the model, making it too complex for rapid repeated simulations.

7.4 Present Procedure

Flash flood forecasting was carried out with the north west flash flood model only. Though the flash flood model is also set up for the north east, it was not possible to develop routine forecasting due to the irregularity of data transmission from Sherpur.

Procedurally, flash flood forecasting is the same as SuperModel forecasting. The difference lies in the frequency of boundary estimation. In the SuperModel, the boundary estimates are made for 24, 48 and 72 hours from the time of forecast. The requirement for the flash flood model are boundary estimates of both water level and rainfall at three hour intervals for the next 24 hours. Whereas estimation of water level is relatively simple, estimation of rainfall requires online satellite information at an maximum interval of 6 hours, and an interpretation of the images to quantify the rainfall.

The north west flash flood model updates and forecasts at two stations, Dinajpur and Bhushirbandar, and was implemented in August 1997. A minor event in that month provided an opportunity to test the approach.

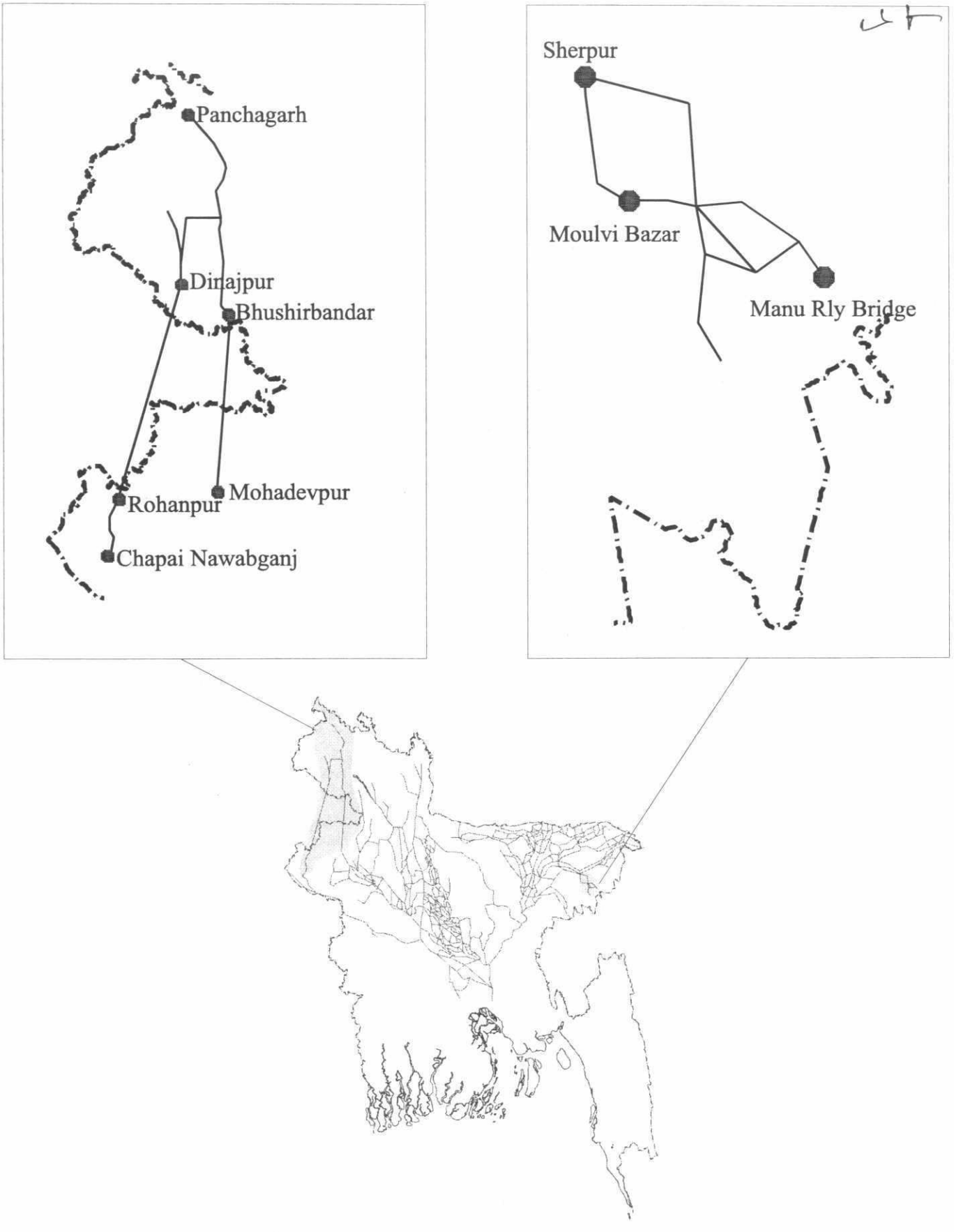
Using observed data up to that date, a forecast was made on 13th August for the 14th. The forecast was later plotted with the observed data to assess the quality of the forecast, as presented in figure 7.2. At Dinajpur, the mean difference is about 25cm and at Bhushirbandar it is about 10cm. The accuracy of the forecast is significantly less than for the SuperModel on the main rivers.

7.5 Conclusions and Recommendations

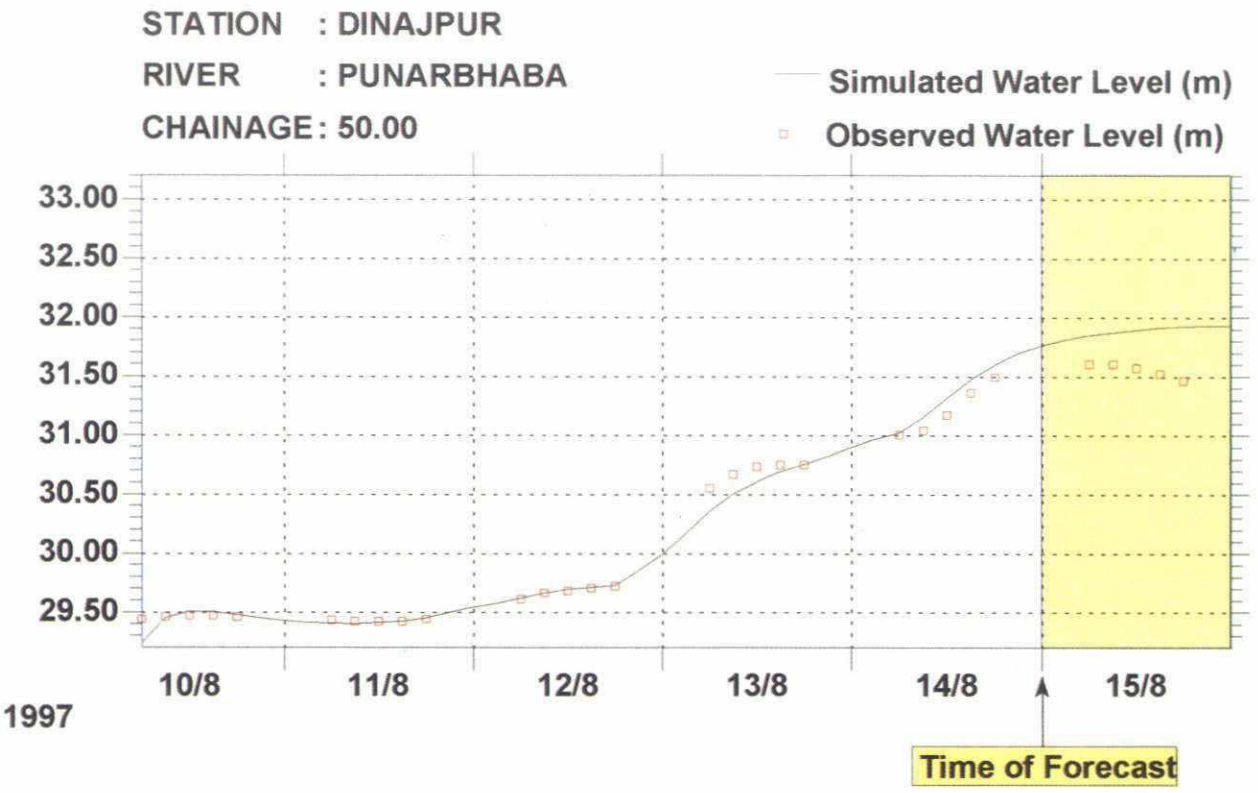
A procedure other than that of the SuperModel forecasting is required to improve forecasting for flashy catchments. Development of the flash flood forecasting methodology is a step in that direction. The forecasting solution may remain the same as it has been established that MIKE11 performs well enough to simulate flash floods. More emphasis has to be placed on boundary estimation.

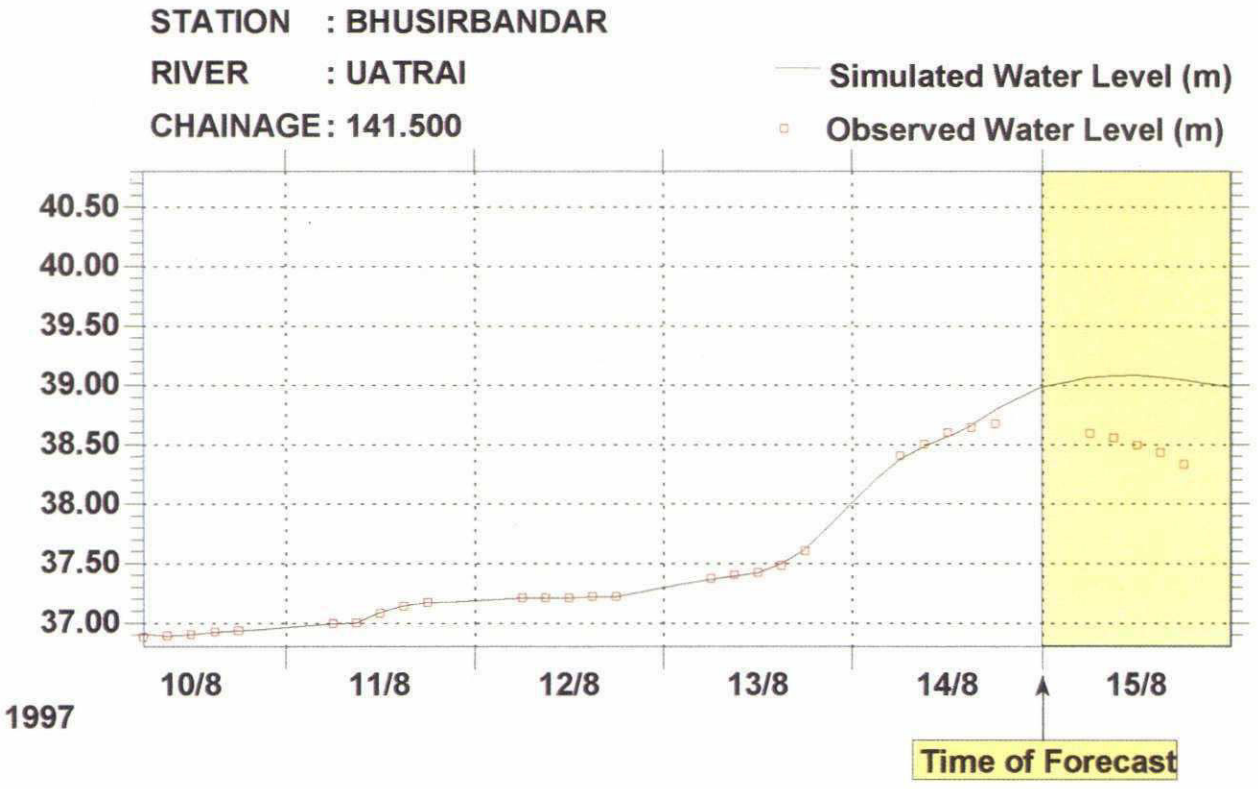
Boundary estimation is in itself flood forecasting at the model boundaries. MIKE11 propagates this information into the model domain. Estimation of flashy boundaries in the present case requires more real time water level and, more importantly, rainfall data from cross boundary location.

Quantitative estimation of rainfall from remote sensing data is invaluable; reception and interpretation of satellite data has been initiated at FFWC and these skills can be further developed to improve estimation of flash flood boundaries. Decision support tools based on statistics or neural networks should be developed. The knowledge so far acquired of ANNs should be extended and a generic routine developed to aid boundary estimation.



LEFT : North-West Model **RIGHT : North-East Model**	**FFWC**
FLASH FLOOD FORECASTING MODEL AREAS	**FIGURE 7.1**





North West Flash Flood Model Forecasts for 15th August 1997, shown in shaded areas	FFWC
FLASH FLOOD MODEL FORECASTS	**FIGURE 7.2**

8. SUPERMODEL FORECASTING

8.1 Previous Procedures

Prior to the initiation of the Expansion of Flood Forecasting and Warning Services (FAP10) there has been a number of overseas funded projects whose primary aim has been to improve data collection and storage and to improve flood forecasting in Bangladesh. In 1990 FFWC issued a daily flood status bulletin with around 36 water level stations and 34 rainfall stations. During the large floods which occurred in 1987 and 1988, FFWC issued two flood status reports a day, for 0900 and for 1800 hours.

Water level forecasts used the co-axial correlation method based on the Muskingum Routing Method and trend analysis. Forecasts were made for Hardinge Bridge, Bahadurabad and Goalundo for the coming 24 hours.

In the course of the UNDP/DANIDA funded project (1990 to 1994), training was given to FFWC staff on the principles and operation of MIKE11 at DHI in Denmark. MIKE11 was installed in FFWC and set up for operational testing for 24 hour flood forecasts in Bangladesh.

8.2 Development Process

8.2.1 SuperModel Improvements

The need for improvement to the mathematical forecasting model has been primarily driven by the objective of large scale area inundation forecasts for the northern regions of Bangladesh. The initial plan to develop local area inundation forecasting at two or three selected pilot areas was amended at the request of GoB to area inundation forecasts at a coarse level for the major part of northern Bangladesh. Additional objectives have been an increased number of real time data inputs and forecast locations, and improved accuracy.

The development of the MIKE11 model for flood forecasting in Bangladesh has been a continuous process from the incipient stages of FAP10 to the present final product. The models developed under FAP10 are the largest MIKE11 models ever to be developed. The model is a combination of the General and three Northern Region models developed in SWMC. It is referred to as the SuperModel.

The SuperModel covers the entire North and Central Regions of Bangladesh, north of the Ganges and the Padma, and the North East Region above Bhairab Bazar (see figure 8.1). All major rivers and flood plains are included in the model. The modelled catchment area is 82,000 km^2, and comprises 7,270km of rivers and flood plain.

Several catchments extend across the international border into India, particularly in the north west and north east. The rainfall-runoff process is modelled using data from the 8 real time rainfall stations located within or bordering the model area.

In addition to the most significant rivers, namely the Jamuna, Ganges, Padma and Meghna, the SuperModel includes all major rivers in the North West, North Central and North East regions. The coverage of the model has been greatly expanded and intensified compared to the model available before FAP10 was initiated.

The SuperModel has a total of 26 boundary stations, where data are mainly available from real time water level stations. Where rating curves are available at upstream boundaries, discharges are generated for the model boundary. Mean tidal water level is specified at the downstream boundary at Chandpur. A rating curve is used for the downstream boundaries on the Arial Khan. The remaining boundaries are discharges scaled according to relative catchment areas from adjacent discharge boundaries, generally in the north east where there are numerous small streams in inaccessible areas.

River embankments are common in the north east and north west regions and along the banks of the Ganges and Jamuna. Embankments, including railways and roads, prevent or impede the exchange of water between the rivers and flood plains. They are taken into account in the model. There are several locations where breaches in embankments regularly occur. The present model reflects the position of the breaches at the end of the 1995 monsoon, as far as available information allows.

Following the major land survey in the north east carried out jointly by the Survey of Bangladesh and the North East Water Resources Project (FAP6), a large number of corrections has been made in the North East Region. Both the cross sections used in the model and the water levels used for boundaries and water level comparisons have been adjusted according to the survey results.

Updating is the term used for forcing the model to reproduce observed water levels at key points so that the model truly represents the actual hydraulic state at the time of forecast (see figure 8.2). Updating is applied from the simulation start (say five days before the time of forecast) to the time of forecast. By forcing the model to reproduce the hydraulic state of the system at a network of points covering the model domain, the model's hydraulic state will lie very close to the actual hydraulic state at the time of forecast. Updating is carried out on 25 water level stations throughout the model domain.

8.2.2 Staff Training

Mathematical modelling is the most technically demanding of all the tasks carried out by the staff of FFWC. Two four month training courses at the headquarters of DHI in Denmark were given each to four FFWC staff. The training covered all aspects of model development, including the forecasting updating procedure and incorporation with GIS for flood inundation mapping. In addition, a concluding Workshop was given in FFWC for one week for all the staff of the Centre.

The SuperModel is almost certainly the largest and most complex river model constructed anywhere to date, and has the additional features of updating for forecasts and linkage with GIS. The staff of the Centre are familiar with the model, and are fully capable of operating the model on a daily basis. They are also aware of the limitations of the model in respect of accuracy, and spatial and temporal resolution.

The model is a crucial part of the forecasting and warning process. Like any computer software, it can fail. Usually the problem will be incorrect input data which have not been detected in the quality control process, but the problem nonetheless has to be recognised and dealt with promptly. The staff of the Centre have only limited experience in this area, and future training should concentrate on troubleshooting to be aware of a problem, to identify it and to correct it as quickly as possible.

The rivers of Bangladesh are morphologically dynamic, and this is reflected in the resulting pattern of flooding. Over the years, major changes will occur in parts of the river system. The model will need to be brought up to date by incorporating the new river cross sections and possibly also new river connections. Significant changes are likely to require a local recalibration of the model.

In this respect, the staff of FFWC will require expert assistance, which is available for instance from SWMC. The incorporation of changes may only be required say once every three years. The Centre's staff should be fully involved in the process, in order that over time they can acquire the skills to carry out the task independently.

8.3 Present Procedure

8.3.1 Running MIKE11 Flood Forecasting Model

The MIKE11 model is run by clicking the appropriate sequence of icons in the Flood Watch Group (part of the entire forecasting procedure described in overview in chapter 6).

The data necessary to run the MIKE11 Flood Forecasting model are first transferred to the MIKE11 databases. The simulation is made starting between four to eight days before the time of forecast until three days after the forecast. Water levels (and discharges) throughout the system are calculated every hour, though only stored every 24 hours of simulation time. Previous model runs provide the initial starting state in the rivers, and the model run time is around one hour.

A summary of the accuracy of the forecasts comparing the predicted water levels with those actually recorded is presented in figure 8.3.

On completion of the forecast, the final step is to transfer the model results to the Flood Watch database, and to a folder from where they will be automatically backed up in the evening.

8.3.2 Flood Inundation Mapping

The results of the MIKE11 model are time series of water levels and discharges throughout the model area. These can be presented in tables and plotted as hydrographs and longitudinal profiles.

A highly visual presentation of the results can be made showing the flooded areas and depths in plan. This is achieved through the integration of MIKE11 with a digital model of the flood prone terrain, termed a digital elevation model (DEM) through the medium of GIS. The accuracy of the results depends not only on the accuracy of the water levels calculated by MIKE11, but also on the accuracy of the topographic data in the DEM.

Flood inundation maps are produced from the forecast results showing the areas and depths of flooding for the entire forecasting area. A maps for one specific day in the course of the 1997 monsoon is shown in figure 8.4.

As the DEM is relatively coarse, 1.0km resolution, and there are inaccuracies in the DEM, the presentation is relatively coarse and cannot be relied to present a highly accurate picture of the flooding. Nonetheless, the presentation has a high impact, and can be used to provide an overall impression of the state of flooding in the country. Improved topography can be built in as it becomes available.

8.4 Conclusions and Recommendations

8.4.1 Conclusions

Flood forecasts at a large number of stations throughout Bangladesh have been regularly produced each day of the monsoon season under the Flood Watch system. Flood forecasting with the SuperModel under the setup installed at FFWC is fast, stable, reliable and the procedure has been automated as much as possible.

Flood maps have been produced regularly throughout the monsoon season. These flood maps include:

- real time (water level and rainfall) status maps
- thana status maps based on water levels/danger levels and area inundation
- flood inundation map

The FFWC officers possess the knowledge to operate the flood forecasting system and carry out the mapping, and possess sufficient theoretical background knowledge of the MIKE11 modelling system, including the MIKE11-GIS.

8.4.2 Future Improvements

The following lists some relatively minor but worthwhile improvements that could be usefully be made to the SuperModel to improve the accuracy of the forecasts. Details are provided in the documentation.

(1) The north west region of the SuperModel could give more accurate forecasts using available rainfall data from the real time water level stations.

(2) The accuracy of forecast gives an indication of where model calibration could be improved: these areas should be examined for possible improvements.

(3) Forecasts within the model domain are computed directly by the SuperModel. In order to carry simulations into the future the forecaster must provide the state of all boundaries in the forecast. There is a number of minor changes which would simplify the task for the FFWC officer: always desirable in critical situations.

(4) A large area in the north east is regularly inundated in the monsoon. The area stores a significant volume of water. An updating station near Bhusirbandar would improve the SuperModel forecasts downstream.

(5) The SuperModel though complex is robust. It may nonetheless crash for some reason, eg an undetected data input error. An alarm (eg a flashing red screen) should be triggered to inform the user of the problem. Otherwise the user may not be aware that a problem exists for some time.

(6) The rivers of Bangladesh are in a continual state of evolution which is a dynamic balance between the flow of water and the flow of sediment. Because the rivers are in a continual state of change the model must also be continually adjusted to account for these changes. Only the most significant changes need be included. Model maintenance should be carried out once every two or three years, or on major sudden changes in the river regime.

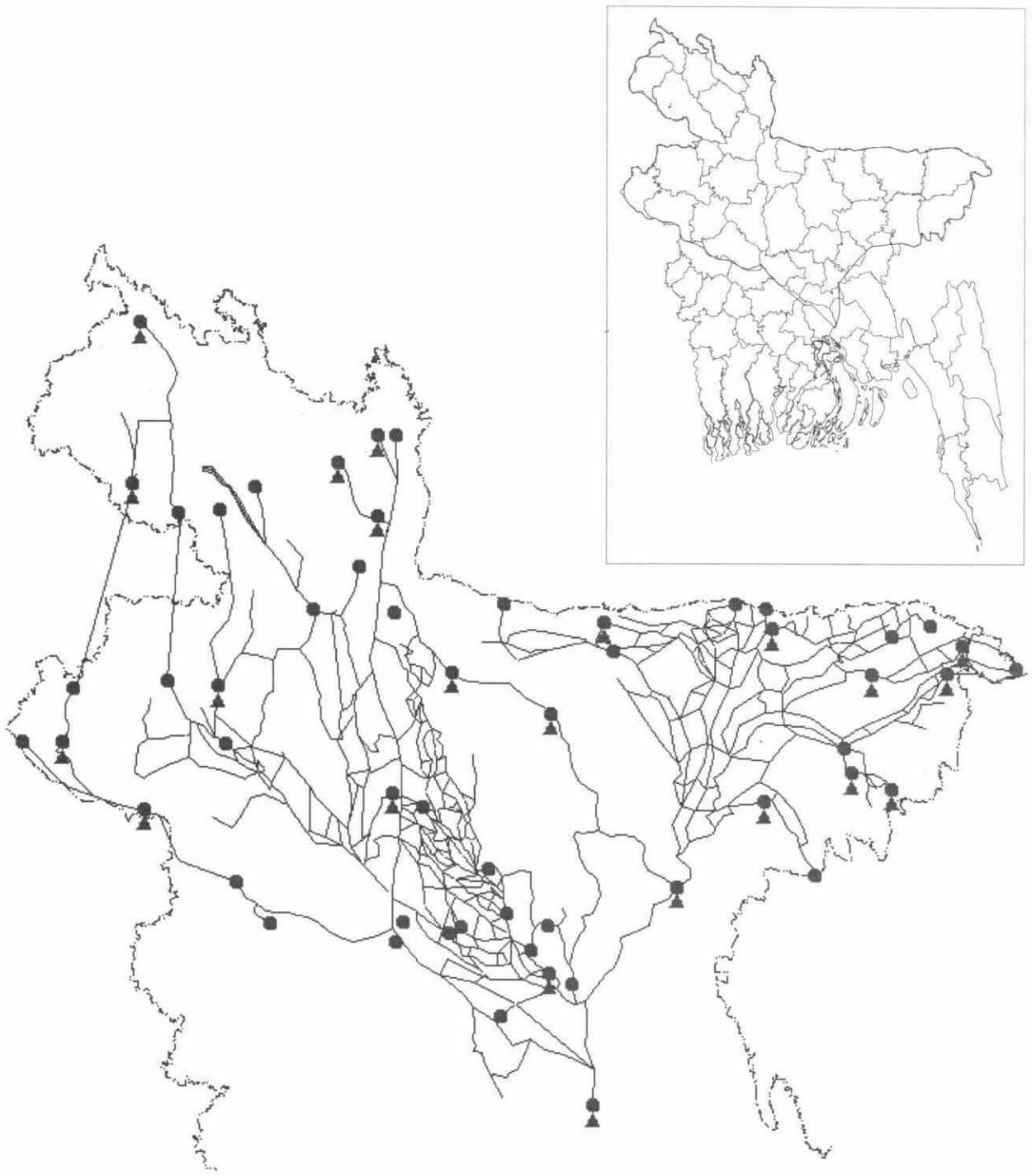
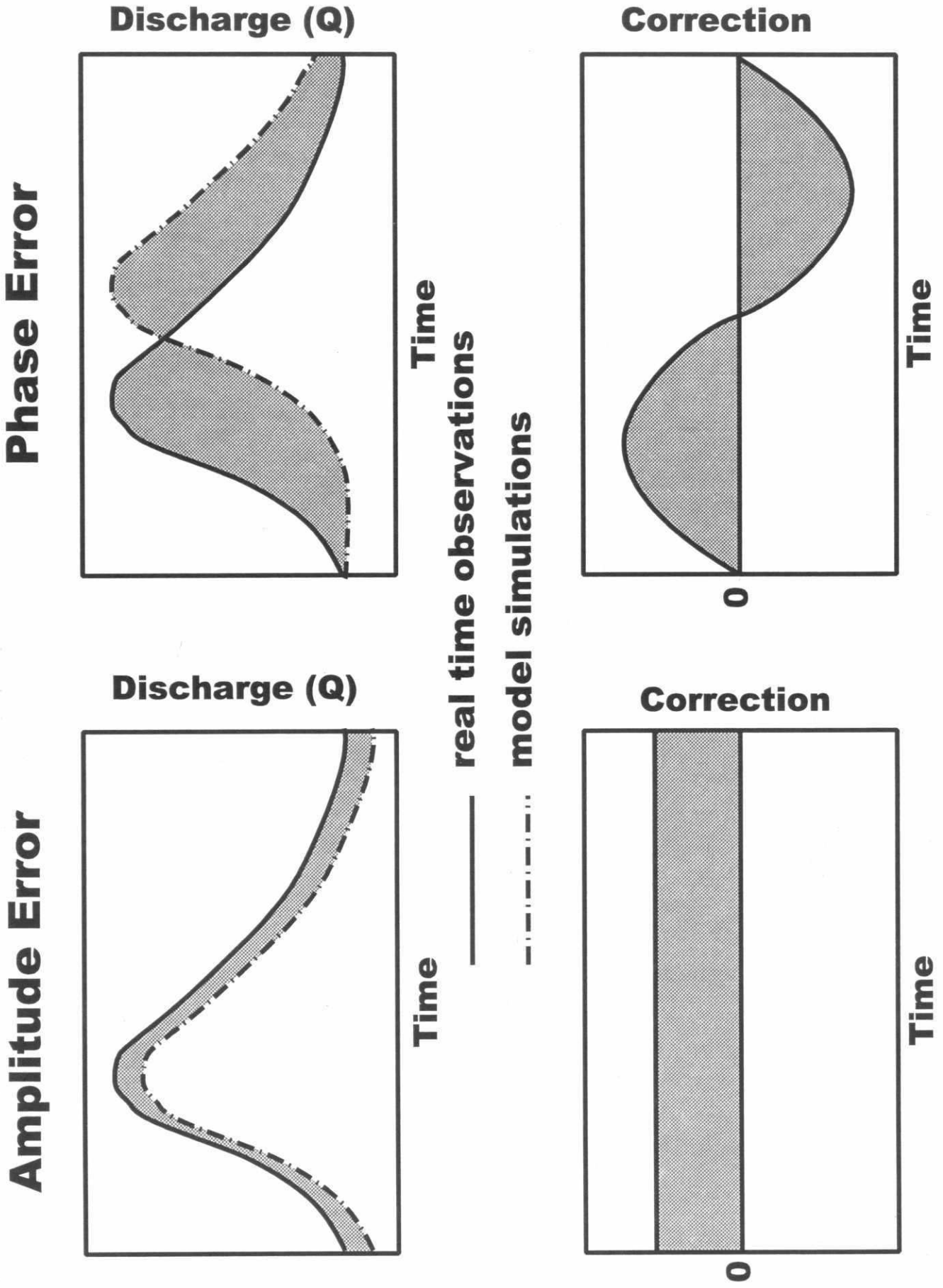


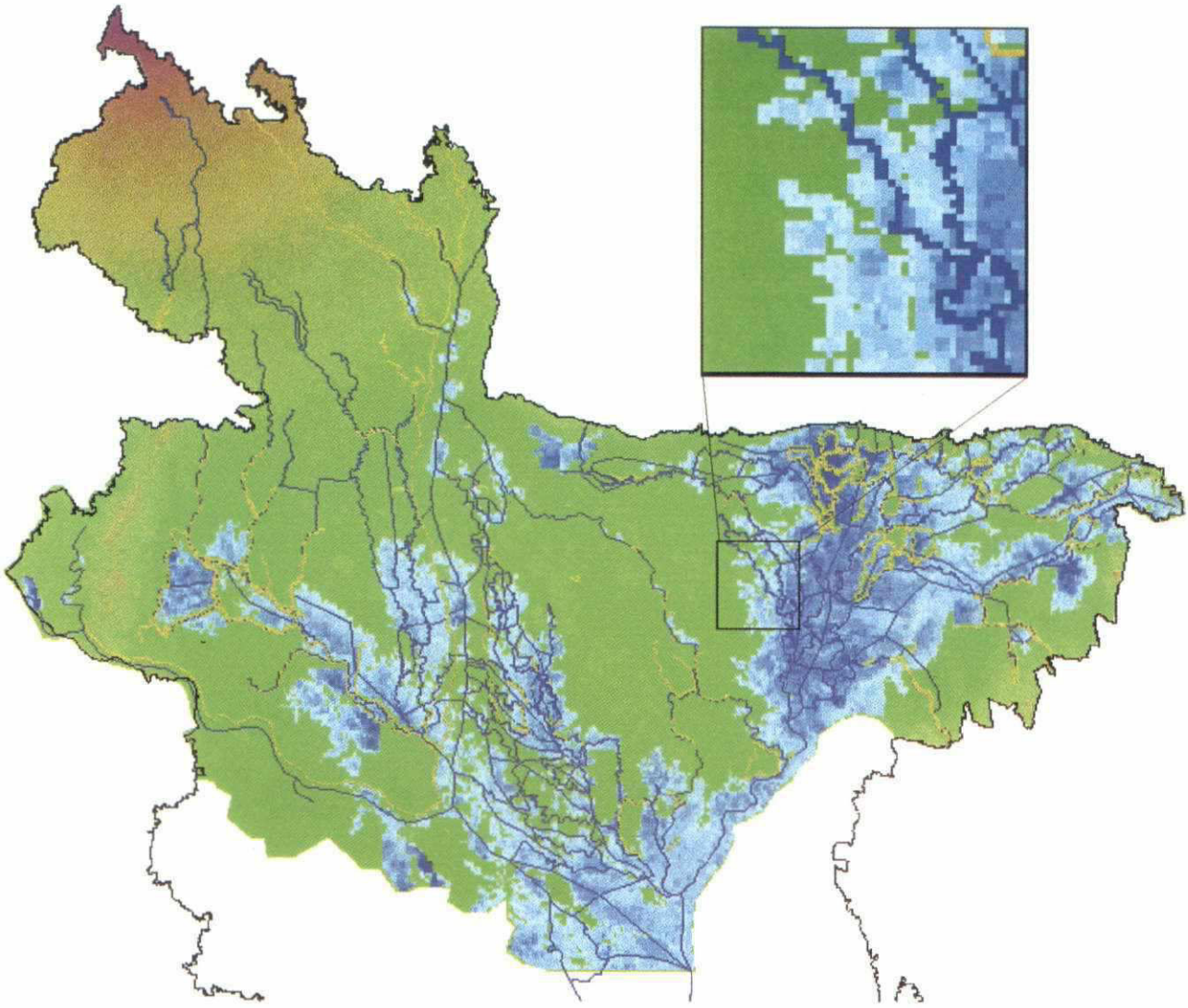
Figure showing detail, extent and real time Rainfall and Water Level stations of the forecasting model area	FFWC
SUPERMODEL	FIGURE 8.1



UPDATING PROCEDURE	FIGURE 8.2

Under Preparation

Performance of the Forecasting Procedure	FFWC
SUPERMODEL FORECASTS	FIGURE 8.3



Map showing flood extent and depth for 24th July 1997	FFWC
FLOOD INUNDATION MAP	**FIGURE 8.4**

9. PREPARATION OF FLOOD WARNINGS

9.1 Previous Procedure

Following the run of the flood forecasting model, the forecasts at 16 forecast sites on the main river system are extracted for 24 hours, 48 hours and 72 hours ahead of the last entered real time data. Forecasts are issued for 0600 on the three following days at 1300 on the day of the forecast. The forecasts are manually entered into a tabular format by word processor.

The Daily Flood Bulletin and Forecast Statement in addition includes a narrative situation summary report describing the current meteorological situation and state of the rivers according to the three major river basins, and the Chittagong and Hill Tracts. It is distributed to a total of 58 offices of the government, donor organisation, and news and information media by messenger and telefax. Samples of the warnings are shown in Appendix V.

9.2 Development Process

The goal of the project in preparing flood warnings has been to improve the production of the warning information by:

- automating the production of the existing messages easing the pressure on FFWC staff; people who are familiar with and can understand the import of the existing messages will still receive them in the same format
- producing simple flood warnings for immediate broadcast over the radio and television and publication in other media
- producing flood warnings in readily assimilable visual formats for broadcast over television, publication in printed media and general dissemination

The main tools introduced to effect the improvements are:

- exploiting the data exchange facilities offered by new operating and network systems
- Geographic Information System for the analysis and display of the data and forecasts

Owing to the limitations of the DOS address space, the previous use of MIKE11 for flood forecasting in Bangladesh was on a UNIX platform. Running UNIX in Bangladesh has the problem that if the system fails or requires maintenance, the required skills are not readily available. The Windows platform removes the memory constraint, and also permits ready interchange of data and text among the software utilised for forecasting and for warning preparation.

During the 1996 monsoon, the flood inundation mapping facilities were developed and used on an experimental basis as part of the daily routine in FFWC. The initial plan to develop local area inundation forecasting at two or three selected pilot areas was amended at the request of GoB to area inundation forecasts at a coarse level for the major part of northern Bangladesh (North West, North East and North Central Regions).

In 1997, the main river embankments were added to the digital elevation model in MIKE11-GIS. Some teething troubles were experienced, but the flood inundation mapping has been fully operational from August 1997.

9.3 Present Procedure

The components developed for the improved warning format are:

- maps displaying the status of the real time rainfall and water level stations
- simple messages designed for immediate broadcast on radio, television, and publication in other media
- maps show the severity of forecasted flooding in individual thanas
- maps showing the area and depth of flooding throughout the forecasting area

The procedure to generate the warnings is described in chapter 6. Examples of the warnings produced in the course of the 1997 monsoon are shown in figures 9.1 to 9.3.

9.4 Internet Site

The Internet as a medium for communication is growing at a phenomenal rate worldwide, and in Bangladesh also. The medium allows rapid and economical communication of information in both textual and visual formats.

This would be an excellent medium to disseminate flood information and warnings to a wide range of users. While the number of organisations or individuals with access to the Internet in Bangladesh is presently limited, it is growing rapidly. Among the potential present users are:

- the Prime Minister's Office
- government departments
- district offices
- NGOs
- international donor and funding agencies (both inside and outside Bangladesh)

The site would also provide the opportunity for feedback and comments from interested parties in Bangladesh and internationally.

An outline design is is shown in figure 9.4 for the design of the information which might be displayed on the FFWC home page. In order to receive the information, the end-user requires a Personal Computer with a modem, access to a telephone line and membership of an Internet Service. The cost is very modest in consideration of the benefits to be realised.

9.5 Conclusions and Recommendations

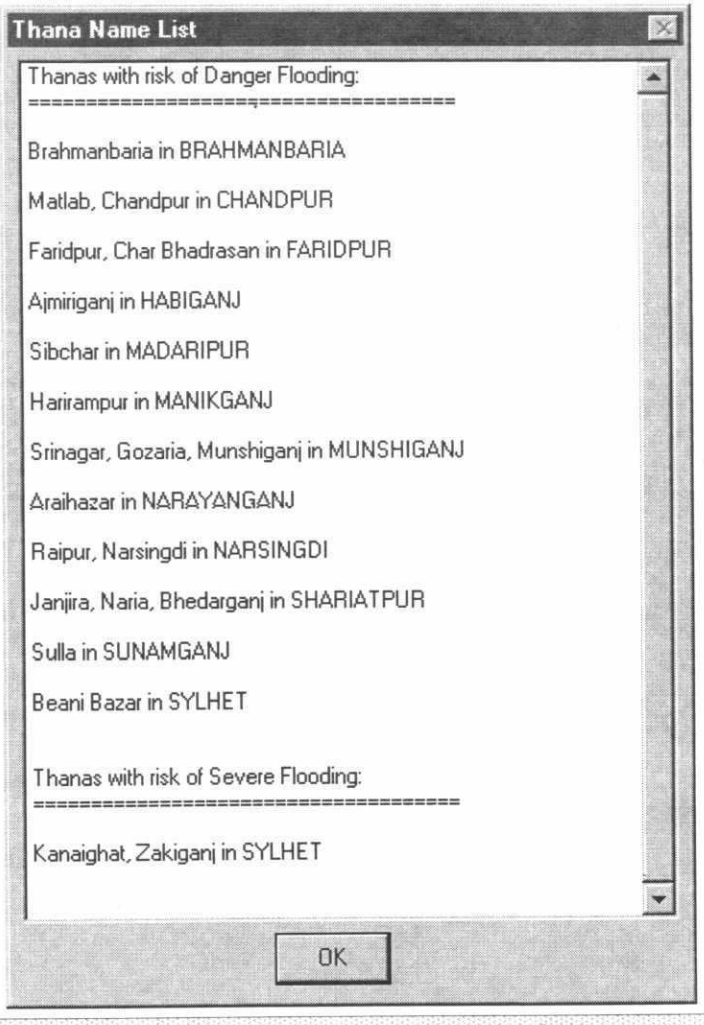
Owing to teething troubles with the production of the flood inundation maps from the enhanced SuperModel, and the continued development of the visual warning presentation, the system was not running smoothly and reliably until August 1997. Formal approval of the proposed warning messages was not obtained from the Steering Committee. The new visual formats were not reliably generated over a sufficient period of time to instill confidence in the project management in widespread broadcast.

Consequently, while the achievements in improved forecasting and warning preparation within FFWC have been considerable, there has not been the opportunity to take advantage of these advances through widespread dissemination. It is recommended that in the interim period the formats are approved by the Steering Committee, with amendments as deemed necessary, the forecasting and warning is commenced early in the next monsoon and, once the forecasts and visual warnings have been reliably generated for say one month continuously, they are utilised for broadcast and dissemination.

This Flood Warning is issued by Flood Forecasting and Warning Centre Telephone (02) 955 3118 (02) 955 0755

DISASTER MANAGEMENT BUREAU should IMMEDIATELY transmit this message to DISTRICTS.

BANGLADESH RADIO and TV should broadcast this Flood Warning IMMEDIATELY after every news bulletin.



A Warning of Severe Flooding for <*list of districts*> was issued at <*time*> on <*day*> <*date*>.

The BWDB Flood Forecasting & Warning Centre reports that the River(s) <*river names*> are flowing well above Danger Level.

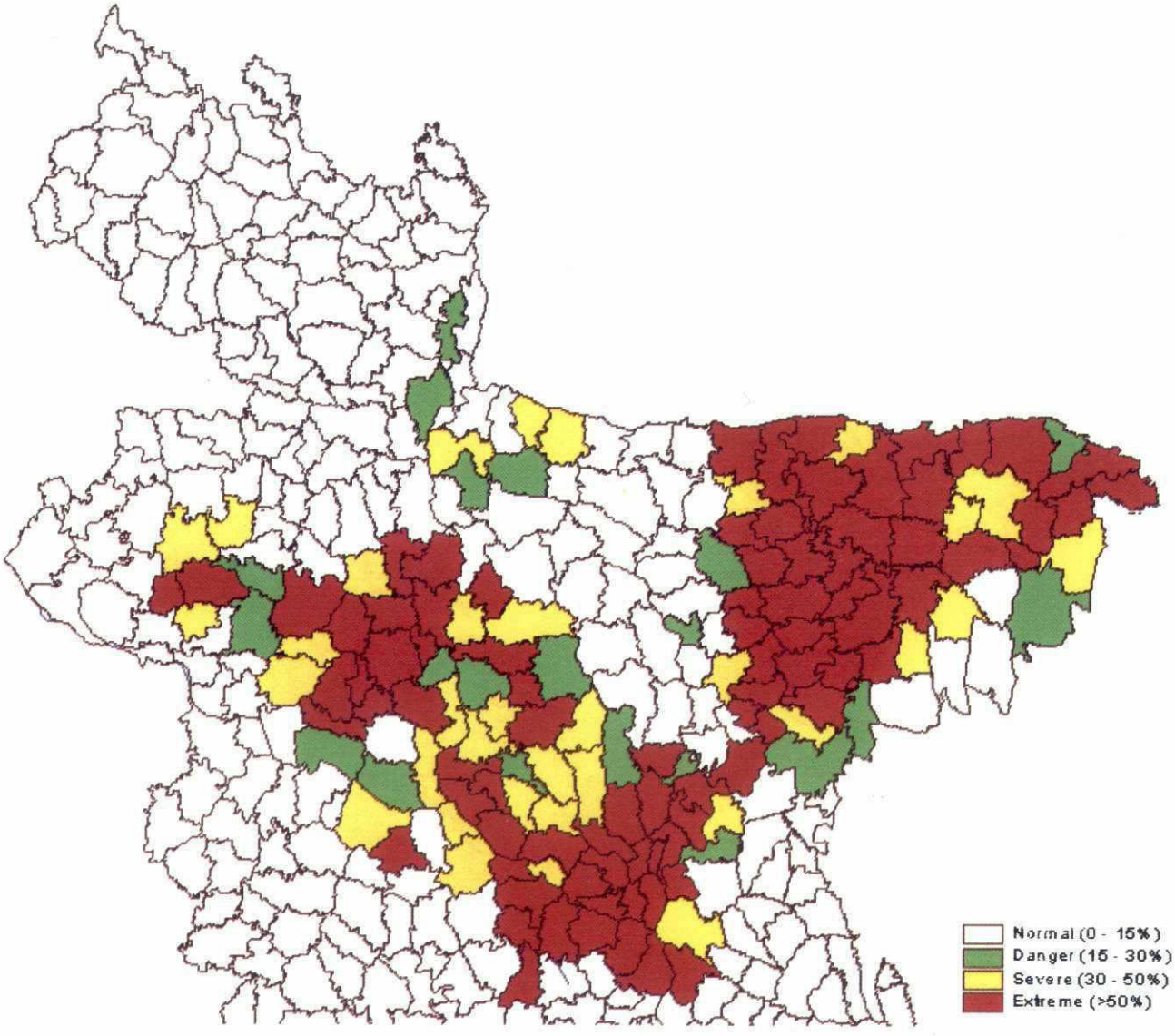
FF&WC forecasts predict that river levels will increase further over the next <...> hours. Flood water will rise above the BLUE zone in villages with a Flood Marker Post. Severe Flooding will inundate large areas of all these Districts during the next <...> hours.

Flooding will occur in many rural areas and may affect some towns. Damage to property is expected. Roads, railways, embankments and bridges are likely to be submerged and damaged.

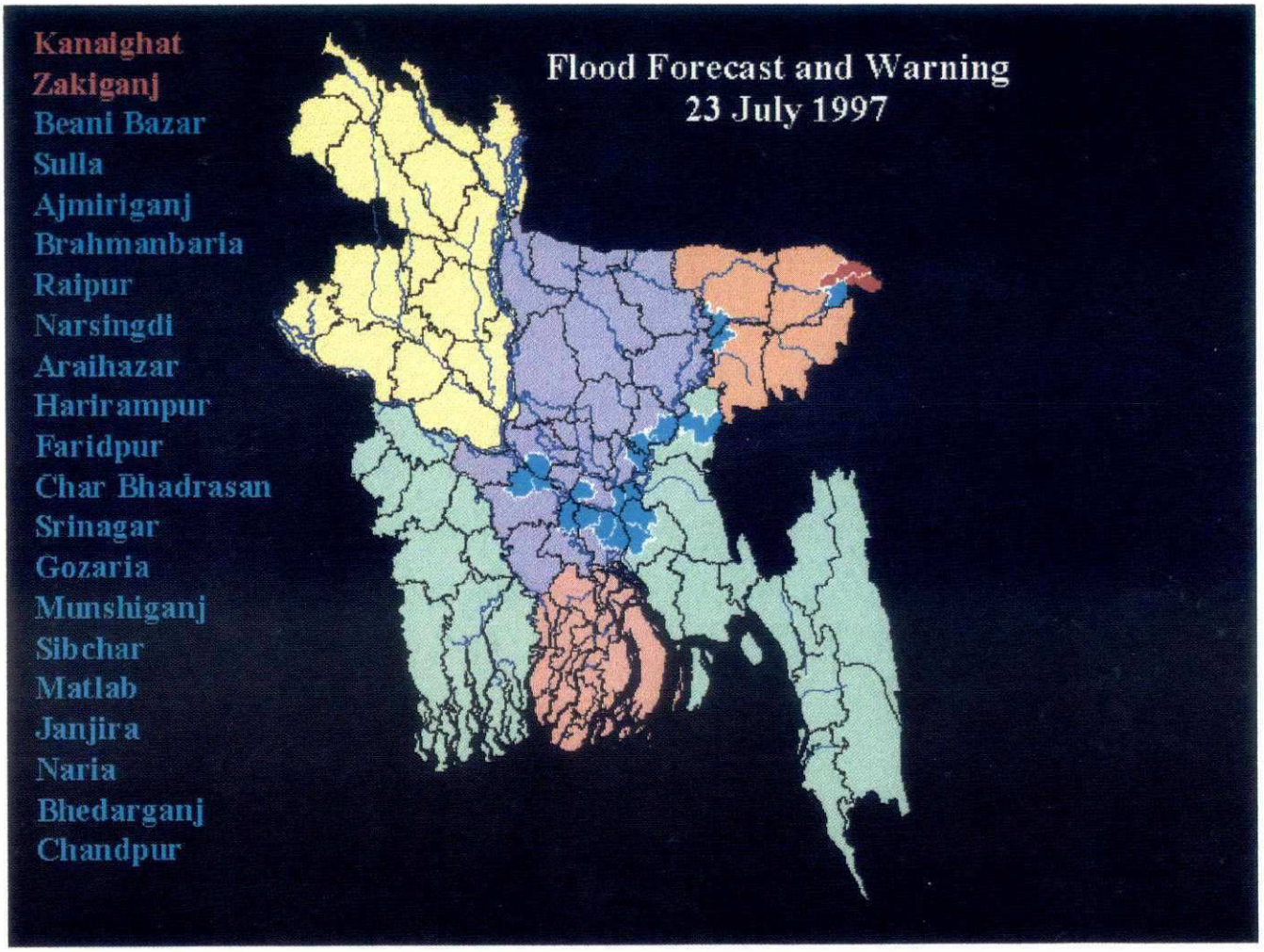
You should remain alert and listen to the radio bulletins for further information. This information will be updated following the next news bulletin.

A Warning of Severe Flooding has been issued for <*list of districts*>.

Warning Message Text and Affected Thana Name List	FFWC
FLOOD WARNING MESSAGES	**FIGURE 9.1**



Map showing percentage of thana flooded for 24th July 1997	FFWC
THANA FLOOD MAP	FIGURE 9.2



Thanawise inundation map including list of affected thanas produced for television transmission	FFWC
SUPERMODEL FORECASTS	FIGURE 9.3

Under Preparation

FFWC Homepage	FFWC
FFWC INTERNET SITE	FIGURE 9.4

10. DISSEMINATION OF FLOOD WARNINGS

10.1 Previous Procedure

Since its establishment the Bangladesh FFWC has developed a strong capability in hydrological monitoring and flood forecasting. The centre produces a range of forecast and information products including a two page daily Bulletin accompanied by a commentary on the main hydrologic features of interest known as the Rainfall and River Situation Summary. In addition a Flood Warning and Flood Forecast Statement is issued when forecast river levels are close to or exceed Danger Level, defined as the level at which flooding becomes a serious threat. The Bulletin and Summary are normally issued daily. During periods of flooding an updated Forecast Statement is also issued during the early evening.

The information passes slowly through the various levels of different organisations down to the local level. Delays up to two to three days are reported. The mass media in general has little awareness of the importance and benefit of flood warning: newspapers and the broadcast media reproduce the reports verbatim with no attempt to interpret the impacts at the local level. No emphasis is given to the difference between routine situation reports and warnings of severe flooding. A number of FAP reports comment that the existing broadcasts are not meaningful to the public as the terms are not well understood and listeners are unable to translate the forecasts into meaningful information at the local level.

Technical *forecasting* process is well developed, but a true *warning* system as such does not exist. The GoB established the Disaster Management Board (DMB) in 1992 with a wide brief for disaster management in Bangladesh, which included ensuring the effective dissemination of appropriate warnings of floods and developing planning and preparedness activities at all levels of the community. Development activity to improve flood warning dissemination as part of FAP10 would need to be closely coordinated with DMB if a fully effective national warning system was to be developed.

10.2 Development Process

10.2.1 Introduction

The development goal is to improve the flood warning dissemination processes, increasing the awareness of the availability and understanding of flood warning information at local levels. For improved flood warning dissemination to be effective there is also a need to integrate the flood forecasting operations of FFWC into the disaster management framework that is being developed by DMB.

This requires both the development of a suitable conceptual framework to ensure that any improved information disseminated from FFWC is integrated with the dissemination activities of other agencies, as well as an investment in training for FFWC staff to build

their awareness of disaster management concepts and the needs of other stakeholders in the system.

In preparation, local consultants undertook a review of relevant literature from Bangladesh and other countries, interviews with a number of the key stakeholders in the system, and several field trips. An assessment of the content of text books at the primary and secondary levels for government and non-formal schools was also conducted to evaluate the availability of materials relating to flood warning.

This work is reported in the Module 3 documentation (see Appendix II) and recommends viewing the flood forecasting and response system in Bangladesh as both a system and a social process, with development following a staged approach. A number of further recommendations is made for the overall improvement of the system which were used to guide future work.

Development proceeded in three main areas:

- strategic and training activities
- establishment of principles and development of flood warning products
- public awareness and evaluation

10.2.2 Strategic and Training Activities

Liaison with Disaster Management Bureau

Liaison with DMB was to be taken up through cooperative involvement with the project Comprehensive Disaster Management Programme (FAP11). This activity was initially delayed until the appointment of the expatriate consultant and, although a number of useful meetings and discussions took place, delays and a reduction in the scope of FAP11 meant that little effective liaison took place.

A copy of the Emergency Standing Orders for Disasters was obtained and used to guide the development of various documents in the project (Flood Forecasting and Warning Action Plan, Flood Warning Manual). This document was subsequently updated and the most recent copy has not yet been available.

Flood Warning Manual

The preparation of the Bangladesh Flood Warning Manual is one of the key developments in the project. This was undertaken largely by local consultants under the guidance of the expatriate WMO consultant. The manual contains the framework for a comprehensive and integrated approach to flood preparedness, warning and response,

and is intended to inform and guide those working in flood forecasting and warning and flood response.

The manual describes the flood problem in Bangladesh and sets out the main components of a total flood warning system: forecasting, interpretation, dissemination, response, along with review and analysis. Each of these elements is described in detail and guidance is provided on approaches to implementing new systems and practices. The manual includes the essential information to guide the long term development of a complete Flood Forecasting, Warning and Response System (FFWRS) for Bangladesh.

The manual has been adopted in principle by the key agencies concerned.

Flood Forecasting and Warning Action Plan

The Emergency Standing Orders for Disasters requires that each agency prepare an Action Plan. The initial draft of this plan was framed and circulated for comment in March 1996. The plan was further refined during 1997 with detailed input supplied by FFWC staff. The plan sets out the basic operational procedures for FFWC in undertaking flood forecasting and warning dissemination activities, and includes the nature and detail of their liaison with DMB and other agencies in the dissemination of flood warning information. The plan is intended to consolidate the new procedures developed in the project into the operations of the FFWC.

It was planned to undertake training of FFWC staff in the preparation and updating of this plan; this has not yet been done.

FFWC Staff Development and Training

The development of improved flood warning messages and information products was undertaken through participative workshops held with FFWC staff. These workshops were used to also introduce the staff to disaster management concepts and the requirements of good flood warning message design and dissemination.

A total of 12 workshops was held: six in November 1995 on total flood warning system concepts, including forecast interpretation, message construction and warning dissemination. Six further workshops over the period May to June 1996 were also held: two to revise the material from the earlier workshops and four practical development workshops to develop a full suite of flood warning messages.

Training Manual

To meet the training needs of staff in both FFWC and other agencies involved with flood warning, a manual Flood Warning and Flood Management in Bangladesh: A Training Manual was drafted. This is designed to introduce readers to the flood

problem in Bangladesh, flood warning concepts including the system as it operates in Bangladesh, and to some of the activities to be undertaken during a flood to guide response planning. The manual also identifies a range of further reading material.

10.2.3 Establishment of Principles and Development of Flood Warning Products

Flood Warning Messages

The need for new stand alone messages was identified to give more prominence to flood forecast and warning information generated in FFWC and, in particular, to improve the response to warnings at the grass roots levels. Most of the development work on this aspect was undertaken through a series of workshops held with FFWC staff under the guidance of the expatriate consultant and local academics.

These workshops focussed on the development of the essential principles behind flood warning, in particular the important difference between a *forecasting* system and a *warning* system. The workshops further developed the concept of phased flood warnings to improve the interpretation of the warnings and the introduction of an additional Flood Watch stage was proposed. In addition a number of standard terms and definitions of flood severity to use in the warnings was agreed.

Model flood warning messages suited to the different types and phases of flooding in Bangladesh were developed, following best practice principles for message design. The messages are designed to be issued as a product of FFWC to Bangladesh TV and Radio, and other agencies involved in dissemination. The messages utilise the depth-area inundation maps generated by the forecasting model to provide warnings at the thana level. The messages are presented in the preceding chapter 9.

Flood Marker Posts

To complement the new warning messages, various initiatives were undertaken at the local village level to improve the interpretation of the centrally issued flood warning information. These included a flood marker post to assist with communication and interpretation of the impact of flooding at the most local levels. These posts (see figure 10.1) have two colour bands (red and blue) positioned on the post to correspond as closely as possible to the flood levels (Medium Flood, Severe Monsoon and Catastrophic) referred to in the flood warning messages. The posts are placed in a prominent position in local villages where people and officials would be able to relate the current and predicted flood level to their local situation through reference to the colour bands in the new warning messages.

A pilot study to test the impact of the posts in four villages (Anupnagar in Nawabganj District, Muljan in Manikanj District, Goalbathan in Jamalpur District, Chakran Chap in Maulavibazar District) was undertaken during the 1996 monsoon flood season. The value of this study was limited due to delays in obtaining GoB approval to use the new

flood warning messages, and only one of the villages (Anupnagar) was flooded. Nevertheless useful information was gathered and the flood marker posts were received favourably and considered by the local people to have provided a useful aid to local interpretation of river conditions.

The study revealed three technical difficulties with the marker posts that should be taken into account in future implementations. Firstly it can be technically difficult to establish the correct flood severity levels on the posts and errors can be counter productive. Because of the complex flood behaviour in some areas it can be difficult to locate the post such that it relates accurately to the village as a whole and, finally, factional politics may try to influence where the post should be installed.

The pilot study also tested a range of educational and publicity material as described later.

Flood Warning Dissemination Arrangements

To improve the effectiveness of flood warning dissemination, arrangements were made with Bangladesh Radio and Television to broadcast the warnings nationwide. The use of these channels was supported by the results of field surveys in four pilot areas which identified the rapid diffusion of radio and television in the villages. Many of those surveyed indicated a preference to receiving flood warning information by television, although there was also a need to balance this with information through local channels.

In addition to warning message texts, the information for broadcast includes graphical displays of flooding down to thana level. Procedures were developed for use in FFWC to generate the warning texts and maps for transfer to the media (see chapter 9). In addition to these broadcast arrangements, local consultants undertook background work to establish more effective dissemination arrangements, including examination of the optimum time of day for broadcasting flood warnings, establishing the willingness of local radio to broadcast in local dialects, and proposals to use the wireless networks of BWDB and the Ministry of Disaster Management and Relief.

Delays in GoB approval to use the new messages and flood warnings meant that there has been no opportunity to test the dissemination of the new products using any of these procedures to date.

10.2.4 Public Awareness and Evaluation

Education and Publicity Material

An illustrated booklet on flood warning containing an introduction to the flood marker posts and an action guide to motivate villagers to take protective measures in preparation for the flood was prepared (see figure 10.2). This booklet was distributed throughout the four pilot villages along with posters (see figure 10.3) highlighting some

of the information from the booklet to help publicise the marker post. In addition education material on flood warning was prepared and taught to students of three grades in the pilot villages.

A baseline survey conducted prior to the introduction of the flood marker posts and educational material revealed that villagers had little or no awareness of flood warnings, but felt a strong need for effective flood warnings. Feedback from surveys conducted after the flood season showed a number of positive impacts from the various interventions. The flood marker posts were received enthusiastically, although a number of technical difficulties was identified.

The illustrated booklet was highly appreciated by the villagers and useful feedback on its content was gained to help guide future productions. The posters were judged to be less useful, those placed in public places being defaced or removed and those in offices not widely accessible. Teachers and students generally found the education material informative and easy to follow, although some of the material was found to be too difficult for children from some of the poorer (and more vulnerable) areas. Some important suggestions were made to improve the quality.

10.3 Present Procedure

The present procedure for flood warning dissemination remains basically the same as that existing before the project. It has not been possible to implement changes in the flood warning dissemination procedures as developed, mainly due to difficulties in conducting the essential liaison between FFWC and DMB and other GoB agencies, and delays in gaining the necessary GoB approval to introduce the new procedures, particularly the flood warning messages.

Many of the tools are now available to build a national flood forecasting, warning and response system which is necessary if the full effectiveness of the warning system is to be felt at the grass roots levels. In particular:

- the Bangladesh Flood Warning Manual provides a solid conceptual framework around which the future system can develop and evolve
- flood warning messages (and other information) have been designed with participative input from a range of stakeholders to improve the effectiveness of the technical flood forecasting capabilities of the FFWC at the grass roots levels
- there is good integration at the technical level between the flood forecasting and flood warning dissemination systems
- the use of the flood marker posts shows strong promise as a means of effecting a closer link between the centrally prepared flood warning information and the local flood interpretation and response activities

- tested public education and publicity material is available to use in any expanded program to improve the flood preparedness and response capacity of local village people

- key agencies and FFWC staff have a greater awareness of the need for more a complete integration of their various roles in the total system

10.4 Conclusions and Recommendations

The dissemination component of the project has had only moderate success. Despite the development of a number of sound tools and concepts matching the best practice standards of other more developed countries and WMO, the impact of the products of the development work on flood warning practice has been limited. As discussed above, the basis now exists to proceed in a more confident manner and it is recommended that:

- GoB adopt the principles of the proposed national flood forecasting, warning and response system (FFWRS) as embodied in the Bangladesh Flood Warning Manual

- the model flood warning messages as included in the manual, along with the thana-wise flood inundation maps, be disseminated in their present form during the 1998 monsoon flood season through Bangladesh Radio and TV

- further evaluation of the use of flood marker posts to improve local interpretation and dissemination of this information be supported and the results shared freely among agencies involved in flood warning dissemination

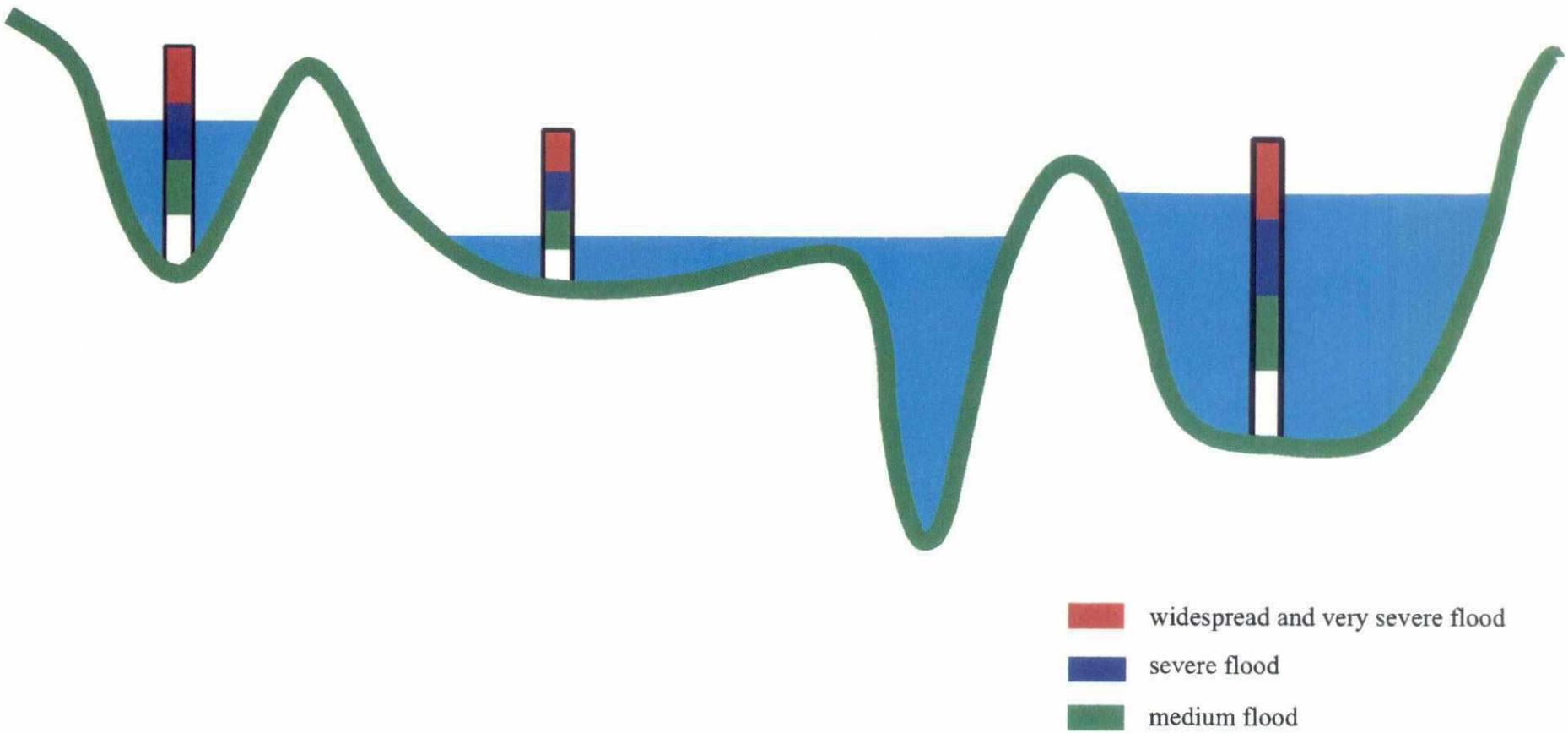
- separate initiatives to test the use of NGOs to assist with flood warning dissemination and the interpretation of the centrally produced warning information be supported

- public education and publicity material developed during the project be made available to groups interested in its further testing

FLOOD MARKER POSTS

FIGURE 10.1

Three Marker Posts set at different levels with different scales reflecting differing severity of flooding in adjacent areas



আপনি জানেন কি আপনার গ্রামে একটি বন্যা ফলক বসানো হয়েছে?

তিন কোনা ফলকটির নীচের অংশে নীল ও উপরের অংশে লাল রং দেয়া আছে

সর্বোচ্চ প্লাবন রেখা

বন্যার পানি ফলকের নীল রং স্পর্শ করলে বুঝতে হবে মাঝারি বন্যার সম্ভাবনা রয়েছে

বন্যার পানি ফলকের লাল রং স্পর্শ করলে বুঝতে হবে মারাত্মক বন্যার সম্ভাবনা রয়েছে

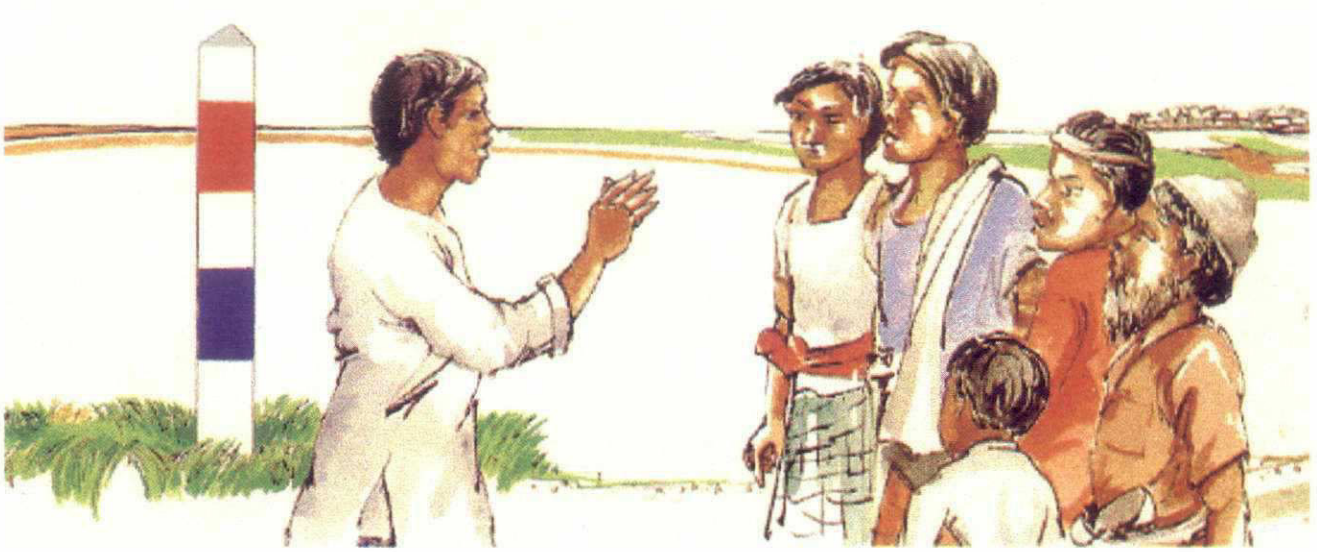
বিপদ সীমা

বন্যার পানি লাল রং অতিক্রম করে গেলে ভয়াবহ বন্যার সম্ভাবনা বুঝতে হবে

বন্যা ফলক

গণপ্রজাতন্ত্রী বাংলাদেশ সরকারের বন্যাপূর্বাভাস এবং সতর্কীকরণ ব্যবস্থার উন্নয়ন প্রকল্প ড্যানিডার সৌজন্যে প্রকাশিত

Poster distributed at Study Areas	**FFWC**
PUBLICITY MATERIAL	**FIGURE 10.2**



সতর্কীকরণের উদ্দেশ্য কি?

বন্যা সতর্কীকরণের উদ্দেশ্য হচ্ছে জনগণ ও বিভিন্ন সংস্থাকে সুযোগ মোকাবিলায় প্রস্তুত থাকতে, নিরাপত্তা বাড়াতে এবং বন্যার ক্ষয়ক্ষতি কমাতে সক্ষম করা, অনুপ্রাণিত করা। সতর্কসংকেত ঘোষণা করা হলে "মধ্যবর্তী" সময় সম্পর্কে জেনে নেওয়া উচিৎ। মধ্যবর্তী সময় হচ্ছে সতর্কসংকেত ঘোষণা হওয়ার পর থেকে বন্যা প্লাবিত হওয়ার মাঝখানের সময়টুকু। বন্যা মোকাবিলার সামগ্রিক প্রস্তুতির জন্য এটা জরুরী।

Pages of Booklet Distributed to Study Areas	FFWC
EDUCATION MATERIAL	FIGURE 10.3

11. FUTURE OPERATIONS OF FLOOD FORECASTING AND WARNING

11.1 Summary of Conclusions

Conclusions and recommendations for the individual components of flood forecasting and warning are made at the end of each of the respective chapters of this report. They are summarised below.

Institutional — The duties and responsibilities of the FFWC are critical to the ability of Bangladesh to deal with flooding. The status of the Centre and its staff should be raised to increase staff moral and increase the importance given to its invaluable output.

Data Transmission — There are severe administrative problems within BWDB which seriously handicap the dependable transmission of real time data and the maintenance of the established station. Future technical development should be based on communication satellites.

Satellite Reception — There is great potential in the reception of frequent real time images over Bangladesh for rainfall forecasting and flood inundation.

Flash Flood Forecasting — Flash flood forecast models set up for the north west and north east require improved boundary estimates for further development.

SuperModel — Owing to the dynamic nature of the rivers in Bangladesh, the forecasting model should be updated with new survey data and recalibrated every three years. Specific local improvements are required for the SuperModel to increase accuracy. FFWC staff require training in model troubleshooting.

Warnings — The Flood Warning Manual including the new warnings should be approved and published by GoB as provisional, which may be revised on the basis of feedback from the recipients. FFWC should set up an Internet Site for dissemination, including to international organisations,

Dissemination — Activities related to the dissemination have only reached a preparatory stage. Cooperation with agencies outside FFWC is required to gain acceptance of the new more informative warnings, eg DMB, BTV and NGOs. The proposal introducing Marker Posts with the assistance of NGOs should be advanced.

11.2 Operations of FFWC

The present Flood Forecasting, Warning and Response System (FFWRS) in Bangladesh has not been fully developed and there is a need to guide future growth of the system with appropriate review and strategic planning procedures. This growth of the system will be driven by the need for practice in all components of the system to reach, and be maintained at, high standards, as well as to extend the scope and areal coverage of the service as guided by a longer term strategic plan for future development.

The planning process is complicated to the extent that the system transcends the boundaries of a number of organisations. There is a need for good coordination to ensure that future development of the FFWC operations is integrated with the plans of other agencies, in particular those concerned with flood warning dissemination and response.

The current operations of FFWC are described in the Action Plan prepared for the Centre. Yearly reviews of the operations of the Centre as set out in the Action Plan will identify problems with the operation of the existing systems and procedures based on the experience of that particular flood season. The output from this form of review will include recommendations on changes to:

- real time data collection
- meteorological data collection (BMD, satellite data, Internet)
- hydraulic modelling procedures
- forecast and warning product preparations
- staffing and organisational practices

These recommendations are aimed primarily at maintaining the existing level and quality of the service and will define activities that ensure that the best possible technical standards are followed within the available resources.

As well as these internal reviews, more wide reaching reviews will be necessary involving consultation with clients of the Centre to determine the effectiveness of the warning and information products that are issued, leading to changes to:

- the design of the different products (warning messages, bulletins, etc)
- their dissemination (dissemination channels, timing, frequency of issue)
- their target audience.

In addition the Centre will need to manage the growth of the system to meet evolving needs and in accordance with strategies developed through a longer term planning process to guide the future development of flood warning services in Bangladesh.

The Action Plan for FFWC includes a description of the annual post flood season review procedure. The approach to the yearly review of flood warning dissemination and an outline of a long term planning process are described in the following sections.

11.3 Yearly Review of Flood Warning Dissemination

11.3.1 FFWC Activities

The general objective of FFWC is the issue of timely and accurate warnings for every occurrence of flooding, for a particular flood season and the dissemination of these warnings to other bodies with more specific responsibilities for dissemination and flood response. These bodies may undertake further dissemination.

For FFWC, the main boundary of any review is the interface with these bodies: the review procedure would identify those areas of the country that experienced flooding during the year and for each area and instance of flooding, reporting on the following:

- were warnings issued?
- did they reach the intended target?
- did the right people get the warnings?
- did they get the warnings in time?
- did they understand them?
- did they do anything with them?
- did they do the right things?

The identification of areas flooded would normally be part of the information flow between BWDB field staff and FFWC as part of their forecast verification activities. It is possible that floods occur without warning in some areas, particularly flash flooding, and sources such as newspaper reports, reports from NGOs and other agencies at the field level, etc, should be regularly monitored. These cases should be analysed as to why warnings were not issued, and fed into the future planning and development processes.

A questionnaire to the different agencies would be one way of collecting the necessary review information as listed above. Another would be the establishment of a system of regular review meetings.

11.3.2 Other Agencies' Activities

Dissemination requirements at the grass roots level should be determined by the objectives of the flood response plans. Information on the effectiveness of the warnings at this level can be collected through post-flood surveys and will require initiatives from other agencies, although BWDB field staff are well placed to provide some input here. These surveys could address the same points as above but from the viewpoint of those at the grass roots level, and be more focussed on an analysis of the response to the warning. Field staff of the different agencies involved would need to be supported with training and resources to undertake these surveys, or the surveys could be undertaken by specialist research staff.

These activities should be a coordinated effort among the different agencies with the lead agency (eg DMB) being responsible for the interpretation of the results of the surveys into what changes are needed, including FFWC. The changes generated from this process for FFWC consideration would be technical matters such as improvement in forecast accuracy and spatial definition, the setting of the different threshold levels of flooding (Danger Level, etc), as well as the format of the warning message information (maps and broadcast messages). For agencies more closely involved with flood response, the need to improve local interpretation of the warning information, for example would be identified.

The ultimate measure of the effectiveness of flood warnings is the extent to which they prevent loss of life and reduce flood damage. Reliable information on either is difficult to gather and the responsibility for the achievement of this objective is shared among many agencies. The extent to which this sort of information can be regularly gathered at this stage is not known, but experience in other countries would suggest that it is likely that it will take some years before a reliable and regular form of reporting of such information would be available

11.4 Scope for Further Extension

At the present stage of development, the FFWRS has scope for extension to cover a larger proportion of the country as well as raising the sophistication of some of the components. Both of these forms of extension should be guided by a proper long term planning process and will involve inputs from a number of agencies. Each of the agencies involved would normally prepare separate plans. The integrated nature of the system means that there are strong advantages in making as much effort as is practicable to coordinate the different agency plans. The outputs from the annual planning activities discussed above will form an input to the long term planning process and such plans will provide a framework for prioritising these outputs into a more coordinated development programme.

A long term flood warning development plan would include the following.

Planning framework and influences on planning Plans should be prepared using the whole FFWRS as the framework. Other influences on planning will include changes in government policy, the attitudes of donors, external influences such as changes in data sharing agreements, changes in the catchment with new structural works, etc.

Links with other planning processes would include coordination with other agencies' plans as well as the outputs from the annual reviews of FFWC operations and flood warning dissemination.

Long Term Development Objectives are improved quality of current services as well as met demands for new services. This will include improved forecast accuracy, provision of forecasts at more locations, increased spatial definition for the area-inundation forecasts, keeping pace with changes in standards, opportunities for using new technologies, etc.

Development Strategies will include detailed plans for aspects like the planned growth in the data collection networks, development needs to include more forecast points in the forecasting model, as well as possible changes in strategic direction in the way services are developed and delivered; for example a shift from centrally developed flash flood warning services to more locally based development and delivery.

Resource requirements will include staffing needs as well as capital and ongoing operational costs. Staff training and development needs should be included as well as changes in institutional arrangements.

Planning Process Preparation of the plan should first involve as wide a consultation as possible with the major stakeholders. This will include other agencies involved in the system as well as representation of grass roots users of the services.

Monitoring, Reviewing and Updating the Plan.

APPENDIX I LOGICAL FRAMEWORK MATRIX

DESCRIPTION	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
Development Objective: To provide improved information to aid nation preparedness for floods and to mitigate flood impacts.	Reduction in number of lives lost in floods and lower property losses on floods through an improved flood warning system.	A. Review of monthly and yearly flood reports. B. Interview of village people regarding disseminated flood warnings. C. Interviews with users in Government, NGOs	FAP 11 implemented and results of project sustainable.
Immediate Objective: To support Flood Forecasting and Warning Centre in order to improve performance with regard to increased mobilization of local resources and efficient utilisation of resources available.	1. Training provided to professional and technical staff. 2. Expanding number of forecast points on main and secondary rivers. 3. Improvement of lead time and accuracy for real time forecasts. 4. Improvement of facilities for hydrological and meteorological monitoring. 5. A fully comprehensive flood forecasting and warning centre established within BWDB. 6. National Flood Forecasting Warning and Response system introduced.	1. Capabilities of the staff now and earlier to be compared. 2. Number of forecasting points now and earlier to be compared. 3. Sample of lead time and accuracy statistics now and earlier to be compared. 4. Review of hydrologic and meteorologic information used for flood warning preparation now and earlier. 5. Review of the established facilities at the flood forecasting and warning centre. 6. GoB approves FFWRS in form of manual.	1. Availability of staff to be trained. 2. Availability of data from improved hydrometric network. 3. Availability of sufficient and reliable data for modelling including data from India. 4. Availability of data from external sources. 5. Interest from Government to establish a comprehensive Flood Operation Centre in a new office with a yearly budget. 6. Interest from Government in total system approach to flood warning.

APPENDIX I LOGICAL FRAMEWORK MATRIX

DESCRIPTION	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
Outputs:			
1. Real time forecasting at regional level and provision of coarse area inundation forecast for major parts of northern Bangladesh.	1a. Number of forecasting points increased from 16 to 30 including forecasts on secondary rivers. 1b. Forecasts of inundation introduced at thana level.	1a. Review of the flood forecasting bulletin and demonstration at FFWC. 1b. as above	1a. Availability of data from new stations. 1b. Availability of good topographic data..
2. Forecast System for 2 flashy rivers established on pilot basis.	2. Forecasting system on 2 flashy rivers has been established.	2. as above	2. Availability of continuous real time hydrologic data from the upstream catchments.
3. Improved data exchange with countries in the Ganges-Brahmaputra-Meghna basins.	3. 8 hours average delay of data from India. compared to around 15 hours before the project.	3. Statistics of received data from India now and earlier.	3. India agrees to improve the data transfer to Bangladesh.
4. A public awareness programme of the availability and understanding of flood warning and forecast information.			4a. Good cooperation with the Disaster Management Bureau. FAP11 project (support to DMB regarding disaster preparedness) is initiated.
4.1 Flood Warning Manual for Bangladesh and related training material.	4.1 Increased awareness and participation by all stakeholders, in particular Government Agencies and NGOs.	4.1 Flood Warning Manual published and distributed.	4b. Flood Warning Manual approved by GoB.
4.2 Flood Warning System for effective dissemination.	4.2 Documented procedures introduced. Phased Level Warnings introduced.	4.2 Examine documents.	4c. Cooperation among Government Agencies.
4.3 Annual Review procedures for Flood Warning Dissemination.	4.3 Section in Action Plan.	4.3 Examine documents.	
5. Trained staff..	5a. At least 8 staff members at FFWC routinely working with the expanded FFWS.	5a. Simple test, through a demonstration of skills, know how and attitude.	
6. Improved institutional structure within FFWC.	5b. Two teams of technicians capable to maintain the wireless radios.	5b. Review of the condition of the wireless radios in the field.	5. Trained counterparts do not leave FFWC, unless strictly necessary.
	6. Improved structure in FFWC with the human and financial resources to provide and maintain the established services.	6. Compare the setup of the FFWC now and earlier.	6. Political support and will to expand the flood forecasting and warning services.

APPENDIX I LOGICAL FRAMEWORK MATRIX

DESCRIPTION	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
Activities :			
1.1 Develop and refine Flood Mapping.	1.1 Flood Mapping facilities implemented.	1.1 Final Report and Steering Group minutes.	
1.2 Verify Model.	1.2 Model performance satisfactory.	1.2 as above	
1.3 Improve qualitative rainfall forecast.	1.3 Improved estimation of model boundaries.	1.3 Statistics before and after	
1.4 Improve station network in the field.	1.4 New radios and databoxes installed in field.	1.4 Inspection in the field	
1.5 Improve computer system at FFWC.	1.5 New PC machines installed at FFWC.	1.5 Inspection of FFWC	
1.6 Improve comunication system at FFWC.	1.6 Upgraded communication system at FFWC.	1.6 as above	
1.7 Prepare model to forecast thana status.	1.7 Thana status forecasting implemented.	1.7 Final Report	
1.8 Operate forecasting with new model.	1.8 Forecast issued and used to prepare warnings.	1.8 Interviews of end users	
1.9 Validate and make recommendations.	1.9 Results of model performance in 1997 monsoon.	1.9 Statistics in final report	
2.1 Develop and test Model.	2.1 Setup of 2 flashy rivers implemented.	2.1 Final report and Steering Group minutes.	
2.2 Improve quantitative rainfall forecast.	2.2 Improved estimation of input to flashy rivers.	2.2 Statistics	
2.3 Experimental forecasting with model.	2.3 Model used on 2 flashy rivers in 1997 monsoon.	2.3 Final Report	
2.4 Prepare plan for nationwide implementation.	2.4 Plan approved for inclusion in final report.	2.4 Final Report	
3.1 Prepare a note for discussion with Indians.	3.1 Note submitted to Indians.	3.1 Final Report	3. GoB not satisfied with existing system.
3.2 Setup e-mail system in Patna and Gowahati.	3.2 E-mail service installed in India.	3.2 Inspection	
3.3 Operational testing of improved data exchange.	3.3 Data from India transmitted via e-mail.	3.3 Inspection	
4.1a Prepare Flood Warning Manual.	4.1a Flood Warning Manual approved.	4.1a Steering Group minutes.	
4.1b Prepare and test education material.	4.1b Education material tested.	4.1b Report	4. Approval procedure of Warning Messages and Manual not delayed
4.1c Prepare and test publicity material.	4.1c Publicity material tested.	4.1c Report	
4.2a Develop phased warning messages.	4.2a Messages tested and approved.	4.2a Steering Group minutes.	
4.2b Develop suite of flood information products.	4.2b Products tested and approved.	4.2b as above	
4.2c Establish dissemination of warnings to TV/radio.	4.2c Dissemination to radio/TV tested and approved.	4.2c as above	
4.2d Pilot study of dissemination to grass roots level.	4.2d Plan for dissemination to grass roots based on study.	4.2d Report	
4.2e Pilot study of the use of flood marker posts.	4.2e Plan for use of flood markers based on study.	4.2e Report	
4.2f Test dissemination of warnings through NGOs.	4.2f Dissemination of warnings through NGOs tested.	4.2f Report	
4.2g Prepare Flood Forecasting and Warning Action Plan.	4.2g Plan approved and owned by FFWC.	4.2g Steering Group minutes	
4.2h Prepare Long Term Plan for nationwide Flood Warning development.	4.2h Plan approved for inclusion in Final Report.	4.2h as above	
4.3 Develop yearly review procedure.	4.3 Review procedures approved.	4.3 as above	
5.1 Overseas training.	5.1 Overseas training programme completed. satesfactorily.	5.1 Interviews with trainees.	
5.2 In-service training through workshops	5.2 Required number of workshops completed satisfactorily.	5.2 Interviews and Final Report.	
5.3 On the job training.	5.3 In-service training completed satesfactorily.	5.3 Interviews and Final Report.	
6.1 Prepare proposal for upgrading of FFWC.	6.1 Proposal approved .	6.1 Steering Group minutes.	6. Interest from GoB in upgrading FFWC.
6.2 Various initiatives to upgrade FFWC.	6.2 Initiatives successfully completed.	6.2 Inspection	

APPENDIX I LOGICAL FRAMEWORK MATRIX

DESCRIPTION	VERIFIABLE INDICATORS	MEANS OF VERIFICATION	ASSUMPTIONS
Inputs: 1. Expatriate consultant services. 2. Local Consultant services. 3. Counterpart input (NPD, staff and Steering Group and other GoB agencies) 4. Administrative supporting staff. 5. Computer hardware and software. 6. Office facilities. 7. Workshop facilities 8. Special data collection. 9. Data transfer links. 10. Remote Sensing. 11. Telemetric network. 12. Other project support. 13. Training programmes in Bangladesh and overseas.	A. Approval of project. B. Progress of project.	A. Documents from Government. B. Progress Reports.	A. Availability of Government staff and funds. B. Approval of expatriate and local consultants. C. Approval of equipment procurement. D. New equipment not delayed in the customs. E. Overseas training not delayed due to slow approval of candidates.

APPENDIX II

PROJECT REPORTS, REVIEWS AND DOCUMENTATION

TITLE	DATE	CONTENTS
Progress Reports		
Inception Report	August 1995	project inception
Quaterly Progress Report No 1	October 1995	progress from June to September 1995
Quaterly Progress Report No 2	January 1996	progress from October to December 1995
Quaterly Progress Report No 3	April 1996	progress from January to March 1996
Quaterly Progress Report No 4	July 1996	progress from April to June 1996
Quaterly Progress Report No 5	October 1996	progress from July to September 1996
Quaterly Progress Report No 6	January 1997	progress from October to December 1996
Quaterly Progress Report No 7	April 1997	progress from January to March 1997
Quaterly Progress Report No 8	July 1997	progress from April to June 1997
Plans and Reviews		
Joint GoB/Danida Review	March 1997	review of project from January 1995 to August 1996
Plan of Operations	November 1996	project plan of operations for October 1996 to December 1997
Improved Public Awareness and Dissemination (Module 3)		
Preparation and Review	September 1995	literature review, interviews with actors and stakeholders, field inspections
Development	August 1996	draft Flood Warning Manual, Training Manual, Warning Messages, Educational Materials, Action Plan, Questionaires
Development and Training	November 1996	Flood Warning Products: trial and rapid appraisal of impact

TITLE	DATE	CONTENTS
Educational Material, Publicity Material and Posters		
Flood Warning Manual	October 1997	framework for comprehensive and integrated approach to flood preparedness and response
Flood Forecasting and Warning Action Plan	October 1997	standard operating procedures and essential reference information
Staff Training		
User Manuals		
Operating Procedure		overview of flood forecasting and warning system
System Maintenance		maintenance of transmission, reception and computer equipment
Data Transmission and Reception		operation of data boxes and radios, and transfer of data to database
Satellite Image Reception and Processing		reception, processing and interpretation of satellite images
SuperModel		running the MIKE11-FF flood forecasting model
Flash Flood Forecasting		running the MIKE11-FF flash flood forecasting models

APPENDIX III TRAINING ACTIVITIES

COURSE TITLE	LOCATION	DATES	STAFF
Total Flood Warning Concepts (6 workshops)	FFWC, Dhaka	Apr to Sep 1995	8 officers from FFWC
Workshop on Module III	FFWC, Dhaka	Nov 1995	8 officers from FFWC
Advanced Hydrological/ Hydraulic Forecasting Modelling	DHI, Denmark	Jan to May 1996	4 officers from FFWC
Workshop and Training for Radio Operators	C&I Division, Dhaka	May 1996	40 radio operators
Revision Workshops (2)	FFWC, Dhaka	May to June 1996	8 officers from FFWC
Workshops to Develop Warning Messages (4)	FFWC, Dhaka	May to June 1996	8 officers from FFWC
Workshop on New Flood Forecasting	FFWC, Dhaka	June 1996	8 officers from FFWC
Wireless Communication and Field Measurement	Eddystone, UK and DHI, Denmark	June to July 1996	3 officers from C&I Division
Training in Meteorology	BMD, Dhaka	Jul 1996	8 officers from FFWC
Project Progress Workshop	FFWC, Dhaka	Aug 1996	8 officers from FFWC
Flood Forecasting and Warning: Role in Disaster Management	AIT, Thailand and Australian Bureau of Meteorology	Oct to Nov 1996	8 officers from FFWC
Hydrological/Hydraulic Forecasting Techniques	DHI, Denmark	Jan to May 1997	4 officers from FFWC
Workshop in Flash Flood Forecasting	FFWC, Dhaka	May 1997	8 officers from FFWC
Training in Satellite Image Reception	FFWC, Dhaka	May 1997	8 officers from FFWC
Training for Gauge Readers and Radio Operators	north west field stations	Jul 1997	22 gauge readers and 36 radio operators
Workshop on SuperModel	FFWC, Dhaka	Aug 1997	8 officers from FFWC
Data Communication and Computer Networking	AIT, Thailand	Sep to Nov 1997	2 officers from FFWC

APPENDIX IV

PROPOSAL TO TEST AND EVALUATE A LOCAL FLOOD WARNING DISSEMINATION SYSTEM USING NON-GOVERNMENT ORGANISATIONS

1. Objective

To test and evaluate a locally based flood warning system using Non-Government Organisations (NGO) as a means of improving the effectiveness at the grass roots level of centrally generated flood forecasting and warning information.

2. Background

Work undertaken in FAP10 (Expansion of Flood Forecasting and Warning Services) has demonstrated that the effectiveness of flood warning dissemination to the local village level at present is very limited. Pilot development and evaluation of a number of initiatives to improve the effectiveness of flood warning dissemination at this level were undertaken by the project. This included the use of flood marker posts and associated public education and publicity material to assist with local interpretation and dissemination of centrally generated flood warning information. Although delays in approval of the use of the specially designed flood warning messages and the lack of flooding in the pilot areas hampered the value of these trials, the results were encouraging.

The potential for NGOs to help with local level dissemination was also identified. The role of NGOs here was also seen as important by the joint GOB/Danida review. This review concluded that there was a need to undertake a quick analysis of the feasibility of dissemination through a few major NGOs active in the Northern regions and recommending that findings should be ready before the end of 1996 with implementation before the 1997 monsoon season. Again, delays in approving the new flood warning information and dissemination arrangements prevented this from happening.

This proposal is put forward to build on the work done in FAP10, and to develop the concepts further into the establishment of a locally based flood warning dissemination system to complement and support the national system.

3. Description of Proposal

The Flood Forecasting, Warning and Response System (FFWRS) as developed through FAP10 involves the preparation of stand alone flood warning messages by the Flood Forecasting and Warning Centre (FFWC) for dissemination to the Disaster Management Bureau (DMB) and Bangladesh Radio and Television (BRT). DMB are to disseminate this further to the District Offices, but further dissemination from that level is uncertain.

The arrangement with BRT is that the flood warning information is broadcast over radio and television. This includes message texts as well as maps showing degrees of flood inundation down to the thana level. The FFWC also use their radio network to disseminate flood forecast information to a single contact in most districts. The "gap" in the dissemination system being addressed here is that between the District Office (or in some cases Thana) level and the villagers. Although the broadcast of the information over radio and TV reaches these levels there is still a need for the message to arrive by other channels to provide the all important opportunity to confirm the message. This is an essential component of warning effectiveness.

What this proposal is testing is the success with which the NGOs can fill this dissemination gap. The idea is that dissemination to the District (or Thana) level would be achieved through three possibilities; through the wireless network of the BWDB/FFWC, the broadcast over radio and TV, and through the DMB. Most NGOs have a representative at these levels and good communication systems to get information right down to the village level (see later for more discussion on NGO aspects). Some NGOs are able to effectively disseminate messages received at their national office (check this). There would need to be specialised training of the locally based staff in flood warning and flood warning interpretation, as well as training for those involved at the District (Thana) level in the dissemination.

The proposal includes the establishment of a local flood warning committee. This could include NGO representative(s) as well as respected local people such as school teachers, imams, traditional birth attendants, etc. With the local government role in this area being strengthened with new administrative reforms, representation from this level would be essential and would provide the required stability to the committee since some of the members (NGO staff for example) may not always be permanent in the area.

The flood marker post, and associated public education and publicity material used in the earlier pilot studies would be used again. The local committee would be used to select the site (with suitable technical input from BWDB hydrologists and surveyors) and their role would primarily be to oversight the local dissemination of the warnings and to guide the development of improved interpretation and use of these warnings among the local people. This would include establishing the different flood levels (normal, medium, severe, widespread and very severe) for the village and liaising with the FFWC to ensure this level is used in warnings prepared for the area. In addition to its use for warning interpretation, the marker post could be used to monitor the flood behaviour at the site and provide a valuable source of forecast verification data for the FFWC as well as a local flood data base.

The above elements would in effect constitute a local flood warning dissemination system which is tied into the national system through reference to the flood levels set on the marker post in the centrally generated flood warning messages. The role of NGOs is seen as critical in this kind of decentralized flood warning system. There is as yet no viable local government at the village level which can maintain flood markers, educate the public about its use and interpret flood forecasting initially. The NGOs have the

resources and capability to do it. With a short training local NGO officials can interpret flood warnings in consultation with local people and can disseminate the warning as well. In the past NGOs have been mainly concerned with various forms of post-flood assistance, however this proposal provides the opportunity for them to assist in creating a "culture of prevention" using the indigenous knowledge system and through active community participation.

4. Project Sites

A total of 4-6 project sites are suggested. The criteria for site selection would include:

- villages/areas with a history of regular flooding so as to maximise the chances of getting a good sample of flood behaviour
- choice of one or more from the four villages used in the previous studies so as to utilise the base data already collected
- include at least one site with flash flooding problems
- villages should be located in Districts where the proposed dissemination arrangements can be achieved
- areas where the performance of the flood forecasting model is acceptable for preparing warnings down to the thana level
- "typical" villages in terms of population, size, flood characteristics, etc as far as this is practicable so that the results can be applicable to as many other villages as possible

It may also be beneficial to include a smaller number of further test sites in the study where there would be none of the proposed interventions to act as a form of control to measure the impact of the interventions.

5. Study Duration

The study should go for 3 years to ensure that any recommendations are supported by evidence collected from a strong sample of flood behaviour and to assist with overcoming initial "settling down" problems.

6. Products to be Tested

- flood marker posts
- an illustrated booklet describing the flood marker and safety measures

- education materials describing floods and protective practices for use in schools and for the literate population

- Bangladesh Flood Warning Manual for NGOs, local government, community leaders and others involved in flood warning activities. The Manual details 'best practices' for flood warning in Bangladesh.

- Posters to highlight the advantages of preventative measures.

7. Discussions with NGOs

The proposal has been discussed recently (October 1997) with the following NGOs:

- Credit and Development Forum (CDF)
- Palli Karma-Sahayak Foundation (PKSF)
- Association for Social Advancement (ASA)
- Proshika Manobik Unnayan Kendra (Proshika)
- NGO Affairs Bureau
- Association of Development Agencies in Bangladesh (ADAB)
- OXFAM - Disaster Forum
- Bangladesh Disaster Prevention Committee (BDPC)

The important outcomes from these discussions have been:

- flood warning information can have a high benefit to the operations of the NGOs;

- many NGO operations are so intimately linked with the village life that these benefits will flow directly on to the grass roots levels;

- NGOs have a suitable infrastructure to support effective warning dissemination; ie access to radio and TV, close and regular access to the villagers and good communication structures.

- the more widespread transfer of the results of any trials to NGOs not participating would appear to be easily managed through one or more of the peak umbrella bodies (eg ADAB, NGO Affairs Bureau).

- the links between NGO dissemination and the official government agency system can be readily developed to ensure the two systems are complementary.

- the discussions have identified a number of possible sites.

- the NGO's approached showed an enthusiastic attitude to the proposal.

8. Outputs

The expected output from this project will be

- recommendations on the feasibility of the proposal (based on sound evidence in the form of reports and analyses of results),
- recommended strategies for future implementation, including improvements in the design and use of the tools tested, effectiveness of the system for collecting local flood (intelligence) data and
- identification of the costs involved.

If successful the study will provide a strong platform from which to build a more effective warning dissemination system to the grass roots level, thereby addressing a major shortcoming in the present national flood warning system.

9. Activities

Activities can be considered under five headings:

- ***establishment*** - including site identification and selection, initial negotiation and briefing of NGOs, research design, further development and refinement of products to be tested, establish links as needed between FFWC and local dissemination systems, training of NGO field staff to be involved in the trial, confirmation of communication channels, determine flood threshold levels, installation of marker poles, establishment of local committee, distribution of public education material, etc.
- ***pre-flood preparations*** - including initial (refresher in later years) briefing by field research staff with local committee (and others), ensure communication channels are functioning, further distribution of public education material, baseline surveys, etc..
- ***during flood period*** - activity during this period will be mainly one of monitoring the performance of the system, including peoples response to flood warning information, impact of marker poles, role of NGO workers (including any adverse impacts on their normal role), warning dissemination, accuracy of forecast/warning information (including feedback), etc.
- ***post-flood survey and analysis*** - to include follow up surveys of response to information, effectiveness of marker posts, debriefing of NGO staff, debriefing with local committee, etc.

- ***review*** - the procedures will be reviewed after each flood season and modified as appropriate.

- ***reporting*** - brief progress reports will be prepared after each flood season and a final report at the end of the project.

A draft schedule of activities is included as Attachment 1.

10. Inputs Needed

The proposal involves the following inputs:

- suitably experienced local consultants and associated field research staff to undertake the design and conduct of the trial

- an expatriate consultant with experience in this particular area of disaster management to guide the project and facilitate the liaison among the different agencies.

- Close links with the FFWC would need to be established to streamline the flow of information to and from the field. This function would be best provided by the expatriate who could be based in the FFWC, acting as the link person between the Centre and the dissemination and local warning system activities.

- Input from the BWDB would be needed for establishing the threshold flood levels, any surveying required for the installation of the marker post, and guidance and possibly training on local flood data collection.

- Construction and installation of the marker posts would be by contract arrangements. Installation will be done in coordination with BWDB as appropriate.

- Maintenance of the flood marker posts is expected to be very low and would be undertaken at the local level either by the NGO or local administration staff.

A draft budget is at Attachment 2.

SCHEDULE OF ACTIVITIES