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No. 22

Feasibility Study for Improvement of Flood Forecasting and Warning Services in the People's Republic of Bangladesh

Final Report

Volume I

Executive Summary

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December 2003

Nippon Koei Co., Ltd.

Japan International Cooperation Agency

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Feasibility Study for Improvement of Flood Forecasting and Warning Services in the People's Republic of Bangladesh

Final Report

Volume I

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The cost estimate is based on the price level and exchange rate of May 2003.
The exchange rate is:

US$1.00 = BDT58.10 = ¥116.28

PREFACE

In response to the request from the Government of People's Republic of Bangladesh, the Government of Japan decided to conduct "Feasibility Study for Improvement for Flood Forecasting and Warning Services in the People's Republic of Bangladesh" and entrusted the study to Japan International Cooperation Agency (JICA).

JICA dispatched a study team headed by Mr. Hideki Sato of Nippon Koei Co., Ltd. to Bangladesh three times between November 2002 and December 2003. In addition, JICA set up an Advisory Committee headed by Mr. Akinori Masuda of Kyushu Regional Bureau Ministry of Land, Infrastructure and Transport, which examined the Study from specialist and technical point of view.

The team held a series of discussions with the officials concerned of the Government of Bangladesh and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Bangladesh for their close cooperation extended to the team.

December 2003

Matsuoka Kazuhisa
Vice-President
Japan International Cooperation Agency

December 2003

Mr. Kazuhisa Matsuoka
Vice-President
Japan International Cooperation Agency (JICA)
Tokyo, Japan

Letter of Transmittal

It is with great pleasure that we submit to you the Final Report of "Feasibility Study for Improvement of Flood Forecasting and Warning Services in the People's Republic of Bangladesh".

The Study has prepared the framework plan for the improvement of existing flood forecasting and warning system in Bangladesh, and conducted the feasibility study for the optimal improvement plan. The Report presents the said framework plan and feasibility study results.

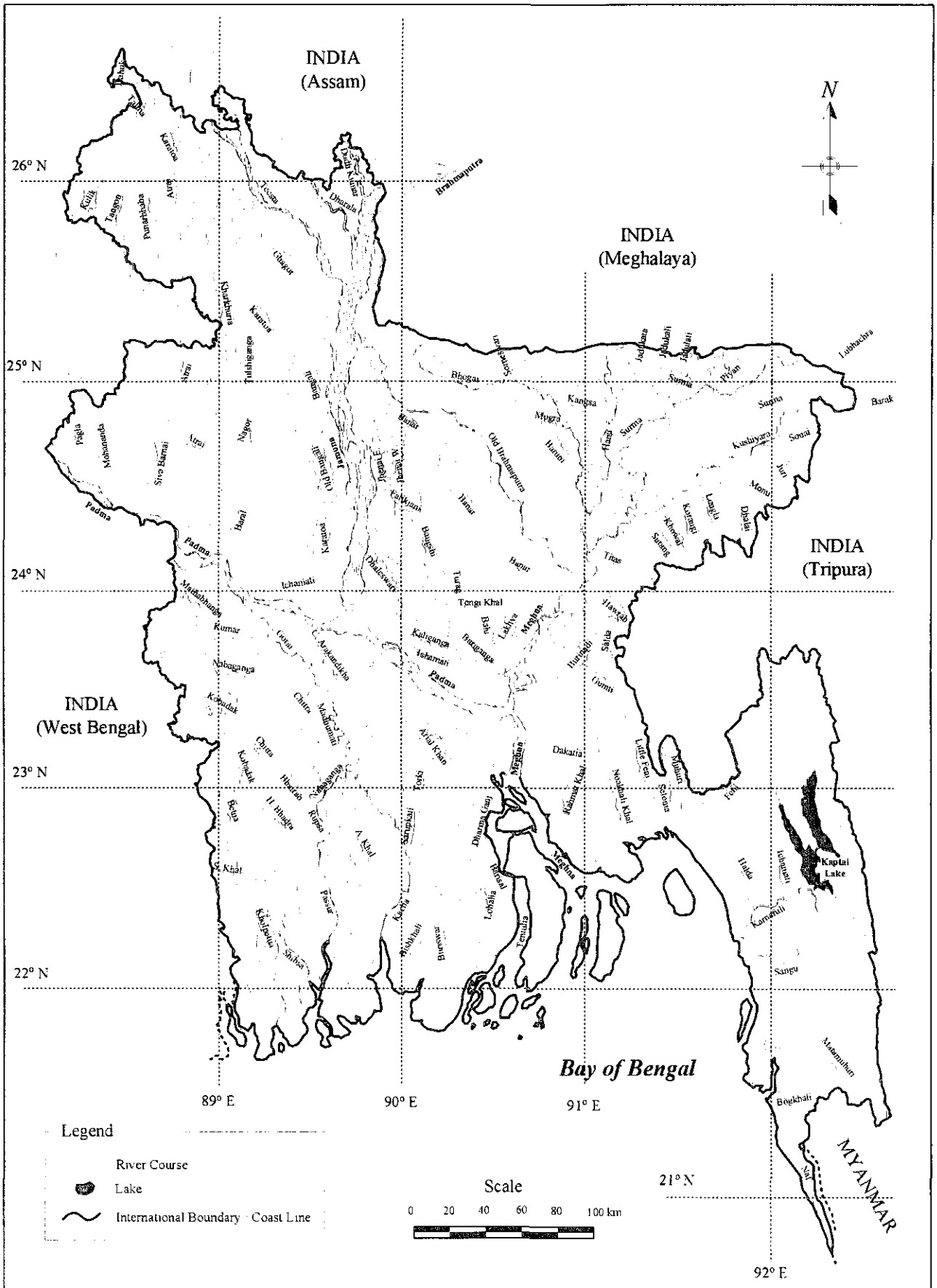
We hope that this Report will be helpful for realization of the projects and programs proposed in this Study to mitigate the flood damage, and will contribute to the socio-economic development of Bangladesh.

We wish to express our deep appreciation and gratitude to the personnel concerned of your Agency, JICA Bangladesh Office, the Embassy of Japan in Bangladesh, Ministry of Water Resources, Bangladesh Water Development Board and the authorities concerned of the Government of the People's Republic of Bangladesh for the courtesies and cooperation extended to us during our Study.

Very truly yours,

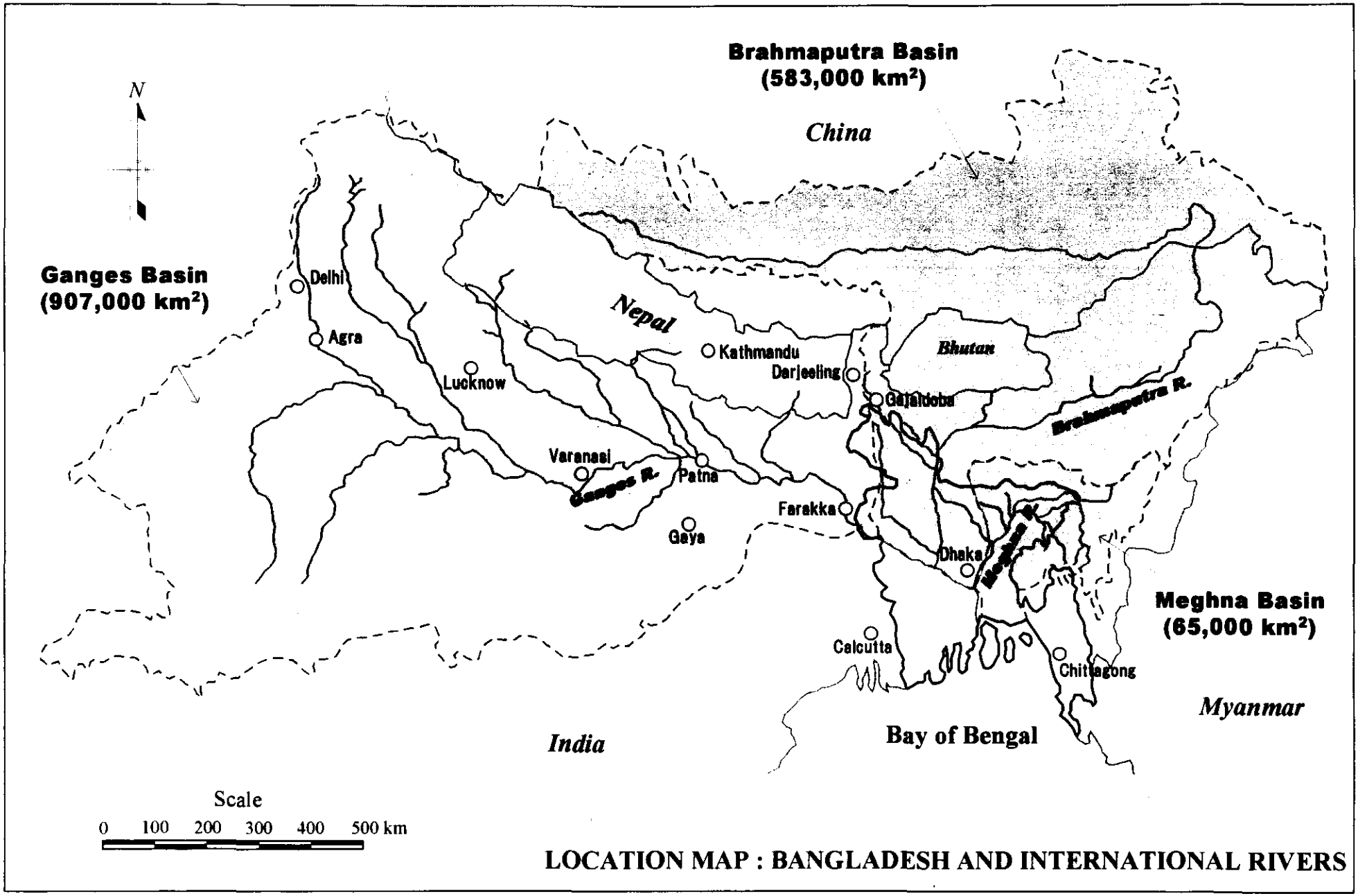
Hideki Sato
Team Leader
for Feasibility Study for Improvement
of Flood Forecasting and Warning Services
in the People's Republic of Bangladesh

LOCATION MAP : BANGLADESH



Source : BWDB

LOCATION MAP : RIVERS OF BANGLADESH



LOCATION MAP : BANGLADESH AND INTERNATIONAL RIVERS

FEASIBILITY STUDY FOR IMPROVEMENT OF
FLOOD FORECASTING AND WARNING SERVICES IN
THE PEOPLE'S REPUBLIC OF BANGLADESH

OUTLINE OF THE STUDY

1. Present Condition

Bangladesh	Location:	Northeastern part of South Asia
	Total land area:	147,000 km^2
	Major international rivers:	Ganges / Padma (907,000 km^2), Brahmaputra / Jamuna (583,000 km^2), and Meghna (63,000 km^2)
Socio-economy	Population:	121.4 million (2001)
	GDP:	2,450 billion Taka (2000/01)
	Per-capita GDP:	20,182 Taka (2000/01)
Hydrometeorology	Annual rainfall:	1,200 mm (west) to over 5,000 mm (northeast)
	Flood types:	Monsoon Flood, Flash Flood, Tidal Surge, and Local Inundation
Flood Damage	Flood affected area (Number of deaths):	89,970 km^2 (2,379 persons) in 1988 monsoon 100,250 km^2 (918 persons) in 1998 monsoon
	Annual flood damage:	12.2 billion Taka
Telecommunication	Diffusion rate:	Fixed phone 0.39 units/100 habitants Mobile phone 0.40 units/100 habitants
Institutions	Water-related agencies:	i) National Water Resources Council (NWRC) ii) Ministry of Water Resources (MOWR) a) Bangladesh Water Development Board (BWDB) b) Joint Rivers Commission (JRC) c) Water Resources Planning Organization (WARPO) d) River Research Institute (RRI) e) Bangladesh Haor and Wetland Development Board (BHWDB) f) Institute of Water Modeling (IWM) g) Center for Environment and GIS (CEGIS)
	Water-related law and regulations:	i) National Water Policy ii) National Water Management Plan iii) National Water Code (under preparation)
Current FFWS	Observation system:	91 manual water level gauging stations 56 manual rainfall gauging stations [Existing Telemeters] a) 14 locations (installed in 1985 and 1996) b) 5 operational (as of September 2003) c) Not effectively used in the current FFWS

Data transmission system:	Voice communication by means of HF wireless (SSB)
Analysis system:	Supermodel based on hydrological-hydraulic calculation software (MIKE11)
Dissemination system:	Flood warning messages issued by Flood Forecasting and Warning Center (FFWC)
Response system:	Led by Disaster Management Committee (DMC) of local authorities
Ongoing projects:	i) Consolidation and Strengthening of FFWS (DANIDA) ii) Water Management Improvement Project (WB) iii) Comprehensive Disaster Management Program (UNDP), etc.

2. Approach to the Improvement of FFWS

Study Period: November 2002 – December 2003

Scope of Work:

1) Formulation of Improvement Plan of FFWS
2) Feasibility Study of the Selected Optimum Scheme
3) Transfer of Technology

Basic Approach

1) Clarification of present conditions of existing FFWS and problems encountered therein
2) Formulation of improvement plans of FFWS based on the study of conceivable alternative plans
3) Selection of optimum plan
4) Feasibility study on the optimum plan

3. Framework Plan of FFWS (Feasibility Project)

Proposed Optimum Scheme (Framework Plan of FFWS):

Control System

1) Central Control System (Control Station: Dhaka)
2) Five Regional Control System
   a) NE Region (Control Station: Sylhet)
   b) NW Region (Control Station: Rangpur)
   c) SE Region (Control Station: Chittagong)
   d) SW Region (Control Station: Barisal)
   e) NC Region (Control Station: Dhaka)

Manual-Telemeter Combined Observation System

1) Water Level Gauging Stations
   a) Manual: 68 (NE: 11, NW: 17, SE: 7, SW: 12, NC: 21)
   b) Telemeter: 23 (NE: 7, NW: 5, SE: 2, SW: 5, NC: 4)

2) Rainfall Gauging Stations
   a) Manual: 45 (NE: 7, NW: 10, SE: 9, SW: 10, NC: 9)
   b) Telemeter 23 (NE: 7, NW: 5, SE: 2, SW: 5, NC: 4)

Project Cost:

Investment Cost: 1,148.2 million Taka

Annual O&M Cost: 65.6 million Taka (excluding depreciation cost)

Economic Evaluation:

EIRR: 26.4 %, NPV: 708 million Taka, B/C: 1.1 (Applied Discount Rate: 12 %)

Social / Environmental Evaluation: No negative effect

4. Pilot Project

Project Features

Control System

1) Central Control System (Control Station: Dhaka)
2) NE (Sylhet) Regional Control System

Manual-Telemeter Combined Observation System

1) Water Level Gauging Stations
   a) Manual: 68 (NE: 11, Others: 57)
   b) Telemeter: 23 (NE: 7, Others: 16)
2) Rainfall Gauging Stations
   a) Manual: 45 (NE: 7, Others: 38)
   b) Telemeter 23 (NE: 7, Others: 16)

Project Cost:

Investment Cost: 813.7 million Taka

Annual O&M Cost: 51.2 million Taka (excluding depreciation cost)

Project Implementation

Leading Agency: BWDB

Implementation Period: Jan. 2004 – Dec. 2008 (including financial arrangement, design, and guidance period)

5. Priority Studies to be Conducted

Components of Priority Study:

1) Formulation of O&M Plan of Improved FFWS
2) Clarification of River Management
3) Strengthening of Dissemination and Evacuation (Response) System
4) Institutional Study
5) Collection of the Information on River Management and Review of Danger Level

FEASIBILITY STUDY
FOR
IMPROVEMENT OF FLOOD FORECASTING AND WARNING SERVICES
IN
THE PEOPLE'S REPUBLIC OF BANGLADESH

FINAL REPORT

VOLUME-I : EXECUTIVE SUMMARY

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ABBREVIATIONS

ADB	Asian Development Bank
ADCP	Acoustic Doppler Current Profiler
ADG	Additional Director General
ADPC	Asian Disaster Preparedness Center
AE	Absolute Error
ARGS	Automatic Rainfall Gauging Station
ASCE	American Society of Civil Engineers
AWLGS	Automatic Water Level Gauging Station
BADC	Bangladesh Agricultural Development Agency
BBS	Bangladesh Bureau of Statistics
BIWTC	Bangladesh Inland Water Transport Corporation
BM	Bench Mark
BMD	Bangladesh Meteorological Department, Ministry of Defense
BR	Bangladesh Railway
BRAC	Bangladesh Rural Advancement Committee
BRTA	Bangladesh Rural Telecom Authority
BTRC	Bangladesh Telecommunications Regulatory Commission
BTTB	Bangladesh Telegraph and Telephone Board
BUET	Bangladesh University of Engineering and Technology
BUP	Bangladesh Unnayan Parishad (Bangladesh Development Council), NGO
BWDB	Bangladesh Water Development Board
C&I	Construction and Instrumentation Division, BWDB
CAP	Community Action Plan
CBO	Community Based Organizations
CC	Community Contract
CCC	Community Coordination Committee
CDMP	Comprehensive Disaster Management Program
CE	Chief Engineer
CEGIS	Center for Environmental and Geographic Information Services
CFAB	Climate Forecast Applications in Bangladesh
CFD	Controlled Flooding and Drainage
CIDA	Canada International Development Agency
CPI	Consumer Price Index
CPP	Cyclone Preparedness program
CPR	Center for Policy Research, NGO in India
CSFFWS	Consolidation and Strengthening of Flood Forecasting and Warning Services
CVCF	Constant Voltage Constant Frequency
DAE	Department of Agriculture Extension
DANIDA	Danish International Development Agency
DEM	Digital Elevation Model
DFID	Department for International Development, UK
DG	Director General
DHI	Danish Hydraulic Institute
DL	Danger Level
DMB	Disaster Management Bureau
DMC	Disaster Management Committee
DMIC	Disaster Management Information Center
DOE	Department of Environment
DOF	Department of Fisheries
DPHE	Department of Public Health Engineering
DRR	Directorate of Relief and Rehabilitation
ECA	Environment Conservation Act
ECR	Environment Conservation Rules
EIA	Environmental Impact Assessment
EOC	Emergency Operation Center
ERD	Economic Relations Division, Ministry of Finance
FAO	Food and Agriculture Organization of the United Nations

FAP	Flood Action Plan
FCDI	Flood Control, Drainage and Irrigation Project
FFMI	Flash Flood Magnitude Index
FFWC	Flood Forecasting and Warning Center, BWDB
FFWS	Flood Forecasting and Warning System (Service)
FFYP	Fifth Five Year Plan
FHC	Flood Hydrology Circle (proposed)
FPCO	*Flood Plan Coordination Organization*
FPP	Flood Proofing Project
GBM	Ganges-Brahmaputra-Meghna (Basins or Rivers)
GDA	Ganges Dependent Area
GDP	Gross Domestic Product
GIS	Geographical Information System
GK	Ganges Kobadak (project)
GMS	Geostational Meteorological Satellite
GNP	Gross National Product
GOB	Government of Bangladesh
GOJ	Government of Japan
GP	Grameen Phone (Mobile Phone Service Company)
GPS	Global Positioning System
GWHC	Ground Water Hydrology Circle, BWDB
GWPB	Ground Water Processing Branch, BWDB
HDI	Human Development Index
HF	High Frequency
HYV	High Yielding Variety
ICB	International Competitive Bidding
IDA	International Development Association
IEE	Initial Environmental Examination
IFCDR	*Institute of Flood Control and Drainage Research*, BUET, now renamed as Institute of Flood and Water Management (IFWM)
IFWM	Institute of Flood and Water Management, BUET, formerly known as IFCDR
IIDS	Institute for Integrated Development Studies, NGO in Nepal
ILA	International Law Association
IMD	India Meteorological Department
IMDMCC	Inter-Ministerial Disaster Management Co-ordination Committee
IT	Information Technology
ITCZ	Inter-tropical Convergence Zone
IWM	Institute of Water Modeling, formerly known as Surface Water Modeling Center (SWMC)
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
JOCV	Japan Overseas Cooperation Volunteers
JRC	Joint Rivers Commission
JRC	Japan Radio Co., Ltd.
LCG	Local Consultative Group
LDAP	*Local Disaster Action Plan*
LGD	Local Government Division, MOLGRDC
LGED	Local Government Engineering Department
LGI	Local Government Institutions
MAE	Mean Absolute Error
MIS	Management Information System
MODMR	Ministry of Disaster Management and Relief
MOE	Ministry of Education
MOEF	Ministry of Environment and Forest
MOLGRDC	Ministry of Local Government, Rural Development and Cooperatives
MOU, MoU	Memo of Understandings
MOWR	Ministry of Water Resources
MPO	Master Plan Organization
MPT	Ministry of Posts and Telecommunications
MSL	Mean Sea Level

MTBF	Mean Time between Failures
NDC	National Disaster Council
NEC	National Economic Council
NEP	National Environmental Policy
NGO	Non-governmental Organization
NOAA	National Oceanic and Atmospheric Administration, USA
NPO	Non Profit Organization
NWDA	National Water Development Agency
NWMP	National Water Management Plan
NWP	National Water Policy
NWRC	National Water Resources Council
NWRD	National Water Resources Database
O&M	Operation and Maintenance
ODA	Official Development Assistance
OS	Operating System
PC	Planning Commission, Ministry of Planning
PCM	Project Cycle Management
PDB	Power Development Board
PFFC	Processing and Flood Forecasting Circle, BWDB
PPPDU	Program, Policy, and Partnership Development Unit
PRA	Participatory Rapid Appraisal
PWD	Public Work Department or Public Works Datum (Water Level)
R&H	Roads and Highways Department
RF	Rain Fall (stations)
RMPB	River Morphology Processing Branch, BWDB
RMR	River Morphology and Research
RMRC	River Morphology and Research Circle, BWDB
RRI	River Research Institute
SAARC	South Asia Association for Regional Cooperation
SDE	Sub Divisional Engineer
SDH	Synchronous Digital Hierarchy
SE	Superintending Engineer
SM	Supermodel
SPARRSO	Space Research & Remote Sensing Organization
SW	Scope of Work
SWHC	Surface Water Hydrology Circle, BWDB
SWMC	Surface Water Modeling Center, now renamed as Institute of Water Modeling (IWM)
SWPB	Surface Water Processing Branch, BWDB
TBM	Temporally Bench Mark
TDS	Total Dissolved Solids
TOF, ToF	Time of Forecast
TOR, ToR	Terms of Reference
UNCHS	United Nations Center for Human Settlement (Habitat)
UNDP	United Nations Development Programme
UNO	Upa-Zilla Nirbahi (Executive) Officer
UPS	Uninterrupted Power Supply
USAID	United States Agency for International Development
USD	United States Dollar
UZ	Upa-Zilla
VHF	Very High Frequency
VSAT	Very Small Aperture Terminal
WARPO	Water Resources Planning Organization
WB	World Bank
WL	Water Level (stations)
WMA	Water Management Association
WMIP	Water Management Improvement Project
WMO	World Meteorological Organization
WSIP	Water Sector Improvement Project
XEN	Executive Engineer

MEASUREMENT UNITS

Area

cm^2	=	Square Centimeters
m^2	=	Square Meters
km^2	=	Square Kilometers
ha	=	Hectares (10,000 m^2)

Length

mm	=	Millimeters
cm	=	Centimeters
m	=	Meters
km	=	Kilometers

Currency

US$	=	United State Dollars
JPY	=	*Japanese Yen*
Tk. (BDT)	=	Bangladesh Taka

Energy

kVA	=	Kilovolt Ampere
kW	=	Kilowatt

Economy

EIRR	=	Economic Internal Rate of Return
FIRR	=	Financial Internal Rate of Return
NPV	=	Net Present Value
B/C	=	Benefit Cost Ratio

Volume

cm^3	=	Cubic Centimeters
m^3	=	Cubic Meters
m^3/day	=	Cubic Meters per Day
m^3/h	=	Cubic Meters per Hour
m^3/min	=	Cubic Meters per Minute
m^3/sec (cumec)	=	Cubic Meters per Second
ft^3/sec (cusec)	=	Cubic Feet per Second
l or lit	=	Liter (1,000 cm^3)
lpcd	=	Liter per capita per day
MCM	=	Million Cubic Meter

Weight

g	=	Grams
mg	=	Milligrams (1/1,000 g)
mg/l	=	Milligrams per liter
µg/l	=	Micrograms per liter
kg	=	Kilograms (1,000 g)
kg/cm^2	=	Kilograms per square centimeter
t	=	Metric ton (1,000 kg)

Time

s	=	Seconds
min.	=	*Minutes*
h	=	Hours

Others

per/km^2	=	Persons per Square Kilometer
rpm	=	Revolutions per Minute
Hz	=	Hertz
MHz	=	*Megahertz*
B (b)	=	Byte
KB (kb)	=	Kilobytes
dB	=	Decibel
MSL	=	Mean Sea Level
Lakh	=	One Hundred Thousand
Crore	=	Ten Million

Part-I GENERAL

I. INTRODUCTION

Background and Authority of the Study

1.1 Bangladesh is located in the delta area formed by three international rivers, namely the Padma (Ganges), the Jamuna (Brahmaputra), and the Meghna Rivers. Although the lifestyle of the people in Bangladesh is well adapted to flood phenomena, damage due to inundation, river bank erosion or breach of river structures, etc. still occur in various regions in every monsoon season.

1.2 In addition to the extensive and serious damage, floods in Bangladesh limit the effectiveness of land use planning, economic growth and so on. To cope with this, a Flood Action Plan (FAP) was launched immediately after the occurrence of 1988 flood with an initiative of the World Bank, and a number of projects under the auspices of FAP were implemented. FAP is now being taken over by the National Water Management Plan (NWMP), whose final version is subject to the approval of the Government of the People's Republic of Bangladesh (GOB).

1.3 In terms of the flood forecasting and warning services (FFWS) in Bangladesh, a forecasting analysis system has been developed and continuously improved through the technical and financial assistance of DANIDA (Danish International Development Agency). However, since the hydrometeorological records utilized for the forecasting analysis are obtained by manual operation, transmitted through wireless voice communication, and manually input to the model, problems related to reliability, accuracy and immediacy of the input data have occurred. Furthermore, telemeter systems installed in 1985 and 1996, funded by Japanese debt relief, have not been effectively utilized in the forecasting system due to the limited number and inadequate alignment of telemetry stations. GOB nonetheless recognizes the importance of the improvement and expansion of the existing telemetry network to ensure prompt and accurate forecasting analysis.

1.4 Based on the above circumstances, GOB submitted a request to the Government of Japan (GOJ) in 2001 for technical assistance to conduct **"the feasibility study for upgradation and expansion of data communication / transmission network for flood forecasting and warning services"**. In response to the request, the GOJ decided to conduct the study covering not only the data communication network but also other system components such as dissemination. The name of the study was subsequently modified to **"feasibility study for improvement of flood forecasting and warning services"** (the Study) and the Scope of Work (S/W) and the Minutes of Meeting (M/M) on the technical cooperation for the Study was agreed upon among Ministry of Finance (MOF), Ministry of Water Resources (MOWR), Bangladesh Water Development Board (BWDB) and Japan International

Cooperation Agency (JICA) on July 11, 2002 in Dhaka. The Study was performed conformity with these S/W and M/M.

1.5 JICA organized the Study Team with the selected consultant in order to carry out the Study. The Team conducted the Study in close cooperation with the GOB through counterpart officials of BWDB. JICA also established an Advisory Committee formed by staff of the Ministry of Land, Infrastructure and Transport, Ministry of Foreign Affairs in order to guide the Study Team and review study findings. The GOB established a Steering Committee to support the Study Team chaired by the Secretary of the MOWR with members from various related agencies.

Objectives and Scope of the Study

2.1 The objectives of the Study are;

i) To formulate the improvement plan of flood forecasting and warning system in Bangladesh in order to mitigate flood damage focusing particularly on improvement of data communication system,
ii) To conduct a feasibility study of the selected optimal scheme, and
iii) To perform technology transfer to Bangladesh counterpart personnel in the course of the Study.

2.2 The area subject to the Study is the entire area of Bangladesh. In the Study, FFWS is considered to be divided into 5 sub-systems, namely, 1) Observation System, 2) Data Transmission System, 3) Analysis System, 4) Warning Dissemination System, and 5) Response System. To improve existing FFWS, following works are conducted:

i) Clarification of present conditions of existing FFWS and problems being encountered therein,
ii) Formulation of improvement plans of FFWS based on the study of conceivable alternative plans and selection of optimal plan, and
iii) Feasibility study on the selected optimal plan

Study Schedule and Activities

3.1 The Study is conducted dividing into two stages, i.e. 1) Basic Study, and 2) Feasibility Study. The Study commenced in November 2002 and the field investigations, the study on conceivable alternative plans, and selection of optimum improvement plan were completed and framework plan of FFWS was proposed in the Basic Study Stage. The proposed framework plan was studied in detail in the Feasibility Study Stage through field reconnaissance, radio tests, etc. The Study will be completed in December 2003.

3.2 The transfer of technology has been made through on-the-job training in the course of day-to-day Study works, joint meetings with counterparts, PCM workshops and technology transfer seminar/workshop.

Final Report

4.1 This Final Report contains all the findings of the field investigations and results of the Study including the Basic Study (Framework Plan) and the Feasibility Study.

4.2 This Final Report consists of four (4) volumes; Volume-I Executive Summary, Volume-II Main Report, Volume-III Supporting Report, and Volume-IV Data Book.

II. PRESENT CONDITION

Geography

5. Bangladesh is located in the northeastern part of South Asia with total land area of 147,000 km^2. The country is bounded by India, Myanmar and the Bay of Bengal. Eighty percent of the country is categorized in flood plain formed by alluvial and deltaic deposits.

Socio-Economy

6.1 *Administration:* Bangladesh is divided into 6 administrative divisions. Those divisions are formed by 64 districts. Each district is further divided into sub-districts (Upazilla or Thana).

6.2 *Population:* The population of Bangladesh as of 2001 was 121.4 million with an average annual growth rate of 1.49 %. The overall population density was 826 persons/km^2 (2001). In the district base, Dhaka, most densely populated area in the country, has population of 8.6 million with density of 5,858 persons/km^2.

According to the result of population projection conducted by the Study Team, the population will grow to 144 million in 2010 and to 163 million in 2020.

6.3 *GDP:* The GDP in 2000/01 was about 2,450 billion Taka with average annual growth rate of 8.9%. The per capita GDP was 20,182 Taka.

According to the result of GDP projection carried out by the Study Team, the total GDP will increase to 6,102 billion Taka in 2020 with average annual growth rate of 5.5 % under the medium growth scenario. The per capita GDP is projected to increase to 31,401 Taka in 2020 with average annual growth rate of 3.0 %.

6.4 *Financial Conditions of GOB:* Total revenue of the GOB in 2001/02 was 423 billion Taka while expenditure was 356 billion Taka. Total revenue is formed by revenue receipt and development receipt revenue. In 2001/02, the former occupied 64 % of the total. Total expenditure is broken down into revenue expenditure and development expenditure and the former shared 62 % of the total in 2001/02.

6.5 *Development Expenditure of GOB:* The development expenditure of GOB in 2001/02 was 136 billion Taka. The most rapid growth is recorded by education and training sector with 43.4 % per annum. The largest proportion of expenditure was in transport (19.7 %). The expenditure for flood control and water resources shows the decrease with the average annual growth rate of -3.1 %.

6.6 *Commitment and Disbursement of Foreign Economic Assistance:* The commitment of foreign economic assistance indicates the slight increase from 1.9 (1991/92) to 2.1 billion US$ (2000/01). The percentage of grants was 45.7 % and that of loan was 54.3 % in 2000/01. The disbursement of foreign economic assistance recorded

1.4 billion US$ in 2000/01. Comparing donors providing foreign economic assistance, Japan is the one of the most contributing countries as well as ADB, IDA, USA and UK.

6.7 *Socio-economic Framework:* The five year plan framework was reinstated in 1980 and since then, three five year plans were implemented in succession. After the Fifth Five Year Plan (1995 – 2000), there has been no long-term development plan in Bangladesh till now (the Sixth Three Year Plan are being prepared by GOB but not published yet).

Major Natural Disasters

7. Bangladesh is prone to many kinds of natural disaster. The major disasters recognized in Bangladesh are cyclone, flood, drought, earthquake, river bank erosion, tornado, and so on.

Hydrometeorology

8.1 *Climate:* Bangladesh is located in a sub-tropical monsoon zone with 4 main seasons (winter, summer, monsoon and post-monsoon (autumn)). Annual average temperatures range from 19 to 29 ^{o}C by regions. Annual average rainfall varies from 1,200 mm in the west to over 5,000 mm in the northeast. Tropical cyclones attack almost every year mainly in pre-monsoon (March-May) and post-monsoon seasons (October-November).

8.2 *Hydrological Conditions:* Bangladesh is located in the confluence area of the Padma (907,000 km^2), the Jamuna (583,000 km^2) and the Meghna (65,000 km^2) rivers, and more than 90 % of discharge in Bangladesh originates outside of the country. The calculation results show that annual average total runoff of the Padma (344×10^9 m^3) is about 50 % of that of the Jamuna (679×10^9 m^3), although the drainage area of the Padma is more than 1.5 times of that of the Jamuna.

8.3 *Flood Characteristics:* Four types of floods are generally considered in Bangladesh, namely, 1) monsoon flood, 2) flash flood, 3) lowland inundation, and 4) tidal surge caused by cyclone.

8.4 *Observation Network in Bangladesh:* Bangladesh Meteorological Department (BMD) and Bangladesh Water Development Board (BWDB) are the main organizations in charge of hydrometeorological observations. BMD has 35 surface observatories widely distributed across the country and 4 radar equipment with each coverage area of 400 km radius. BWDB also has huge observation network consists of surface water hydrology, ground water hydrology, climate and river morphology.

River and Flood Control

9.1 *River System:* According to BWDB, the total number of rivers in Bangladesh is around 290 including tributaries and distributaries. Although there is no clear definition, four rivers, namely, 1) the Padma, 2) the Jamuna, 3) the Meghna and 4) the Karnaphli can be referred to as major rivers in the country.

9.2 *River Morphological Survey:* BWDB has conducted river cross section surveys for 1) three major rivers for every year, 2) five medium rivers for every 2 years, and 3) thirty seven minor rivers for every 3 years. Major rivers moves severely more than several kilometers in cross section direction annually. Scouring in the riverbed is more than 30 meters in depth.

9.3 *Flood Action Plan (FAP):* After the 1988 flood, FAP, which consists of 11 main component and 15 supporting activities, was formulated by assistance of international aid. Although almost all studies were completed, very few of the new projects implemented are among those identified in FAP.

9.4 *Views on Flood Control:* The Study Team defines the flood damage by the conceptual formula "[Disaster] = [Hazard] × [Vulnerability]". This indicates that minimizing disaster is to minimize the hazard by 'structural measures' or to minimize the vulnerability by 'non-structural measures' such as evacuation. Structural and non-structural measures should be connected by effective 'supporting measures'. FFWS is one of the most essential supporting measures.

9.5 *Questionnaire Survey:* The Study Team conducted Questionnaire Survey to the O&M Divisional Offices under BWDB aiming at grasping O&M situation of the river structures constructed by BWDB.

a) Distribution of the Questionnaire Formats to 60 O&M Divisional Offices
b) Responses from 22 offices
c) Major findings are;
   - Flood Warning messages have been received sometimes, but not regularly
   - No operation Manual for emergency operation except INSTRUCTIONS given by BWDB central office annually
   - FFWS is necessary except some offices
   - Anticipated benefit from FFWS is very high
   - O&M Cost is very high
   - No ledger sheets of the river structures

9.6 *River and Flood Control Structures, Existing and Proposed:*

a) BWDB undertook planning, design, and implementation of 625 projects during 1959-2002
b) GOB formulated Flood Action Plan in 1990's which was followed by National Water Policy in 1999 and National Water Management Plan in 2001.

c) GOB has intended to promote river management covering entire area of the Bangladesh. Three gigantic barrage projects have been contemplated, one each on the Ganges, Brahmaputra and Meghna. The pre-Feasibility study on the Ganges Barrage was presented in NWMP. This Project has contemplated multipurpose water development in the Ganges Dependent Area (GDA). However, further detailed study would be essential

9.7 *River Structures in Indian Territory:* There are many river structures in Indian Territory, among which Farakka Barrage located about 40 km upstream of the main Ganges and Gojaldoba Barrage located in the Teesta River are the rather big-scale structures. It is advisable that such structures should have a water release warning system.

Flood Damage

10.1 *Historical Performance:* According to the historical records, 19 floods with affected area of more than 30,000 km^2 occurred after 1954. The most number of deaths was recorded in 1988 (2,379 persons). The largest amount of damage, which was roughly estimated by Bangladesh side, was recorded in 1998 flood as 160 billion Taka, but the damage due to injury or death and the damage to homesteads are not included in this estimated amount. Moreover, there are no regularly published records of flood damage in monetary form.

10.2 *Actual Flood Damage:* The Study Team tried to assess the actual flood damage amount for the 1998 flood including the damage due to injury and death, and the damage to homesteads. As a result, the total flood damage of 1998 flood was estimated to be about 156 billion Taka at the current prices in 2002.

10.3 *Annual Average Flood Damage:* Based on the damage of 1998 flood (considered as 50 years probable flood), the annual average flood damage was estimated by the Study Team, employing a several assumptions. The estimated annual average flood damage is about 12.2 billion Taka.

Telecommunication

11.1 *Current Telecommunication Network:* The diffusion of fixed telephone, mobile phone, and television set in Bangladesh as of 2001 are 0.39, 0.40, and 1.5 units/100 habitants, respectively. Although the density of telecommunication infrastructure in Bangladesh is poor, the increase rate of mobile phone is significantly high.

11.2 *Wired Communication Network:* The nationwide telephone network in Bangladesh is managed by Bangladesh Telegraph and Telephone Board (BTTB) in principle, while several private companies such as Bangladesh Rural Telecom Authority (BRTA) operate some part of that. As for BTTB lines, although the trunk lines' capacity has been enhanced rapidly, the service level to the end users has not been improved promptly. Regarding the BRTA, it has grown steadily by offering

agreeable services especially in rural areas, and now BRTA operates its own dedicated network.

11.3 *Wireless Communication Network:* There are several mobile phone service providers. Among them, GRAMEEN has the widest coverage area. The mobile phone service network has grown substantially in recent years owing to its lower installation cost.

11.4 *Satellite Communication Network:* VSAT and INMALSAT systems are available in this country. The former is a global trunk-line satellite network and is exclusively operated by SQUARE, a multi-faced company. The latter has been developed and is being operated to facilitate ocean communications facilities, and it is widely utilized as stationary communications as well as mobile communication facilities. BTTB acts as a window for handling subscription applications and payments for INMALSAT system in Bangladesh.

11.5 *Inter-agency Network:* There is no firm inter-agency network in Bangladesh. Inter-agency network, connecting among disaster related agencies such as BWDB, DMB, BMD, IWM, SPARRSO, CPP, CEGIS, etc., is essential especially in an emergency situation such as flood or cyclone.

11.6 *Future Development Plans of Fixed Telephone:* The number of pending demands on fixed phone is getting larger in recent years. To cope with this, BTTB now taking a program including; 1) installation of new digital telephone exchanges, 2) installation and expansion of Trunk Automatic Exchanges, and 3) replacement of analog transmission links with digital ones.

11.7 *Future Development Plans of Mobile Phone:* Mobile phone networks can be installed much more rapidly than fixed networks. And the wide availability of second-generation mobile systems may be realized in near future in Bangladesh.

11.8 *Future Development Plans of IT:* GOB established IT (Information Technology) policy regarding IT as the key driving element for socio-economic development. It includes, 1) permission for private sector to create broadband telecommunication backbone, 2) development of national access platform by BTTB, 3) set up of internet exchange for national inter-connectivity among internet service providers, and 4) conversion of all analog telephone exchanges to digital ones.

Institutions

12.1 *National Government:* Bangladesh is governed by a parliamentary form of government. The executive power lies with Prime Minister. There are 38 ministries and FFWC comes under the jurisdiction of Ministry of Water Resources (MOWR).

12.2 *Local Government:* All local government institutions come under administrative responsibility of the Local Government Division (LGD) of the Ministry of Local

Government, Rural Development and Cooperatives (MLGRD). The country is divided into 6 Divisions headed by Divisional Commissioner. Each Division is divided into some Districts (Zilla) headed by Deputy Commissioner. Each District is further divided into some Upazilla or Thana (sub-District). At present, there are 64 Districts, and these are formed by 507 Upazillas or Thanas.

12.3 *Water-related Agencies:* Water-related agencies in Bangladesh are enumerated below:

i) National Water Resources Council (NWRC)
ii) Ministry of Water Resources (MOWR)
   a) Bangladesh Water Development Board (BWDB)
   b) Joint Rivers Commission (JRC)
   c) Water Resources Planning Organization (WARPO)
   d) River Research Institute (RRI)
   e) Bangladesh Haor and Wetland Development Board (BHWDB)
   f) Institute of Water Modeling (IWM)
   g) Center for Environment and GIS (CEGIS)

12.4 *Water-related Law and Regulations:* Major water-related law and regulations in Bangladesh are, 1) National Water Policy, 2) National Water Management Plan (NWMP), and 3) National Water Code. National Water Policy is the umbrella policy for the water sector prepared by MOWR and enacted in 1999. NWMP was prepared by WARPO and is now under active consideration by NWRC for approval. National Water Code is now under preparation by WARPO.

12.5 *Bangladesh Water Development Board (BWDB):*

i) *Institutional Setup:* BWDB was originally established 1959 and its organization was restructured in 1972. Until few years before, there was around 18,000 staff in BWDB. A re-organization was ordered in 1998, where total staff strength was set at 8,860. The number of staff is 10,069 as of June, 2001.

ii) *Organizational Structure:* There is a 13 member Governing Council of BWDB, whose function is to give advice on board's policy, planning and operation. Director General (DG) is the Chief Executing Officer, and there are 5 Additional Director Generals (ADG) in charge of administration, finance, planning, O&M-1 and O&M-2. Under the ADG (Planning), there are Chief Planning, Chief Engineer Design and Chief Engineer Hydrology. FFWC comes under Chief Engineer Hydrology.

iii) *Human Resources Development:* BWDB is an engineering based organization. Officers are firstly recruited at the level of Assistant Engineer and are provided with basic training at the Central Training Academy of BWDB. Afterwards, demand based short training is given. However, there is no provision for continuing education and advanced training.

iv) *Budget Allocation:* The budget of BWDB is divided into 1) revenue and 2)

development budgets. Development budget is for implementation of new projects. The revenue budget includes establishment, non-development and loan repayment. In 2000/01, total budget of BWDB was about 11.3 billion Taka formed by revenue (1.4 billion Taka) and development (9.9 billion Taka).

12.6 *Flood Forecasting and Warning Center (FFWC):* FFWC was established within BWDB in 1972. The principal functions are, 1) data collection, 2) flood forecast model operation, 3) flood warning issue, and 4) operating 'Flood Information Center' during flood period. FFWC is headed by an Executive Engineer.

III. CURRENT FLOOD FORECASTING AND WARNING SERVICES

History of FFWS Development in Bangladesh

13. In the initial stage of the establishment of FFWC in 1972, there was 10 real-time flood monitoring points and forecast information was based on the correlation analysis and Muskingum-Conge flood routing model. During the time of 1989-94, through UNDP assistance project and DANIDA funded FAP10 project, hydrological/hydraulic approach utilizing MIKE11 was employed and forecast was made at 16 locations. During the time of 1995-99, through extension of FAP10, expansion of FFWS (MIKE11 with GIS) was made and forecast was made at 30 locations. Flood inundation map was also introduced in this project. At present, beside this JICA Study, DANIDA funded CSFFWSP is undergoing to be completed in the middle of 2005. At the same time, FFWS is associated with EMIN, CFIS and CFAB study projects.

Overall FFWS in Bangladesh and Existing Telemeter System

14.1 Bangladesh now has in place a FFWS comprising:

a) An observation network of real-time water level and rainfall gauging stations coupled with a data transmission network for the transfer of this information to FFWC in Dhaka.
b) A hydrological and hydraulic flood simulation and forecasting system
c) Flood warning bulletins issued daily during the flood season and dissemination of flood warnings by FFWC to the relevant authorities.
d) Monthly and annual flood reports are regularly published and distributed.

As mentioned above, overall FFWS is considered to be formed by 5 sub-systems, namely, 1) Observation System, 2) Data Transmission System, 3) Analysis System, 4) Warning Dissemination System, and 5) Response System. In this Study, present conditions, problems encountered and conceivable solutions were extracted by component.

14.2 A telemeter system, which is composed of 14 automatic hydrometeorological observatories, 5 repeater stations and 1 control office in Dhaka, was established partially in 1985 and partially in 1996 by GOB with money source of debt relief fund of GOJ. As seen in the table below, a large part of the system became dysfunctional at present and the number of the telemetric gauging stations whose data is continuously transmitted to FFWC is 5 out of 14, as of September 2003.

Status of Existing Telemeter System as of September 2003

No	Location	Year of Installation	Present Condition	Notes
1	Tongi / Dhaka	1996	Under repair	
2	Mirpur / Dhaka	1996	Working	
3	Rekabibazar /Dhaka	1996	Working	
4	Mill Barak / Dhaka	1996	Under shifting	Will complete soon
5	Nayarhat / Dhaka	1996	Working	
6	Narayanganj /Dhaka	1996	Working	
7	Jatrapur	1996	No working	WL gauge pipe destroyed
8	Pankha	1996	No working	River cause shifted
9	Sherpur	1985	No working	Partially repaired in 1996
10	Shayestaganj	1996	No working	Equip. shifted to Dhalai
11	Dhalai	1985	Under Repair	Equip. shifted from Shayestaganj
12	Monu	1996	Partially working	Transmission problem, under investigation
13	Kamalganj	1985	No working	Partially repaired in 1996, under repair
14	Zakiganj	1996	No working	No repeater connection

Although BWDB is planning to reactivate additional 4 telemetric gauges, those reactivated telemetric system may not be the key ingredient of existing FFWS, considering that 1) the equipment are old and almost expiring their life time, and 2) huge investment is necessary for the construction of suitable interface structures of this old telemeter system.

Therefore, the incorporation of existing telemetric equipment or facilities into the proposed improvement plan of FFWS is not considered.

Observation System

15.1 *Present Status:* Present condition of observation system is as follows:

a) 91 water level gauging stations (manual operation)
b) 56 rainfall gauging stations (manual operation)
c) 13 automatic water level gauging stations (float type)
d) 6 automatic rainfall gauging stations (tipping bucket type)
e) Interval of manual water level observation; 3 hours (6:00 to 18:00)
f) Interval of manual rainfall observation; 24 hours ending at 9:00
g) Interval of automatic observation (water level and rainfall); 1 hour
h) 8 automatic water level gauging stations out of 13 are not operational (as of Feb. 2003)
i) 4 automatic rainfall gauging stations out of 6 are not operational (as of Feb. 2003)

15.2 *Problems Encountered:* Problems encountered are as follows:

a) Miss reading of manual gauging equipment
b) Default of observation and inconsistency of time of observation (due to lack of gauge readers or accessibility)

c) Insufficient clearance of rainfall gauging stations
d) Interruption of water level observation in night time
e) Staff gauge sifting in accordance with the rising and lowering of water level
f) Insufficient O&M of automatic gauging equipment
g) Being washed out or being buried due to frequent river course sifting

15.3 *Conceivable Solutions:* Conceivable solutions are as follows:

a) Strengthening of the reliability of observed hydrometeorological data and ensuring of regular observation by installation of automatic gauging equipment
b) Acquisition of sufficient clearance for rainfall gauging stations
c) Prevention of washing out or burying of water level gauging station by installations of stations at existing river structures
d) Strengthening of O&M system for gauging equipment

Data Transmission System

16.1 *Present Status:* Present condition of data transmission system is as follows:

a) The manually observed hydrometeorological data is transmitted to FFWC through voice communication by means of HF wireless.
b) Although there are 14 telemetric observatories, those data are not effectively utilized for current FFWS.
c) Data of 5 observatories out of 14 are available at FFWC.

16.2 *Problems Encountered:* Problems encountered are as follows:

a) Transmission of wrong information due to noise or miss operation of wireless equipment
b) Weak operation and maintenance system due to lack of budget and manpower
c) Unexpected interruption of public telecommunication lines of BRTA and BTTB

16.3 *Conceivable Solutions:* Conceivable solutions are as follows:

a) Installation of telemeter system
b) Establishment of digital data transmission system from the manually operated hydrometeorological ganging stations
c) Strengthening of operation and maintenance system for telecommunication equipment
d) Establishment of own telecommunication lines

Analysis System

17.1 *Present Status:* Present condition of analysis system is as follows:

a) One-dimensional (quasi-two-dimensional) hydrodynamic calculation by means of MIKE11 Supermodel 2001 is conducted.
b) Time consumption for hydraulic calculation: 20 minutes/once

c) Generation of flood inundation maps by means of MIKE11-GIS
d) Time consumption for generation of inundation map: 60 minutes (including import of the result of hydraulic calculation)
e) Real-time simulation and forecast simulation (24, 48, 72 hours) are conducted.
f) Number of modeled branches: 272
g) Number of link channels (virtual water ways): 227
h) Weirs: 38, Culverts: 15
i) Number of river cross sections input in the model: about 1,100 (Survey result of BWDB)
j) Number of sub-catchments for rainfall-runoff model: 114
k) Number of rainfall gauging stations for input of rainfall-runoff model: 37
l) Number of boundary conditions (water level, discharge) required for model run: 52
m) Actual (observed) data of 23 stations out of 52 is available, and the boundary conditions for remaining 29 stations are estimated based on the observed data nearby stations.
n) Number of water level forecast points: 54 (as of December 2002)
o) Evaluation of the forecasting accuracy at each forecast point is made every year after the end of flood season.
p) The model shows its relatively good accuracy at monsoon flood area, but the accuracy is sometimes poor at flash flood areas.
q) The update and expansion of analysis model are conducted by IWM (Institute of Water Modeling).

17.2 *Problems Encountered:* Problems encountered are as follows:

a) Input errors due to manual input operation
b) Ineffective use of exiting telemetric data due to lack of interface
c) Insufficiency for short cycle flood phenomena such as flash flood due to one day interval of model simulation
d) There is a model requirement that future hydrological status of boundary stations should be input for future water level forecast, and those future boundary conditions are estimated by FFWC staff based on the experiences.
e) Low accuracy of generated flood inundation maps due to old topographic information
f) Impossibility of water level forecast more than 72 hours ahead due to limitation of hydrometeorological information in the upstream countries
g) Difficulties in staff training due to the complication of setting up and running of simulation model
h) Non-availability of manuals for operation of supermodel (Only the manuals for original software published by DHI are available.)

17.3 *Conceivable Solutions:* Conceivable solutions are as follows:

a) Development of automatic input system

b) Update of topographic information
c) Strengthening of applicability for flash flooding by more frequent operation of the forecasting model
d) Extension of lead time and establishment of the method of accurate boundary forecast by collection of continuous hydrometeorological information of upstream countries
e) Training of staff for the ability of model operation and update and preparation of operation manual

Warning Dissemination System

18.1 *Present Status:* Present condition of dissemination system is as follows:

a) Flood warning is issued by FFWC based on the monitoring and simulation.
b) Flood bulletin is issued by FFWC in daily basis in monsoon (May – October).
c) FFWC sends flood bulletin or warning to office of PM, local government authorities, the media, NGOs, and donors by means of telephone, facsimile, e-mail and so on.
d) Flood information is also disseminated through FFWC's web page.
e) The contents of information are, observed rainfall, observed water level, water level forecast (24 and 48 hours ahead), flood inundation map and so on.
f) Observed water level in m PWD and the gap between observed water level and Danger Level (DL) is reported.
g) Officially, the flood warning issued by FFWC is transmitted to local inhabitants through Disaster Management Committee (DMC) of each District, Upazilla, and Union etc.

18.2 *Problems Encountered:* Problems encountered are as follows:

a) Flood warning information does not reach local inhabitants (there are missing links between Upazilla and Union levels).
b) There is no enough time for local inhabitants to take necessary actions due to insufficient lead time.
c) People do not understand the meaning of flood warning due to unclearness of warning messages.
d) The information on the safety of river related structures is not included in the warning messages.
e) The recipients do not understand the accuracy or reliability of forecasted water level because the accuracy and reliability are not mentioned in the flood warning issued by FFWC.

18.3 *Conceivable Solutions:* Conceivable solutions are as follows:

a) Establishment of reliable dissemination route from FFWC to local inhabitants
b) Definition (clarification) of responsibilities of concerned agencies in the flood situations
c) Extension of the lead time

d) Clarification of the contents of flood warning messages (visualization by means of flood hazard maps in local level, review of danger levels, etc.)
e) Indication of current and forecasted safety level of major river structures
f) Clarification of the forecast accuracy by forecast point and making the accuracy official

Response System

19.1 *Present Status:* Present condition of response system is as follows:

a) Officially, the response activity is headed and supported by DMC of each local authority.
b) Dissimilar to cyclone response, there are no systematic organizations for response or flood fighting, inhabitants therefore take actions based on their own experiences and judgments.
c) In case of abnormal flood situation, inhabitants evacuate on highways, flood dikes, or other relevant buildings.

19.2 *Problems Encountered:* Problems encountered are as follows:

a) There is no systematic organization for flood response and flood fighting.
b) There are only 95 flood evacuation shelters, while totally 1,841 cyclone shelters are effectively used.
c) People do not want to evacuate due to lack of security of their houses and properties.
d) Lack of transportation for flood evacuation
e) Bad environmental conditions for living at evacuated places
f) Lack of knowledge of inhabitants for flood response and flood fighting
g) Lack of space for the evacuation of livestock
h) Lack of guidelines for the mitigation of flood damage
i) Lack of guidelines for prevention of damage for river structures

19.3 *Conceivable Solutions:* Conceivable solutions are as follows:

a) Establishment of organizations for flood response and flood fighting (effective assistance of DMC, NGOs, etc.)
b) Establishment of flood shelters (flood evacuation centers)
c) Ensuring of security or houses and properties of local inhabitants
d) Ensuring of transportation in flood situation
e) Management and improvement of environment at the places where people evacuate
f) Strengthening of the people's awareness on flood response and flood fighting
g) Ensuring of space for evacuation of livestock and agricultural products
h) Preparation of guidelines for prevention of flood damage for river structures

Institutional Matters

20.1 In addition to abovementioned 5 sub-systems, institutional aspects relating to FFWS were also analyzed.

20.2 ***Present Conditions***

On-going Relevant Projects: The ongoing relevant projects concerning to FFWS are as follows:

i) Consolidation and Strengthening of FFWS (CSFFWS) funded by DANIDA
ii) Water Management Improvement Project (WMIP) funded by World Bank
iii) Comprehensive Disaster Management Program (CDMP) coordinated by UNDP
iv) Environment Monitoring Information Network (EMIN) funded by CIDA
v) Community-based Flood Information System (CFIS) funded by USAID
vi) Climate Forecast Application in Bangladesh (CFAB) funded by USAID

Donor Activities in FFWS Sector: A large number of donors are actively supporting the sector. There is a committee on water sector under Local Consultative Group (LCG) for coordinating the donor side.

Trans-boundary Information Acquisition and Application: The Joint Rivers Commission (JRC) is responsible to deal with co-riparian countries for information acquisition.

Disaster Management: Ministry of Disaster Management and Relief (MDMR) is the responsible ministry for disaster management and implements the activities through;

- two line agencies, i.e. 1) Disaster Management Bureau (DMB), and 2) Directorate of Relief and Rehabilitation
- one center, i.e. Emergency Operation Center (EOC)
- Local Government Institutions
- NGOs

And there is an Inter-ministerial Disaster Management Coordination Committee headed by the Minister of MDMR and National Disaster Management Council chaired by the Prime Minister.

Role of Local Government in Flood Situation: In the context of flood, Local Government Institutions (LGIs) are responsible for root level warning dissemination and evacuation. However, it is not always possible for them to deliver the required services due to their weak institutional strength.

Role of NGOs in Flood Situation: Some of the NGOs are already engaged in the flood related sectors in different ways. These include mainly post flood response, flood proofing livelihood, and recently, warning dissemination, evacuation and flood awareness building.

Information Management and Research and Development: In accordance with the recommendations by the National Water Policy, the National Water Resources Database (NWRD) has been setup in WARPO. Institute of Water and Flood Management (IWFM; established in 1974) of BUET is one of the leading research bodies in the water sector.

20.3 *Problems on Institutional Matters*

Institutional Weakness of BWDB:

- Centralized administration of BWDB
- Centralized administration and inadequate organizational setup of Hydrology
- Insufficient O&M budget
- Weak accountability
- Poor monitoring system

Operation and Maintenance:

- No formal operational procedure
- Untimely budget allocation
- Poor water levy collection
- Vacancies in key positions
- Insufficient logistic support

Information Management:

- Lack of integrated data management
- Old topographic mapping

Skill Development:

- Inadequate staff training
- Seniority based promotion
- Quick rotation
- Lack of incentives
- Lack of multi-disciplinary staffing

Inadequate Warning Dissemination and Response:

- Weak LGIs
- No setup like Cyclone Preparedness Program (CPP)
- No warning and response for river structures

Planning Issues:

- No specific targets and execution course for FFWS in NWMP
- Insufficient definition of FFWS in CDMP
- No water code

International River Issues:

- Insufficient Indian data
- No direct application of Indian data

- Lack of proper water sharing treaty

Participation of NGOs:

- No definition of NGOs' participation in flood disaster management

Part-II FORMULATION OF FFWS

IV. FRAMEWORK PLAN OF FFWS

Needs of FFWS

21.1 *Objectives of FFWS:* Disaster management is a responsibility of the Government, and FFWS is one of the essential supporting measures for damage mitigation. Comparing to large-scaled structural measures, small-scaled structural measures and non-structural measures are much more practical and economical especially in Bangladesh. The FFWS is essential as supporting measures in the following point of view:

a. Evacuation and/or flood cooping operation for the people
b. Operation of river structures
c. Operation of transportation system
d. Earlier harvest of crops
e. Social and economic activities

21.2 *Objective Areas of FFWS:* Based on the result of analysis on 1998 flood data, which shows that damage is recorded almost evenly over the country, the Study Team set the object area of FFWS to be the entire area of Bangladesh.

21.3 *Required Accuracy:* The error (required accuracy) of the 24-hour forecast, defined as the difference between observed and forecast water levels, should not exceed:

- 20cm when the change in water level over the 24-hour period is less than 1m, or
- 20% of the change in water level over the 24 hour period if this exceeds 1m.

21.4 *Required Lead Time:* Necessary times for the response activity were established as follows:

Necessary Time by Response Activities

Response Activity	Necessary Time for Completion of Activity
Evacuation with minimum necessary belongings	4 hours
Protection of river structure from flood damage	12 hours
Early harvesting of crops	4 ~ 5 days

Component Alternative Development Plan

22.1 Based on the analysis on the present conditions and problems on existing FFWS, the alternative development or improvement plans are set up by components considering that those are to form the combined alternative framework plans. As mentioned later on, the combined alternative framework plans are largely divided as follows:

1) manual observation system, telemeter system, or combined system of manual observation and telemeter
2) central control system or regional control system

22.2 *Observation System:* Following three alternatives were set up for improvement of observation system:

1) Remain present manual observation system as it is (only data communication system will be improved)
2) Installation of automatic water level and rainfall gauging equipment with telemetric system at all of FFWC observatories (91 water level and 56 rainfall gauging stations)
3) Installation of automatic water level and rainfall gauging equipment with telemetric system at proposed 23 observatories (data communication system will be improved for remaining manually operated observatories)

The location and number of observatories mentioned above item 3) was decided employing criteria fixed considering the following aspects:

- Flood characteristics
- Degree of the development of the area where each gauge is located in
- Model requirement
- Strategic point in view of hydrology

As a result, following 23 observatories (refer to **Figure 1**) were selected to be telemeterized as above alternative 3). Both automatic water level and rainfall gauging equipment is proposed to be installed in this alternative.

Proposed Telemetric Observatory as Alternative-3

Sl. No.	Station Name	River Name	Sl. No.	Station Name	River Name
1	Panchagarh	Karatoa	13	Chatlaghat	Monu
2	Dalia	Teesta	14	Bhairab Bazar	Upper Meghna
3	Noonkhawa	Brahmapurta	15	Comilla	Gumti
4	Kurigram	Dharla	16	Dhaka (Mill Barak)	Buriganga
5	Sirajganj	Jamuna	17	Mongla	Pasur
6	Pankha	Upper Padma	18	Rayenda	Baleswar
7	Nakuagaon	Bhugai	19	Patharghata	Bishkhali
8	Durgapur	Someswari	20	Dasmina	Tetulia
9	Laurergarh	Jadukata	21	Daulatkhan	Shahbazpur
10	Sarighat	Sarigowain	22	Panchapukuria	Halda
11	Kanaighat	Surma	23	Chittagong (Sadarghat)	Karnafuli
12	Amalshid	Kushiyara			

22.3 *Data Transmission System:* The requirements of the data transmission system were set as follows:

- establishment of an unified administration and dissemination structure
- utilization of data as shared resources
- diversification of way for dissemination
- improvement of network reliability

Several alternatives on data transmission, which may meet above requirements, were set from the different viewpoints as follows:

i) In view of data communication routing
   - Distributed system (Regional Office Plan)
   - Centralized system (Central Control Plan)

ii) In view of data acquisition
   - Manual system
   - Telemeter system

iii) In view of communication method for manually observed data
   - Mobile data communication
   - Wireless radio data communication

The characteristics and merits of above alternatives were extracted and analyzed.

In addition, the optimum communication means were determined for two transmission routes, namely, 1) from observatory to office, and 2) from regional office to FFWC Dhaka.

As to the route 1) 'from observatory to office', four alternative means, i.e. a) VHF, b) BTTB public network, c) Mobile network, and d) INMALSAT, were set as candidates, and VHF radio was selected as the most reliable and suitable communication means.

Regarding the route 2) 'from regional office to FFWC Dhaka', six candidate means, i.e. a) Digital HF, b) BWDB's microwave, c) VSAT, d) GRAMEEN's mobile network, e) BTTB public network, and f) BTTB lease line were considered. As a result, Digital HF, with utilization of BTTB public network as backup, was selected as the most suitable communication means for the route in case of the regional control system. In terms of the central control system, it was concluded that the installation of BWDB's microwave was necessary to secure the reliability of telecommunication. Although the reliability is lower, Digital HF with BTTB public network is still applicable in case of the central control system, considering the O&M aspect.

22.4 *Analysis System:* Based on the study on current analysis system, it was concluded that the simulation and forecast system (Supermodel) based on MIKE11 software performs well within available resources. The alternatives were not proposed for the analysis system but some recommendations are made as follows:

- to operate the model more frequently
- to operate the regional models in conjunction with the Supermodel for more detailed flood information
- to conduct detailed topographic surveys and to update existing 1:50,000 and 1:250,000 topographic maps with initiative of GOB
- to continue the effort of FFWC for collection of hydrometeorological data outside Bangladesh to improve the accuracy of future boundary estimate

- to continue the effort of FFWC for establishment of suitable method for quantitative estimation of rainfall outside Bangladesh especially in flash flood origins
- to clarify and inform the limitation of current flood forecasting result to the local population

22.5 *Warning Dissemination System:* Following requirements are extracted in order to improve the current warning dissemination system:

i) "Up-gradation in the lower tiers together with feedback" includes;
   - Local BWDB staff to be a member of District Disaster Management Committee (DMC)
   - Local BWDB staff to monitor the dissemination process in the lower tiers
   - Introduction of reward/punishment for the Upazilla level responsible officer to inform Union DMC
   - Involvement of local NGOs
   - Arrangement of wireless or mobile phone at Union by participatory contribution
   - Introduction of 'feedback' system
   - Training of volunteers

ii) "All river structure operation must receive flood forecasting and warning" includes;
   - Warning to be provided to central O&M office of BWDB
   - Warning to be provided directly to the operation office of major structures
   - BWDB district office to inform field operation offices after receiving warning
   - Warning to be provided to all relevant agencies and respective agencies to inform their field operation office
   - Warning to be given to field operation offices of major facilities

22.6 *Response System:* Following requirements are recognized for improvement of the current response system:

i) Evacuation
   - Actual responsibility of evacuation should lie on Union DMC
   - Volunteers should be trained
   - Upazilla DMC should earmark evacuation center and transportation
   - Upazilla DMC should arrange security for the evacuated houses

ii) Other Non-structural Response
   - A response management guideline should be prepared by DMB,
   - District DMC should issue response measures for agriculture and fisheries taking into consideration of the flood warning,
   - District DMC will work closely with the relevant agencies like Directorate of Agriculture Extension (DAE) and Fisheries Department,

and

- Union DMC should inform the people and monitor the response undertaken.

iii) Response for River Structures

- A response management guideline should be prepared by all concerned agencies including BWDB,
- Operation and Maintenance office of each agency should issue response measures for river structures taking into consideration of the flood warning,
- Field operation offices of each agency should undertake proper response measures as stipulated in the guideline, and
- District level offices of the concerned agencies should monitor the action taken by the field offices.

Institutional Alternatives

23. Since the present institutional setup has serious bottleneck to deliver desired services in relation to flood forecasting, following three alternatives were considered in addition to the component alternatives mentioned above:

i) Current organizations with some major improvement
ii) Establishment of regional offices of Hydrology Services
iii) Establishment of regional offices of BWDB

Combined Alternatives and Selection of Optimum Framework Plan

24.1 *Candidate Alternatives:* Based on the component alternatives and institutional alternatives, the candidate alternative framework plans of FFWS in Bangladesh were set as follows:

Alternative 1 Central Control System (FFWC central office as same as current organization with some improvement)

Alternative 1-1: All manual observation system
Alternative 1-2: All telemeter system
Alternative 1-3: Combined system of manual observation and telemeter system

Alternative 2 Regional Control System (Regional office under BWDB or under Chief Engineer, Hydrology)

Alternative 2-1: All manual observation system
Alternative 2-2: All telemeter system
Alternative 2-3: Combined system of manual observation and telemeter system

In terms of the communication method between the center and region,

"Microwave" and "Digital HF with back up of BTTB public line" were selected for Alternative 1 and 2, respectively. However, since the microwave has difficulty in the operation and maintenance, "Digital HF with back up of BTTB public line" for Alternative 1 was also included in the comparative study as Alternative 1'.

24.2 *Institutional Arrangement:* Current FFWS never become effective only by the installation of sophisticated equipment or facilities. Organization should be changed in order to improve the biggest problem of current FFWS that is the warning information is not reaching to the residents.

1) Decentralization: Regional offices to be set up for Hydrology Division
2) Smooth Operation of Hydrology Service: Flood Hydrology Circle will be placed directory under the Hydrology service. And under this circle, there are three division, Data transmission division, Data collection division, and Forecasting division

24.3 *Comparative Study of Combined Alternatives:* Each combined alternative plan was evaluated from 1) Technical, 2) Institutional and 3) Financial viewpoints.

Following four indexes with goal to be achieved were set up, and every alternative were standardized to meet the requirement:

Goals to be Achieved by the Alternative Framework Plans

Index	Goals to be achieved
1. Sureness	MTBF (Mean Time between Failure) of more than 99 %
2. Accuracy	Margin of the error of less than 20 % (If the actual water level change is 100 cm, the forecasted water level change should be between 80 and 120 cm) or absolute error of within 20 cm
3. Timeliness	Lead time of more than 4 hours for evacuation, 12 hours for protection of river structures, and 4 days for early harvesting of crops
4. Official-ness	The information to reach to residents surely and to be clearly understood by them. All the information to be given is a responsibility of the Government

[Technical Evaluation]

To achieve the target set above, following countermeasures are necessary for each alternative:

Countermeasures to be Taken for Alternative 1 (Central Control System)

	Alternative 1-1	Alternative 1-2	Alternative 1-3
	Telemeter = 0 Manual = All	Telemeter = All Manual = 0	Telemeter = 23 Manual = Rest
Sureness	*Manual Station* Doubling of gauge readers for 23 gauging stations Automatic entry system with Mobile phone	*Telemeter Station* Stable and expensive structures	*Telemeter Station* Stable and expensive structures *Manual Station* Automatic entry system with Mobile phone
Accuracy	*Manual Station* Double check of reading data for 23 gauging stations Check program for mis-typing		*Manual Station* Check program for mis-typing
Timeliness	*Manual Station* Hourly reading for 23 gauging stations		(Manual Station) Hourly reading
	Timely dissemination and activity with field Hot line from Central office to O&M division, Union and other related organizations Enough staff in central office in charge of region		
Official-ness	Confirmation of response activity and collecting local situation and information by O&M division		

Countermeasures to be Taken for Alternative 2 (Regional Control System)

	Alternative 2-1	Alternative 2-2	Alternative 2-3
	Telemeter =0 Manual = All	Telemeter =All Manual = 0	Telemeter = 23 Manual = Rest
Sureness	*Manual Station* Doubling of gauge readers for 23 telemeter stations Automatic entry system with Mobile phone	*Telemeter Station* Stable and expensive structures	*Telemeter Station* Stable and expensive structures *Manual Station* Automatic entry system with Mobile phone
Accuracy	*Manual Station* Double check of reading data for 23 gauging stations Check program for mis-typing		*Manual Station* Check program for mis-typing
Timeliness	*Manual Station* Hourly reading for 23 gauging station		

[Institutional Evaluation]

In order to assure the sureness of provided information, the coordination with Union, the authorities responsible for evacuation and with other supporting organizations like NGOs is necessary. Furthermore, it is also important to join DMC so that one can effectively use the provided information and participate in the flood management and evacuation activities.

- In centrally controlled system, it would be difficult to participate in Local DMCs.

- In regionally controlled system, the participation in Local DMC is possible and quick and proper responses and actions are also available.

[Cost Evaluation]

Investment cost and annual O&M cost were estimated by alternatives for implementing the countermeasures shown above. The results of cost estimate are summarized in the table below:

Estimated Investment Cost and Annual O&M Cost for Alternatives 1 and 2

(Unit: Million Taka)

	Alternative 1 (Central Control with Microwave)			Alternative 2 (Regional Control)		
	A1-1	A1-2	A1-3	A2-1	A2-2	A2-3
Investment Cost	1,156	2,339	1,495	785	1,968	1,130
Annual O&M Cost (excluding depreciation cost)	85.2	85.1	81.1	70.7	68.8	65.6
Annual O&M Cost (including depreciation cost)	225.6	364.4	262.1	166.1	303.1	202.4

For the central control system, in addition to Alternative 1, an Alternative 1', in which Digital HF with backup of BTTB's public line be applied for the communication between the regional and central offices, was considered. BWDB's microwave network was not applied in this alternative. The costs associated with this Alternative 1' (central control system without microwave) are shown in the table below.

Estimated Investment Cost and Annual O&M Cost for Alternative 1'

(Unit: Million Taka)

	Alternative 1' (Central Control without Microwave)		
	A1'-1	A1'-2	A1'-3
Investment Cost	686	1,871	1,026
Annual O&M Cost (excluding depreciation cost)	67.3	67.2	63.1
Annual O&M Cost (including depreciation cost)	150.7	289.7	187.2

On the other hand, the pertinent annual investment cost (PAIC) was estimated based on the annual average flood damage up to 100-year probable flood (12,161 million Tk./year), employing the assumptions that;

- 5 to 10 % of annual flood damage (608.1 to 1,216.1 million Tk.) can be avoided if the FFWS is perfectly operated and dissemination and response system are also functioning perfectly (referred to as avoidable damage).
- 10 % of the avoidable damage (61 to 122 million Tk.) is considered to be the PAIC for FFWS, and remaining 90 % is that for other activities such as flood fighting etc.

Comparing the annual O&M cost excluding depreciation cost to the PAIC (61 ~ 122 million Tk.), the annual O&M cost of all 9 alternatives are reasonable.

Accordingly, it was concluded that all 9 alternatives are economically feasible.

24.4 *Selection of Optimum Framework Plan:* Alternative 2-3, the Regional Control System with Combined Observation System of Manual and Telemeter, was selected by the Study Team as the optimal Framework Plan from the viewpoints of institutional, technical and financial aspects.

[Institutional Aspect]

Flood information issued must reach to the end beneficiaries. For that, establishment of regional Hydrology offices, joining in the local disaster management committee and participation in the local disaster management activities are suggested.

[Technical Comparison on Sureness]

In the regional control system, the sureness of telecommunication between the central and regional offices is less important than that in the central system. In the central control system, the central office should conduct emergency activities for local community. To meet this requirement, BWDB's own microwave network may be necessary to provide the service with the competitive level as the regional control system.

[Cost Comparison]

Cost Comparison in View of Institution (Central vs. Regional)

Although Alternative 1' showed a little lower cost than Alternative 2 both in the investment and O&M costs, the costs of Alternative 1 became much higher than those of Alternative 2. This shows that the costs of the central control system is higher than those of the regional control system of the reliability and effectiveness of FFWS to be secured in the competitive levels both in the central and regional systems.

Cost Comparison in View of Data Collection and Transmission

Regarding the investment cost, the system with all manually operated observatories was lowest. However, the combined observatory system takes the least O&M cost (excluding depreciation cost).

Operation and Maintenance

25. *Organizational Setup for O&M:*

(Organization)

The proposed FFWS organization basically consists of central FFWC in Dhaka and five regional FFWCs. The task of existing and newly proposed divisions is summarized in **Table 1**.

(Staffing)

Staff of BWDB needs to be deployed so that the organization can function full.

Especially, the regional FFWC has to support the local disaster management activities as a member of the Local Disaster Management Committee (DMC). It also should be able to analyze information accurately, make a quick and proper decision, and provide the information based on such analysis and decision. The proposed staffing table is given in **Table 2**.

(Legal Arrangement)
In order to extend the activity of proposed Flood Hydrology Circle (FHC) to the participation in Local DMC, its role and responsibilities need to be defined clearly.