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

Final Report

Volume III

Supporting Report

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

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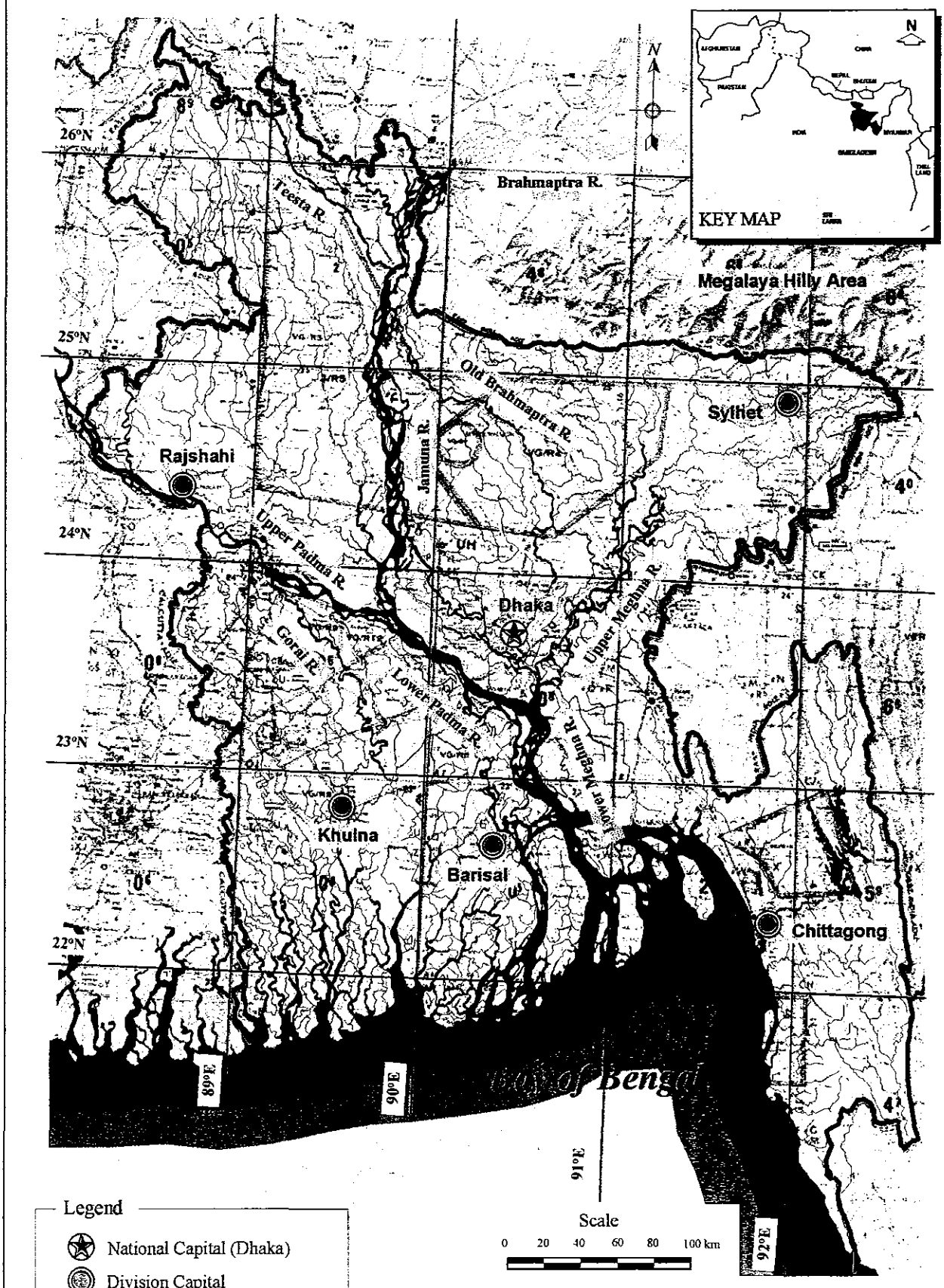
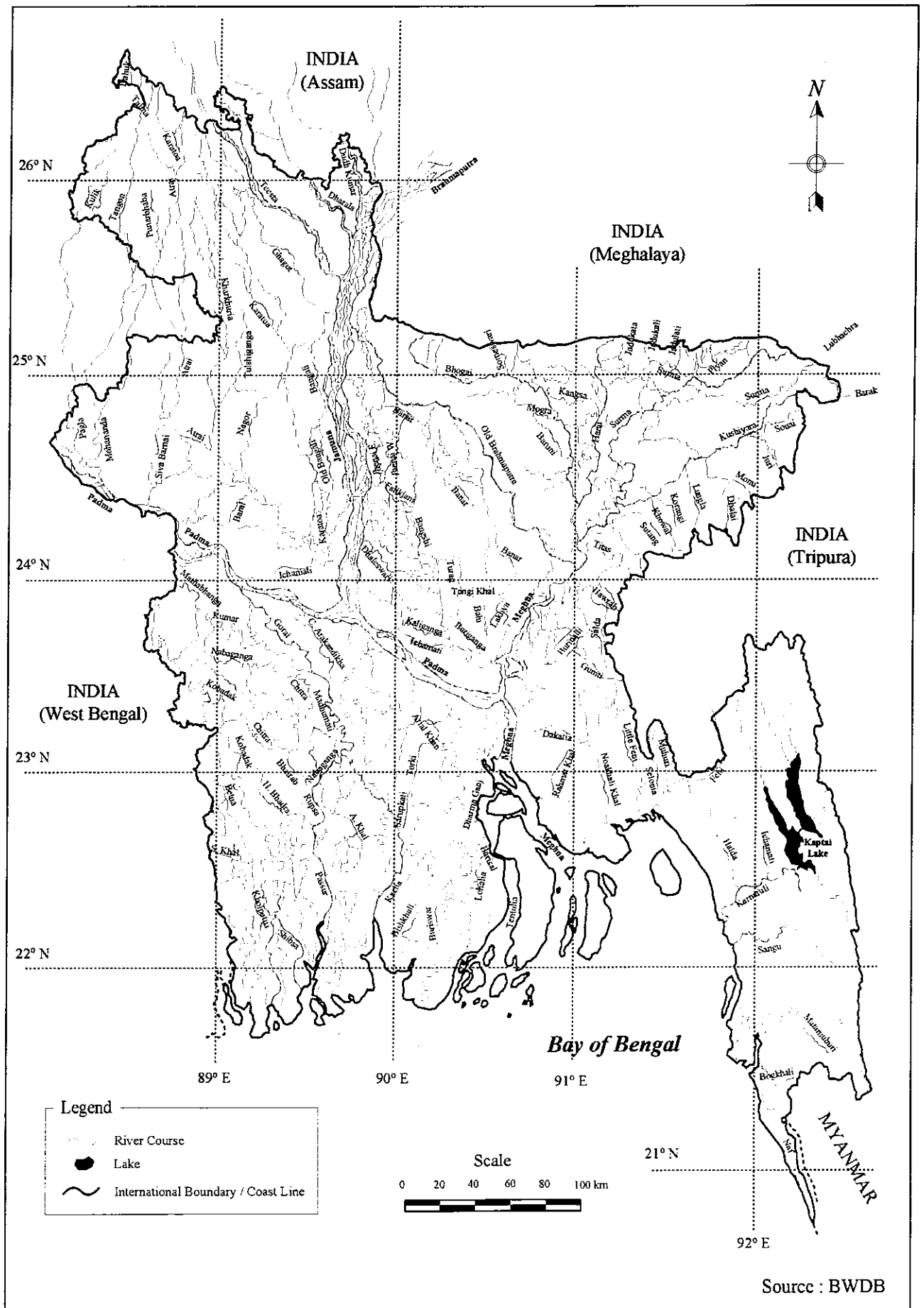
The cost estimate is based on the price level and exchange rate of May 2003.
The exchange rate is:

US$1.00 = BDT58.10 = ¥116.28

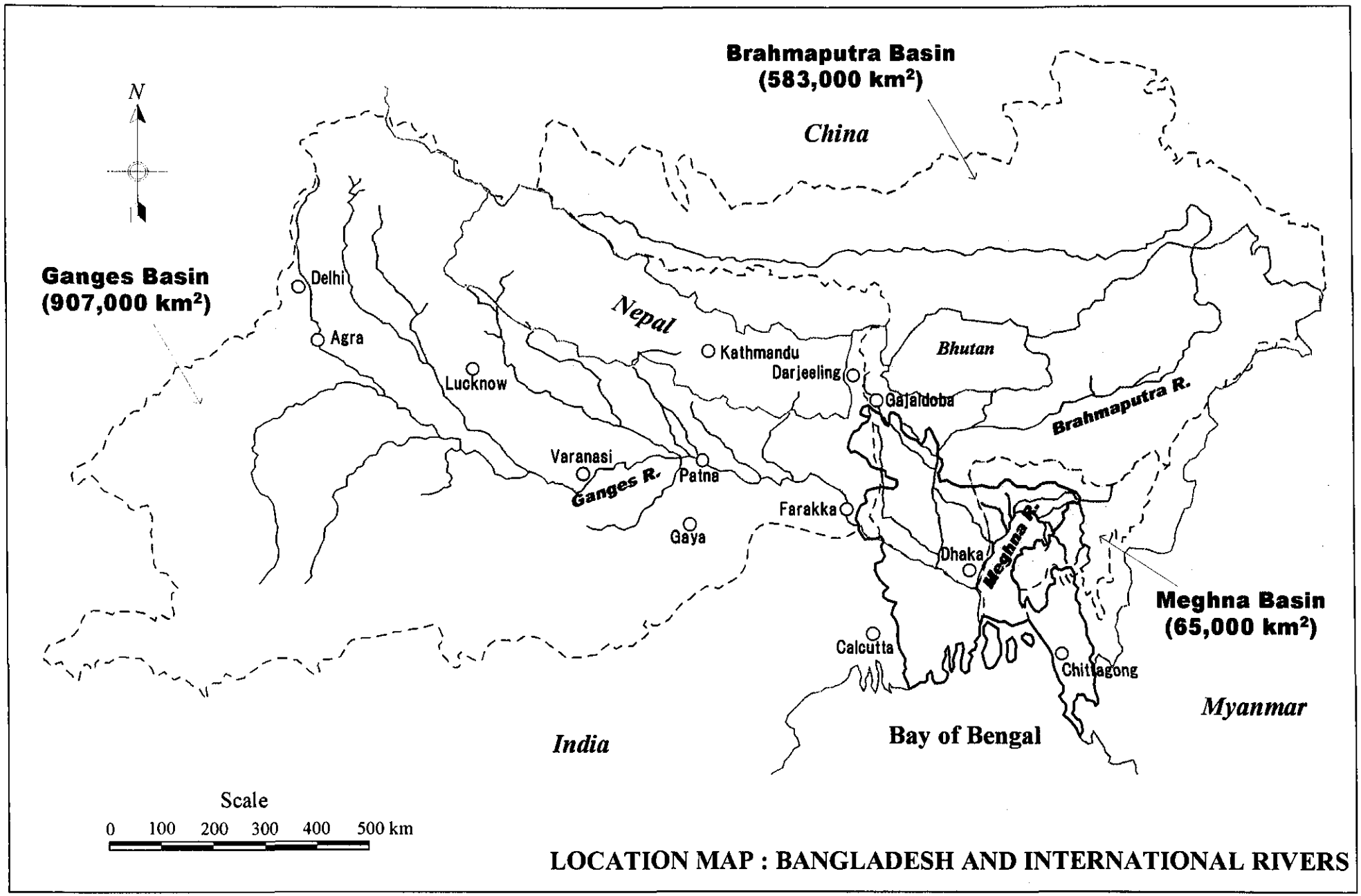


LOCATION MAP : BANGLADESH



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-III : SUPPORTING REPORT

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ATTACHMENT

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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

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

Bangladesh is located in the delta area formed by three international rivers, namely the Padma (Ganges), Jamuna (Brahmaputra) and 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 occurs in various regions in every monsoon season. In the 1988 and 1998 monsoon seasons, about 2/3 of the country was submerged and extensive damage was reported. Other than the monsoonal flood, floods referred to as "flash flood", "tidal surge" and "local inundation" are also recognized and contribute to flood damage in this country.

In addition to 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 the 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).

In terms of 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.

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 "**the feasibility study for improvement of flood forecasting and warning services**" (the Study) under a consensus between GOB and GOJ. The Scope of Work (S/W) and Minutes of Meeting (M/M) of the technical cooperation for the Study were agreed between the 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. This Study has been performed in conformity with the S/W and M/M.

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 and the Ministry of Foreign Affairs (GOJ) 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.

1.2 Objectives of the Study

The objectives of the Study are as follows:

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

1.3 Scope of the Study

The area subject to the Study includes the whole of Bangladesh.

The flood forecasting and warning system is considered to consist of five (5) sub-systems in view of its operational process. These are outlined below:

1) Observation System
2) Data Transmission System
3) Analysis System
4) Warning Dissemination System
5) Response System

To improve the existing flood forecasting and warning system, the following works were conducted:

1) Detailed investigations in order to clarify the present condition of the existing FFWS and problems being encountered therein,
2) Formulation of improvement plans of FFWS after detailed study of conceivable alternative solutions from which an optimal plan was selected, and
3) Feasibility study on the selected optimal plan.

1.4 Study Schedule and Activities

1.4.1 Study Schedule

In order to achieve the objectives mentioned above, the overall work schedule of the Study was divided into two phases as shown in **Figure 1.4.1** and as summarized

below:

(1) First Year of the Study (November 2002 – March 2003)

Phase 1: Basic Study

a) Collection and review of existing data and information
b) Field reconnaissance
c) Detailed field investigation by sub-contract
   i) Inventory survey on meteorological and hydrological observation system
   ii) Survey on evacuation condition and awareness of flood victims
   iii) Inventory survey on electric communication system
d) Analysis on present FFWS and extraction of problems
e) Flood damage analysis
f) Formulation of alternative improvement plan of FFWS

(2) Second Year of the Study (May 2003 – November 2003)

Phase 2: Feasibility Study

a) Comparative study of alternative improvement plans and selection of optimal scheme
b) Technology Transfer Seminar/Workshop (1) and (2)
c) Supplemental data collection and field reconnaissance
d) Study on appropriate international river management
e) Preliminary design of facilities
f) Implementation planning and cost estimate
g) Project evaluation

1.4.2 Activities

(1) Explanation and Discussion of Inception Report

Upon submission of the Inception Report to BWDB on November 17, 2002, the contents of the report were explained by the Study Team to the counterpart staff of BWDB on November 20, 2002. The Steering Committee meeting was held on November 23 and 24, 2002. The study approaches and methods proposed in the Inception Report were accepted in principle by the Committee.

(2) Collection and Analysis of Data/Information and Field Survey

Data/information relevant to the Study were collected from the national government agencies and local government authorities. Field reconnaissance was also conducted in the study area to acquire necessary information on natural and social conditions.

(3) Field Investigations

Field investigations conducted for the basic study included: a) inventory survey on meteorological and hydrological observation systems, b) survey on evacuation condition and awareness of flood victims, and c) inventory survey on electric

communication system. All field investigations were completed during the phase 1 study period.

(4) Analysis of Current Flood Forecasting and Warning Services

Based on the data/information collected and the results of field investigations, the current flood forecasting and warning services were analyzed. The analysis was conducted for each sub-component, that is, 1) observation system, 2) data transmission system, 3) analysis system, 4) warning dissemination system, and 5) response system. In addition to these 5 sub-components, the institutional aspects supporting the current FFWS were also analyzed.

(5) Flood Damage Analysis

Analysis to quantify flood damage was conducted. Based on the available information of damage from previous floods and the results of field investigations, items such as 1) flood affected area, 2) number of affected people, and 3) damaged properties were integrated. Flood damage in monetary terms was estimated according to the recurrence period of flood events and annual average flood damage was calculated.

(6) Extraction of Problems Encountered by Current FFWS

The problems associated with the current FFWS were extracted for each sub-component. These also included institutional aspects. In addition, PCM (Project Cycle Management) workshops were conducted at five (5) different locations in January 2003, and the problems to be overcome to meet the requirements raised by the end users were defined.

(7) Formulation of Alternative Improvement Plans

Alternative plans for improvement of each FFWS sub-component and institutional aspects were firstly proposed. From these, six (6) combined alternative improvement plans were formulated.

(8) Preparation, Explanation and Discussion of Progress Report (1)

The Progress Report (1) was prepared and submitted on March 5, 2003. Prior to submission of the report, a discussion on its contents was held with BWDB counterpart staff on March 1, 2003. The Steering Committee meeting was held on March 5, 2003, and Progress Report (1) was accepted in principle by the Committee.

(9) Comparative Study of Alternative Plans and Selection of Optimum Plan

The six alternative improvement plans were studied and analyzed in detail leading to the selection of one optimum improvement plan.

(10) Preparation of Interim Report

The Interim Report was prepared in the middle of June 2003 as originally scheduled.

This presented all results of the investigation and study conducted during the phase-1: Basic Study stage.

(11) Explanation and Discussion of Interim Report

The Interim Report was submitted on June 21, 2003. The contents of the report were explained and discussed with the counterparts on June 22, 2003. The Steering Committee meeting was held on June 25, 2003, and the contents of the report were accepted in principle by the Committee.

(12) First Technology Transfer Seminar/Workshop

The first Technology Transfer Seminar/Workshop was held in Dhaka on June 25 and 26, 2003. Four (4) presentations were made by the Japanese Consultants and Advisory Committee and two (2) presentations were made by Bangladesh counterparts.

(13) Additional Data Collection and Field Survey

Additional data/information necessary for the feasibility study (phase-2) stage were collected and further field surveys including 1) reconnaissance for the determination of exact location of telemeter facilities/equipment and 2) radio propagation tests were undertaken.

(14) Study on International River Management

The effective river management in Bangladesh cannot be realized without proper cooperation among the countries related to the three international rivers, i.e. the Ganges/Padma, Brahmaputra/Jamuna and Meghna Rivers. The current status of the water-related issues on the international rivers was analyzed and recommendations for proper international river management were raised.

(15) Feasibility Design

Feasibility design was conducted for the selected optimum improvement plan. The design includes the hydrometeorological observation method/system at the proposed telemetric gauging sites, data transmission method/system, analysis system and dissemination system.

(16) Construction Plan and Project Cost Estimation

A construction plan was formulated for the proposed project and project cost was estimated.

(17) Project Evaluation

The evaluation of the proposed project was conducted taking into consideration the economic, social and environmental aspects. The economic efficiency of the project was confirmed, while no negative social and environmental impact would arise as a result of the project.

(18) Preparation of Implementation Program

The implementation schedule and institutional arrangement were formulated and discussed with the counterpart agency.

(19) Preparation, Explanation and Discussion of Progress Report (2)

Progress Report (2) was prepared and submitted on September 8, 2003. The discussion on the contents of the report was made with BWDB counterpart staff on September 9, 2003. Although the Steering Committee meeting was held on September 14, 2003, no conclusions resulted from the meeting.

(20) Preparation of Draft Final Report

The Draft Final Report including all aspects mentioned above was prepared and submitted on October 21, 2003.

(21) Explanation and Discussion of Draft Final Report

The contents of the Draft Final Report were explained to the Bangladesh side in detail through the Joint Meeting and Steering Committee Meeting held on October 23 and 26, 2003, respectively. Detailed discussions on the proposed project were made between Japanese and Bangladesh sides.

(22) Second Technology Transfer Seminar/Workshop

The second Technology Transfer Seminar/Workshop was held in Dhaka on October 29 and 30, 2003. Three (3) presentations were made by the Japanese Consultants and Advisory Committee and two (2) presentations were made by Bangladesh counterparts.

(23) Preparation of Final Report

Based on the Draft Final Report, the Final Report was prepared in December 2003 taking the comments and/or suggestions raised by the Bangladesh side into consideration.

1.5 Staffing

JICA organized the Study Team and Advisory Committee for the Study.

The Study Team totally comprised nine (9) members, consisting of a team leader and seven (7) experts and an administrative coordinator as shown in **Figure 1.5.1** and enumerated below:

The JICA Study Team

Designation/Work Assignment	Name
(1) Team Leader / River and Flood Control Expert	Hideki SATO
(2) Deputy Team Leader / Telecommunication System Expert	Masato OKUDA
(3) Flood Forecasting and Warning System Expert	Gregory R. HOOKEY
(4) Radio Transmission Expert	Masahiro SAKAGAMI
(5) Hydrologist	Kensuke SAKAI
(6) Economist / Financial Analyst	Kiminari TACHIYAMA
(7) Institutional Expert	A. K. M. Nurul ISLAM
(8) Expert of International Coordination	Naoko ANZAI
(9) Administrative Coordinator	Hiroto NAKAGAWA / Tadahiro FUKUDA

The Advisory Committee was formed to provide technical guidance and advice to the JICA Study Team during the period of the Study. Members of the Advisory Committee included:

a) Chairman of the First Year Works

Mr. Shigetsugu YAMAMOTO

Kyushu Regional Development Bureau, Ministry of Land, Infrastructure and Transport, Japan

b) Chairman of the Second Year Works

Mr. Akinori MASUDA

Kyushu Regional Development Bureau, Ministry of Land, Infrastructure and Transport, Japan

c) Member

Mr. Yasunobu MAEDA

Kinki Regional Development Bureau, Ministry of Land, Infrastructure and Transport, Japan

1.6 Transfer of Technology

The Study Team made considerable efforts to ensure transfer of technology on investigation/planning methods and skills as well as the basic data/information required for the planning. During the Works in Bangladesh, two methods were applied for technology transfer. These included on-the-job training and Joint Meetings between the counterparts and Study Team. In addition to these routine activities, the technology transfer seminars/workshops were held at the beginning of the Second Works in Bangladesh (June 25 and 26), and at the end of the Third Works in Bangladesh (October 29 and 30). Brief descriptions of those activities and the evaluation of those activities are presented below.

1.6.1 On-the-Job Training

Efforts were made to provide on-the-job training to each counterpart through day-to-day works. Each team member attempted not only to undertake their investigation responsibilities but also to provide the counterpart with guidance as to

the purpose and procedures of the investigation.

However, the counterpart assignment of GOB was not sufficient for the desired level of on-the-job training and opinion exchanges during the Works in Bangladesh.

1.6.2 Joint Meeting

Joint Meetings with the counterparts and the Study Team were held in Dhaka during the Work Stages in Bangladesh. The dates and main subjects of the Meetings are as follows:

First Joint Meeting held on December 4, 2002

a) Introduction of the Study Team members and counterparts of BWDB,
b) Explanation of the Inception Report and work schedule by the Study Team,
c) Explanation of the detailed field investigations by the Study Team,
d) Explanation of basic strategy of the study on the telecommunication system by the Study Team, and
e) Explanation of the Organization of GOB by counterparts.

Second Joint Meeting held on January 11, 2003

a) Explanation of the Study progress by the Study Team,
b) Explanation of the PCM Workshop held on January 2, 2003 in Sylhet by the Study Team,
c) Explanation of the River Management Strategy in Bangladesh by counterparts,
d) Explanation of hydrometric system in Bangladesh by counterparts, and
e) Explanation of river morphological survey system in Bangladesh by counterparts.

Third Joint Meeting held on February 1 and 2, 2003

a) Discussion on the basic concept of the selection of automatic gauge sites, and
b) Presentation on suitable location of telemeter stations in view of flood analysis model by counterparts.

Fourth Joint Meeting held on March 1, 2003

a) Explanation of the draft of Progress Report (1) by the Study Team, and
b) Discussions on the contents of Progress Report (1).

Fifth Joint Meeting held on March 11, 2003

a) Report of the discussion results of the Steering Committee Meeting held on March 5, 2003 by the Study Team, and
b) Confirmation of undertakings of the counterparts during the absence of the Study Team from Dhaka.

Sixth Joint Meeting held on June 22, 2003

a) Explanation of the Interim Report by the Study Team, and
b) Discussions on the contents of the Interim Report.

Seventh Joint Meeting held on July 3, 2003

a) Confirmation of the result of the Steering Committee meeting held on June 25, 2003,
b) Explanation of the outline of proposed institutional arrangement by the Study Team, and
c) Confirmation of the possibility of a field visit to India by the Study Team and counterpart members.

Eighth Joint Meeting held on August 14, 2003

a) Brief reporting of the progress of the Study by the Study Team, and
b) Discussion on the necessary arrangement for the implementation of the proposed project.

Ninth Joint Meeting held on September 9, 2003

a) Explanation of Progress Report (2) by the Study Team, and
b) Discussions on the contents of Progress Report (2).

Tenth Joint Meeting held on September 15, 2003

a) Confirmation of the result of the Steering Committee meeting held on September 14, 2003, and
b) Detailed discussions on the contents of Progress Report (2).

Eleventh Joint Meeting held on October 23, 2003

a) Explanation of the Draft Final Report by the Study Team, and
b) Discussions on the contents of the Draft Final Report

Twelfth Joint Meeting held on November 1, 2003

a) Reconfirmation and Detailed Explanation of the proposed project, and
b) Confirmation of the actions to be taken by BWDB and the Study Team

1.6.3 Technology Transfer Seminar/Workshop

(1) First Technology Transfer Seminar/Workshop

The first Technology Transfer Seminar/Workshop was held on June 25 and 26, 2003. The number of participants was approximately 60 on the first day and 30 on the second day. The following presentations were made by Bangladeshi and Japanese personnel:

Day 1 (June 25, 2003)

Morning Session

a) Opening Session

b) Explanation of the Interim Report by the JICA Study Team

Afternoon Session

c) Basic Strategy of Strengthening FFWS in Bangladesh by BWDB
d) Flood Control and FFWS in Japan by the JICA Advisory Committee

Day 2 (June 26, 2003)

Morning Session

e) Telecommunication System for FFWS in Japan by the JICA Advisory Committee
f) River Management in the International Rivers by the JICA Study Team
g) Estimation of Rainfall Amount by Radar Raingauge by the JICA Study Team

Afternoon Session

h) Basic Strategy of Strengthening Disaster Management in Bangladesh by the Disaster Management Bureau (DMB)
i) Summary and Conclusion by the JICA Study Team
j) Closing Session

(2) Second Technology Transfer Seminar/Workshop

The second Technology Transfer Seminar/Workshop was held on October 29 and 30, 2003. The number of participants was approximately 60 on the first day and 30 on the second day. The following presentations were made by Bangladeshi and Japanese personnel:

Day 1 (October 29, 2003)

Morning Session

a) Opening Session

Afternoon Session

b) Explanation of the Draft Final Report by the JICA Study Team
c) River Management in Bangladesh by BWDB
d) River Management in Japan by the JICA Advisory Committee

Day 2 (October 30, 2003)

Morning Session

e) Regional Disaster Management in Japan by the JICA Study Team

Afternoon Session

f) Disaster Management in Bangladesh by BDPC
g) Summary and Conclusion by the JICA Study Team
h) Closing Session

1.6.4 Evaluation of Technology Transfer

The technology transfer was one of the main objectives of the Study as mentioned above. Although effective transfer of technology through on-the-job training was not realized due to the manpower deficit of BWDB, a few counterparts showed their keen interest in the planning and design technique applied in the Study. Those competent counterparts gave sincere and valuable suggestions for the planning and design works conducted by the Study Team, based on their own experiences.

On the other hand, counterparts obtained valuable knowledge through their exposure to this Study. As mentioned before, though it was not possible on the part of BWDB to provide one-to-one full time counterparts, one full time counterpart was provided at the later stage. He attended various discussions, participated in the questionnaire survey and feasibility design. Through this, he obtained important planning techniques that can be applied for other projects.

A number of part time counterparts were provided by BWDB for the entire period of the Study. The counterparts for telecommunication not only participated in the field investigation and analysis but also carried out radio communication test. The counterpart for economic analysis received valuable on-the-job training on socio-economic analysis, flood damage assessment, project cost estimation and project evaluation. The counterparts for analysis received vital exposure to understand the inherent limitation of the model.

Based on this, it can be inferred that extensive technology transfer has taken place through this Study. However, this could have been much more effective if full time one to one counterparts had been provided by BWDB.

Two BWDB counterpart personnel visited Japan to participate in the counterpart training provided by JICA during the period from September 23 to October 11, 2003. This training course gave broad-based knowledge on flood forecasting and warning, river management, and telecommunication to them. Specifically, they understood the importance of the regional disaster management through the training in Japan.

1.7 Final Report

The Final Report presents all findings of the field investigations and results of the Study including the Basic Study (Framework Plan) and Feasibility Study undertaken by the Study Team and BWDB counterparts.

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

CHAPTER 2 PRESENT CONDITION

2.1 Geography

Bangladesh lies in the northeastern part of South Asia between latitudes 20°34' and 26°38' north and longitudes 88°01' and 92°41' east. The country is bordered on the west, north and east by a 2,400 km land frontier with India and in the southeast, by a short land and water frontier (193 km) with Myanmar (Burma). On the south, it is a highly irregular deltaic coastline of about 600 km, fissured by many rivers and streams flowing into the Bay of Bengal (see **Location Map: Bangladesh**). The area of the country is around 147,000 km^2 and extends 820 km north to south and 600 km east to west. The territorial waters of Bangladesh extend 12 nautical miles, and the exclusive economic zone of the country is 200 nautical miles.

Bangladesh occupies a unique geographic location spanning a stretch of land between the great Himalayan mountain chain to the north and the ocean to the south. It is virtually the only drainage outlet for a vast river basin complex made up of the Ganges, the Brahmaputra and the Meghna Rivers and their tributaries.

Three broad physiographic regions are discernible within the country including flood plains (representing 80% of the land area), terrace (8%) and hills (12%). Each of these regions exhibits its own geo-morphological characteristics, which are further divided into 9 sub-divisions according to the physiographic map published by Geological Survey of Bangladesh (1990).

The country is crisscrossed by a network of rivers including the Padma, Jamuna, Meghna, Teesta, Surma and Kharnaphuli Rivers and their tributaries. Together these number about 230 with total length of 24,000 km (see **Location Map: Rivers of Bangladesh**). River slopes in Bangladesh are extremely low due to ongoing deposition of sediment by these rivers during the monsoon season. This results in flooding being a regular occurrence almost every year.

Geological map of Bangladesh is presented in **Figure 2.1.1**. As shown in the figure, the country is mainly formed by Alluvial and Deltaic deposits.

More than 60% of Bangladesh's non-urban land is arable. Permanent crops cover only 2%, meadows and pastures cover 4%, and forests and woodland cover about 16%. The country produces large quantities of quality timber, bamboo and sugarcane. Bamboo grows in almost all areas, but high-quality timber grows mostly in the highland valleys.

A variety of wild animals are found in the forest areas, such as in the Sundarbans on the southwest coast, which is the home of the world-famous Royal Bengal Tiger.

2.2 Socio-Economy

2.2.1 Administration

Bangladesh is governed by a Parliamentary form of Government. The Government of Bangladesh is headed by the President. However, the executive power lies with the Prime Minister, who is assisted by a council of Ministers of 38 ministries.

The country is divided into 6 administrative Divisions, i.e. Dhaka, Chittagong, Khulna, Rajshahi, Sylhet and Barisal. Each division is divided into some Districts (Zilla) as shown in **Figure 2.2.1**. At present, there are 64 Districts. Each District is further divided into some sub-districts (Upazilla). Currently, there are 507 Upazilla, of which 36 are in Metropolitan cities. In urban areas, the Upazilla is called Thana.

For each urban area, there are municipalities and for bigger urban areas, there are city corporations. Each municipality and city corporation is divided into wards. This is the lowest tier of administration in the urban area.

For rural areas, each sub-district (Thana) is divided into some Unions, and again, each Union is further divided into some Villages.

Administrative Units of Bangladesh

Administrative Unit	Number of Units
Division	6
District/Zilla	64
Upazilla / Thana	507
Union	4,484
Village	87,319
City Corporation	6
Municipality	223

Source: BBS, 2000

2.2.2 Socio-Economic Indicators

(1) Population

The population of Bangladesh increased from 106.3 million to 121.4 million during ten years from 1991 to 2001 at the average annual growth rate of 1.49%. The population density has increased from 723 person/km^2 to 826 person/km^2 during the same period as shown in **Table 2.2.1**. Comparing by Division, the most population is occupied by Dhaka Division with 31.4 % followed by Rajshahi Division with 24.4% and Chittagong Division with 19.5 %, respectively. These three Divisions occupy 75.4 % of all population in Bangladesh. The most dense Division is Dhaka of which density is 1,243 person/km^2 followed by Rajshahi Division with 869 person/km^2 and the least dense Division is Barisal with 610 person/km^2 in 2001. With regard to District, the densest district is Dhaka District with 5,858 person/km^2 followed by Narayanganj with 2,818 person/km^2 in Dhaka Division and Narsindgi with 1,658 person/ km^2 in Dhaka Division, respectively (see **Table 2.2.2**). It is quite obvious that the most population is concentrated into Dhaka District and the densest district is

Dhaka Division. From point of disaster management, this district indicates the high potentiality of flood damages.

The population density map by District as of 2001 is presented in **Figure 2.2.2**.

(2) GDP

In spite of huge amounts of damages by flood which attacked on the most of the area of this country in 1998, the Bangladesh economy seems to have recovered gradually and steadily.

The gross domestic product (GDP) at current prices grew from 1,155 billion Taka to 2,450 billion Taka during ten years from 1991/92 to 2000/01 at the average annual growth rate of 8.9%. The per capita GDP at current prices grew from 10,194 Taka in 1991/92 to 20,182 Taka in 2000/01 at the average annual growth rate of 7.1%. Comparing among industrial origins, the most rapid growth is shown by industry with 10.6% per annum followed by service with 9.2%. The highest grown sector is fishing of agriculture of which growth rate is 14.5% and the slowest one is agriculture and forestry with 5.3% (see **Table 2.2.1**).

The main crop cultivated in Bangladesh is rice. The type of rice is largely divided into three, i.e. 1) Aus, 2) Amon, and 3) Boro. Aus is transplanted or broadcasted before rainy season, and harvested during July and August. Amon is transplanted or broadcasted before or at the beginning of rainy season, and harvested after rainy season (November to January). It has a subspecies called 'floating rice', which puts up with long-period and deep inundation. Boro is for dry season harvesting. It is planted after the end of rainy season and harvested before or at the beginning of rainy season.

Despite of massive losses of Aus and Amon crops due to devastating flood in 1998/99, Boro production increased following the implementation of post-flood emergency agricultural rehabilitation programme. The production of Amon and Boro has been satisfactory in 2000/01 because of favorable climate and government support programs and the prospect of Aus crop also look promising.

The share of service occupies the largest share of 49.2% in 2000/01 showing slight increase from 48.1% in 1991/92. But agriculture indicates decrease from 29.4% to 24.9% and industry increased from 22.5% to 25.9% (see **Table 2.2.3**).

The fluctuation of annual growth rate is shown in **Table 2.2.4**.

On the other hand, the gross domestic product (GDP) at constant prices of 1995/96 shows the substantial economic growth of Bangladesh by excluding the influence of inflation on the GDP at current prices. It grew from 1,344 billion Taka to 2,178 billion Taka during ten years from 1991/92 to 2001/02 at the average annual growth rate of 4.9%. The per capita GDP grew from 12,639 Taka in 1991/92 to 17,675 Taka in 2001/02 at the average annual growth rate of 3.4%. Comparing among industrial origins, the most rapid growth is shown by industry with 7.2% per annum followed by service with 4.8%. The highest grown sector is construction of industry of which

growth rate is 8.5% and the lowest one is agriculture and forestry with 2.6% (see **Table 2.2.5**).

The service occupies the largest share of 48.9% in 2001/02 showing slight increase from 48.14% in 1991/92. But agriculture indicates decrease from 28.7% to 24.6% and industry increased from 21.6% to 26.5% (see **Table 2.2.6**).

The fluctuation of annual growth rate is shown in **Table 2.2.7**. The peak of growth is recorded in the year of 1999/2000 as 6.1 % and shows gradually decrease in these two years from 2000/01 to 2001/02. It could be guessed that if the flood in 1998/99 would not bring the catastrophic damage to Bangladesh, the economy of Bangladesh could have grown at higher rate without slow down of growth pitch from 5.3 % in 1997/98 to 5.0 % in 1998/99.

(3) Other Indicators

a. Labor Force

Total number of labor force is 60.3 million, employed population is 58.1 million and unemployed population is 2.2 million in 1999/2000. Then unemployment ratio is 3.6% but has increased from 1.3 % in 1985/86. It is noticeable that the ratio of employment of female grew from 10.2 % in 1985/86 to 37.7 % in 1999/2000. Composition of employment is agriculture including forestry and fishery (62.4 %), industry (10.2 %) and service (27.4 %), respectively. The agricultural sector has still dominant share in spite the least share in GDP (25.3 %) showing the lowest labor productivity.

b. Poverty Level

It has been said that economic development and poverty alleviation are a synonymous in the context of Bangladesh and hence, poverty alleviation is the core issue of development policy. Through available data from various sources declining trend, poverty is still deep rooted and all pervasive. According to the latest Household Expenditure Survey, 1995/96, it was revealed that 47.1% of rural households were below poverty line in 1995, measured in terms of less than 2,122 kcal and 24.6% of households were below hardcore poverty line measured in terms of less than 1,805 kcal. In 1983/84, these figures were 61.9 % and 36.6 %, respectively. Analysis of data indicates improvement of poverty situation at slow pace.

c. Literacy

Literacy is a basic human need, which enables one to make informed decisions and to control affairs of ones own affairs so as to achieve a better life and living-economic, social and in all other respects. Empowerment of the poor, especially girls and women and community development cannot be achieved without participation of people from all walks of life, particularly the women. With this end in view, government, NGOs and other organizations are now engaged in various ways for imparting literacy through formal and non-formal setting, to reach people in disadvantaged situation, specially girls and women

There is some discrepancy with regard to the adult literacy rate for the people of age 15 and over. According to the estimation of UNESCO, the adult literacy rate is 42.6 % in total, 49.4 for male and 30.2 % for female. On the other hand, according to the estimation of BHDR (Botswana Human Development Report supported by UNDP), it is 56 % in total, 63 % for male and 49 % for female. In the long-term social targets, the goal for adult literacy rate is set up at 90 % in 2015 on the basis of the adult literacy rate of 56 % in 2000 year as bench mark data estimated by BHDR.

d. Foreign Trade

The economy has suffered massive damage by devastating flood of 1998. Most affected were agriculture sector including communication and infrastructure of non-agriculture sector. As communication network was disrupted during flood, production suffered in non-agriculture sector and production remained suspended in many fields. As extensive damage was caused to crops in Amon season, food deficits was estimated as 20 lakh (2 million) tons in 1998/99 over normal deficit. There was no possibility to cope with the deficit domestically. As a result, food import bill increased substantially in addition to import under foreign assistance. In this context, the output of export industries declined during the flood period. Apart from this, as communication system was disrupted and became unstable, export was hampered. But the situation started improving since January, 1999 due to policy and activity taken by the government.

The export grew from 27 billion Taka to 247 billion Taka during fourteen years from 1985/86 to 1999/2000 at the average annual growth rate of 17.0 %. On the other hand, the import shows the increase from 63 billion Taka to 342 billion Taka at 12.9 % per annum. In spite of higher growth rate of export, the deficits were 125 billion Taka in 1999/2000 and have been increased year by year.

In 1999/2000, the major exported commodities are textiles and textile articles, 211 billion Taka (85.4 %) which has dominant share, followed by live animals and animal products, 16 billion Taka (6.6 %), followed by raw hides and skins, leather furskins and articles there and articles of animal guts, 5 billion Taka (2.2 %) and so on. On the other hand, the major imported commodities are occupied by also textiles and textile articles, 83 billion Taka (22.2 %), followed by machinery and mechanical appliances, electrical equipment, sound recorders and parts of them, 43 billion Taka (11.5 %), base metals and their articles, 40 billion Taka (10.9 %), mineral products, 40 billion Taka (10.8 %) and so on.

e. Inflation

General consumer price index (CPI) of whole country as an indicator for inflation increased from 154.4 to 239.1 during from 1990/91 to 2000/01 at the average inflation rate of 5.0 %. CPI of food recorded from 154.3 to 241.4 at growth rate of 5.1 % per annum and that of non-food has changed from 154.7 to 237.2 at inflation rate of 4.9 % per annum. Comparing latest years' inflation rate, general CPI decreased from 227.3 in 1998/99 to 236.2 showing the inflation rate of -1.4 % reflecting reaction of higher

rate of inflation devastating damage by flood to production in 1998/99, 8.9 % (general CPI in 1997/98: 208.7).

2.2.3 Financial Conditions

(1) Overview

According to the consolidated receipts and expenditure of the Government, total revenue increased from 232 billion Taka in 1994/95 to 423 billion Taka in 2001/02 at the average annual growth rate of 9.0 %. On the other hand, the expenditure increased from 209 billion Taka to 356 billion Taka at the average annual growth rate of 7.9 %. Then the balance increased from the surplus of 23 billion Taka to 67 billion Taka. But the balance between the revenue receipt and total expenditure grew from the deficit of 60 billion Taka to 84 billion Taka. This means that the ordinary annual revenue could not recover the total expenditure.

The total revenue is broken down into the revenue receipt and the development revenue. The revenue receipt occupies 64 % and the development receipt occupies 36 % in total revenue in 2001/02 and grew at 9.0 % per annum and at 8.9 % per annum respectively. On the other hand, the total expenditure is broken down into the revenue expenditure (62 %) and the development expenditure (38 %) and grew at 11.1 % per annum and at 4.0 % per annum, respectively (see **Tables 2.2.8** and **2.2.9**).

(2) Development Expenditure of the Government by Sector

The development expenditure increased from 103 billion Taka in 1994/95 to 136 billion Taka in 2001/02 showing the average annual growth rate of 11.1 %. The most rapid growth is recorded by education and training of 43.4 % followed by physical training and housing of 35.1 %, others of 23.2 % and transport of 15.5 % respectively. It is clearly recognized that the Government has strengthening the educational policy to improve the literacy of nations. The most shares are occupied by transport of 19.7 % followed by power and natural resources of 15.0 % and education and training of 14.1 %. It is noticeable that the share of education and training shows the big increase from 1.1 % to 14.1 %. On the contrary, the shares of flood control and water resources, and power and natural resources show the significant decrease from 15.0 % to 5.4 % and from 37.3 % to 15.0 % respectively. In particular, the expenditure for flood control and water resources shows the decrease with the average annual growth rate of -3.1% (see **Table 2.2.10**).

The financing of the development expenditure grew from 60 billion Taka to 175 billion Taka during the period from 1990/91 to 2000/01 showing 13% of average annual growth rate. On the other hand, the resources changed from 72 billion Taka to 152 billion Taka by the growth rate of 9% per annum. After 1998/99, the resources were shortened and the amounts of shortage were 23 billion Taka in 2000/01.

The resources are broken down into the domestic resources and foreign assistance. The domestic resources have increased more rapidly than the foreign assistance. Then

the share of domestic resources show increase from 30% to 38% while the foreign assistance recorded the decrease of its share from 70% to 62% respectively, but still maintains the dominant share of resources in financing of the development expenditure. In 2000/01, the financial revenue surplus has the predominant share of 30% in the domestic resources and the project assistance occupies the highest share of 52% in the foreign assistance (see **Table 2.2.11**).

(3) Commitment and Disbursement of Foreign Economic Assistance

The commitment of foreign economic assistance indicates the slight increase from 1,916 million US$ in 1991/92 to 2,052 million US$ in 2000/01. The grants show the decrease of their share from 59.6 % to 45.7 % and the loans show the increase of their share from 40.4 % to 54.3 % on the contrary. The food and commodity aid are assumed to be closely related to the disaster damage. Especially, those in the grants were 411 million US$ in 1991/92 and 467 million US$ in 2000/01, respectively. These food aids are obviously reflecting the flood damage which was the one of the most devastating disasters in Bangladesh. The project aid occupies the predominant share both in the grants (50.2%) and the loans (100.0%) respectively in 2000/01.

The disbursement of foreign economic assistance recorded also the slight decrease from 1,611 million US$ to 1,369 million US$. The shares of grants and loans indicate the same character as those of the commitment. The food aid and commodity aid are also reflecting the flood damages of which amounts were 433 million US$ and 196 million US$, respectively. The project aid also occupies the predominant share both in the grants (41.9 %) and in the loans (95.5 %) respectively in 2000/01 (see **Table 2.2.12**).

Comparing among donors of foreign economic assistance, Japan is one of the most contributing countries as well as ADB, IDA, USA and UK, during the period from 1991/92 to 2000/01. The amounts of commitment of Japan ranges from 156 million US$ (5.9 % of all amounts of commitment) to 591 million US$ (36.6 %). These amounts are the largest next to IDA of which share ranges from 9.2 % to 39.2 %. On the other hand, Japan has also the extreme share for the disbursement, ranging its share from 9.5 % to 24.9 % following to IDA (see **Tables 2.2.13** and **2.2.14**).

2.2.4 Socio-Economic Framework

(1) National Economic Development Plan

Review of the Past Development Plan

Bangladesh has had two and a half decades of development efforts at lifting the economy out of its abject poverty. The country has followed the course of planned development since 1973. In a medium term framework, the First Five Year Plan was launched in June 1973. This was followed by a Two Year Plan (1978-80) in the background of world wide inflation and uncertainties. In 1980, the five year plan framework was reinstated and since then three five year plans were implemented in

succession. There was no development during 1995-97 after the expiry of the Fourth Plan (1990-95). The planned outlay and GDP growth targets with their actual of the successive Plans are shown in **Tables 2.2.15** and **2.2.16**.

During the period from 1973 to 1995, the annual growth rate target of GDP was set up between 5.0 % and 5.6 % and the realized growth rate ranged from 3.5 % to 4.2 %. But the target growth rate in the average for the Fifth Five Year Plan was set up at 7.0 % and the realized the growth rate of 5.6 % (1997-2000). Both of target and realized growth rate shows the highest level of all plans implemented since 1973. Comparing with each year for the growth rate during the plan period, the achievement ratio indicates more than eighty percent except in the year of 1989/90.

It could be observed from this figure that the economy of Bangladesh has grown steadily on the basis of sound and indomitable policies by the Government and the positive economic activities of private sectors in spite of the serous damages by natural disasters including the one of the most devastating flood damages which happened in 1998.

The Fifth Five Year Plan aims to put Bangladesh on a path of self sustaining growth for the improvement of socio-economic condition of the people. Acceleration of GDP growth will allow the economy to break through the continuing poverty syndrome. While there has been substantial improvement, the Plan recognizes the need for massive investment, with private sector playing the major role for rapid growth and efficiency.

Development goals and objectives of the Fifth Plan are briefly presented below:

1. Alleviation of poverty through accelerated economic growth during the Plan period to bring about a noticeable improvement in the standard of living of people by raising their level of income and meeting their basic needs,
2. Generation of substantial employment opportunities and increase in productivity through an optimal choice of the traditional labor incentives and new capital-intensive technologies,
3. Improvement in the quality of life of the rural population through mobilization of the rural masses and resources at their command,
4. Transformation of the rural socio-economic structure into a more equitable, just and productive one and empowerment of the rural poor through ensuring their increased access to resources,
5. Attainment of food production beyond the self-sufficiency level in the shortest possible time with higher production of diversified high valued export goods,
6. Human resources development with emphasis on compulsory primary education and vocational training and foundation lying of knowledge based society,
7. Development of necessary infrastructure, utilities and other services needed to promote growth, particularly in the private sector such as natural resources (power, gas and coal) and rural infrastructure including market outlets,
8. Development of industries essentially based on comparative advance of the

country,

9. Development of hitherto neglected areas like the north-west region, Chittagong Hill Tracts and coastal areas,
10. Achievement of lower population growth rate (1.32 %) by the terminal year of the Plan, coupled with provision of necessary health care and improved nutrition of mother and child,
11. Strengthening of the country's scientific and technological base with emphasis on research and development of new generation technologies such as electronics and genetic engineering,
12. Protection and preservation of environment by putting in place adequate regulatory regimes and effective institutions,
13. Closing the gender gap, giving priority to women's education, training and employment and special support for education of the girl child,
14. Establishment of social justice through equitable distribution of income, resources and opportunities, and creation of effective safety nets for socially and economically disadvantaged sections of the population and by strengthening the law and order a rule of the law, and
15. Putting in place effective local government institutions, at the union, thana and zilla levels, and vesting on them the power and responsibilities for design, formulation and implementation of local level development programs and projects, with active participation of people belonging to all strata of the rural society.

In order to bring about the planned growth rate of 7%, total outlay was projected to be about 1,953 billion Taka with 44 % in the public sector (859 billion Taka) and the rest in the private sector (1,101 billion Taka). Besides trade and other services, the largest share of investment is going to be in agriculture (16.5 %), closely followed by industry (15.9 %) and transport and communication (13.5 %). Plan outlay by major sectors is shown in the table below.

Sectoral Distribution of Plan Outlay (at 1996/97 Prices)

(Unit: Million Taka)

Sectors		Public Sector		Private Sector		Total	
		Outlay	%	Outlay	%	Outlay	%
1	Agriculture	202,675	23.6	119,864	10.9	322,539	16.5
2	Industry	11,794	1.4	298,776	27.2	310,570	15.8
3	Housing and Construction	49,816	5.8	180,018	16.4	229,834	11.7
4	Power and Gas	114,401	13.3	37,726	3.4	152,127	7.8
5	Transport and Communication	145,540	16.9	118,877	10.7	264,417	13.5
6	Trade and Others	334,714	39.0	345,321	31.4	680,035	34.7
Total		858,940	100.0	1,100,582	100.0	1,959,522	100.0

Source: 2000 Statistical Yearbook of Bangladesh, BBS.

In conformity with overall objectives of the Plan and greater role of the private sector than ever before in a market economy, the public sector resource allocation has been determined to address the sectoral priorities concerning public interventions for social

justice, supply of basic needs, poverty alleviation, productive employment generation, human resource development and development of social and economic infrastructures. Accordingly, agriculture, water resources and rural development, physical infrastructure development, energy, health and education have been given high priority in the public sector.

A National Strategy for Economic Growth, Poverty Reduction and Social Development

After the Fifth Five Year Plan, "A National Strategy for Economic Growth, Poverty Reduction and Social Development" was published on January 2003, by the Economic Relations Division of Ministry of Finance. The outline of this report is as follows.

Strategy

The present strategy of the Government addresses three key tasks facing the nation. The first one focuses on the need for consolidating past economic and social successes (the task of sustaining the positive gains). The second one pertains to the compulsions of avoiding the pitfalls of past development experiences (the task of overcoming the negative tendencies). The third one draws attention to the new challenges that the nation has to confront in the context of globalization as well as new challenges that arise from the present phase of domestic development (the task of addressing new challenges). The success of the strategy of poverty reduction and attainment of Millennium Development Goals (MDGs) would depend on the extent to which the above three tasks are addressed in the coming decade.

Outlining Development Vision

The vision in the present strategy embraces a comprehensive approach premised on a right-based framework, that highlights the need of progressive realization of rights in the shortest possible time. For this, poverty reduction (with special focus on the removal of hunger and chronic poverty) and accelerating the pace of social development (with particular emphasis on empowering the poor and achieving gender equality) have been made the overarching strategies goals. Adopting a comprehensive approach and taking into account the country's past international commitments (such as MDGs) and evolving national realities, the strategy envisions that, by the year 2015, Bangladesh would achieve the following targets :

- Remove the 'ugly faces' of poverty by eradicating hunger, chronic food insecurity, and extreme destitution;
- Reduce the number of people living below the poverty line by 50 per cent;
- Attain universal primary education for all girls and boys of primary school age;
- Eliminate gender disparity in primary and secondary education;
- Reduce infant and under five mortality rates by 65 per cent, and eliminate gender disparity in child mortality
- Reduce the proportion of malnourished children under five by 50 per cent

and eliminate gender disparity in child malnutrition;
- Reduce maternal mortality rate by 75 per cent;
- Ensure access of reproductive health services to all;
- Reduce substantially, if if not eliminate totally, social violence, against the poor and the disadvantaged groups, especially violence against women and children; and
- Ensure disaster management and prevent environment degradation for overcoming the persistence of deprivation.

The poverty targets and social development goals are presented in **Table 2.2.17**. Major goal posts worked out in this table by taking the 2000 figures as the benchmark estimates are premised on this vision. A comparison of the projected targets with the actual pace of progress achieved during the nineties shows that for some indicators, while being higher than the historical trends, these are not far off the mark. Thus, the projected reduction rate for child mortality and child malnutrition is only slightly higher than the average progress recorded in the nineties. If the goal of reducing the incidence of national poverty by half is to be achieved by 2015, Bangladesh needs to sustain a GDP growth rate of about 7 % per year over the next 15 years. However, these targets will not be met through economic growth alone. Pro-active public actions will play a significant role in attaining the national targets set in the light of MDGs and national priorities.

With regard to the Poverty Reduction Strategy, telecommunication is considered to be the third critical element following to roads and bridges in the infrastructure package for pro-poor growth. The relative importance of telecommunication has increased manifold following the revolution in information technology. Telecommunication will help in regional market integration, increase the effectiveness of the early-warning system for prevention and preparedness for disasters including flood disaster closely related to the FFWS, improve the system of governance and, service delivery to the poor and poor areas (e.g. satellite learning, tele-medicine etc.). The policies will also support the development of ICT at all levels of education, inducing development of institutions on vocational and technical education and technology transfer.

Medium Term Macroeconomic Framework

To facilitate the implementation of the strategy mentioned above, a Medium Term Macroeconomic Framework (MTMF) has been specified covering the period Fiscal Year (FY) 2004, to FY 2006. The framework has been worked out on the basis of the estimated values of FY 2003 as the benchmark. The purpose is to enable the tracking of relevant indicators and monitor the progress based on key intermediate outcomes. As a first step, key macroeconomic fundamentals have been specified which provide the policy outcome targets.

The framework envisages a stable macroeconomic environment during the period FY 2004 to FY 2006. It seeks to achieve an accelerated growth with the rate of GDP growth in real terms rising from 5.8 % in FY 2004 to 7.0 % in FY 2006. The target rate

of growth has been set to ensure a real breakthrough in poverty reduction in the medium term.

Accelerated poverty reduction would require higher amount of government revenue which can be spent on programs benefiting the poor. The Government plans to mobilize larger amount of domestic revenue so that the revenue/GDP ratio would rise from 11 % in FY 2003 to more than 12 % in FY 2006 and the tax/GDP ratio from 8.7 % to 9.4 % during the same period.

Summary of the projected values of selected macroeconomic indicators under the MTMF is given in the following table.

Projection of Selected Macroeconomic Indicators under MTMF

(Unit: %)

Indicator	Actual	Revised Estimate	Budget Estimate / Benchmark	Projection		
	FY01	FY02	FY03	FY04	FY05	FY06
Real GDP Growth	5.3	4.8	5.3	5.8	6.5	7.0
Inflation	1.6	2.3	3.0	3.0	3.0	3.0
	As of GDP					
Gross Investment	24.2	22.8	24.3	25.4	26.0	27.0
Gross Domestic savings	18.0	18.0	18.5	19.2	20.0	20.7
Gross National Savings	22.1	23.3	24.0	24.3	25.2	26.5
Total Government Revenue	9.3	10.2	11.3	11.5	11.8	12.3
Total Government Expenditure	14.0	14.4	15.2	16.7	16.9	17.2
Overall Budget Deficits	4.7	4.2	3.9	5.2	5.1	5.0
Net Foreign Financing	2.0	1.6	2.2	3.1	3.2	3.3
(Multi and Bilateral Prog. Budget Financing)	0.0	0.0	0.0	1.2	1.3	1.2
Net Domestic Financing	2.7	2.6	1.7	2.1	1.9	1.7
Export	13.7	12.5	12.8	13.1	13.4	13.6
Import	17.9	16.2	16.8	17.5	18.1	18.9
Current Account Deficit	2.3	0.4	0.9	1.7	1.4	1.1

Source : "A National Strategy for Economic Growth Poverty Reduction and Social Development", Economic Relations Division, Ministry of Finance, January 2003

(2) Population Projection

Total Population

Total population of Bangladesh was projected by referring to the result of projection which was conducted by BBS on the basis of census in 1991. In the census, the projection was conducted on the basis of three assumptions such as low, medium and

high respectively. The medium assumption was adopted in this Study. The process of projection was as follows.

i) Comparison of the population in 2001 between the result of projection and the census population conducted in 2001

The projection conducted by BBS was conducted for the period from 1991 to 2010. After projection, more than ten years have passed away already. Then it was found out that there was difference of population in 2001 between the actual population in 2001 census and projected population by BBS in 1991.

ii) Adjustment of the projected population

Proportionate adjusting was conducted on the basis of ratio of actual population in 2001 to the projected population of 2001 conducted by BBS. Then the same growth rate of the population estimated by BBS was applied into the projection of this study.

The population will grow from 123 million to 144 million in 2010 at the average annual growth rate of 1.8% and to 163 million in 2020 at that of 1.2 %.

Regional Population

Regional population is broken down into Division, District and Thana (Upazilla). The population of these regional areas was projected by the following process.

i) Population projection by Thana on the basis of the average annual growth rate of population of Thana during the period from 1981 and 1991,
ii) Adjustment of the population projection by Thana by ratio of actual total population of each year (2010 and 2020) as a control total to the total population of population by Thana,
iii) The population of District was derived by accumulating of the population of Thana, and
iv) The population of Division was derived by accumulating of the population of District.

The result of population projection by Division is shown in **Tables 2.2.18** and **2.2.19**. The most rapid growth is expected to Barisal Division with the growth rate of 1.8% per annum during the period from 2001 to 2010 and 1.3 % per annum from 2010 to 2020 followed by Dhaka Division with 1.8 % and 1.2 %, respectively. On the contrary, the slowest Division is predicted for Chittagong and Sylhet Division with the same growth rate of 1.7 % and 1.2 % followed, respectively.

(3) GDP Projection

As already mentioned above, there has been no the long-term development plan in Bangladesh. Then the GDP projection as one of the socio-economic framework was executed by the Study Team by the following process.

i) Setting up of three growth scenarios

Three growth scenarios were set up, i.e. Low, Medium and High.

ii) Projection of Total GDP (All Sectors)

First of all, the total GDP including all industrial origins (sectors) was projected. The average annual growth rates at the constant prices of 1995/96 were set up for the three growth scenarios on the basis of the historical trend of average annual growth rate during the period from 1991/92 to 2000/01 and the Fifth Five Year Plan (1997-2002). Those growth rates are 4.5 % for "low", 5.5 % for "medium" and 7 % for "high", respectively.

iii) Projection of GDP by Industrial Origin (Sector and Sub-Sector)

The tentative average annual growth rate was set up for sub-sector on the basis of the past trend with regard to the annual growth rate and share in the total GDP. After the calculation of GDP by sub-sector by adopting the tentative average annual growth rate, the GDP by sub-sector was accumulated. By comparing between the accumulated GDP as total and the total GDP as a control total which was projected by the average annual growth rate by the three growth scenarios mentioned above, the GDP by sub-sector was adjusted. In the process of adjusting, the balance of growth rate and share with among three sectors (agriculture, industry and service) and sub-sectors were carefully taken into consideration. Then the projection by sector and sub-sector was finalized.

The result is shown in **Tables 2.2.20**, **2.2.21** and **2.2.22**. According to the medium growth scenario, the total GDP will increase from 2,091 billion Taka in 2000 to 6,102 billion Taka in 2020 at 5.5 % of average annual growth rate and the most rapid growing sector is expected to be industrial sector and its share will increase from 26.3 % to 29.7 %. The dominant share is and will be occupied by service sector of which share will reach to mostly 50 %. But agricultural sector shows the lowest growth rate and its share will decrease from 25.3 % to 20.9 %. The share structure by sector will not differentiate by the growth scenario.

On the other hand, the per capita GDP at constant prices of 1995/96 will increase from 17,228 Taka in 2000 to 31,401 Taka in 2020 showing the annual average growth rate of 3.0 % which means the increase of 80% (around two times) during twenty years.

2.3 Major Natural Disasters

Bangladesh is prone to many kinds of natural disasters. **Table 2.3.1** shows major natural disasters attacked Bangladesh. As shown in the table, the most important ones to mention are tropical cyclones associated with storm surges, floods, droughts, tornadoes and river bank erosions. Besides these disastrous weather systems, the occurrence of earthquakes at times makes significant impact on social and economic activities.

2.3.1 Cyclones

Tropical cyclones are frequent in the Bay of Bengal. Immediately pre- and post-monsoon periods are the seasons when cyclones and depressions form in the Bay

of Bengal. In the last 50 years, cyclonic storms have been responsible for the largest number of deaths and immediate devastations. These cyclones hit the coastal area of Bangladesh. Cyclones are formed in the Bay of Bengal at the rate of 1.3 per year. Cyclones generally generate speeds of 150 - 225 km/hr or more and surges which are 5 - 14 m above the normal astronomical tide.

Actually, storm surges are far more dangerous than the storms themselves as they wash away people, houses, crops and livestock.

2.3.2 Floods

Floods in Bangladesh are a complex phenomenon. They pose enormous threats to the population, but at the same time, moderate floods contribute to the fertility of the land. Extensive river floods cause great disruption on social and economic activities and damage to infrastructure and loss of crops. Floods indirectly contribute the concentration of land ownership and wealth as small land owners are forced to sell their property as a result of flooding. Bangladesh has always experienced some degree of flooding. Apart from a few small hills in the northwest and southeast, the country is totally flat. Very little of the country is more than 20 m above sea level. In a normal monsoon, one third of its 9 million hectares of cultivated land is flooded. Flooding is a fact of life to the people of Bangladesh and they demonstrate great resilience and skill in coping with it. Monsoon flooding, which normally affects about one third of cultivated land, is regarded by farmers as beneficial. They have developed agricultural practices to make use of the floodwater for rice and jute as well as for fisheries. It is when flooding increases beyond the normal level when problem arise.

2.3.3 Droughts

Bangladesh experiences drought conditions at some intervals of time. Records show that Bangladesh had, in the recent past, drought conditions having disastrous crop failure. In 1979, Bangladesh passed through a major drought year which was trend by many as the worst in the recent past. Crop failure by drought comes as a significant strain also to the socio-economic structure of Bangladesh.

2.3.4 Earthquakes

Bangladesh is a part of the Bengal basin which is the most seismically active zones of the world. Lying as it does in the confluence of the India, Burma and Eurasia plates, the land is extremely prone to earthquake disasters and in the past have experienced some of the worst earthquakes in the history.

However, a relatively long period of rest from major hazards and high attention paid to other disasters such as cyclone, flood etc. have led to both neglect and denial of earthquake as the most destructive of all natural disasters.

Corresponding to this, on the course of establishing building code in 1993, Bangladesh was divided into three earthquake prone areas: First zone is the high-risk earthquake prone and consists of Kurigram, Rangpur, Bogra, Greater Mymensing, Greater Sylhet

and Brahmanbaria; Second zone includes medium-risk earthquake prone areas like Dinajpur, Rajshahi and Dhaka regions, Greater Chittagong, Comilla and the northern part of Noakhali; Third zone which is the least earthquake prone area includes Khulna and Barisal divisions and southern part of Noakhali.

2.3.5 River Bank Erosions

According to BWDB, annual average sediment loads entering Bangladesh is 770 million tons. The sediment flow is not uniform throughout the year and this can stretch the load carrying capacity of rivers. When that occurs, the flow overcomes the banks and the currents cause the erosion. The health of the channels also influences erosion. While those which remain active are less susceptible to erosion, the clogged ones can be eroded due to sudden flow of monsoon or rain water or any other water discharge.

The result of satellite image analysis shows that the annual erosion loss is about 87,000 hectares. Most of this lost land was used for agriculture. About one million Bangladeshis are affected by river erosion though other disasters including cyclones and floods get far greater publicity because of their dramatic nature.

2.3.6 Tornadoes

Tornadoes cause localized devastation and demand an immediate response. They occur suddenly and fearsomely. The death and injury rate can be awesome. In the last decade, two tornadoes are remembered for their ferociousness. On April 26, 1989, a tornado hit parts of Manikganj district focused on 50 km^2. Damage to crop and livestock was almost total and 800 people were killed.

On May 13, 1996, another high intensity tornado hit two districts, i.e. Tangail and Jamalpur. Tangail was devastated and over 100 people were killed. Crop and livestock loss was extremely high.

2.4 Hydrometeorology

2.4.1 Climate

Bangladesh is located in a sub-tropical monsoon zone and has four main seasons, namely winter (from November to February), pre-monsoon or summer (from March to May), monsoon (from June to September) and post-monsoon (from October to November). Annual average temperatures range from 19 to 29 °C. Temperature varies from 21 to 34 °C during April to September, while from 9 to 29 °C during November to January. Generally, regional climatic differences in this flat country are minor.

Following table shows the maximum and minimum monthly average temperature and monthly average rainfall:

Climate of Bangladesh

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Max. Temp. (°C)	25.4	28.1	32.3	34.2	33.4	31.7	31.1	31.3	31.6	31.0	28.9	26.1
Min. Temp. (°C)	12.3	14.0	19.0	23.1	24.5	25.5	25.7	25.8	25.5	23.5	18.5	13.7
Rainfall (mm)	7.0	19.8	40.7	110.7	257.5	460.9	517.6	431.9	289.9	184.2	35.0	9.4

Source: BMD

Winds are mostly from the north and northwest in winter, blowing gently at 1 to 3 km/hour in northern and central areas and 3 to 6 km/hour near the coast. From March to May, violent thunderstorms produce winds of up to 60 km/hour.

Annual average rainfall varies from 1,200 mm in the west to over 5,000 mm in the north-east. Long periods of steady rainfall persisting over several days are common during the monsoon, but sometimes, local high intensity rainfall of short duration also occurs. Because of its location just south of the foothills of the Himalayas, where monsoon winds turn west and northwest, the region of Sylhet in northeastern Bangladesh receives the greatest average precipitation.

Figure 2.4.1 shows the isohyetal map of Bangladesh together with monthly average rainfall hyetographs at 6 locations, i.e. Dhaka, Rangpur, Rajshahi, Khulna, Sylhet and Chittagong. Average annual rainfall at Sylhet exceeds 4,000 mm with high rainfalls being concentrated in the north-eastern area. Seventy three percent of rainfall over Bangladesh occurs between June and September.

The basic cause of the meteorological condition for monsoon rainfall is the extensive, deep incursion of warm and saturated air from the Bay of Bengal over the whole northern Indian sub-continent. Within this system, the detailed synoptic conditions vary to give periods of greater or lesser rainfall activity. The occurrence of monsoon low pressures, passing over Bangladesh and West Bengal, produces periods of heavy rainfall, as do fluctuations in the position of the monsoon axis, which at its fullest northward extent lies along the southern margin of the Himalayan Range. This in turn is controlled by complex upper air pressure and wind pattern in relation to the Tibetan plateau. The squally, thundershower outbreaks are due to convergence of warm air from the Bay of Bengal below cold continental air at upper levels.

Tropical cyclones, which are originated in Indian Ocean or Bay of Bengal, attack Bangladesh almost every year mainly in pre- (March – May) and post-monsoon seasons (October – November). Inter-tropical Convergence Zone (ITCZ) is located in the latitude between 10°N and 20°N in summer in north hemisphere. Cloud clusters generated in ITCZ often grow into tropical depression. Since the temperature of seawater in this area in pre- and post-monsoon seasons is high, huge amount of aqueous vapor is supplied to the depression. Cyclone is the tropical depression whose wind velocity at the center is 17 m/sec or more.

Bangladesh has the worst record of cyclones and storm surges in the world. They destroy crops, damage infrastructure, homes and vital installations, and cause widespread health hazards for the people. Storm surge create both short and long-term problems because the salt water ruins the soils. They occur frequently and in such magnitude in Bangladesh that they have multiplied the problem of poverty and seriously challenged the efforts of the country towards self-reliance. Occasionally, tropical cyclones also cause enormous numbers of casualties. The cyclone disaster in 1970 (500,000 dead) and 1991 (150,000 dead) are among the worst natural disaster in the world.

2.4.2 Hydrometeorological Conditions in Bangladesh

Bangladesh is located in the confluence area (delta area) of the Padma (Ganges), Jamuna (Brahmaputra) and Meghna rivers. The flood plains of the three major rivers, together with smaller rivers and streams, cover about 80% of the country; 60% of the country is lower than 6 m above sea level. These topographical characteristics of the country result in an average river gradient in the delta area of about 6 cm/km (1/17,000).

Total drainage area of the major international rivers is 1,555,000 km^2 (Padma: 907,000 km^2, Jamuna: 583,000 km^2, Meghna: 65,000 km^2). Only 7 to 8 % of the total drainage area is in Bangladesh, while 62% is in India, 18% in China, 8% in Nepal and 4% in Bhutan. It is widely recognized that more than 90% of discharge in Bangladesh originates outside the country (see **Location Map: Bangladesh and International Rivers**).

Monthly average runoff hydrographs at three locations (Hardinge Bridge on the Upper Padma, Bahadurabad on Jamuna, Bhairab Bazar on Meghna) are shown in **Figure 2.4.1**. Peak runoff of the Jamuna river occurs in July and for the Upper Padma river in August to September. Although the drainage area of the Upper Padma is more than 1.5 times of that of the Jamuna, the total runoff volume of the Upper Padma is about 50% of that of the Jamuna. This reflects the fact that the upstream reaches of the Jamuna (Brahmaputra), especially in the Indian territory (Assam), is one of the highest rainfall regions in the world.

Cyclones occur in the Bay of Bengal and affect Bangladesh on average 2 to 3 times yearly. However, since cyclones normally occur in the period of April to May and October to November, simultaneous occurrence of cyclones and river flooding is not generally observed.

2.4.3 Flood Characteristics in Bangladesh

Four types of floods are generally considered in Bangladesh, namely, 1) Normal Flood (Monsoon Flood), 2) Flash Flood, 3) Tidal Surge, and 4) Local Inundation (Rainfed Flood). Of these, since local inundation is caused by poor drainage due to high water levels of major rivers, it can be considered as a part of the monsoon flood. **Figure 2.4.2** shows the affected areas for the remaining three types of floods. For the FFWS,

monitoring/forecasting are the main targets and the following discussions focus on the impacts of monsoon and flash flooding.

(1) Monsoon Flood

Three catastrophic floods were reported in the last two decades, i.e. 1987, 1988 and 1998. The flood affected area of 1988 and 1998 floods are illustrated in **Figure 2.4.3**, and maximum flood water levels and number of days above danger level at selected 43 gauging stations both for 1988 and 1998 flood are shown in **Table 2.4.1** together with recorded maximum water level of each station. In the 1998 flood, more than 100,000 km^2 (68%) of the Bangladesh territory was inundated according to the survey result of BWDB and its duration was also extremely long. In Dhaka for example, the number of days with water level above the danger level was 57 days in 1998 flood, while it was 23 days in the 1988 flood (see **Table 2.4.1**).

Hydrographs of water level and runoff discharge of the 1998 flood at Hardinge Bridge, Bahadurabad and Bhairab Bazar are presented in **Figure 2.4.4**. The time scale of water level fluctuations is quite large and the slope of the hydrographs is low. This is the typical characteristic of monsoon flooding.

Based on the discharge data available in the BWDB database, the inflow volume to the central area of Bangladesh during the period between June and October was estimated as defined below:

$$V = V_{HB} + V_{BH} + V_{BB}$$

where, V : inflow volume to the central area of Bangladesh (June ~ October),
V_{HB} : total runoff volume at Hardinge Bridge (June ~ October),
V_{BH} : total runoff volume at Bahadurabad (June ~ October), and
V_{BB} : total runoff volume at Bhairab Bazar (June ~ October).

The inflow volume was calculated for the years from 1983 to 1993, and 1998 according to the availability of continuous discharge data at these locations. The plot of flood-affected area by the total inflow volume of respective years is presented in **Figure 2.4.5 (1)**. The inflow volume and flood-affected areas are also summarized in the table below:

Inflow Volume from Three Major Rivers and Flood Affected Area

Year	Inflow Volume (10^6 m^3)				Flood Affected Area* (km^2)
	V_{HB}	V_{BH}	V_{BB}	Total	
1983	285,803	447,144	145,069	878,016	11,100
1984	316,030	504,299	137,433	957,761	28,200
1985	335,664	474,225	120,302	930,192	11,400
1986	299,894	375,927	91,869	767,690	4,600
1987	341,904	531,049	131,877	1,004,830	57,300
1988	327,738	568,897	176,186	1,072,821	89,970
1989	239,218	613,319	145,474	998,011	6,100
1990	337,609	638,681	128,566	1,104,856	3,500
1991	246,170	634,889	156,943	1,038,002	28,600
1992	169,931	458,720	100,268	728,920	2,000
1993	235,649	542,757	161,629	940,035	28,742
1998	389,400	642,897	132,797	1,165,093	100,250
Mean	293,751	536,067	135,701	965,519	

* Source: FFWC

The maximum inflow volume was recorded in 1998. This coincided with the maximum flood affected area. In the 1990 monsoon, the flood affected area is very small although the associated inflow volume is larger than that of 1988 monsoon. A similar observation is found in the 1991 monsoon.

Figure 2.4.5 (2) shows the 10-day mean inflow runoff hydrographs for the monsoon seasons of 1987, 1988, 1990, 1991 and 1998. This figure shows deviation of the inflow runoff from the average value of the certain period based on the historical record. This deviation is called as '10-day mean excess inflow' in this Study. A common characteristic in the shape of graph in the large-scale floods (black marker) is observed, that is, the 'excess inflow' continues for more than two months. On the contrary, during small-scale monsoon floods with large inflow volume (white marker), the excess inflow hydrograph occurs over several periods. There is also around a two month delay in the peak flow of the Upper Padma in comparison to that of the Jamuna based on the monthly average runoff (refer to **Figure 2.4.1**). From these observations, it is concluded that the temporal distribution of the monsoon runoff of the major rivers is one of the important factors in determining the extent of flood affected area.

Simple correlation of water level record 1) between Pankha and Hardinge bridge on the Upper Padma, and 2) between Noonkhawa and Sirajganj on Jamuna were also evaluated. The correlation plots are shown in **Figure 2.4.6**. Although there are some inconsistencies between years, the plots show good correlation of water levels along the major rivers.

Data on flood affected area is estimated and compiled every year by BWDB and available from the year of 1954. The maximum flood affected area was recorded in 1998 monsoon season as more than 100,000 km^2, which is around 68% of the total

land area of Bangladesh. Probability analysis on recorded flood affected area was conducted with 42 samples from 1954 to 2001. **Table 2.4.2** shows the result of the analysis and probable flood affected area and share in total land area of the country for 2-, 5-, 10-, 25-, 50- and 100-year return periods are summarized in the table below:

Result of Probability Analysis on Flood Affected Area

Return Period (years)	2	5	10	25	50	100
Flood Affected Area (km^2)	30,000	39,900	49,100	89,500	97,400	103,700
Share in Total Area	20.4 %	27.1 %	33.4 %	60.9 %	66.3 %	70.5 %

Note: Total land area of Bangladesh is 147,000 km^2.

According to abovementioned results, the severe flood occurred in 1998 is estimated as around 70-year probable from the viewpoint of the extent of total flood affected area, although the estimated return period of 1998 flood ranges between 40- and 85-year return periods according to the plotting method employed as seen in **Table 2.4.2**. Also, the 1987 and 1988 floods are estimated as around 15-year and 25-year probable, respectively.

(2) Flash Flood

Flash flood is characterized by a steep rise and rapid recession of water level, often causing damage to crops and property due to inundation and high river flow velocities. According to the information obtained from BWDB, the duration of flash flood is several hours at shortest. The cause of flash floods is heavy rainfall concentrated in short periods. Particularly in the north-eastern area of Bangladesh, which is subject to heavy and highly intense rainfall and has very steep catchment slopes in the upstream hilly area in India, damage due to flash floods is reported almost every year.

Water level and discharge hydrographs of 3 locations, i.e. 1) Monu railway bridge on the Monu river, 2) Sarighat on the Sarigoain river, and 3) Panchagarh on the Koratoa river, are presented in **Figure 2.4.7**. Extremely large fluctuations in both water level and discharge are observed.

The forecast of flash flood is very difficult because hydrological data such as water level, discharge or rainfall from those parts of the catchments in Indian territory are not sufficient and timely.

Compared to the characteristics of monsoon flood, the time scale or duration of one flood event is much smaller in the flash flood areas.

(3) Quantitative Analysis of Flash Flood Characteristics

In Bangladesh, flash flood is recognized as the flood with "rapid" rise and recession of water level. However, the definition of flash flood is still quantitatively ambiguous, although lots studies and researches have been undertaken. All kinds of hydrometeorological data, such as precipitation, flood runoff, flood water level etc., both in Bangladesh and in upstream countries, are essential for the acquisition of

reasonable quantitative explanation of flash flood.

As a trial, some analyses were conducted based on the available water level and discharge record in Bangladesh.

A) Quantitative Analysis Based on the Water Level Record

To assess the speed of water level rising, water level increase rate (WLIR) was calculated based on the records at BWDB observatories. WLIR was defined as follows:

$$\Delta WL_t^T = \frac{(WL_{t+T} - WL_t) \times 100}{T} \times 24$$

Where,

T :	Sampling interval (hour)
t :	Time (hour)
ΔWL_t^T :	Water level increase rate at time "t" for T-hours sampling interval (cm/day)
WL_t :	Water level at time of "t" (m PWD)
WL_{t+T} :	Water level at time of "t+T" (m PWD)

In the above equation, the actual water level increase is extrapolated for the daily basis, and this extrapolated value is called as WLIR. For example, if the actual water level increase in 3 hours is 10 cm, the WLIR at this time will be 80 cm/day. And if the sampling interval is set as 24 hours, the WLIR coincides with actual water level increase.

Based on the 3-hourly observed water level data of BWDB or FFWC, the WLIR was calculated at each time after when the water level reached the elevation that was set as 1 m below danger level.

The maximum WLIR for 3-hour observation interval is shown in **Figure 2.4.8** together with the maximum actual water level increase for 3 hours. **Figure 2.4.9** shows the maximum actual water level increase for 24 hours. North-eastern, north-western, south-eastern area of the country shows the high WLIR. Some part of south-western tidal affected area also shows the high WLIR. The WLIRs are considerably small in the apparent monsoon flood area along the large scale international rivers.

If the points with the maximum WLIR in 3-hour of more than 650 cm/day, except for those in tidal affected area, are taken up, the line passes on them may almost correspond to the ambit of flash flood area recognized in Bangladesh.

Multiplier is defined based on the WLIR for 3- and 24-hour observation interval as follows:

$$M = \frac{\Delta WL^{3}_{\max}}{\Delta WL^{24}_{\max}}$$

Where,

M: Multiplier

ΔWL_{max}^{3}: Maximum water level increase rate for 3-hours sampling interval (cm/day)

ΔWL_{max}^{24}: Maximum water level increase rate for 24-hours sampling interval (cm/day)

This indicates the difference of steepness by observation intervals. If the multiplier shows large figure, the shorter observation interval may be necessary. The multiplier of each observatory is shown in **Figure 2.4.10**. In addition to the tidal affected area and the flashy flood regions recognized in Bangladesh, rather high values are observed at the stations around Dhaka. This is estimated that water logging and the shortage of flow capacity of the waterway around Dhaka metropolitan area might cause this situation.

B) Quantitative Analysis Based on the Discharge Record

Checking the speed of the water level increase is one of the important measures to assess the magnitude of flash flood. And it is also important to check the variation of annual maximum runoff because if the variation of annual maximum runoff is high, it is difficult for people to prepare necessary countermeasures to cope with that. Contrary, if the variation of that is low, that is, the maximum runoff discharge is almost same year by year, people may take necessary countermeasures for such routine floods rather easily.

Flash flood magnitude index (FFMI) has been proposed and employed widely for assessment of annual peak flow variation (Baker, 1977). FFMI is expressed by the standard deviation of the logarithms of the annual maximum discharge. In this analysis, FFMI was defined as follows:

$$FFMI = \sqrt{\frac{n\sum \log^2 Q^i_{\max} - (\sum \log Q^i_{\max})^2}{n^2}} \times 1000$$

Where,

FFMI: Flash flood magnitude index

n: Number of samples

Q_{max}^{i}: Annual maximum discharge (m^3/sec) of year "i"

Figure 2.4.11 shows the location of BWDB's discharge measuring stations which were taken up for this analysis. Since only daily mean discharge data were available at those stations, the analysis was carried out daily discharge basis. The average annual maximum daily mean discharge (Q_m) at each station is illustrated in **Figure 2.4.12**.

The calculated FFMI is illustrated in **Figure 2.4.13**. High FFMI values are