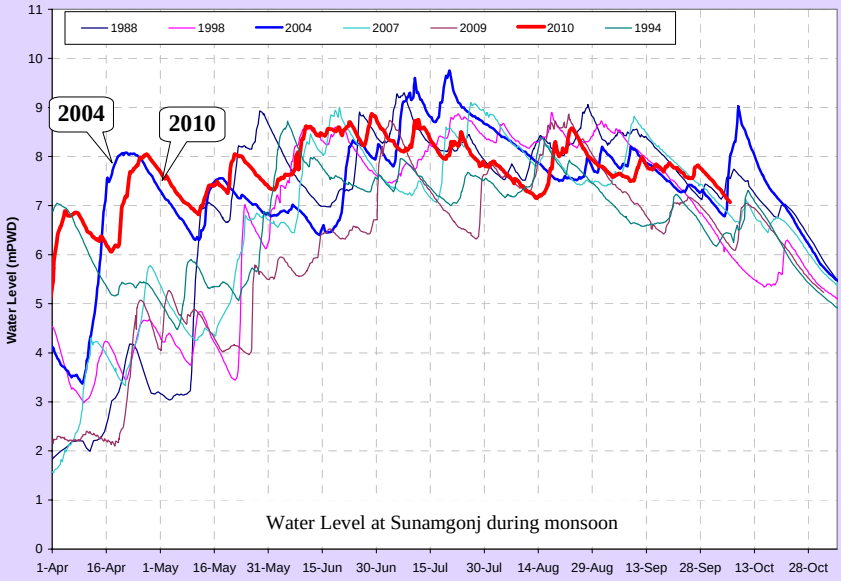
ANNUAL FLOOD REPORT 2010



Water Level at Sunamgonj during monsoon

FLOOD FORECASTING & WARNING CENTRE

PROCESSING & FLOOD FORECASTING CIRCLE

BANGLADESH WATER DEVELOPMENT BOARD

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PREFACE

Bangladesh is the part of world's most dynamic hydrological and the biggest active delta system. The topography, location and outfall of the three great rivers shapes the annual hydrological cycle of the land. Too much and too little water in a hydrological cycle is the annual phenomenon. Regular monsoon event is the flood, the depth and duration of inundation are the deciding factors whether it affecting beneficially or adversely. Monsoon inflow along with rainfall historically shapes the civilization, development, environment, ecology and the economy of the country. Extreme events of flood adversely affect the development, economy, poverty and almost every sector. In flood management, Bangladesh has been taken many structural and non-structural measures. One of the main non-structural measures is the flood forecasting and warning.

As stated in the BWDB Act-2000, Flood Forecasting in Bangladesh is the mandate and responsibility of Bangladesh Water Development Board (BWDB) and Flood Forecasting and Warning Center (FFWC) is being carried out this. The FFWC was established in 1972 and is fully operative in the flood season, from April to October every year, as directed by the Standing Orders for Disaster (SOD) of the Government of Bangladesh. The FFWC is acting as the focal point in co-ordination with other ministries and agencies like BMD, DMB, DAE etc during the monsoon for flood disaster mitigation and management.

The objectives of flood forecasting and warning are to enable and persuade people and organizations to be prepared for the flood and take action to increase safety and reduce damage. Its goal is to alert the agencies/departments to enhance their preparedness and to motivate vulnerable communities to undertake protective measures.

The professionals of FFWC gratefully acknowledge the valuable advice and leadership of Mr. Habibur Rahman, Director General, BWDB for his interest, continuous drive and suggestion. The valuable suggestions and encouragement provided by the ADG(Planning), to improve the quality of works of the center. The direct contribution and sharing of Mr. A H M Kausher, Chief Engineer, Hydrology, BWDB, Mr. Md. Salim Bhuiyan, Superintending Engineer, Processing & Flood Forecasting Circle, BWDB are respectfully remembered in implementing and monitoring the activities the FFWC.

The services of Gauge Reader's, Wireless operators and other support service providers are gratefully acknowledged. The FFWC is also grateful to the print and electronic news media and those who helped in disseminating the flood information during flood 2010. A number of NGOs have been working in different areas for dissemination of the FFWC flood warning message in village level, this provide flood preparedness at local level.

It is great pleasure that the regular observer of the FFWC web-site, noted by distinguished personalities at home and abroad is source of inspiration for improving the quality of services. Suggestion, feed-back and appreciation from policy level, ministries, different levels of GOs and NGOs is great encouragement of the professionals working in the FFWC. This is indeed a struggle and commitment to continue the services from April to October continuously, without week-ends and holidays. The FFWC with its very limited resources and manpower is working very hard to carry out the responsibility during the monsoon. The FFWC is trying to develop further the process and system to cope-up with the technological and computational development. On the main struggle and demand is to increase flood forecasting and warning lead time.

The FFWC hopes that this report might be a point of interest to the planners, designers, administrators, working in the water sector, disaster managers/fighters and various activities of formulating measures for flood mitigation/management in Bangladesh. The FFWC warmly welcomes comments and suggestions; these would certainly improve the services, activities and output of the FFWC in the coming days.

Finally, I sincerely thank and acknowledge my colleagues of the FFWC whose earnest and sincere co-operation made it possible to publish this annual report.

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EXECUTIVE SUMMARY

The characteristics of flood of 2010, is a representative one in respect of flood timing, duration and magnitude. During the monsoon 2010, the flood was not severe one stayed for short duration in the north (along the Brahmaputra-Jamuna River), west (along the Ganges river) and in the south eastern part. Duration of flood in the central part(along the Padma river) was moderate. In the north eastern part of the country, in the Meghna basin, duration of WL above DL was prolong in few stations, longer then the previous flood years(1988 and 1998). The north eastern part adversely affected by the pre-monsoon flash flood, in the last part of April and again the first part of May in 2010 resulted standing crop damages. This unusual pre-monsoon high water level in the north east part is similar to the year of 2004. As a whole, the monsoon 2010 was a normal flood year.

The country as a whole received 12% less rainfall than normal during the monsoon-2010. The Ganges, South Eastern Hill and Brahmaputra basins received 26%, 17% and 18% less rainfall than the normal value respectively and only the Meghna basin (in the north-eastern region of the country) received 6% more rainfall. Considering monthly value, all the basins experienced more rainfall than their respective normal in June. In the Meghna basin during the monsoon 2010 all monthly rainfall value are higher than the normal, except July. For the Meghna basin the monsoon 2010 may be considered as a wet year. In July all the basins received less rainfall than the normal. Basin wise monthly percent less(-) or more(+) rainfall than the normal is presented in the following table.

Month	Brahmaputra basin	Ganges basin	Meghna basin	SE Hill basin
April	-9.5%	-83.4%	+56.95%	-62.2%
May	-12.8%	-18.7%	+12.4%	-6.8%
June	+12.7%	+4.3%	+27.7%	+12.6%
July	-47.7%	-42.5%	-28.4%	-50.5%
August	-12.8%	-47.6%	+7.95%	-26.6%
September	-27.7%	-26.3%	+15.6%	-41.4%
October	-14.0%	-3.6%	+12.0%	+75.0%

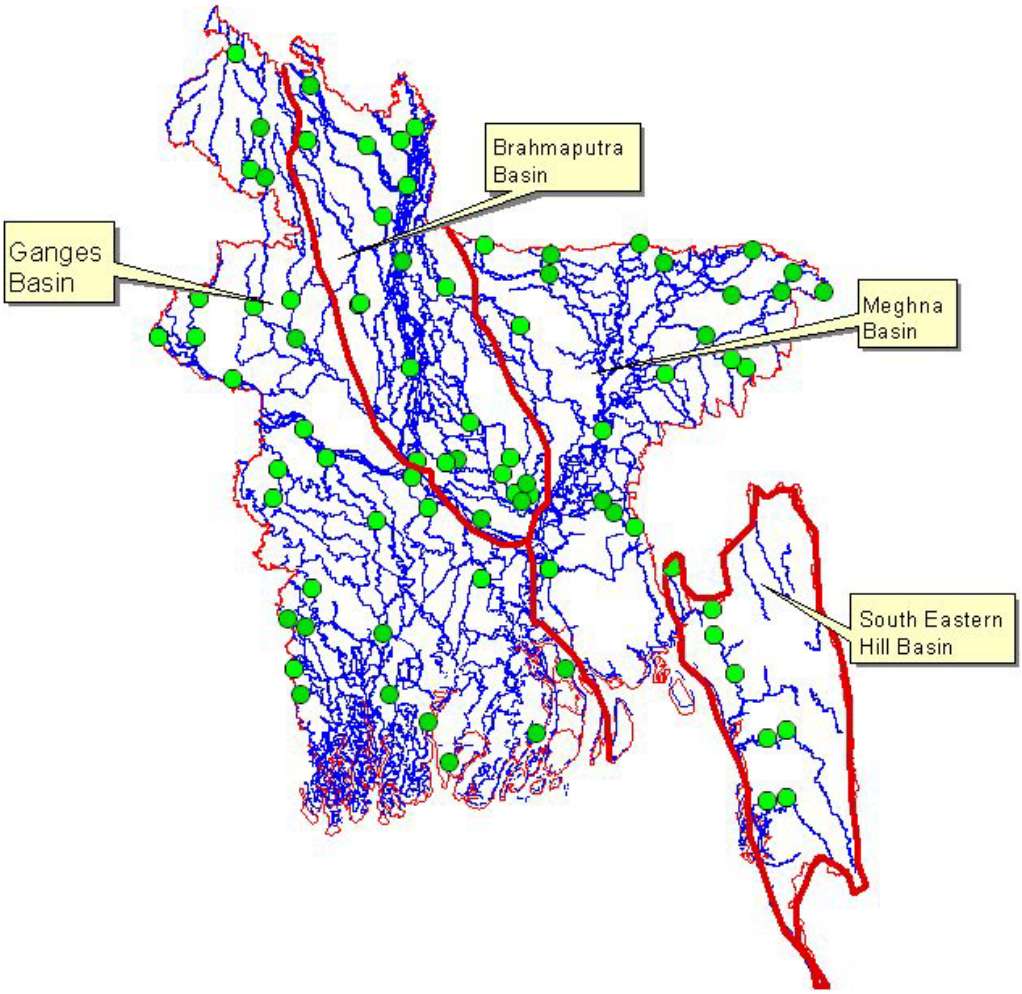
BWDB Data 2010

Professionals of the FFWC has been fully dedicated and committed to generate and disseminate flood forecasting and warning services despite of its limited resources, technology, logistics and man-power.

In 2010, the maximum flooded area was 18% of the whole country (26,530 sq-km approximately). Inspite of moderate magnitude of flood occurred in the year 2010, some of the regions experienced river bank errosion and flash flood.

List of Abbreviations

ADG	Additional Director General
ADPC	Asian Disaster Preparedness Centre
BWDB	Bangladesh Water development Board
BMD	Bangladesh Meteorological Department
CEGIS	Centre for Environmental Geographical Information Services
CFAB	Climate Forecast Application Bangladesh
CARE	Cooperative for American Relief Everywhere
CFAN	Climate Forecast Application Network
DG	Director General
DL	Danger Level
DMB	Disaster Management Bureau
DHI	Danish Hydraulic Institute
ECMWF	European Centre for Medium-Range Weather Forecasts
DEM	Digital Elevation Model
DAE	Department of Agriculture Extension
FFWC	Flood Forecasting and Warning Centre
GM	General Model
GBM	Ganges Brahmaputra Meghna
IWM	Institute of Water Modelling
MAE	Mean Absolute Error
NGO	Non-Government Organization
MSL	Mean Sea Level
SOD	Standing Order on Disaster
SSB	Single Site Band
SPARRSO	Space Research and Remote Sensing Organization
USAID	United States Agency for International Development
WL	Water Level



Basin Map of Bangladesh

CHAPTER 1: INTRODUCTION

1.1 THE PHYSICAL SETTING

Bangladesh lies approximately between 20°30' and 26°40' north latitude and 88°03' and 92°40' east longitude. It is one of the biggest active deltas in the world with an area of about 1,47,570 sq-km. The country is under sub-tropical monsoon climate, annual average precipitation is 2,300 mm, varying from 1,200 mm in the north-west to over 5,000 mm in the north-east. India borders the country in west, north and most part of east. The Bay of Bengal is in the south, Myanmar borders part of the south-eastern area. It has 230 rivers including 57 transboundary rivers, among them 54 originated from India including three major rivers the Ganges, the Brahmaputra and the Meghna. Three rivers originated from Myanmar. Monsoon flood inundation of about 20% to 25% area of the country is assumed beneficial for crops, ecology and environment, inundation of more than that causing direct and indirect damages and considerable inconveniences to the population.

The country is mostly flat with only few hills in the southeast and the northeast part. Generally ground slopes of the country extend from the north to the south and the elevation ranging from 60 meters to one meter above Mean Sea Level (MSL) at the boundary at Tentulia (north) and at the coastal areas in the south. The land in the west of the Brahmaputra is higher than the eastern part. Several large depressions have been formed, particularly in greater Mymensingh, Sylhet and part of Pabna-Rajshahi districts. The country consists of the flood plains of the Ganges, the Brahmaputra and the Meghna rivers and their numerous tributaries and distributaries. The Ganges and the Brahmaputra join together at Aricha-Goalundo and is known as the Padma River. The river Meghna joining the Padma near Chandpur flows to the Bay of Bengal as the Meghna River.

1.2 THE RIVER SYSTEM

The Ganges, Brahmaputra and Meghna river systems together, drain the huge runoff generated from large area with the highest rainfall areas in the world. Their total catchment area is approximately 1.6 million sq-km of which only about 7.5 % lies in Bangladesh and the rest, 92.5% lies outside the territory. It is assumed that an average flow of 1,009,000 Million cubic meters passes through these river systems during the monsoon season. Most of the rivers are characterized by having sandy bottoms, flat slopes, substantial meandering, banks susceptible to erosion and channel shifting. The river system of Bangladesh is one of the most extensive in the world, and the Ganges and the Brahmaputra are amongst the largest rivers on earth in terms of catchment size, river length and discharge.

The Brahmaputra (Jamuna) river above Bahadurabad has a length of approximately 2,900 km and a catchment area about 5,83,000 sq-km. Started from the glaciers in the northernmost range of the Himalayas and flows east far above half its length across the Tibetan plateau. In the complex mountain terrain bordering north-east India and China it bends through a series of gorges and is joined by a number of major tributaries, e.g., the Dihang and the Luhit before entering its broad valley section in Assam. This stretch is about 720 km long to the border of Bangladesh and throughout most of this, the course is braided. This braided channel is continued to the confluence with the Ganges.

Within Bangladesh, the Brahmaputra receives four major Right Bank tributaries - the Dudkumar, the Dharla, the Teesta and the Hurasagar. The first three are flashy rivers, rising in steep catchments on the southern side of the Himalayan between Darjeeling and Bhutan. The Hurasagar River is the outlet to the Karatoa-Atrai river system, which comprises much of the internal drainage of northwest of Bangladesh.

The Old Brahmaputra is the main left-bank distributaries of the Brahmaputra river presently known as the Jamuna. The shift of courses appears to have been taken place after a major earthquake and catastrophic floods in 1787. It is now a high flow spill river contributing largely to flood, as in the Dhaleswari, and their behavior is highly dependent on the variations of siltation at their entries.

Total length of the Ganges River is about 2,600 km to its confluence with the Brahmaputra -Jamuna at Aricha-Goalondo and a catchment area of approximately 9,07,000 sq-km. Started from the high western Himalayans glaciers, the Ganges has a short mountain course of about 160 km. From there it flows south easterly in a vast plain with major tributaries from the southern Himalayans in Nepal and smaller rivers from the central Indian Plateau to the south. With deep-water channel with numerous bar formations (chars), the Ganges is not braided. After its confluence with the Jamuna at Goalondo, the river, known as the Padma, flows in a wide and straight. At Chandpur, the Padma is joined to the Meghna from where it flows to the sea with tidal influence.

The Meghna system originates in the hills of Shillong and Meghalaya of India. The main source is the Barak River, which has a considerable catchment in the ridge and valley terrain of eastern Assam bordering Myanmar. On reaching the border with Bangladesh at Amalshid in Sylhet district, it bifurcates into Surma and the Kushiyara rivers. The Surma, flowing on the north of the Sylhet basin receives Right Bank tributaries from Khasia and Jaintia Hills of Shillong. These are steep, highly flashy rivers, originating in one of the wettest area of the world, the average annual rainfall at Cherrapunji at Assam being about 10,000 mm. The Kushiyara receives left bank tributaries from the Tripura Hills, the principal ones being the Manu. Also flashy in nature with less elevations and rainfall of Tripura makes these rivers less violent than the northern streams.

Between the Surma and Kushiyara, there are many internal draining depressions (haors), meandering flood channels and abandoned river courses, which are widely flooded every monsoon season. The two rivers rejoined at Markuli and flow via Bhairab as the Meghna to join the Padma at Chandpur. The major tributaries of any size outside the Sylhet basin are the Gumti and the Khowai River, which rises in Tripura and other hilly streams from Meghalaya and Assam of India to join the Meghna.

The streams of the southeast region are all short and of a flashy nature, rising in the Chittagong Hill Tracts or adjacent parts of eastern India. The main streams are the Muhuri, Halda, Sangu, Matamuhuri, etc.

1.3 ACTIVITIES OF FFWC

The importance of the flood forecasting and warning is widely recognized as a vital non-structural measures to aid the mitigating the loss of lives, crops and properties caused by the annual flood occurrence. The Flood Forecasting and Warning Centre, under the Directorate of Processing and Flood Forecasting Circle, Hydrology, BWDB carries out monitoring of 86 representative water level stations and 56 rainfall stations throughout the country. The principal outputs are the daily statistical bulletin of floods, river situation, a descriptive flood bulletin, forecast for 24, 48 & 72 hours about 52 monitoring points, production of Upazilla/Thana Status Map, Satellite Imageries, special flood report along with different graphical and statistical presentation during the monsoon season. The Centre is also involved in preparation of flood status report on National level, a weekly bulletin during dry season and monthly and annual flood reports. The Centre is responsible to act as a focal point in respect of flood from the month of April to November as per Government order for formulating the flood forecasts that are issued with the river situation bulletin and also provide support services to DMB, BMD and SPARRSO during cyclonic disaster.

Earlier before 1990, forecast for six locations viz. Bahadurabad, Serajganj, Aricha, Goalondo, Bhagyakul and Hardinge Bridge on the Padma – Brahmaputra –Jamuna system were issued by Co-axial correlation, Gauge to Gauge relation and Muskingum-Cunge Routing Model. After the devastating flood of 1987 and catastrophic flood of 1988, it was deeply realized that the forecast formulation should be introduced in the process of river modelling. In view of the above, the simulation model MIKE11 developed by Danish Hydraulic Institute (DHI) was installed at FFWC and a special version of MIKE11 FF conceptual Hydrodynamic model is in operation for forecast formulation.

The General Model (GM) developed under MIKE11 was adapted to real time operation in which boundary extended near to the Indian border on all main rivers. A supermodel now is in operational at FFWC covering entire northern flood affected area of Bangladesh.

The Supermodel covers about 82,000 km^2 of entire country, except the coastal zone of the country. The areas are sub-divided into 107 sub-catchments. It includes 195 river branches, 207 link channels, 40 Broad Crested Weirs. The total river length modeled is about 7300 km. Model operation and data base management, a well-managed server based (Widows 2000) LAN– Operating System has been installed with 15 PCs at the FFWC.

1.4 OPERATIONAL STAGES BEFORE FORECAST MODEL RUN

Data Collection: The real time hydrological data (86 WL stations and 56 rainfall stations) is collected by SSB wireless, fixed & mobile telephone from the BWDB hydrological network. WL for non-tidal stations are collected five times daily at 3 hourly intervals during day time from 6:00 AM to 6:00 PM, and for tidal stations collected hourly. Rainfall is collected daily period beginning at 9 AM. The data collections at FFWC are usually completed by 10:30 A.M. Limited WL, rainfall and forecasts of upper catchments from Indian stations are also collected through internet, e-mail, and from BMD.

Essential Information's: Estimation of WL at the model boundaries and rainfall for the catchments are required input to the model upto the time of Forecast (24h, 48h & 72h). For the rainfall estimation, satellite images from NOAA and IMD is used. In addition a dedicated land line radar link with BMD (Bangladesh Meteorological Department) provided frequent (five minutes interval) rainfall information.

Forecast Calculation: Collected/observed WL and rainfall data are given input to the computer database and checked. The WL and rainfall estimation has to be prepared. The basis for WL estimation is considering trend Hydrograph extrapolated upto the period of forecast from previous few days data, response characteristics of rivers, effect of rainfall on WL and Indian available WL & forecasts data. Rainfall estimation based on previous 2-day's rainfall and analysis of information collected. After input required data and boundary-estimated data to the model, model run started. It takes 30 to 40 minutes time to complete the calculations.

Daily forecast bulletin is prepared upto 72 hours for important locations and region-wise flood warning messages. The bulletins are disseminated to more than 600 recipients including different ministries, offices(central & district level), individuals, print & electronic news media, development partners, research oraganisations, NGO's etc. including President's & Prime Minister's Secretariat. Whenever, the forecast river stage cross the DL, the concern field offices and limited key officials are informed through mobile SMS.

The flood forecast is intended to alert the people of the locality about the predicted WL of floodwater 3-days ahead of its occurrence. An accurate forecast would be one where the forecast level and corresponding observed level at the stipulated time are within a small range of variation.

1.5 NATURE AND CAUSES OF FLOODING

1.5.1 CAUSATIVE FACTORS

There are two distinct seasons, a dry season from November to April (or May) and the wet (flood) season from June to September (or October). Over 80% of the rainfall occurs during the monsoon or rainy season also known as flood season. The normal annual rainfall of the country varies approximately from 1,200 mm in the west to over 5,000 mm in the 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.

Floods in Bangladesh occur for number of reasons. The main causes are excessive precipitation, low topography and flat slope of the country; but others include:

- *The geographic location and climatic pattern:* Bangladesh is located at the foot of the highest mountain range in the world, the Himalayas, which is also the highest precipitation zone in the world. This rainfall is caused by the influence of the south-west monsoon. Cherapunji, highest rainfall in the world, is located a few kilometres north east of the Bangladesh border
- *The confluence of three major rivers, the Ganges, the Brahmaputra and the Meghna:* the runoff from their vast catchment (about 1.72 million km^2) passes through a small area, only 8% of these catchments lie within Bangladesh. During the monsoon season the amount of water entering Bangladesh from upstream is greater than the capacity of the rivers to discharge in to the sea.
- *Bangladesh is a land of rivers:* there are about 310 major and minor rivers in the country. The total annual runoff of surface water flowing through the rivers of Bangladesh is about 12,000 billion cubic meters.
- *Man-made environment:* the construction of embankments in the upstream catchments reduces the capacity of the flood plains to store water. The unplanned and unregulated construction of roads and highways in the flood plain without adequate opening creates obstructions to flow.
- *The influence of tides and cyclones*: the frequent development of low pressure areas and storm surges in the Bay of Bengal can impede drainage. The severity of flooding is greatest when the peak floods of the major rivers coincide with these effects.
- *Long term environmental changes:* climate changes could influence the frequency and magnitude of flooding. A higher sea level will inhibit the drainage from the rivers to the sea and increase the impact of tidal surges. Deforestation in hilly catchments causes more rapid and higher runoff, and hence more intense flooding.

The springtides of the Bay of Bengal retards the drainage of floodwater into the sea and locally increases monsoon flooding. A rise of MSL at times during the monsoon period due to effect of monsoon winds also adversely affect the drainage and raise the flood level along the coastal belt.

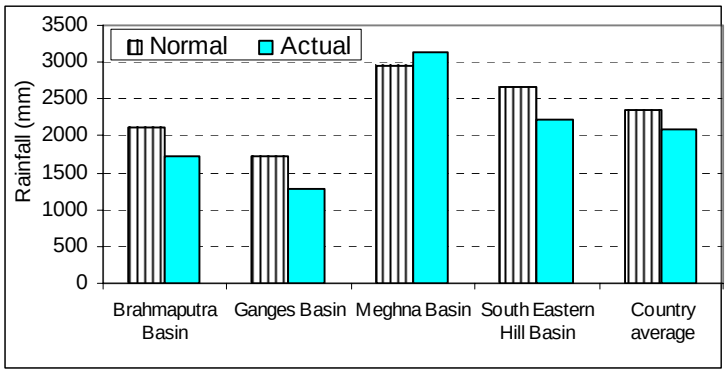
1.5.2 STATISTICS OF FLOODING

Many parts of the Asia during monsoon frequently suffer from severe floods. Some parts of India and Bangladesh experience floods almost every year with considerable damage. The floods of 1954, 1955, 1974, 1987, 1988, 1998, 2004 and 2007 all caused enormous damages to properties and considerable loss of life. The floods of 1987, 1988 1998, 2004 and 2007 flood caused heavy damage. During the monsoon 2010, the flood was not severe one and stayed for short duration in three basins, the Brahmaputra, the Ganges and South Eastern Hill Basin. In the North Eastern part of the country, in the Meghna basin duration of WL above DL was prolong in few stations, longer then the previous flood years(1988 and 1998). The north eastern part also adversely affected by the pre-monsoon flash flood, in the last part of April and again the first part of May resulted standing crop damages. Flood statistics for Bangladesh are available since 1954 and are summarized in Table 3.1.

Table 1.1: Year-wise Flood Affected Area in Bangladesh

Year	Flood Affected area		Year	Flood affected area		Year	Flood affected area	
	Sq-Km	%		Sq-Km	%		Sq-Km	%
1954	36,800	25	1974	52.600	36	1993	28,742	20
1955	50,500	34	1975	16,600	11	1994	419	0.2
1956	35,400	24	1976	28,300	19	1995	32,000	22
1960	28,400	19	1977	12,500	8	1996	35,800	24
1961	28,800	20	1978	10,800	7	**1998**	**1,00,250**	**68**
1962	37,200	25	1980	33,000	22	1999	32,000	22
1963	43,100	29	1982	3,140	2	2000	35,700	24
1964	31,000	21	1983	11,100	7.5	2001	4,000	2.8
1965	28,400	19	1984	28,200	19	2002	15,000	10
1966	33,400	23	1985	11,400	8	2003	21,500	14
1967	25,700	17	1986	6,600	4	2004	55,000	38
1968	37,200	25	1987	57,300	39	2005	17,850	12
1969	41,400	28	**1988**	**89,970**	**61**	2006	16,175	11
1970	42,400	29	1989	6,100	4	**2007**	**62,300**	**42**
1971	36,300	25	1990	3,500	2.4	2008	33,655	23
1972	20,800	14	1991	28,600	19	2009	28,593	19
1973	29,800	20	1992	2,000	1.4	2010	26,530	18

CHAPTER 2: RAINFALL SITUATION



During the monsoon-2010 (May to October), the country experienced as a whole 12% less rainfall than normal. The Ganges, South Eastern Hill & Brahmaputra basins received 26%, 17% and 18% less rainfall than the normal value respectively and only the Meghna basin (in the north-eastern region of the country) received 6% more rainfall. Comparison of the basin and country average of normal and actual rainfall for the monsoon-2010 (May to October) is presented in the bar chart. Considering monthly value, all the basins experienced more rainfall than their respective normal in June. In the Meghna basin during the monsoon 2010 all monthly rainfall value are higher than the normal, except July. For the Meghna basin the monsoon 2010 may be considered as a wet year. Monthly total of normal, actual and comparisons of monsoon rainfall is shown in Table 2.1.

Table 2.1: Rainfall statistics for the monsoon 2010 over the four Basins:

Month	Brahmaputra Basin(mm)		Ganges Basin(mm)		Meghna Basin(mm)		South Eastern Hill Basin(mm)		Monsoon average (mm)	
	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual	Normal	Actual
May	315.4	274.8	204.8	166.6	491.1	551.8	290.4	270.7		
June	433.5	488.7	340.3	354.8	621.0	792.8	599.8	675.6		
July	496.1	259.7	413.6	237.7	650.5	465.6	728.5	360.4		
August	346.5	302.1	337.8	176.9	538.9	580.6	536.9	393.9	2358	2084
September	359.5	259.96	298.7	220.0	449.2	519.2	317.9	186.3		
October	155.6	133.7	129.9	125.1	194.7	217.9	183.4	321.8		
Total	2106.6	1718.96	1725.1	1281.1	2945.4	3127.9	2656.9	2208.7		
% More/Less	18% less		26% less		6% more		17% less		12% less	

Monthly rainfall situation of the country for the monsoon-2010 is described in the following sections.

2.1 APRIL

Important Rainfall Information for April 2010
Maximum, at Kanaighat : 955.0 mm
One day maximum, at Sylhet : 190.0 mm

Exceeded Highest Record (May):
Rainfall at Sylhet exceeded its Highest Record.

The country, as a whole, experienced rainfall less than normal in April 2010 except Meghna basin. The Brahmaputra, the Ganges, and the South Eastern Hill basins received 9.5%, 83.4%, and

62.2% less while the Meghna basin received 57% more rainfall than the respective monthly normal Tables 2.2 to 2.5.

Table 2.2: Rainfall in the Brahmaputra Basin during month of April (mm)

Station Name	Rain fall (mm)						% less/more of the basin
	Max.	Nor	Act	Dev	1 dy max	10 dy max	
Kurigram	282.5	119.2	305.8	186.6	93.0	299.3	9.47% less than the normal of the basin
Dalia	242.4	102.1	37.0	-65.1	20.0	36.0	
Kaunia	332.5	113.3	259.0	145.7	114.0	250.0	
Rangpur	189.9	164.8	163.3	-1.6	42.2	129.9	
Chilmari	315.5	116.8	235.7	118.9	60.3	197.9	
Dewanganj	434.3	129.0	60.0	-69.0	25.0	60.0	
Gaibandha	0	101.7	0	-101.7	0	0	
Bogra	242.6	89.4	0	-89.4	0	0	
Jamalpur	345.8	116.4	63.5	-52.9	40.0	63.5	
Mymensingh	346.2	145.3	144.2	-1.1	37.2	127.2	
Dhaka	318.0	159.1	11.0	-148.1	11.0	11.0	
Tangail	267.7	112.7	51.4	-61.3	30.0	39.0	
	Average	122.5	110.9				

Max –Maximum; Nor-Normal; Act-Actual, Dev–Deviation (- less than normal), 1 dy - 1 day, 10 dy- 10 days

In the Brahmaputra basin Kurigram, Kaunia and Chilmari received more rainfall than their normal. Other stations received less rainfall than the normal and the basin as a whole received 9.5% less rainfall than the normal(Table- 2.2). None of the stations received 300mm rainfall in 10-day period.

Table 2.3: Rainfall in the Ganges Basin during month of April (mm)

Station Name	Rainfall (mm)						% less/more of the basin
	Max.	Nor	Act	Dev	1 dy max	10 dy max	
Panchagar	172.8	68.6	104.0	35.4	47.0	86.5	83.4% less than the basin normal
Dinajpur	188.5	69.9	25.7	-44.2	13.5	13.5	
Pabna	-	76.0	12.0	-64	12.0	12.0	
Naogaon	378.5	69.9	0	-69.9	0	0	
Rajshahi	227.2	59.3	6.0	-53.3	5.0	6.0	
Kushtia	250.8	83.0	12.7	-70.3	9.5	9.5	
Jessore	329.9	82.7	33.3	-49.4	17.6	33.3	
Khulna	276.0	87.2	0	-87.2	0	0	
Satkhira	326.3	93.0	33.0	-60	18.8	33.0	
Faridpur	483.1	517.7	9.2	-508.5	7.2	7.2	
Barisal	311.5	105.0	0	-105	0	0	
Patuakhali	306.7	109.8	0	-109.8	0	0	
	Average	118.5	19.7				

In the Ganges basin only the Panchagar received more rainfall than the monthly normal. Other stations received less rainfall than their normal and the basin as a whole received 8.4% less rainfall than the normal during April-2010 (Table- 2.3).

Table 2.4: Rainfall in the Meghna Basin during month of April (mm)

Station Name	Rainfall (mm)						% less/more of the basin
	Max.	Nor	Act	Dev	1dy max	10 dy max	
Kanaighat	960.0	457.0	955.0	498.0	158.0	553.0	56.95% more than the basin normal
Sylhet	928.9	386.5	940.0	553.5	190.0	627.0	
Sunamganj	0	287.0	610.0	323.0	91.0	411.0	
Sheola	994.7	403.7	821.0	417.3	96.0	467.0	
Moulvi Bazar	0	263.0	329.0	66.0	114.0	326.0	
Manu Rly Br	0	262.8	401.0	138.2	78.0	335.0	
Habiganj	0	228.2	199.0	-29.2	64.0	169.5	
Durgapur	0	160.0	243.9	83.9	37.0	163.0	
Bhairab Bazar	388.8	167.7	38.0	-129.7	28.0	35.0	
Comilla	571.3	182.5	47.5	-135.0	14.5	33.5	
Chandpur	0	144.7	36.0	-108.7	29.5	36.0	
Average		267.6	420.0				

Table 2.5: Rainfall in the South Eastern Hill Basin during month of April (mm)

Station Name	Rainfall (mm)						% less/more of the basin
	Max.	Nor	Act	Dev	1dymax	10dmax	
Parshuram	561.9	166.9	24.0	-142.9	16.0	21.0	62.2% less than the basin normal
Noakhali	0	156.0	0	-156.0	0	0	
Narayanhat	172.8	68.6	156.5	87.9	48.0	118.0	
Panchpukuria	0	147.0	78.0	-69.0	34.0	43.0	
Bandarban	786.0	161.7	111.5	-50.2	54.0	69.0	
Rangamati	0	119.0	33.0	-86.0	23.0	23.0	
Lama	0	109.0	16.0	-93.0	9.0	9.0	
Chittagong	0	152.0	84.0	-68.0	47.0	47.0	
Ramgarh	0	119.0.	35.0	-84.0	17.0	33.0	
Sandwip	0	132.0	0	-132.0	0	0	
Cox'sS Bazar	0	81.0	0	-81.0	0	0	
Average		129.3	48.9				

The Meghna basin experienced almost 1.5 times higher rainfall than normal. Among all the monitoring stations, Kanaighat in the Meghna basin is the highest rainfall recipient station of the month (955 mm). Kanaighat, Sylhet, Sunamganj, Sheola, Moulvi Bazar, Manu Railway Bridge and Durgapur received higher rainfall than the monthly normal. Six stations in the north east area received more than 300 mm rainfall in 10-day period. It may be mentioned that 300 mm or more rainfall in 10-day period may cause rain fed flood. Sylhet station experienced 190 mm of rainfall on the 11th April, which was highest rainfall in one day over the country and it exceeded its previous maximum value. Unlike other basins, the Meghna basin received about 57% more rainfall than normal during this month and for this basin, April was the wet month.

All the stations in South Eastern Hill basin, except Narayanhat, received less rainfall than their normal value and the basin as a whole received 62.2% less rainfall than its monthly normal rainfall(Table-2.5).

2.2 MAY

Important Rainfall Information for May 2010
Monthly Maximum at Kanaighat : 1433.0mm
One day maximum at Sheola : 191.0mm

Exceeded Highest Record (May):
Rainfall at none of the stations exceeded its Highest Record.

Among the four hydrological basins, the Brahmaputra, the Ganges and the South Eastern Hill basins received 12.84%, 18.65% and 6.77% less rainfall respectively and the Meghna basin received 12.38% more rainfall than the monthly normal rainfall. Basin-wise rainfall value for month of May 2010 is shown in the Tables 2.6 to 2.9.

Table 2.6: Rainfall in the Brahmaputra Basin during month of May (mm)

Station Name	Rain fall (mm)						% less/more of the basin
	Max.	Nor	Act	Dev	1 dy max	10 dy max	
Kurigram	646.7	317.5	333.9	16.4	69.3	203.9	12.84% less of the basin
Dalia	646.0	292.3	369.0	76.7	118.0	318.0	
Kaunia	795.1	313.4	250.0	-63.4	39.0	111.0	
Rangpur	478.1	265.4	184.7	-80.7	55.0	87.8	
Chilmari	682.2	336.8	400.8	64.0	102.5	230.4	
Dewanganj	593.4	329.3	305.0	-24.3	100.0	160.0	
Gaibandha	1025.7	349.5	130.8	-218.7	72.0	118.8	
Bogra	471.7	244.6	143.8	-100.8	91.5	116.8	
Jamalpur	1114.3	346.4	471.5	125.1	160.0	343.0	
Mymensingh	794.1	389.3	293.1	-96.2	117.2	231.1	
Dhaka	707.0	345.5	152.9	-192.6	72.5	103.6	
Tangail	504.4	254.4	263.1	8.7	107.0	151.9	
	Average	315.4	274.9				

Max –Maximum; Nor-Normal; Act-Actual, Dev–Deviation (- less than normal), 1 dy - 1 day, 10 dy- 10 days

Table 2.7: Rainfall in the Ganges Basin during month of May (mm)

Station Name	Rainfall (mm)						% less/more of the basin
	Max.	Nor	Act	Dev	1 dy max	10 dy max	
Panchagar	517.3	218.6	351.4	132.8	96.5	177.7	18.65% less of the basin
Dinajpur	577.9	223.8	234.0	10.2	67.2	172.8	
Pabna	-	201.1	182.1	-19.0	45.0	116.0	
Naogaon	320.0	168.0	162.0	-6.0	88.0	137.0	
Rajshahi	323.3	143.1	99.0	-44.1	55.0	69.0	
Kushtia	390.5	194.2	161.4	-32.8	38.7	81.2	
Jessore	386.3	196.7	250.0	53.3	55.8	157.6	
Khulna	307.6	226.5	142.0	-84.5	36.0	92.0	
Satkhira	291.8	153.1	176.3	23.2	48.2	107.7	
Faridpur	805.0	264.8	180.1	-84.7	40.0	87.8	
Barisal	520.5	241.0	34.0	-207.0	19.0	25.0	
Patuakhali	412.8	226.7	27.0	-199.7	22.0	22.0	
	Average	204.8	166.6				

In the Brahmaputra basin Kurigram, Dalia, Chilmari, Jamalpur and Tangail received more rainfall than their normal. Other stations received less rainfall than the normal and the basin as a whole received 12.84% less rainfall than the normal(Table- 2.6).

In the Ganges basin Panchagar, Dinajpur, Jessore and Satkhira received more rainfall than their normal. Other stations received less rainfall than their normal and the basin as a whole received 18.65% less rainfall than the normal during May-2010 (Table- 2.7).

Table 2.8: Rainfall in the Meghna Basin during month of May (mm)

Station Name	Rainfall (mm)						% less/more of the basin
	Max.	Nor	Act	Dev	1dy max	10 dy max	
Kanaighat	1433	714.7	937.0	222.3	138.0	510.0	12.38% more of the basin
Sylhet	1270	578.4	741.0	162.6	110.0	443.0	
Sunamganj	-	600.6	747.0	146.4	126.0	448.0	
Sheola	1324	589.2	699.0	109.8	191.0	392.0	
Moulvi Bazar	-	477.8	444.0	-33.8	105.0	290.0	
Manu Rly Br	-	491.0	644.0	153.0	140.0	390.0	
Habiganj	-	495.4	421.5	-73.9	113.3	284.8	
Durgapur	-	425.7	480.4	54.7	89.5	322.9	
Bhairab Bazar	801	379.9	436.0	56.1	110.0	307.0	
Comilla	791	365.7	363.0	-2.7	89.0	238.0	
Chandpur	-	283.1	157.2	-125.9	61.0	134.0	
Average		491.1	551.8				

Table 2.9: Rainfall in the South Eastern Hill Basin during month of May (mm)

Station Name	Rainfall (mm)						% less/more of the basin
	Max.	Nor	Act	Dev	1dymax	10dymax	
Parshuram	946.4	345.4	225.6	-119.8	69.0	134.5	6.77% less of the basin
Noakhali	-	357.3	241.7	-115.6	74.0	230.7	
Narayanhat	517.3	218.6	168.0	-50.6	28.5	131.0	
Panchpukuria	-	241.0	329.8	88.8	128.0	315.0	
Bandarban	553.8	290.7	330.5	39.8	61.0	279.5	
Rangamati	-	324.1	345.5	21.4	135.0	337.5	
Lama	-	286.7	399.0	112.3	73.0	333.0	
Chittagong	-	326.4	280.0	-46.4	37.0	244.0	
Ramgarh	-	280.0	247.0	-33.0	46.0	179.0	
Sandwip	634.2	236.1	66.0	-170.1	19.0	50.0	
Cox'sS Bazar	-	288.1	345.0	56.9	162.0	320.0	
Average		290.4	270.7				

Almost every station in the Mghna basin experienced moderately heavy to very heavy rainfall in May. In 21st May, all of the stations experienced very heavy rainfall in an average of 106.5mm. All the stations except Moulvi Bazar, Habiganj and Chandpur received more rainfall than their normal rainfall. The basin as a whole received 12.38% more rainfall than its normal rainfall during the month of May 2010 (Table-2.8). The

rainfall stations in the north east part received more rainfall than the normal of the month, May-2010 and it may be considered as the wet month for the area.

All the stations in South Eastern Hill basin, except Bandarban, Panchpukuria, Rangamati, Lama and Cox's Bazar received less rainfall than their normal value. The basin as a whole received 6.77% less rainfall than its normal rainfall during May 2010 (Table-2.9). Rainfall isohyets of the actual rainfall for the month of May-2010 is shown in the Figure 2.1.

Tables 2.6 to 2.9 indicated 2 stations (Dalia and Jamalpur) in Brahmaputra basin, 7 stations (Kanaighat, Sylhet, Sunamgonj, Sheola, Manu Railway Bridge, Durgapur and Bhairab Bazar) in Meghna basin and 4 stations (Panchpukuria, Rangamati, Lama and Cox's Bazar) in the South Eastern Hill basin received more than 300 mm rainfall in 10-day period. It may be mentioned that 300 mm or more rainfall in 10-day period may cause rain fed flood.

2.3 JUNE

Important Rainfall Information for June 2010
Maximum, at Kanaighat : 1387.0 mm
One day maximum, at Swandip : 249.0 mm

Exceeded Highest Record (June):
Rainfall at Dalia and Kanaighat stations exceeded its Highest Record.

The country, as a whole, experienced rainfall more than normal during the month of June 2010. The four hydrological basins, the Brahmaputra basin, the Ganges, the Meghna and South Eastern Hill basins received 12.73%, 4.27%, 27.66% and 12.63% more rainfall than their respective monthly normal rainfall. Basin-wise rainfall statistics for the month of June 2010 are shown in the Tables below:

Table 2.10: Rainfall in the Brahmaputra Basin during the month of June (mm)

Station Name	Rain fall (mm)						% less/more of the basin
	Max.	Nor	Act	Dev	1 dy max	10 dy max	
Kurigram	1433.7	526.8	553.0	26.2	90.5	288.0	12.73% more of the basin normal
Dalia	861.9	481.7	876.0	394.3	184.0	491.0	
Kaunia	1155.7	482.1	417.0	-65.1	82.0	216.0	
Rangpur	983.4	460.0	630.7	170.7	102.0	390.2	
Chilmari	1139.0	444.0	798.5	354.5	170.0	534.3	
Dewanganj	984.2	422.4	238.0	-184.4	40.0	115.0	
Gaibandha	715.0	375.5	405.0	29.5	77.0	218.0	
Bogra	820.4	341.4	378.0	36.6	101.8	200.1	
Jamalpur	1015.3	486.0	427.8	-58.2	92.0	251.8	
Mymensingh	952.6	482.5	374.1	-108.4	40.0	204.2	
Dhaka	648.9	348.6	346.3	-2.3	63.0	173.0	
Tangail	799.5	350.7	419.4	68.7	112.0	214.9	
Average		433.5	488.7				

In the Brahmaputra basin Kurigram, Dalia, Rangpur, Chilmari, Gaibandha, Bogra, and Tangail received more rainfall than their normal. Other stations received less rainfall than the normal and the basin as a whole received 12.73% more rainfall than the normal in the month of June-2010(Table- 2.2). In Dalia June-2010 rainfall of 876mm exceeded the previous maximum record of 861.9mm (Table- 2.6).

Table 2.11: Rainfall in the Ganges Basin during the month of June (mm)

Station Name	Rainfall (mm)						% less/more of the basin
	Max.	Nor	Act	Dev	1 dy max	10 dy max	
Panchagarh	1073.7	488.0	639.0	151.0	142.5	398.5	4.27% more of the basin normal
Dinajpur	631.8	362.0	581.1	219.1	145.5	518.8	
Pabna	-	279.0	243.0	-36.0	72.0	152.0	
Naogaon	690.8	262.7	239.0	-23.7	50.0	137.0	
Rajshahi	662.1	243.2	266.0	22.8	60.0	171.0	
Kushtia	573.7	262.3	254.6	-7.7	78.2	174.3	
Jessore	757.7	305.0	341.7	36.7	76.8	190.4	
Khulna	665.0	331.1	328.0	-3.1	49.0	161.0	
Satkhira	808.9	316.6	311.0	-5.6	117.0	204.3	
Faridpur	713.6	308.4	259.5	-48.9	53.0	128.0	
Barisal	1045.2	437.0	400.0	-37.0	86.0	216.0	
Patuakhali	887.1	488.1	395.0	-93.1	88.0	210.0	
	Average	204.8	166.6				

In the Ganges basin Panchagar, Dinajpur, Rajshahi and Jessore received more rainfall than their normal. Other stations received less rainfall than their normal and the basin as a whole received 4.26% more rainfall than the normal during May-2010 (Table- 2.7).

Table 2.12: Rainfall in the Meghna Basin during the month of June (mm)

Station Name	Rainfall (mm)						% less/more of the basin
	Max.	Nor	Act	Dev	1dymax	10 d max	
Kanaighat	1303.0	916.4	1387.0	470.6	170	675	27.67% more of the basin normal
Sylhet	1609.5	841.5	950.0	108.5	130	423	
Sunamganj	-	1084.7	1062.0	-22.7	110	413	
Sheola	1441.5	818.3	1180.0	361.7	217	668	
Moulvi Bazar	-	484.8	699.0	214.2	195	367	
Manu Rly Br	-	516.2	727.0	210.8	110	319	
Habiganj	-	434.2	676.7	242.5	210	307.6	
Durgapur	-	687.6	804.0	116.4	107	457.5	
Bhairab Bazar	674.6	327.4	355.0	27.6	65	189	
Comilla	647.6	386.0	549.6	163.6	118	275.5	
Chandpur	-	334.3	330.7	-3.6	78	180.3	
	Average	621.0	792.8				

In the Meghna basin all the stations received more rainfall than the normal, except Sunamgonj and Chandpur. The basin as a whole received 27.67% more rainfall than the normal in the month of June-2010. In Kanaighat June-2010 rainfall of 1387mm exceeded the previous maximum record of 1303mm (Table- 2.8).

Table 2.13: Rainfall in the South Eastern Hill Basin during the month of June (mm)

Station Name	Rainfall (mm)						% less/more of the basin
	Max.	Nor	Act	Dev	1dymax	10dmax	
Parshuram	912.8	413.5	622.2	208.7	89.5	237.0	12.64% more of the basin normal value
Noakhali	1201.0	622.0	888.5	266.5	117.0	379.8	
Narayanhat	1073.7	488.0	626.0	138.0	170.0	375.5	
Panchpukuria	1256.3	576.0	744.2	168.2	180.0	493.0	
Bandarban	938.8	542.7	521.5	-21.2	92.0	258.5	
Rangamati	1420.2	539.8	461.5	-78.3	105.0	277.5	
Lama	1306.2	712.6	494.5	-218.1	80.0	204.0	
Chittagong	1472.0	628.4	1010.0	381.6	242.0	587.0	
Ramgarh	1696.9	609.0	481.0	-128.0	136.0	237.0	
Sandwip	1994.0	584.7	831.0	246.3	249.0	537.0	
Cox'sS Bazar	1727.7	881.2	751.0	-130.2	186.0	545.0	
Average		599.8	675.6				

The above tables indicated that 5 out of 12 monitoring stations in the Brahmaputra basin, 8 out of 12 monitoring stations in the Ganges basin, 2 out of 11 monitoring stations in the Meghna basin and 5 out of 11 monitoring stations in the South Eastern Hill basin received less rainfall than their monthly normal rainfall for the month of June 2010. Among all monitoring stations, Swanbdip in the South Eastern Hill basin was the daily highest rainfall recipient station.

The tables show that 3 out of 12 monitoring stations in the Brahmaputra basin, 2 out of 12 monitoring stations in the Ganges basin, 8 out of 11 monitoring stations in the Meghna basin and 6 out of 11 monitoring stations in the South-Eastern Hill Basin received more than 300mm rainfall in 10-day period.

Rainfall isohyets of the actual rainfall of the month of June-2010 is shown in the Fig 2.2.

2.4 JULY

The country, as a whole, experienced rainfall less than normal during July 2010. The Brahmaputra, the Ganges, the Meghna and South Eastern Hill basins received 47.66%, 42.53%, 28.42% and 50.53% less rainfall than their respective monthly normal value.

Important Rainfall Information for July 2010
Monthly Maximum at Sunamganj : 1213.0 mm
1 day maximum at Mymensingh : 309.5 mm

Exceeded Highest Record (July):
Rainfall at None of the stations exceeded its Highest Record.

Basin-wise rainfall statistics for the month of July 2010 are shown in the following Tables.

Table 2.14: Rainfall in the Brahmaputra Basin during the month of July (mm)

Name of Stations	Rainfall in mm						% less/more of the basin
	Max	Nor	Act	Dev	1daymax	10daymax	
Kurigram	969.3	530.6	204.9	-325.7	48.5	134.3	
Dalia	1137.5	687.4	531.5	-155.9	121.0	258.0	
Kaunia	1554.5	561.3	200.0	-361.3	79.0	134.0	
Rangpur	1378.6	488.6	372.7	-115.9	78.0	225.5	
Chilmari	1265.8	525.5	215.4	-310.1	50.0	125.3	
Dewanganj	1064.0	493.2	250.0	-243.2	80.0	155.0	
Gaibandha	1164.0	444.9	196.0	-248.9	55.0	124.0	**47.66% Less of the basin**
Bogra	813.1	427.9	93.0	-334.9	24.6	63.4	
Jamalpur	1027.3	521.5	190.3	-331.2	36.0	127.0	
Mymensingh	860.3	569.3	604.5	35.2	309.5	511.3	
Dhaka	694.0	360.2	180.8	-179.4	52.0	104.3	
Tangail	732.1	343.1	76.9	-266.2	35.0	61.9	
	Average	496.1	259.7				

Table 2.15: Rainfall in the Ganges Basin during the month of July (mm)

Name of Stations	Rainfall in mm						% less/more of the basin
	Max.	Nor	Act	Dev	1daymax	10daymax	
Panchagarh	1353.6	812.4	591.1	-221.3	125.0	314.5	
Dinajpur	1020.2	490.2	371.1	-119.1	117.5	238.0	
Pabna	-	290.0	147.7	-142.3	31.0	77.4	
Naogaon	690.7	343.1	113.7	-229.4	22.0	70.0	
Rajshahi	534.1	274.7	117.0	-157.7	23.0	61.0	
Kushtia	656.3	338.3	144.8	-193.5	45.2	81.2	**42.53% Less of the basin**
Jessore	587.0	350.8	169.4	-181.4	49.3	89.1	
Khulna	639.3	351.9	158.0	-193.9	35.0	94.0	
Satkhira	679.7	386.2	174.5	-211.7	58.5	99.4	
Faridpur	842.9	348.9	198.5	-150.4	46.0	137.0	
Barisal	840.0	416.0	249.0	-167.0	56.0	161.0	
Patuakhali	862.7	560.2	417.0	-143.2	90.0	181.0	
	Average	413.6	237.7				

Table 2.16: Rainfall in the Meghna Basin during the month of July (mm)

Name of Stations	Rainfall in mm						% less/more of the basin
	Max.	Nor	Act	Dev	1daymax	10daymax	
Kanaighat	1245.0	814.4	648.0	-166.4	80.0	345.0	
Sylhet	1393.4	829.5	548.0	-281.5	66.0	286.0	
Sunamganj	2097.3	1402.6	1213.0	-189.6	128.0	602.0	
Sheola	1145.5	735.9	535.0	-200.9	62.0	291.0	
Moulvi Bazar	724.4	413.6	174.0	-239.6	45.0	69.0	**28.42% Less of the basin**
Manu Rly Br	643.1	427.4	549.0	121.6	105.0	220.0	
Habiganj	816.1	446.8	291.7	-155.1	72.0	146.0	
Durgapur	1862.3	807.2	726.5	-80.7	140.0	279.5	
Bhairab Bazar	695.4	395.4	135.0	-260.4	39.0	55.0	
Comilla	1019.6	465.0	78.0	-387.0	44.0	50.0	
Chandpur	840.7	417.3	223.3	-194.0	70.0	112.5	
	Average	650.5	465.6				

Table 2.17: Rainfall in the South Eastern Hill Basin during the month of July (mm)

Name of Stations	Rainfall in mm						% less/more of the basin
	Max.	Nor	Act	Dev	1daymax	10daymax	
Parshuram	1133.6	562.7	285.5	-277.2	71.5	138.5	
Noakhali	1285.6	739.3	484.8	-254.5	67.3	244.8	
Narayanhat	1353.6	812.4	262.5	-549.9	140.0	190.5	
Panchpukuria	1201.9	702.0	327.8	-374.2	90.0	154.6	
Bandarban	1398.3	595.5	348.9	-246.6	53.0	181.0	**50.53% Less of the basin**
Rangamati	1491.7	567.5	117.0	-450.5	38.0	65.0	
Lama	1809.5	769.0	426.5	-342.5	95.0	270.0	
Chittagong	1527.0	811.7	252.5	-559.2	95.0	187.0	
Ramgarh	1539.0	626.0	304.0	-322.0	118.0	154.0	
Sandwip	2199.0	882.0	722.0	-160.0	204.0	356.0	
Cox's Bazar	1866.1	945.6	433.0	-512.6	81.0	251.0	
	Average	728.5	360.4				

It may be shown from the tables 2.14 to 2.17, during the month of July all the stations received less rainfall than their normal, except Mymensingh in Brahmaputra basin and Manu Railway Bridge in Meghna basin. The Brahmaputra, Ganges, Meghna and South Eastern Hill basins received 42.65%, 42.53%, 28.42 and 50.53% less rainfall respectively than their normal during the month July 2010.

Isohyets of the actual rainfall of the month of July-2010 are shown in the Figures 2.3.

2.5 AUGUST

The intensity of rainfall in the Brahmaputra, the Ganges and the South Eastern Hill basin was light to moderate at some places during the month of August, whereas that of the Meghna basin was moderate to moderately heavy.

Important Rainfall Information for August 2010
Maximum, at Sunamgonj : 1466.0 mm
One day maximum, at Sunamgonj : 248.0 mm

Exceeded Highest Record (August):
None of the stations in the basin exceeded their respective Highest Record.

Among these four hydrological basins, the Brahmaputra, the Ganges and the South Eastern Hill basin received 12.82%, 47.63% and 26.64% less monthly rainfall than their respective normal rainfall. Conversely the Meghna basin received 7.95% more monthly rainfall than the normal of the basin. Basin-wise rainfall statistics for the month of August 2010 is shown in the following Tables.

Table 2.18: Rainfall in Brahmaputra Basin during the month of August (mm)

Station	Rainfall in mm						Remarks
	Max.	Nor	Act	Dev	1dymax	10dmax	
Kurigram	876.6	340.1	73.6	-266.5	17.5	61.3	
Dalia	1247.5	516.0	483.0	-33.0	196.0	459.0	
Kaunia	745.0	406.2	219.0	-187.2	107.0	210.0	
Rangpur	608.0	340.8	234.4	-106.4	101.0	231.0	
Chilmari	834.4	327.6	221.0	-106.6	60.0	201.5	
Dewanganj	617.0	338.3	415.0	76.7	150.0	365.0	12.82% less than the basin normal
Gaibandha	528.3	236.4	418.0	181.6	109.0	369.0	
Bogra	734.0	297.3	287.1	-10.2	87.5	207.6	
Jamalpur	914.4	367.9	399.1	31.2	98.0	302.1	
Mymensingh	1008.3	396.1	418.6	22.5	85.3	264.6	
Dhaka	484.5	304.8	269.8	-35.0	98.6	182.9	
Tangail	706.5	286.7	186.5	-100.2	46.0	154.9	
	Average	**346.5**	**302.1**				

Table 2.19: Rainfall in Ganges Basin during the month of August (mm)

Station	Rainfall in mm						Remarks
	Max.	Nor	Act	Dev	1dymax	10dmax	
Panchagarh	1341.3	524.9	387.4	-137.5	106.5	310.8	
Dinajpur	891.4	349.7	332.4	-17.3	106.5	273.6	
Pabna	-	264.0	134.8	-129.2	42.3	64.8	
Naogaon	690.5	265.7	154.0	-111.7	68.0	86.0	
Rajshahi	453.0	242.8	123.0	-119.8	36.0	88.0	
Kushtia	767.2	260.3	74.1	-186.2	38.6	42.6	47.63% less than the basin normal
Jessore	751.1	317.8	142.8	-175.0	53.5	88.0	
Khulna	726.5	349.4	217.0	-132.4	65.0	102.0	
Satkhira	571.8	332.1	79.0	-253.1	21.0	39.0	
Faridpur	615.4	259.3	161.0	-98.3	115.0	141.5	
Barisal	817.1	398.0	124.0	-274.0	34.0	88.0	
Patuakhali	798.6	489.2	193.0	-296.2	41.0	115.0	
	Average	**337.8**	**176.9**				

Table 2.20: Rainfall in Meghna Basin during the month of August (mm)

Station	Rainfall in mm						Remarks
	Max.	Nor	Act	Dev	1dymax	10dmax	
Kanaighat	1232.0	800.1	511.0	-289.1	80.0	237.0	
Sylhet	1138.5	605.8	785.0	179.2	186.0	372.0	
Sunamganj	2514.7	1159.4	1466.0	306.6	248.0	1146.0	
Sheola	1070.0	603.0	707.0	104.0	99.0	343.0	
Moulvi Bazar	666.9	377.3	278.0	-99.3	107.0	177.0	
Manu Rly Br	520.6	377.4	526.0	148.6	82.0	236.0	7.95% more than the basin normal
Habiganj	955.5	389.1	576.9	187.8	140.0	316.0	
Durgapur	1093.7	607.0	776.9	169.9	150.0	556.9	
Bhairab Bazar	916.2	314.5	370.0	55.5	71.0	240.0	
Comilla	660.5	347.0	205.0	-142.0	63.0	140.5	
Chandpur	588.6	336.1	185.1	-151.0	66.0	135.0	
	Average	**537.88**	**580.63**				

Table 2.21: Rainfall in South Eastern Hill Basin during the month of August (mm)

	Rainfall in mm						Remarks
Station	**Max.**	**Nor**	**Act**	**Dev**	**1dymax**	**10dmax**	
Parshuram	664.1	403.0	232.0	-171.0	43.5	156.5	26.64% less than the basin normal
Noakhali	994.4	657.4	383.1	-274.3	127.0	286.3	
Narayanhat	1341.3	524.9	361.0	-163.9	105.0	177.0	
Panchpukuria	860.3	478.0	275.5	-202.5	63.0	150.9	
Bandarban	1152.3	440.5	382.3	-58.2	59.0	197.1	
Rangamati	1377.9	439.9	511.6	71.7	75.0	253.5	
Lama	1048.7	607.6	419.0	-188.6	75.0	229.0	
Chittagong	1086.9	538.7	450.0	-88.7	84.0	235.0	
Ramgarh	1075.7	467.0	236.0	-231.0	57.0	156.0	
Sandwip	1820.4	672.1	651.0	-21.1	116.0	492.0	
Cox's Bazar	1286.4	677.1	431.0	-246.1	73.0	291.0	
Average		**536.93**	**393.86**				

According to the tables above (Tables 2.18 to 2.21) the Brahmaputra, the Ganges and the South Easter Hill basins received monthly rainfall below their normal range. Total 8 out of 12 rainfall stations in the Brahmaputra basin and all the stations in the Ganges & South Easter Hill basins received lower rainfall than their respective normal. The Meghna basin received about 8% higher rainfall (7 out of 11 rainfall stations) than normal. Among all the monitoring stations, Dalia in the Brahmaputra, Panchagarh in the Ganges, Sunamgonj in the Meghna and Sandwip in the South Eastern Hill basins are the highest rainfall recipient stations. Tables also indicated 4 stations in the Brahmaputra basin, 1 station in the Ganges basin, 5 stations in the Meghna basin and 1 station in the South Eastern Hill basin received more than 300mm rainfall in 10-day period. Isohyets of the actual rainfall of the month of August are shown in the Figure 2.4.

2.6 SEPTEMBER

Important Rainfall Information for September 2010
Maximum, at Sunamganj : 1036.00 mm
One day maximum, at Dalia : 206.0 mm

Exceeded Highest Record (May):
Rainfall at None of the stations exceeded its Highest Record.

The country, as a whole, experienced rainfall less than normal except in the Meghna basin during September 2010. Among the four hydrological basins, the Brahmaputra, the Ganges, and South Eastern Hill basins received 27.7%, 26.3%, and 41.2% less rainfall respectively and the Meghna basin received 15.6% more rainfall than the respective monthly normal rainfall of the basin. Basin-wise rainfall statistics for the month of September 2010 are shown in the following Tables.

Table 2.22 Rainfall in Brahmaputra Basin during the month of September (mm)

Station	Rainfall in mm						Remarks
	Max.	Nor	Act	Dev	1dymax	10dymax	
Kurigram	746.4	408.5	206.8	-201.7	91.0	147.3	**27.7% less the normal of the month**
Dalia	919.7	412.6	474.0	61.4	206.0	356.0	
Kaunia	1126.9	406.2	254.5	-151.7	144.0	194.0	
Rangpur	876	407.3	330.6	-76.7	93.0	280.2	
Chilmari	728.8	373.2	189.5	-183.7	109.0	159.7	
Dewanganj	742.1	347.0	262.0	-85.0	100.0	199.0	
Gaibandha	753.9	248..0	382.0	134.0	95.0	240.0	
Bogra	762.6	315.6	217.2	-98.4	103.0	152.2	
Jamalpur	844.6	368.7	73.3	-295.4	24.0	65.8	
Mymensingh	1257.0	416.5	287.2	-129.3	84.5	142.3	
Dhaka	712	296.7	274.4	-22.3	70.3	194.0	
Tangail	732	313.9	168.0	-145.9	75.0	137.8	
Average		**359.52**	**259.96**				

Table 2.23 Rainfall in Ganges Basin during the month of September (mm)

Station	Rainfall in mm						Remarks
	Max.	Nor	Act	Dev	1dymax	10dymax	
Panchagarh	1100.9	445.2	600.7	155.5	145.0	403.0	**26.3% less the normal of the month**
Dinajpur	1292.9	383.3	115.2	-268.1	43.0	101.2	
Pabna	-	222.0	160.2	-61.8	45.5	127.2	
Naogaon	616.3	273.2	192.0	-81.2	54.0	113.0	
Rajshahi	650.8	271.0	68.0	-203.0	15.0	48.0	
Kushtia	632.2	249.7	242.3	-7.4	107.6	130.8	
Jessore	694.0	265.1	387.6	122.5	73.5	304.0	
Khulna	667.0	239.0	163.0	-76.0	57.0	147.0	
Satkhira	808.5	314.9	134.0	-180.9	32.0	71.0	
Faridpur	731.1	267.0	203.1	-63.9	62.0	115.0	
Barisal	600.2	313.0	167.0	-146.0	34.0	109.0	
Patuakhali	886.3	340.6	207.0	-133.6	46.0	135.0	
Average		**298.67**	**220.01**				

Table 2.24: Rainfall in Meghna Basin during the month of September (mm)

Station	Rainfall in mm						Remarks
	Max.	Nor	Act	Dev	1dymax	10dmax	
Kanaighat	1032.0	637.8	822.0	184.2	92.0	434.0	**15.6% more the normal of the month**
Sylhet	1220.3	575.2	793.0	217.8	145.0	318.0	
Sunamganj	1130.3	845.3	1036.0	190.7	135.0	549.0	
Sheola	1232.0	551.3	881.0	329.7	137.0	392.0	
Moulvi Bazar	486.6	280.7	152.0	-128.7	21.0	74.0	
Manu Rly Br	640.0	352.9	345.0	-7.9	120.0	189.0	
Habiganj	497.8	301.0	422.0	121.0	63.0	219.5	
Durgapur	1525.2	594.8	362.0	-232.8	180.0	259.5	
Bhairab Bazar	634.8	293.9	361.0	67.1	79.0	293.0	
Comilla	482.6	267.1	388.6	121.5	80.0	203.6	
Chandpur	602.0	241.3	148.5	-92.8	25.0	81.5	
Average		**449.21**	**519.19**				

Table 2.25: Rainfall in South Eastern Hill Basin during September-2010 (mm)

Station	Rainfall in mm						Remarks
	Max.	Nor	Act	Dev	1dymax	10dymax	
Parshuram	510.7	238.5	216.0	-22.5	45.2	139.2	**41.4% less the normal of the month**
Noakhali	733.4	428.4	274.2	-154.2	79.3	242.4	
Narayanhat	1100.9	445.2	142.5	-302.7	22.5	91.5	
Panchpukuria	493.5	236.0	210.3	-25.7	29.0	114.0	
Bandarban	574.2	281.0	166.2	-114.8	31.5	114.7	
Rangamati	436.8	269.6	190.5	-79.1	45.0	125.5	
Lama	662.2	319.7	133.0	-186.7	17.0	68.0	
Chittagong	638.8	289.0	52.0	-237	13.0	37.0	
Ramgarh	472.3	260.0	152.0	-108.0	34.0	84.0	
Sandwip	881.4	389.0	278.0	-111.0	35.0	138.0	
Cox' Bazar	924.1	340.9	234.0	-106.9	40.0	158.0	
Average		**317.94**	**186.25**				

It may be seen from the Tables-2.22 to 2.25 that, all the stations received less rainfall than their monthly normal rainfall except 2 stations in the Brahmaputra basin, 2 stations in Ganges basin and 6 stations in the Meghna basin. Among all monitoring stations, Dalia in the Brahmaputra basin is the daily highest rainfall recipient station. 2 stations in the Brahmaputra, 2 stations in the Ganges and 4 stations in the Meghna basins received more than 300 mm rainfall in 10-day period. Isohyets of actual rainfall of the month of September are shown in the Figure 2.5.

2.7 OCTOBER

Important Rainfall Information for October 2010
Maximum, at Noakhali : 535.0 mm
One day maximum, at Rangamati : 225.0 mm

Exceeded Highest Record (August):
Non of the stations exceeded their respective Highest Record.

Many areas of the country experienced heavy to very heavy rainfall for consecutive two days at the end of the 1st week of the month. But as a whole, among four hydrological basins of the country, the Brahmaputra and the Ganges basin received 14% and 3.6% less rainfall respectively than their monthly normal rainfall while the Meghna (in the north eastern part) and South Eastern Hill Basin (in the south eastern part of the country) received 12% and 75% more rainfall than their monthly normal rainfall. All the rainfall monitoring stations of the south eastern part of the country received significantly higher rainfall than the normal value, though none of the station exceeded the previous maximum rainfall record. As a whole, October 2010 was the wet month in the entire eastern part of the country. Basin wise rainfall statistics for the month of October 2010 is shown in the following Tables.

Table 2.26: Rainfall in Brahmaputra Basin during the month of October (mm)

Station	Rainfall in mm						Remarks
	Max.	Nor	Act	Dev	1dymax	10dmax	
Kurigram	576.8	174.4	100.3	-74.1	45.0	93.3	
Dalia	326.6	138.8	21.0	-117.8	8.0	14.0	
Kaunia	402.6	152.1	77.5	-74.6	34.0	77.5	
Rangpur	293.0	130.0	118.5	-11.5	55.0	118.5	
Chilmari	664.1	160.1	114.7	-45.4	72.2	114.7	
Dewanganj	739.0	176.5	115.0	-61.5	75.0	115.0	14 % less than the basin normal
Gaibandha	490.3	133.2	69.0	-64.2	28.0	69.0	
Bogra	436.4	144.7	235.9	91.2	102.0	213.4	
Jamalpur	437.0	136.1	140.0	3.9	90.0	140.0	
Mymensingh	590.8	209.8	162.8	-47.0	75.3	150.8	
Dhaka	392.0	166.6	149.8	-16.8	84.0	149.8	
Tangail	498.1	144.9	300.0	155.1	80.0	227.0	
Average		**155.6**	**133.7**				

Table 2.27: Rainfall in Ganges Basin during the month of October (mm)

Station	Rainfall in mm						Remarks
	Max.	Nor	Act	Dev	1dymax	10dmax	
Panchagarh	336.9	101.4	61.8	-39.6	22.3	36.8	
Dinajpur	502.9	113.2	48.7	-64.5	30.5	48.7	
Pabna	-	124.0	90.1	-33.9	45.5	88.0	
Naogaon	401.5	113.2	104.0	-9.2	62.0	84.0	
Rajshahi	348.0	97.0	74.0	-23.0	45.0	73.0	
Kushtia	344.5	118.1	73.4	-44.7	41.0	70.1	
Jessore	282.4	120.3	139.9	19.6	52.0	119.8	
Khulna	461.0	143.1	218.0	74.9	130.0	218.0	3.6 % less than the basin normal
Satkhira	391.2	126.0	53.0	-73.0	31.0	53.0	
Faridpur	470.1	137.4	138.2	0.8	81.2	137.2	
Barisal	459.2	175.0	199.0	24.0	155.0	199.0	
Patuakhali	479.8	189.5	301.0	111.5	221.0	301.0	
Average		**129.9**	**125.1**				

Table 2.28: Rainfall in Meghna Basin during the month of October (mm)

Station	Rainfall in mm						Remarks
	Max.	Nor	Act	Dev	1dymax	10dmax	
Kanaighat	569.5	263.2	227.0	-36.2	145	177	
Sylhet	699.4	241.9	263.0	21.1	175	242	
Sunamganj	880.6	273.1	172.0	-101.1	89	162	
Sheola	692.0	211.9	174.0	-37.9	137	166	
Moulvi Bazar	464.1	143.1	266.0	122.9	135	239	
Manu Rly Br	577.0	202.9	100.0	-102.9	75	87	12 % more than the basin normal
Habiganj	732.5	176.8	297.5	120.7	115	237	
Durgapur	595.6	203.6	132.0	-71.6	90	131	
Bhairab Bazar	365.1	153.7	311.0	157.3	141	218	
Comilla	360.3	152.5	301.5	149	112	295	
Chandpur	498.9	119.0	152.9	33.9	80	131.6	
Average		**194.7**	**217.9**				

Table 2.29: Rainfall in South Eastern Hill Basin during the month of October (mm)

	Rainfall in mm						Remarks
Station	**Max.**	**Nor**	**Act**	**Dev**	**1dymax**	**10dmax**	
Parshuram	387.7	142.4	361.2	218.8	154	329	75 % more than the basin normal
Noakhali	537.9	187.4	535.7	348.3	195.4	476.7	
Narayanhat	336.9	101.4	253.0	151.6	95	178.5	
Panchpukuria	378.0	175.0	289.0	114.0	122	227	
Bandarban	410.8	184.5	283.0	98.5	71	255.5	
Rangamati	529.2	151.5	386.5	235.0	225	366	
Lama	445.4	176.0	309.0	133.0	86	294	
Chittagong	636.3	220.3	317.0	96.7	120	284	
Ramgarh	515.2	237.0	333.0	96.0	124	267	
Sandwip	937.8	235.0	252.0	17.0	185	252	
Cox' Bazar	684.0	206.7	220.0	13.3	95	220	
Average		**183.38**	**321.76**				

According to the tables above (Tables 2.26 to 2.29) during the month of October 2010, the Brahmaputra and the Ganges basin experienced less rainfall than their respective normal rainfall by 14 % and 3.6% respectively while the Meghna basin and the South-Eastern Hill basin experienced more rainfall than their respective normal rainfall by 12 % and 75 % respectively. Tangali in the Brahmaputra basin, Patuakhali in the Ganges basin, Comilla in the Meghna Bain and Noakhali in the South Eastern Hill basin are the highest rainfall recorded stations.

The tables also show that 1 out of 11 stations in the Ganges basin, 5 out of 11 Stations in the Meghna basin and 3 out of 11 Stations in the South Eastern Hill basin received more than 300mm rainfall in 10-day period while none of the stations in the Brahmaputra and the Meghna basin received more than 300 mm rainfall in 10-day period. Rainfall isohyets of the actual rainfall of the month of October are shown in the Figure 2.6.

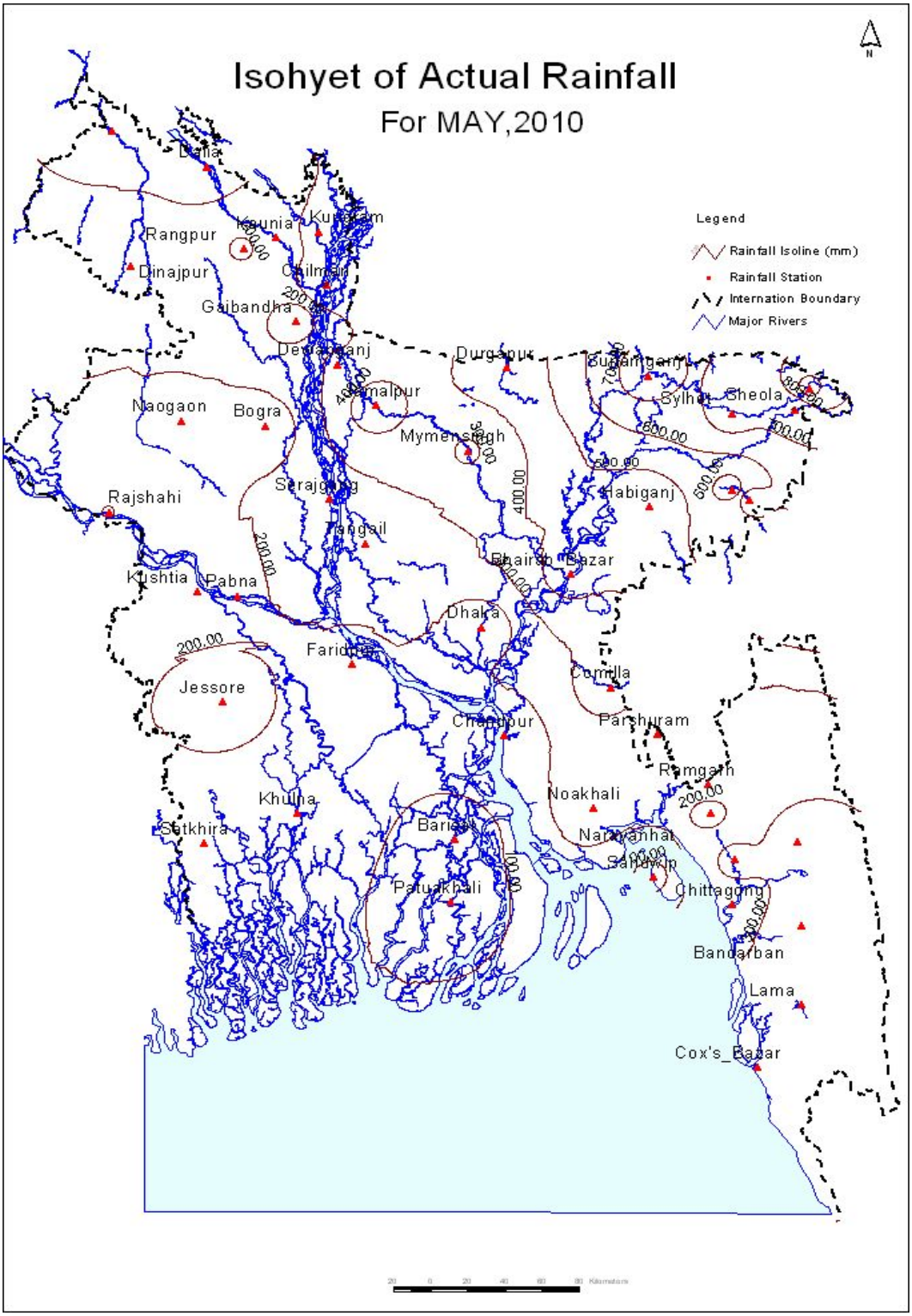


Figure 2.1: Isohyets of Actual Rainfall (May 2010)

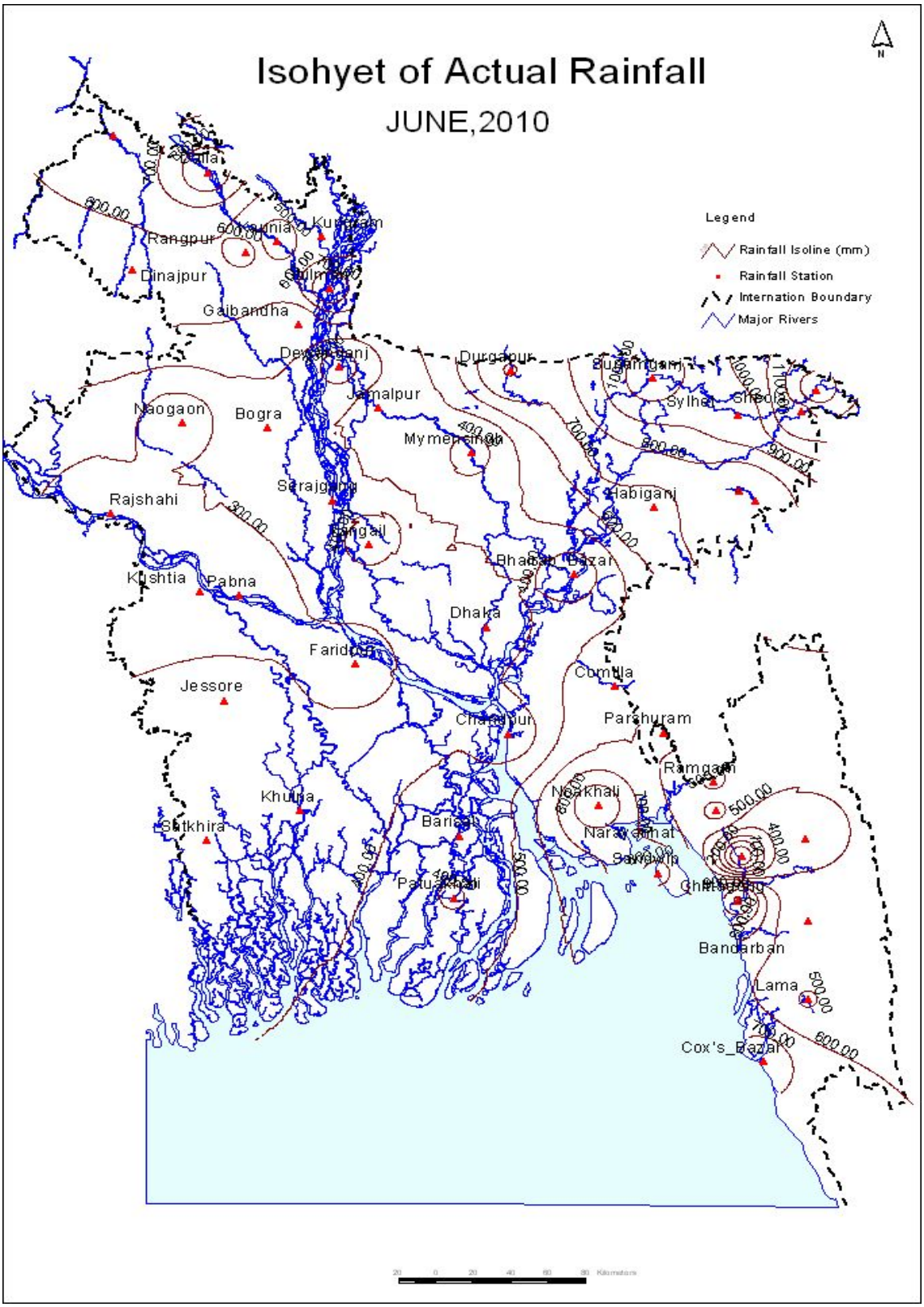


Figure: 2.2: Isohyets of Actual Rainfall (June 2010)

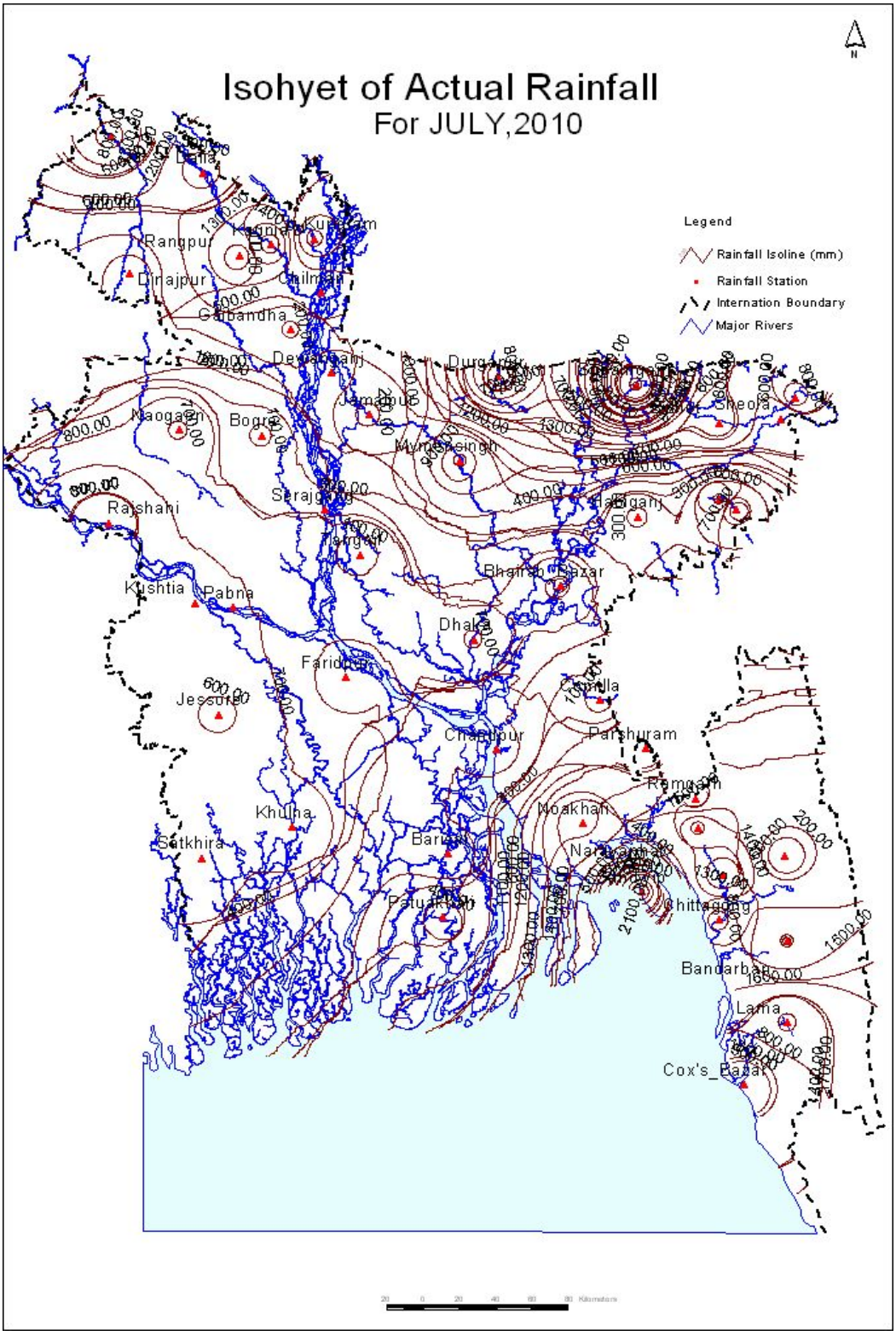


Figure: 2.3: Isohyets of Actual Rainfall (July 2010)

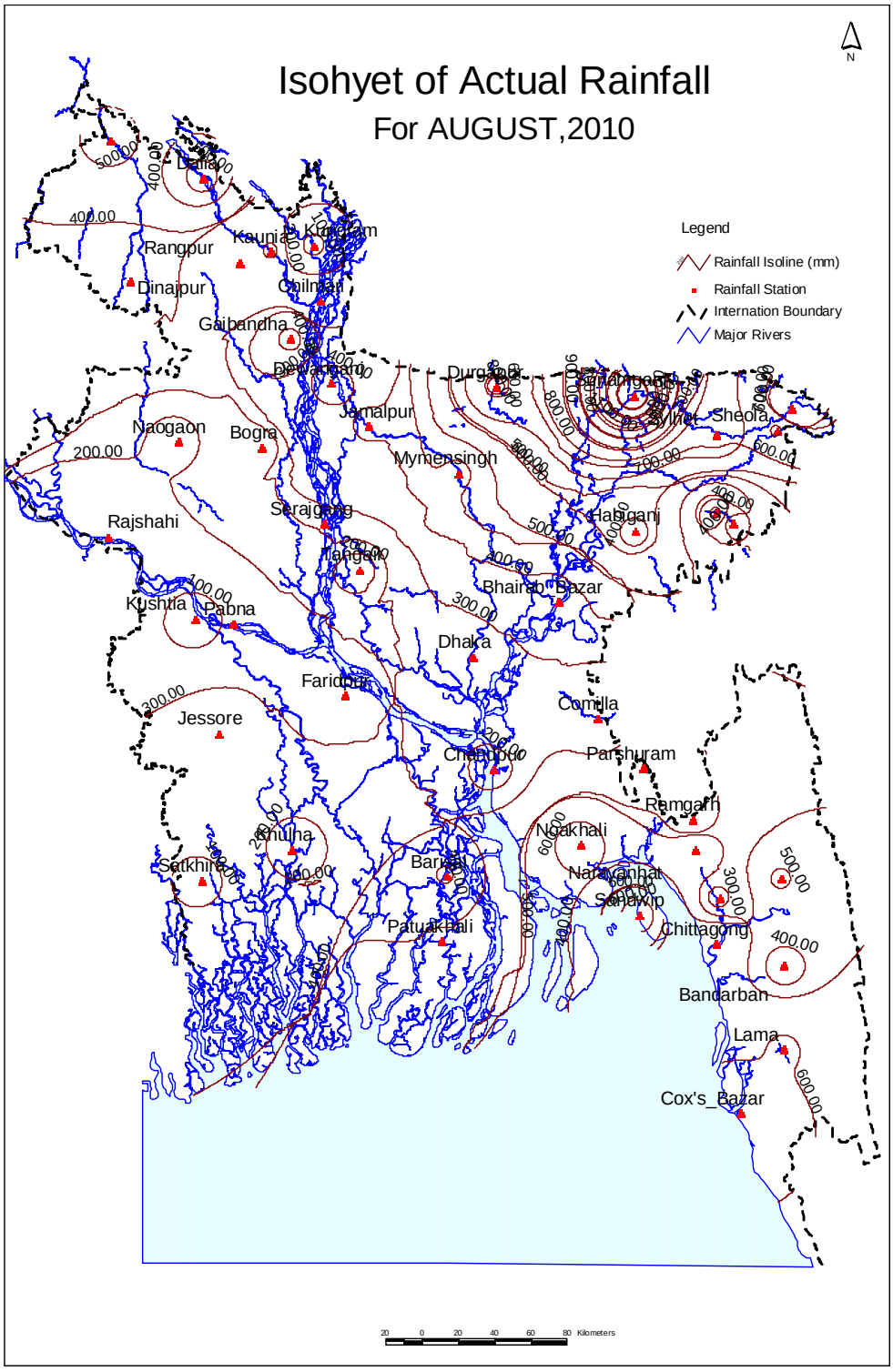


Figure: 2.4: Isohyets of Actual Rainfall (August 2010)

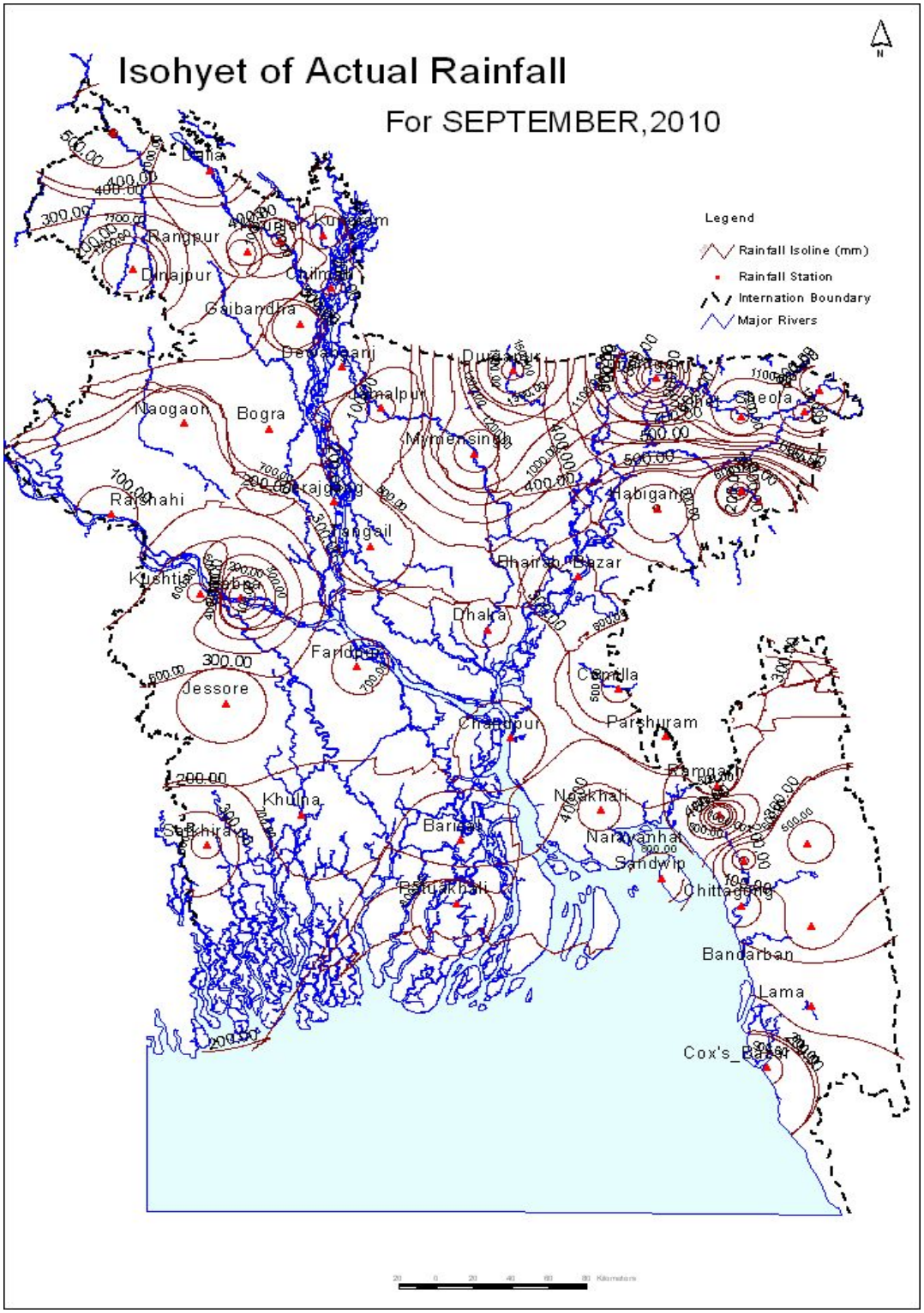


Figure: 2.5: Isohyets of Actual Rainfall (September 2010)

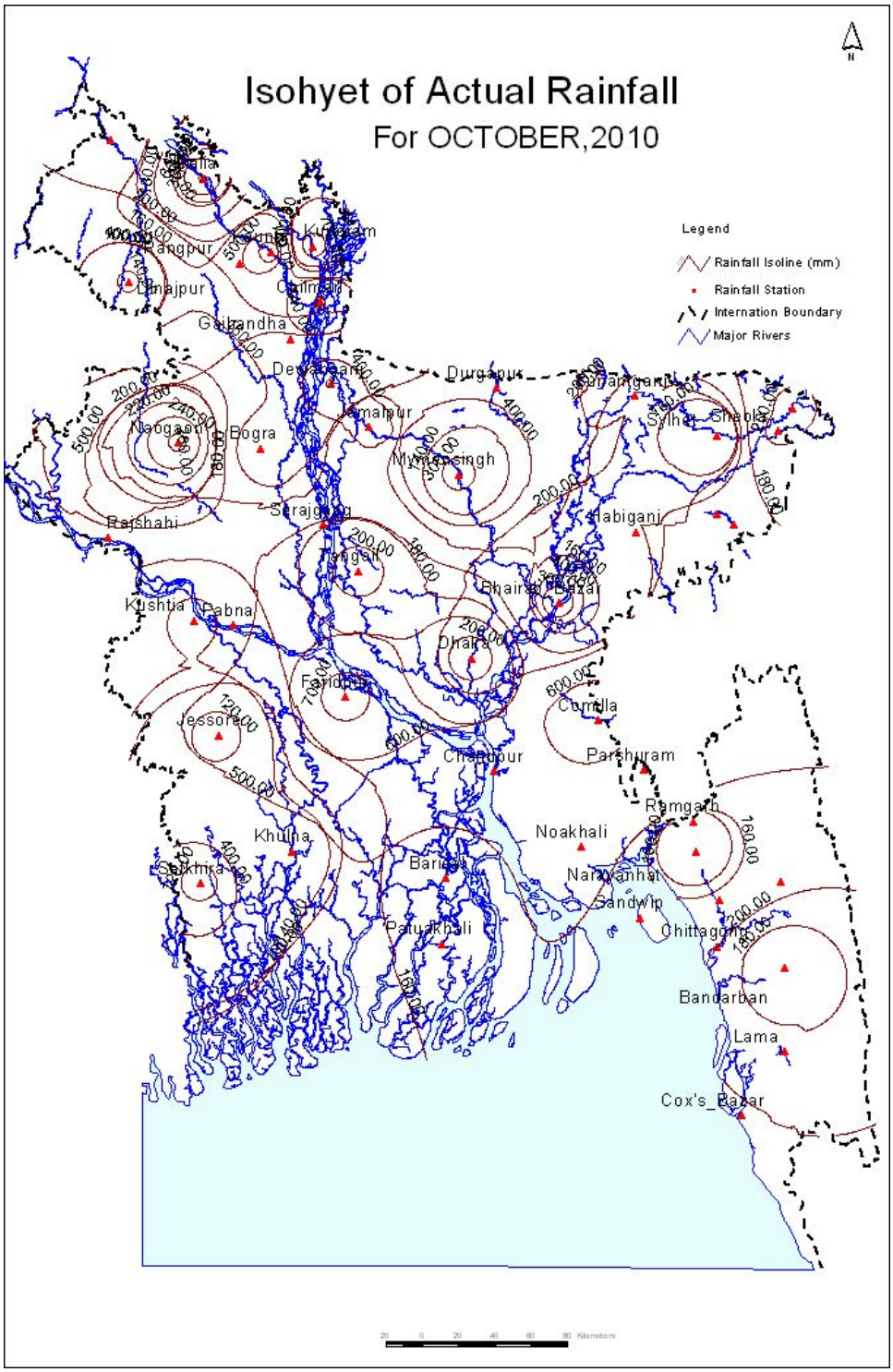


Figure: 2.6: Isohyets of Actual Rainfall (October 2010)

CHAPTER 3: RIVER SITUATION

During the monsoon 2010, the flood was not severe one and stayed for short duration in three basins, the Brahmaputra, the Ganges and South Eastern Hill Basin. In the North Eastern part of the country, in the Meghna basin duration of WL above DL was prolong in few stations, longer then the previous flood years(1988 and 1998). The north eastern part also adversely affected by the pre-monsoon flash flood, in the last part of April and again in the first part of May resulted standing crop damages. Basin wise WL situation is described in the following sections

3.1 THE BRAHMAPUTRA BASIN

Out of 15 WL monitoring stations in this basin, at 6 stations rivers crossed the respective DL, these are Dharla at Kurigram, Teesta at Dalia & Kaunia, Brahmaputra/Jamuna at Chilmari, Bahadurabad, Serajgonj and Aricha during the monsoon 2010. As a result, the low lying areas of Nilphamari, Lalmonirhat, Kurigram, Gaibandha, Sherpur, Jamalpur and Serajganj districts was affected by normal flooding during the month of August and September. A comparative statement of WL for current year 2010 and historical events of 1988 and 1998 for the Brahmaputra Basin is shown in Table 3.1. The details of the river situation in this basin are described in the following sections:

The Dharla at Kurigram

The Dharla at Kurigram registered several peaks during the monsoon 2010. It crossed its danger level (DL) on 20th July and continues to flow above DL till 12:00 hours of 24th July, 2010 (4 days). It attained its highest level 26.83m on 22nd July at 18:00 hours, which was 33cm above the DL (26.50 m).

The Teesta at Dalia and Kaunia

The river Teesta is flashy in nature. The river showed several peaks during the monsoon both at Dalia and Kaunia. At Dalia it crossed its DL marks for five times. It crossed it DL twice in June (3rd & 4th week) and thrice in August(3rd & 4th week). In July at Dalia WL was close to the DL and almost touch the DL four times. As a whole, the Teesta at Dalia was above danger marks for 9 days (June 2 days, July 2 days & August 5 days). But at Kaunia, it followed below DL (30m). The river attained its highest peak at Dalia was 52.65m on 18th June at 09.00hrs, which was 25 cm above its DL (52.40m).

The Brahmaputra at Noonkhawa and Chilmari

The river Brahmaputra at Noonkhawa and Chilmari observed sharp rise and fall at several times throughout the monsoon. At Chilmari it crossed the DL (24.0m) on 29th of August (3cm above) and again crossed DL in 2nd week of September(2cm above). At Chilmary it

flowed above DL for 14 days in different time spans. At Noonkhawa it did not cross DL(27.25m) throughout the year, it attained its peak of 26.82 m in 2nd week of September.

The Jamuna at Bahadurabad, Serajganj and Aricha

The river Jamuna at Bahadurabad, Serajganj & Aricha demonstrated roughly identical trends as Brahmaputra at Noonkhawa and Chilmari. At Bahadurabad the Jamuna crossed its DL on end of June, mid and 3rd week of July on the 29th August (3 days above DL) and again in 15th September (total 22 days above DL). It recorded its highest peak of 19.78m on 15th September at Bahadurabad, which was 25 cm above the DL (19.50 m). At Serajganj and Aricha the Jamuna crossed the DL once in end of August and again in middle of September and remained above DL for 15 days (peak 13.83m on 15th September) and 10 days (peak 9.6m on 15th September) respectively.

The Old Brahmaputra at Jamalpur and Mymensingh

The Old Brahmaputra at Mymensingh and Jamalpur showed similar trend like Jamuna as it feeds from the same. The river did not cross their respective DL, Jamalpur recorded peak of the monsoon was 16.17m (DL 17.0m) on 17th September at 12:00hrs which was 83 cm below the DL & Mymensingh recorded 10.84m on 21st September at 12:00hrs which was166cm below the DL (12.5m) respectively.

The Rivers around Dhaka

Stations near or around Dhaka city like Buriganga at Dhaka, the Lakhya at Narayanganj, the Turag at Mirpur and the Tongi Khal at Tongi attained the peak of the monsoon at the end of the second week of September. All these stations did not cross their respective DL. The Buriganga at Dhaka, the Balu at Demra, the Turag at Mirpur and the Tongi Khal at Tongi recoded their highest peak of 5.16 m (DL 6.0m) on 14th September, 5.92m(DL 5.75m) on 19th September, 5.34 m(DL 5.94m) on 15th September, and 5.54 m(DL 6.08m) on 20th September respectively.

The Kaliganga at Taraghat

The Kaliganga at Taraghat showed steady rise with small peak but did never crossed its danger mark during the monsoon 2010. The highest peak attained during this period was 8.00 m on 19th of September which was 38 cm below its danger mark (8.38 m).

The Lakhya at Narayanganj

The Lakhya at Narayanganj showed a trend similar to that of the Buriganga at Dhaka. The river at this station remained below the respective danger line throughout the season. The highest peak attained in this period was 5.25 m on September 9th at 9:00 hours, which was 25 cm below its danger mark (5.50 m).

Comparative hydrographs for the year of 2010, 1998 & 1988 of Dharla at Kurigram, Teesta at Dalia, Brahmaputra at Bahadurabad and the Buriganga at Dhaka are shown in Figures 3.1, 3.2, 3.3 & 3.4.

Table 3.1: Comparison of Water Level of 2010 and Historical Events of 1988 & 1998 of Some Important Stations in the Brahmaputra Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					10	98	88	10	98	88
1	Dharla	Kurigram	27.66	26.50	26.83	27.22	27.25	4	30	16
2	Teesta	Dalia	52.97	52.25	52.65	52.20	52.89	9	-	8
3	Teesta	Kaunias	30.52	30.00	29.44	29.91	30.43	0	-	38
4	Brahmaputra	Noonkhawa	28.10	27.25	26.36	27.35	NA	0	-	NA
5	Brahmaputra	Chilmari	25.06	24.00	24.28	24.77	25.04	14	22	15
6	Jamuna	Bahadurabad	20.62	19.50	19.80	20.37	20.62	22	66	27
7	Jamuna	Serajganj	15.12	13.75	13.83	14.76	15.12	15	48	44
8	Jamuna	Aricha	10.76	9.14	9.60	10.76	10.58	10	68	31
9	Old Br.putra	Jamalpur	18.00	17.00	16.17	17.47	17.83	0	31	8
10	Old Br.putra	Mymensingh	14.02	12.50	10.84	13.04	13.69	0	33	10
11	Buriganga	Dhaka	7.58	6.00	5.16	7.24	7.58	0	57	23
12	Lakhya	Narayanganj	6.71	5.50	5.25	6.93	6.71	0	71	36
13	Turag	Mirpur	8.35	5.94	5.34	7.97	NA	0	70	NA
14	Tongi Khal	Tongi	7.84	6.08	5.54	7.54	NA	0	66	NA
15	Kaliganga	Taraghat	10.39	8.38	8.00	10.21	10.39	0	66	65

3.2 THE GANGES BASIN

In this basin, all the rivers flowed below their respective DL except the Ganges/Padma at Pankha, Goalondo, Bhagyakul and Arialkhan at Madaripur during the monsoon 2010. The river Padma at Bhyagyakul was flowed 57 days above DL. The low lying areas of Rajbari, Faridpur, Sariatpur, Manikgonj, Munshigonj and Madaripur districts was affected by normal flooding during the month of August and September. A comparative statement of WL for current year 2010 and historical events of 1998 & 1988 for the Ganges Basin is shown in Table 3.2. The details of the river situation in this basin are described below:

The Ganges/Padma at Pankha

The river at Pankha showed steady rise from the beginning of July and continued till the 1st week of September. It crossed its DL on 2nd September for 4 days. It attained peak of 21.51m on 3rd September at 12:00 hours, which was 57 cm above the DL (21.50m).

The Ganges/Padma at Rajshahi and at Hardinge Bridge

The Ganges at Rajshahi and at Hardinge Bridge showed nearly similar trend as at Pankha and flowed below their respective DL throughout the monsoon-2010. In Rajshahi, it attained its highest peak of 17.20m on 5th August at 6:00 hours, which was 130cm below its DL (DL18.50m) and at Hardinge Bridge; it attained its peak of the year 13.69m on 5th August at 6:00 hours, which was 56 cm below its DL (14.25m).

The Padma at Goalundo

At Goalondo river started to rise from June, crossed the DL once in 25th of July, again 3rd week of August and continued above DL upto the end of September. The river at this point as a whole remained above its DL for 39 days. It attained its yearly peak of 9.12 m on 15th September, which was 62 cm above its DL (8.50m).

The Padma at Bhagyakul

The river has tidal influence at this point. At Bhagyakul, the river had the same trend as that of Goalundo and flowed above DL in last part of July and again from 3rd week of August till 1st week of October, total 57 days above DL. The river attained its highest yearly peak of 6.99 m on 16th September, which was 99 cm above the DL (6.00m).

The Gorai at Gorai Railway Bridge

The Gorai at Gorai Rly Bridge showed steady rise and fall in the monsoon till September, it did not cross the DL. It attained its highest peak of 11.84m on 5th September at 6:00 hours, which was 91cm below its DL (12.75m).

The Arialkhan at Madaripur

At Madaripur the river Arialkhan showed similar trend of rise and fall of the river Padma. several peaks during the monsoon but did not cross DL throughout the monsoon. It crossed the DL in the 1st September and remained above DL for continuous 27 days. It attained its highest peak 4.46 m on the 19th of September 29 cm above the DL (4.17m).

Comparative hydrographs for the year of 2010, 1998 & 1988 of Ganges at Rajshahi and Padma at Bhagyakul are shown in figures 3.5 and 3.6.

Table 3.2: Comparison of Water Level of 2010 and Historical Events of 1988 & 1998 of Some Important Stations in Ganges Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					10	98	88	10	98	88
1	Punarbhaba	Dinajpur	34.40	33.50	33.28	34.09	34.25	4	3	4
2	Ganges	Pankha	22.97	21.50	21.51	24.14	NA	0	66	NA
3	Ganges	Rajshahi	20.00	18.50	17.20	19.68	19.00	0	28	24
4	Ganges	Hardinge Bridge	15.04	14.25	13.69	15.19	14.87	0	27	23
5	Padma	Goalundo	10.01	8.50	9.12	10.21	9.83	39	68	41
6	Padma	Bhagyakul	7.58	6.00	6.71	7.50	7.43	57	72	47
7	Gorai	Gorai Rly Bridge	13.65	12.75	11.84	13.45	13.65	0	25	25
8	Arialkhan	Madaripur	5.80	4.17	4.46	NA	NA	27	NA	NA

3.3 THE MEGHNA BASIN

The rivers in this basin are flashy in nature. The river Surma, Kushiyara, Manu and Khowai crossed their respective DLs at different points mostly in the month of July and August. As a result, floods of moderate magnitude were experienced in the districts of Sylhet, Sunamganj, Netrokona, Molvi Bazar and Habiganj during the monsoon 2010. Few of the stations of this basin exceeded previous record of duration of inundation/flooding. A comparative statement of WL for current year 2010 and historical events of 1998 and 1988 for this basin is shown in Table 3.3.

In the Meghna basin most of the rivers due to excessive rainfall in the 2nd fortnight of April and 1st part of May generated onrush of inflow from the hilly region outside Bangladesh got higher water levels resulting flash flood of higher magnitude in the districts of Sylhet, Sunamganj, Habiganj and part of Moulvi Bazar. The rivers Surma, the Kushiyara, the Manu and the Khowai have flown above their respective danger levels for 2 to 13 days which was unusual like other years. The river Kushiyara crossed its recorded highest level for the month of April 14.33m on 18th April and reached to 14.35 m. This unusual high WL in the pre-monsoon(April-May) caused flesh floods in the entire North-Eastern region of Bangladesh resulted huge standing crop damage.

The Surma at Kanaighat

As a flashy river, the Surma at Kanaighat showed several peaks during this monsoon. It crossed its DL several times, on 3rd of April for 2 days, 20th April for 8 days, 13th of May for 4 days, 2nd of June for 67 days and 14th August for 40 days, total 121 days flowed above its DL, exceeded previous duration of 75 days in 1988. It attained its highest yearly peak of 14.83m on 17th June, which was 163cm above its DL (13.20m).

The Surma at Sylhet

Like Kanaighat, the river at this point registered several peaks during the monsoon 2010. It crossed its DL on 9th June for18 days. It attained its highest yearly peak of 11.54m on 12th of June, which was just 29cm above its DL (11.25m).

The Surma at Sunamganj

The river at this point also followed the same pattern as in Sylhet. The Surma at Sunamganj crossed the DL on 9th June for 25 days, 10th July for 6 days and 20th August for10 days (total 41 days). It attained its highest peak 8.87m on 28th June, which was 52cm above its DL (8.25m).

The Kushiyara at Amalshid

The river at this point observed several medium & high peaks during the monsoon 2010. It crossed DL on 4th June for 26 days, 30th July for 9 days and 14th August for 52 days (total 87 days, exceeded previous highest duration of 65 days in 1988). It attained its yearly highest peak 16.64m on 22nd August, which was 79cm above the DL (15.85m).

The Kushiyara at Sheola

The Kushiyara at Sheola observed similar rise and fall as of that Amalshid. It crossed its DL on 21st April for 5 days, 2nd June for 37 days and 22nd July for 71 days (total 113 days, exceeded previous highest duration of 80 days in 1988). It attained its yearly highest peak of 14.61 m (previous highest record 14.60m, exceeded by 1cm) on 10th June, which was 101 cm above its DL (13.50 m). This is a new record for depth and duration of flooding at this station.

The Kushiyara at Sherpur

At Sherpur it flowed above DL for a prolonged period of 92 days in different time span. It crossed its DL on 22nd May for 3 days, 27th May for 46 days(upto 11 July), 16th August for 3 days, 21st August for 1 day and 27th August for 39 days(upto 4th October). It attained its yearly highest peak of 9.52 m on 1st September, which was 52cm above its DL (9.50 m). This is a new record for depth and duration of flooding at this station.

The Manu at Manu Railway Bridge and Moulvi Bazar

As a flashy river, the river Manu at Manu Railway Bridge and Moulvi Bazar observed several peaks, attained its highest peak of the year at Manu Railway Bridge 18.9m on 9th October, which was 90cm above its DL (18.00m) for 11 days and at Moulvi Bazar 12.22m on 6th May, which was 47cm above its DL (11.75m) for 9 days.

The Kangsha at Jariajanjail

As the flashy river in it showed several peaks during the monsoon 2010, remained above its DL for 32 days(June 10 days, July 11 days and August 11 days). It attained its yearly highest 10.42m on 23rd August at 18:00hours, which was 67cm, which was 67cm above its DL (9.75m).

The Khowai at Habiganj

As the flashiest river in Bangladesh, the Khowai at Habiganj showed several peaks during the monsoon 2010, remained above its DL for 12 days. It attained its yearly highest peak 11.06 m on 10th October, which was 146 cm above its DL (9.50m).

Other rivers and stations in the Meghna basin crossed their respective danger levels are Dhalai at Kamalgonj for 5 days in May, Bhugai at Nakuagaon for 4 days in May and Someswari at Durgapur for 5 days (May 3-days, August 1-day and September 1-day).

Comparative hydrographs for the year of 2010, 2004, 1998 & 1988 of Surma at Kanaighat, & Sunamganj, Kushiyara at Sheola, Khowai at Habiganj and Meghna at Bhairab Bazar are shown in figures 3.7, 3.8, 3.9, 3.10 & 3.11.

Table 3.3: Comparison of Water Level of 2010 and Historical Events of 1988 & 1998 of Some Important Stations in Meghna Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					10	98	88	10	98	88
1	Surma	Kanaighat	15.26	13.20	14.83	15.00	15.10	121	73	75
2	Surma	Sylhet	11.95	11.25	11.54	11.72	11.95	18	14	21
3	Surma	Sunamganj	9.46	8.25	8.87	8.90	9.03	41	56	62
4	Kushiyara	Amalshid	18.28	15.85	17.47	17.60	17.50	87	54	65
5	Kushiyara	Sheola	14.60	13.50	14.61	14.14	14.09	113	37	80
6	Kushiyara	Sherpur	9.68	9.00	9.52	NA	NA	92	NA	NA
7	Jariajanjail	Kangsha	13.37	9.75	10.42	NA	NA	32	NA	10
8	Manu	Manu Rly Br	20.42	17.07	18.90	18.63	18.95	11	6	66
10	Manu	Moulvi Bazar	15.50	11.75	12.22	11.68	13.01	10	-	25
11	Khowai	Habiganj	12.00	9.50	11.60	11.44	11.06	13	8	14
12	Upper Meghna	Bhairab Bazar	7.66	6.25	5.93	7.33	7.66	0	68	68
13	Gumti	Comilla	13.56	10.38	11.25	12.79	11.80	0	17	17

3.4 THE SOUTH EASTERN HILL BASIN

The South Eastern Hill basin is constituted with the basin areas of the hilly rivers like the Muhuri, the Halda, the Sangu, the Matamuhuri and the Feni in the South Eastern Part of the country. The Muhuri, The Halda and the Matamuhuri crossed their respective DL for 1 to 3 days during this monsoon. As a result, a short duration flood occurred at Parsurum (Muhuri river), Narayanhat (Halda river), Chiringa (Matamuhuri river) and Lama (Matamuhuri river) during monsoon 2010. All other rivers of this basin flowed below DL. The details of different river situations are given in following sections. A comparative statement of water level for current year 2010 and historical events of 1998 and 1988 for this basin is shown in Table 3.4

The Muhuri at Parshuram

The Muhuri river is a flashy one and observed WL above its DL several times during the monsoon, on 8th October for 2 days,1st July for 3 days, 31st July for 1 day and 9th September for 1 day(total 7-days). It attained its highest peak 13.90m on 9th October, which was 90cm above its DL (13.00 m).

The Halda at Narayanhat

The river Halda at Narayanhat also showed several peaks during this monsoon. It crossed danger mark twice during the monsoon-2010, on 14th June for 2 days and on 8th October for 1 day, total 3 days. The highest peak attained by the river was 16.35 m on 15th June, which was 110cm above its DL (15.25 m).

The Halda at Panchpukuria

The river here observed several peaks, did not crossed its DL during the monsoon 2010. At Panchpukuria it attained its highest peak of 8.72m on 16th June, which was 78cm below its DL (9.50 m).

The Sangu at Bandarban

The river at this point showed several medium and high peaks during this monsoon but did not cross the danger mark during the monsoon. The highest peak of the year attained by the river was 10.80 m on 9th September, 445 cm below its danger mark (15.25m).

The Sangu at Dohazari

The river at this point also showed several peaks as of Bandarban but did not cross the DL during this monsoon. The highest peak attained by the river at this point was 5.36m on 10th October, which was 136cm below its danger mark (7.00 m).

The Matamuhuri at Lama

The river Matamuhuri at Lama observed several peaks and crossed the DL on 7th July for 1 day. The highest peak attained by the river was 13.45 m on 31st July, which was 120cm above its danger mark (12.25m).

The Matamuhuri at Chiringa

The Muhuri at Chiringa recorded several peaks during the monsoon and crossed DL on 12th July for 2 days. It attained its yearly highest peak 6.83 m on 12th July, which was 108 cm above the DL (5.75 m).

The Feni at Ramgarh

The river at this point observed several picks did not crossed its DL. The highest peak attained by the river was 15.88 m on 14th June, which was 149 cm below its DL (17.37m).

Table 3.4: Comparison of Water Level of 2010 and Historical Events of 1988 and 1998 of Some Important Station in South Eastern Hill Basin.

Sl. No	River	Station	Recorded Maximum (m)	Danger Level (m)	Peak of the year (m)			Days above Danger level		
					10	98	88	10	98	88
1	Muhuri	Parshuram	15.03	13.00	13.90	14.60	12.42	2	9	48
2	Halda	Narayanhat	18.05	15.25	16.35	16.57	NA	3	21	NA
3	Halda	Panchpukuria	11.55	7.00	8.72	10.44	10.05	-	4	6
4	Sangu	Bandarban	20.38	15.25	10.80	15.25	16.80	-	1	3
5	Sangu	Dohazari	9.05	5.75	5.36	7.42	NA	-	2	NA
6	Matamuhuri	Lama	15.45	12.25	13.45	13.05	12.18	1	2	-
7	Matamuhuri	Chiringa	6.83	5.75	6.83	6.85	NA	2	5	NA
8	Feni	Ramgarh	21.41	17.37	15.88	17.50	NA	-	1	NA

Comparative hydrographs for the year of 2010, 2004 and 1998 of Muhuri at Parshuram is shown in Figure 3.12.

3.5 RECORDED HIGHEST WATER LEVEL

Table 3.5: Recorded Highest Water Level with Date

Sl. No.	River	Station	Danger level (m)	Recorded highest WL (m) before 2010 flood (date)	WL (date) Exceeding previous Highest WL (m)
1	Dharla	Kurigram	26.50	27.66 (14.07.96)	-
2	Teesta	Dalia	52.40	52.97 (29.07.72)	-
3	Teesta	Kaunia	30.00	30.52 (06.01.68)	-
4	Brahmaputra	Noonkhawa	27.25	28.10	-
5	Brahmaputra	Chilmari	24.00	25.07 (23.08.62)	-
6	Jamuna	Bahadurabad	19.50	20.62 (30.08.88)	-
7	Jamuna	Serajganj	13.35	15.12 (30.08.88)	-
8	Jamuna	Aricha	9. 40	10.76 (02.09.88)	-
9	Old Br.putra	Jamalpur	17.00	18.00 (31.07.54)	-
10	Old Br.putra	Mymensingh	12.50	13.71(1.09.88)	-
11	Buriganga	Dhaka	6.00	7.58 (04.09.68)	-
12	Lakhya	Narayanganj	5.50	6.93 (10.09.98)	-
13	Turag	Mirpur	5.94	8.35 (10.09.88)	-
14	Tongi Khal	Tongi	6.08	7.84 (01.09.62)	-
15	Kaliganga	Taraghat	8.38	10.37(2.09.88)	-
16	Punarbhaba	Dinajpur	33.50	34.40	-
17	Padma	Pankha	21.50	24.14 (07.09.97)	-
18	Padma	Rajshahi	18.50	20.00 (13.09.1910)	-
19	Padma	H- Bridge	14.25	15.19 (10.09.98)	-
20	Padma	Goalundo	8.50	10.21 (03.08.08)	-
21	Padma	Bhagyakul	6.00	7.58	-
22	Gorai	Gorai Rly Br	12.75	13.65 (02.09.98)	-
23	Surma	Kanaighat	13.20	15.26	-
24	Surma	Sylhet	11.25	12.44 (19.07.04)	-
25	Surma	Sunamganj	8.25	9.75 (20.07.04)	-
26	Kushiyara	Amalshid	15.85	18.28 (08.06.74)	-
27	Kushiyara	Sheola	13.50	14.60 (09.09.08)	14.61 (06.10.10)
28	Manu	Manu Rly Br	18.00	20.42 (23.05.02)	-
29	Manu	Moulvi Bazar	11.75	13.25(8.06.93)	-
30	Khowai	Habiganj	9.50	12.00 (18.06.07)	-
31	Upper Meghna	Bhairab Bazar	6.25	7.78 (24.07.04)	-
32	Gumti	Comilla	11.75	13.56 (23.07.93)	-
33	Muhuri	Parshuram	13.00	16.33(13.09.04)	-
34	Halda	Narayanhat	15.25	19.30(13.08.99)	-
35	Halda	Panchpukuria	7.00	12.54(27.06.03)	-
36	Sangu	Bandarban	15.25	20.7 (12.07.97)	-
37	Sangu	Dohazari	5.75	9.05	-
38	Matamuhuri	Lama	12.25	15.46(12.08.99)	-
39	Matamuhuri	Chiringa	5.75	7.03 (10.07.97)	-
40	Feni	Ramgarh	17.37	21.42 (11.07.68)	-

WL - Water Level

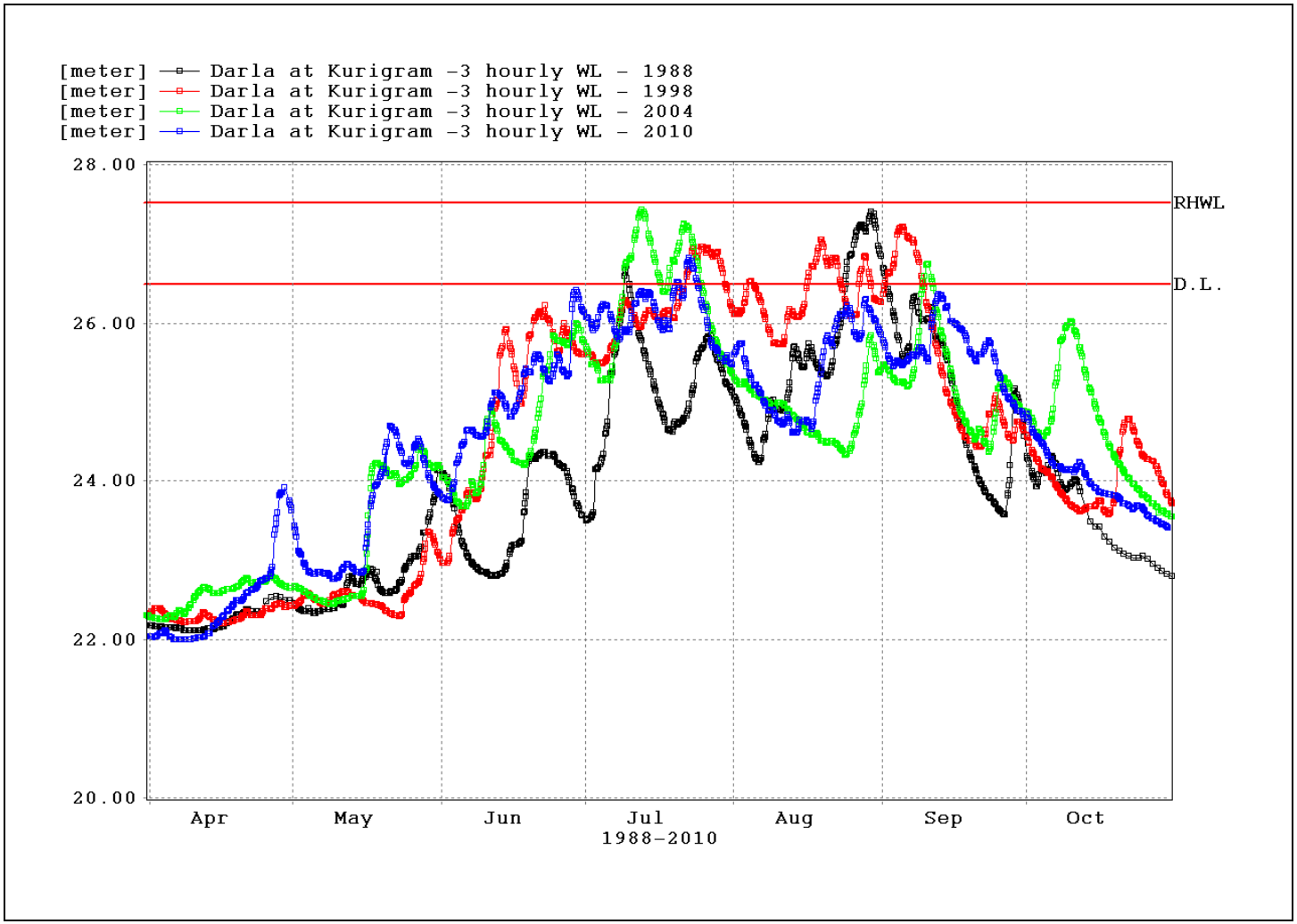


Figure 3.1: Comparison of Hydrographs (Dharla at Kurigram)

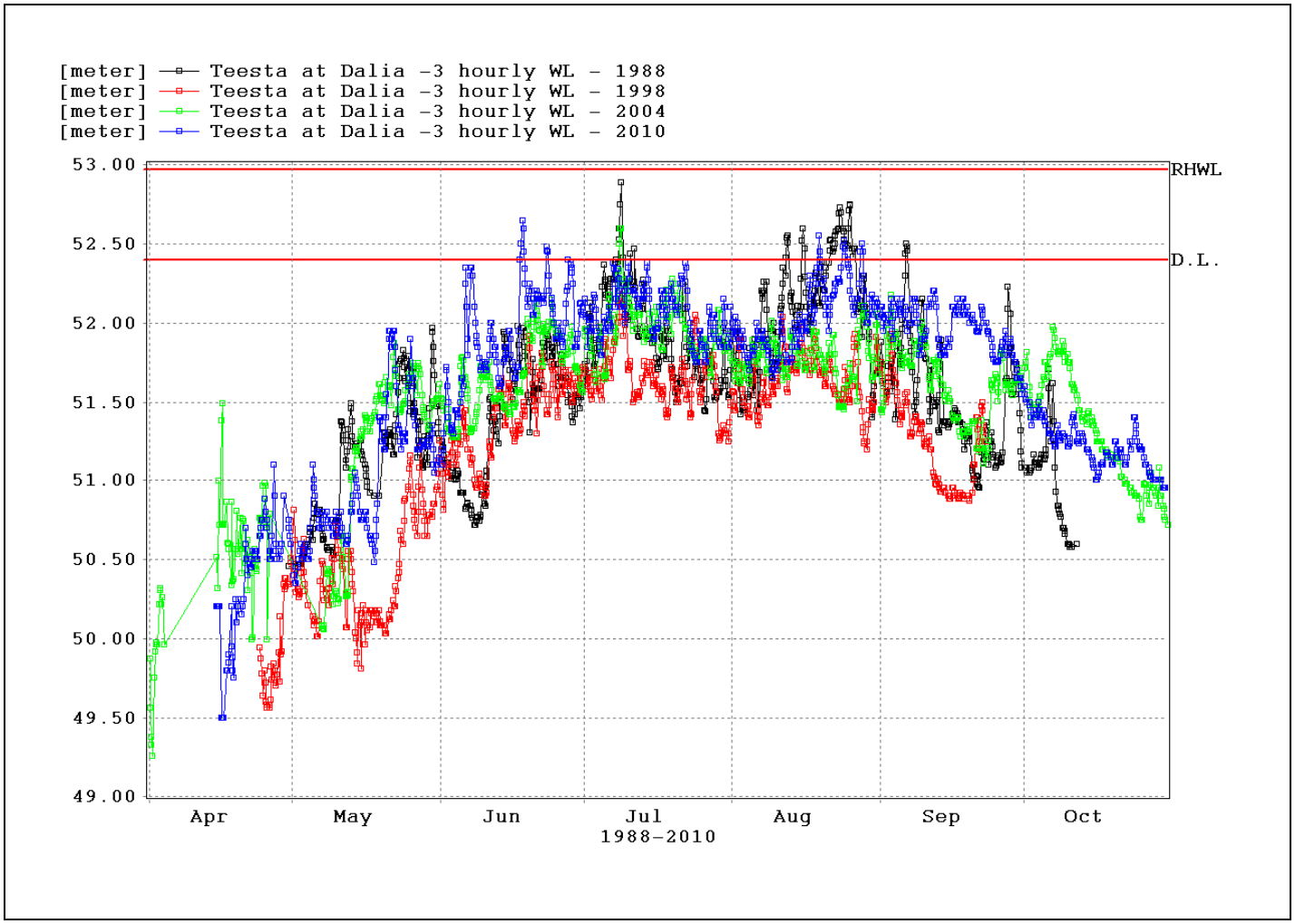


Figure 3.2: Comparison of Hydrographs (Teesta at Dalia)

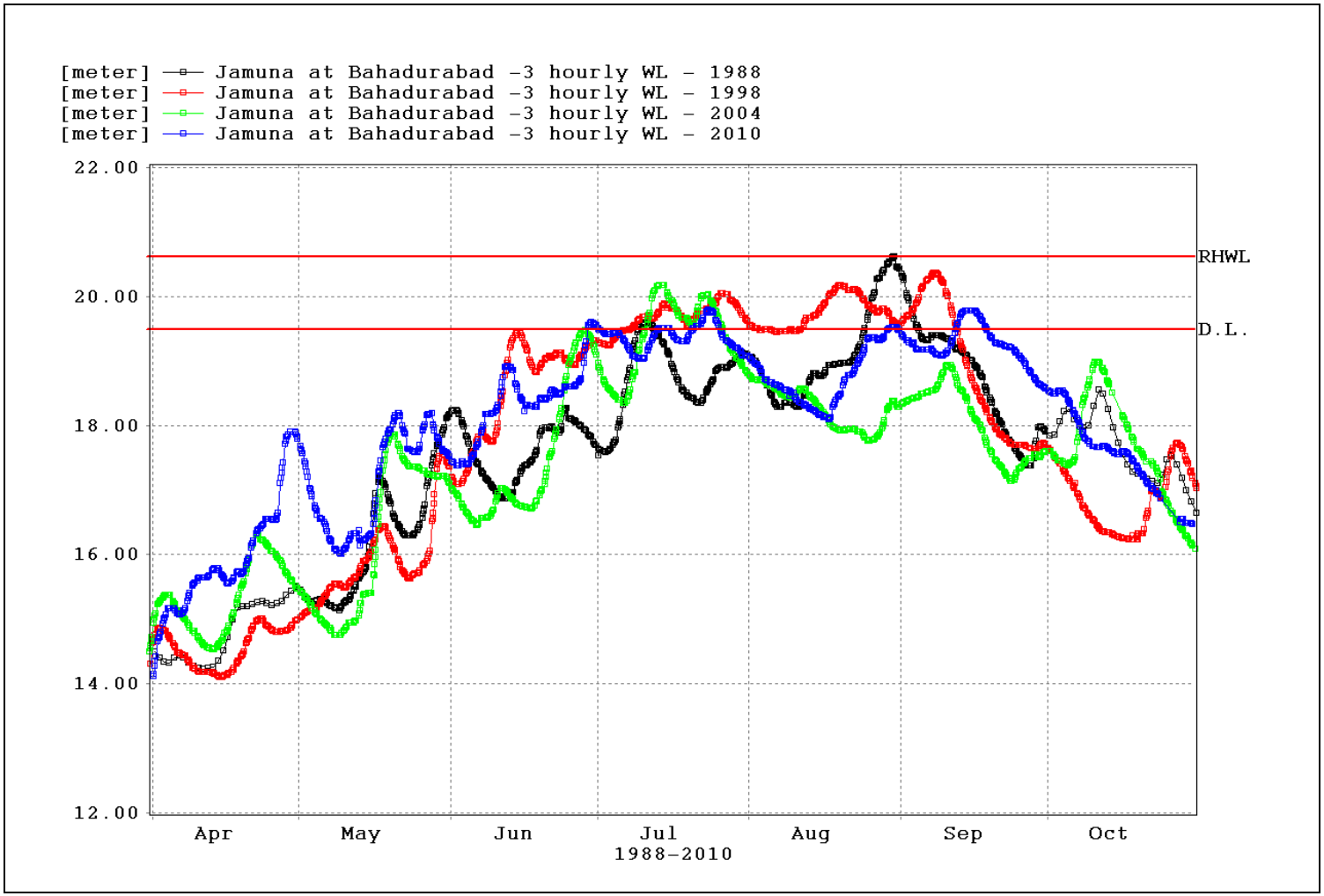


Figure 3.3: Comparison of Hydrographs (Brahmaputra at Bahadurabad)

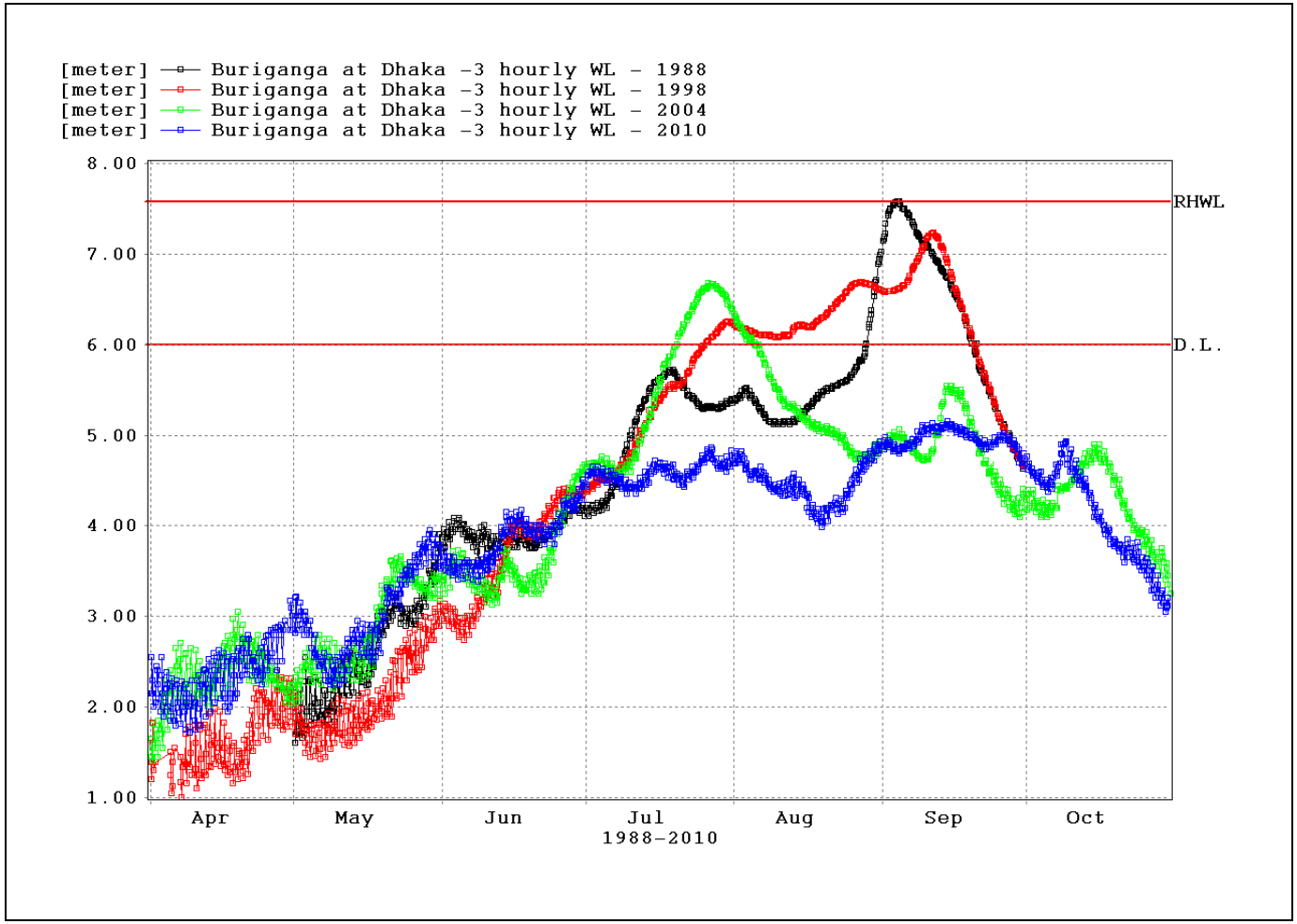


Figure 3.4: Comparison of Hydrographs (Buriganga at Dhaka)

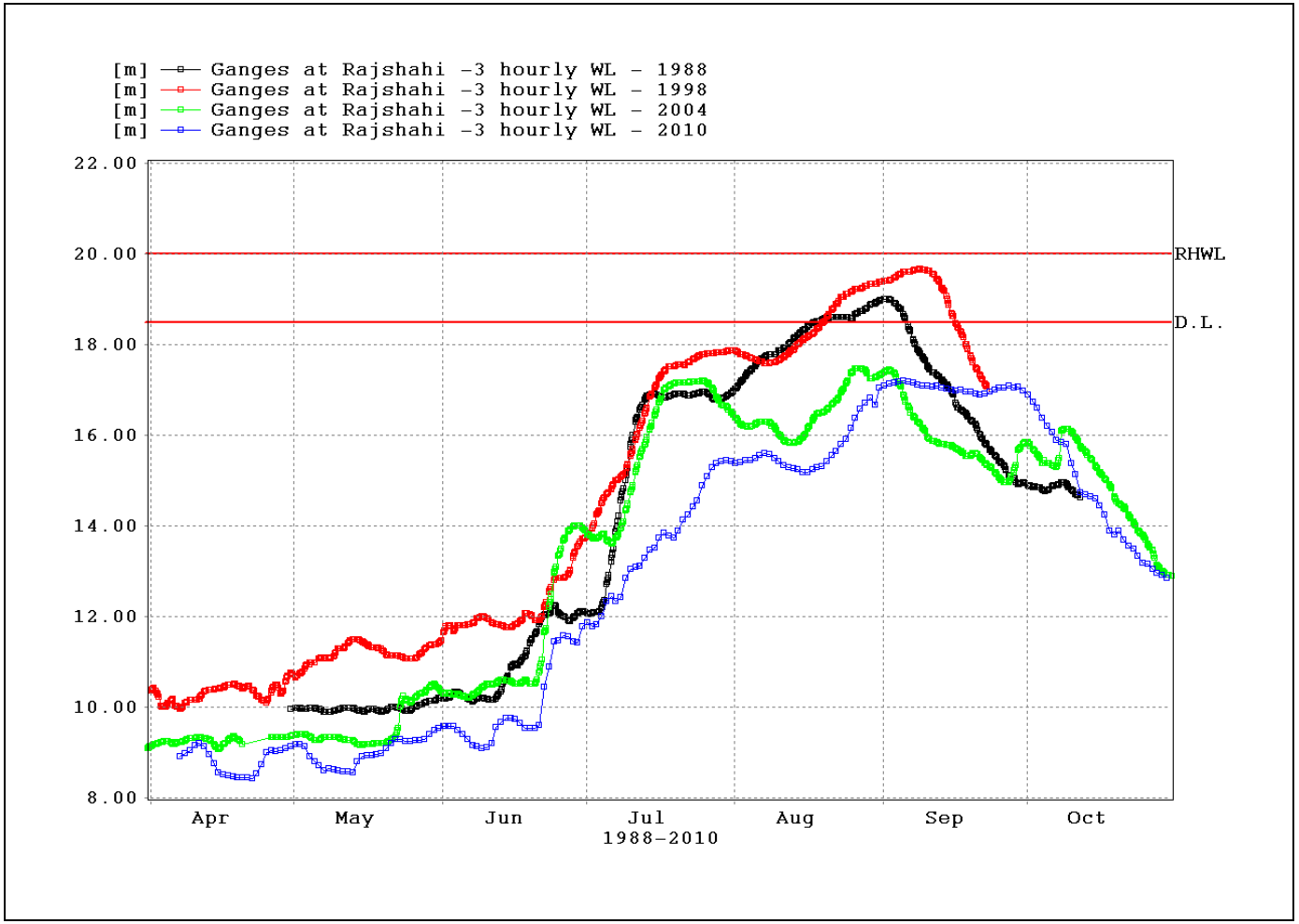


Figure 3.5: Comparison of Hydrographs (Ganges at Rajshahi)

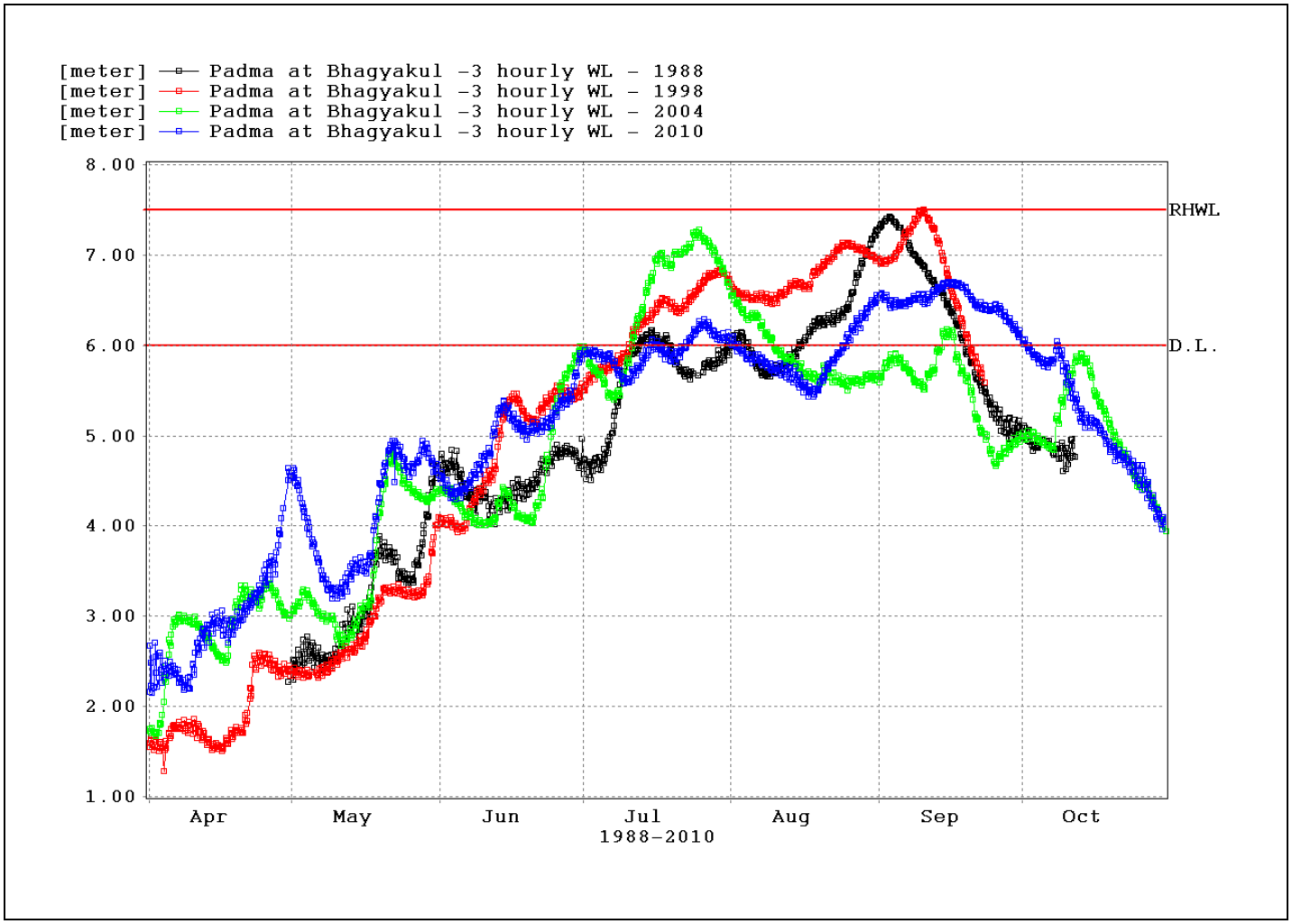


Figure 3.6: Comparison of Hydrographs (Padma at Bhagyakul)

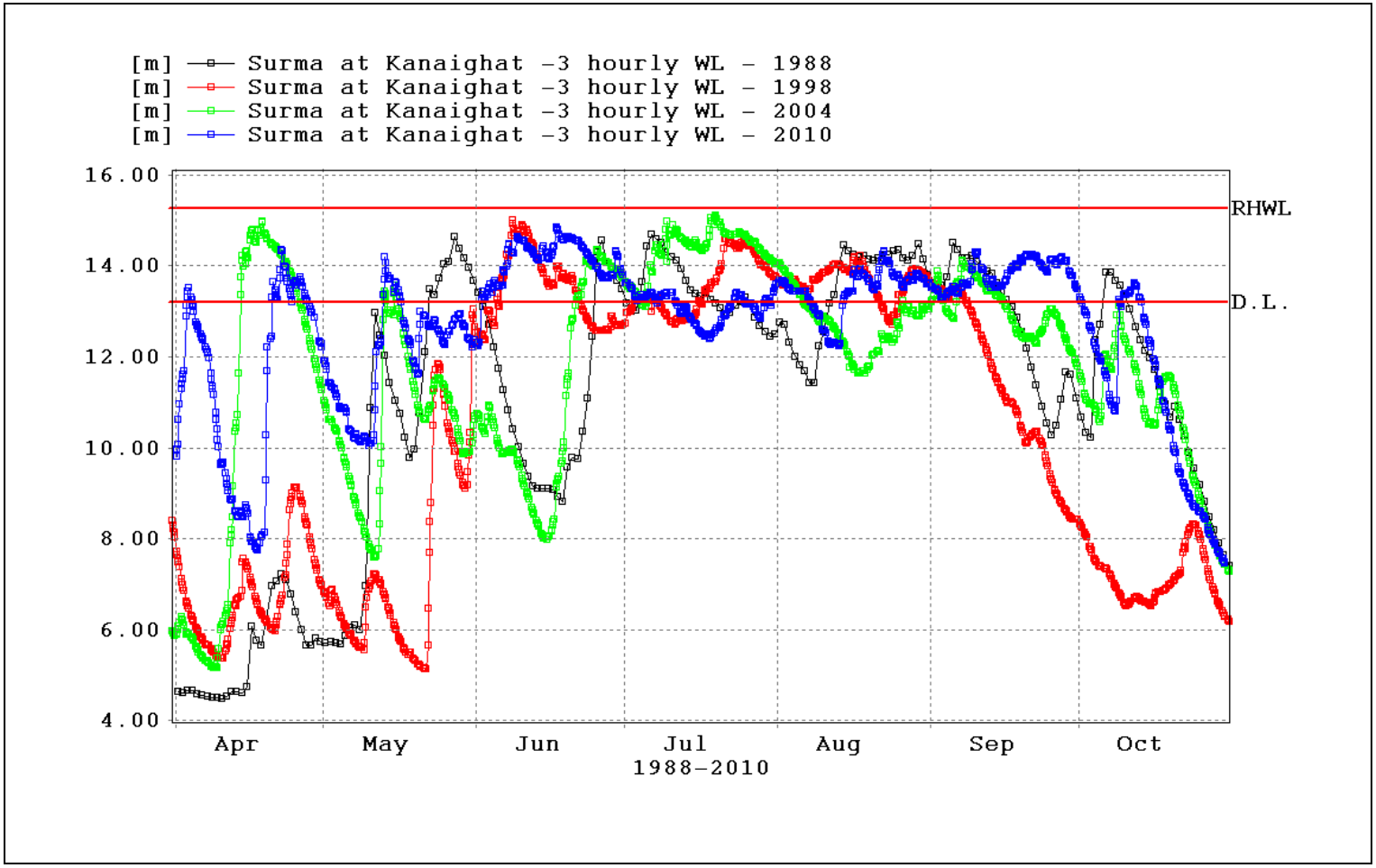


Figure 3.7: Comparison of Hydrographs (Surma at Kanaighat)

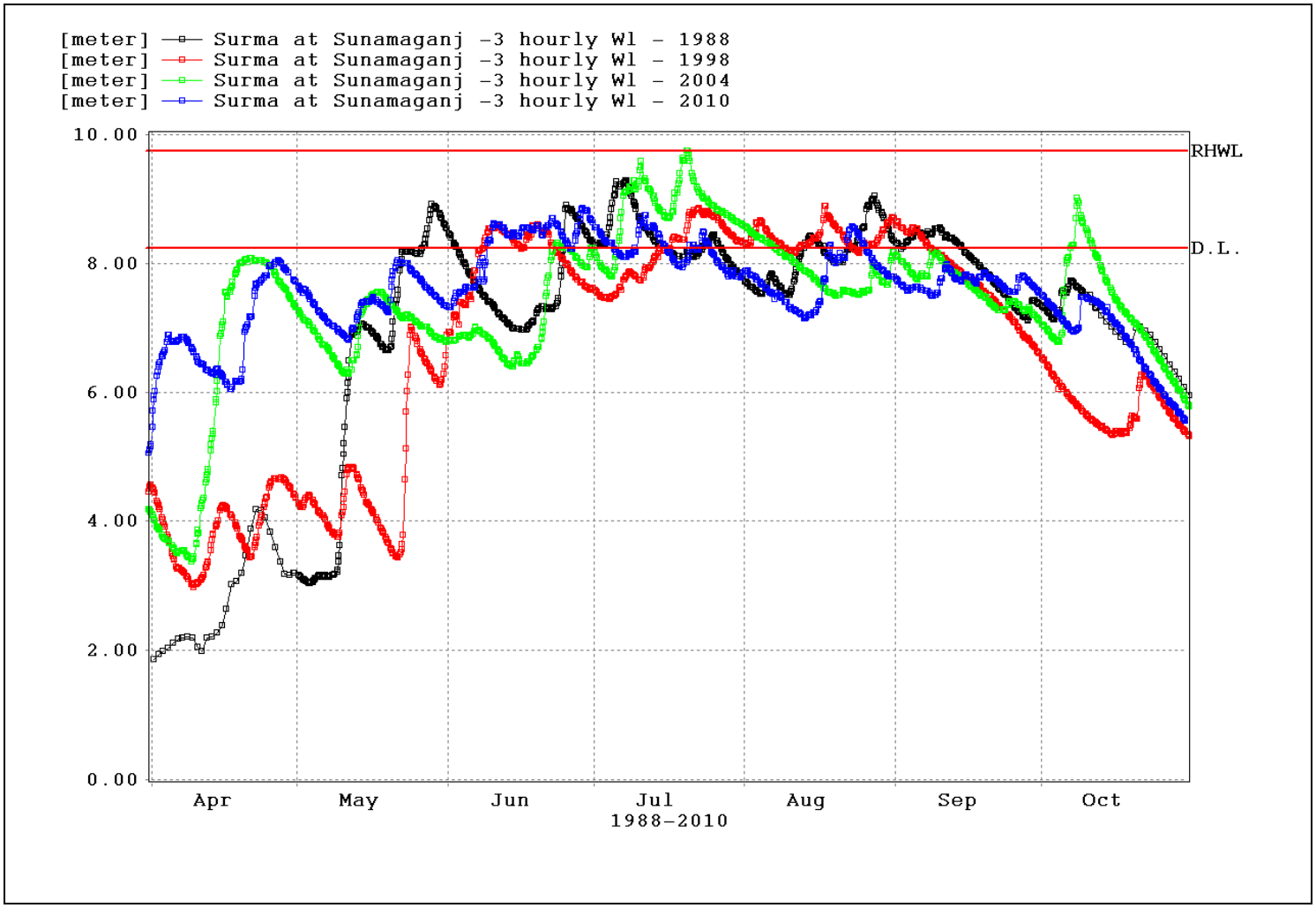


Figure 3.8: Comparison of Hydrographs (Surma at Sunamganj)

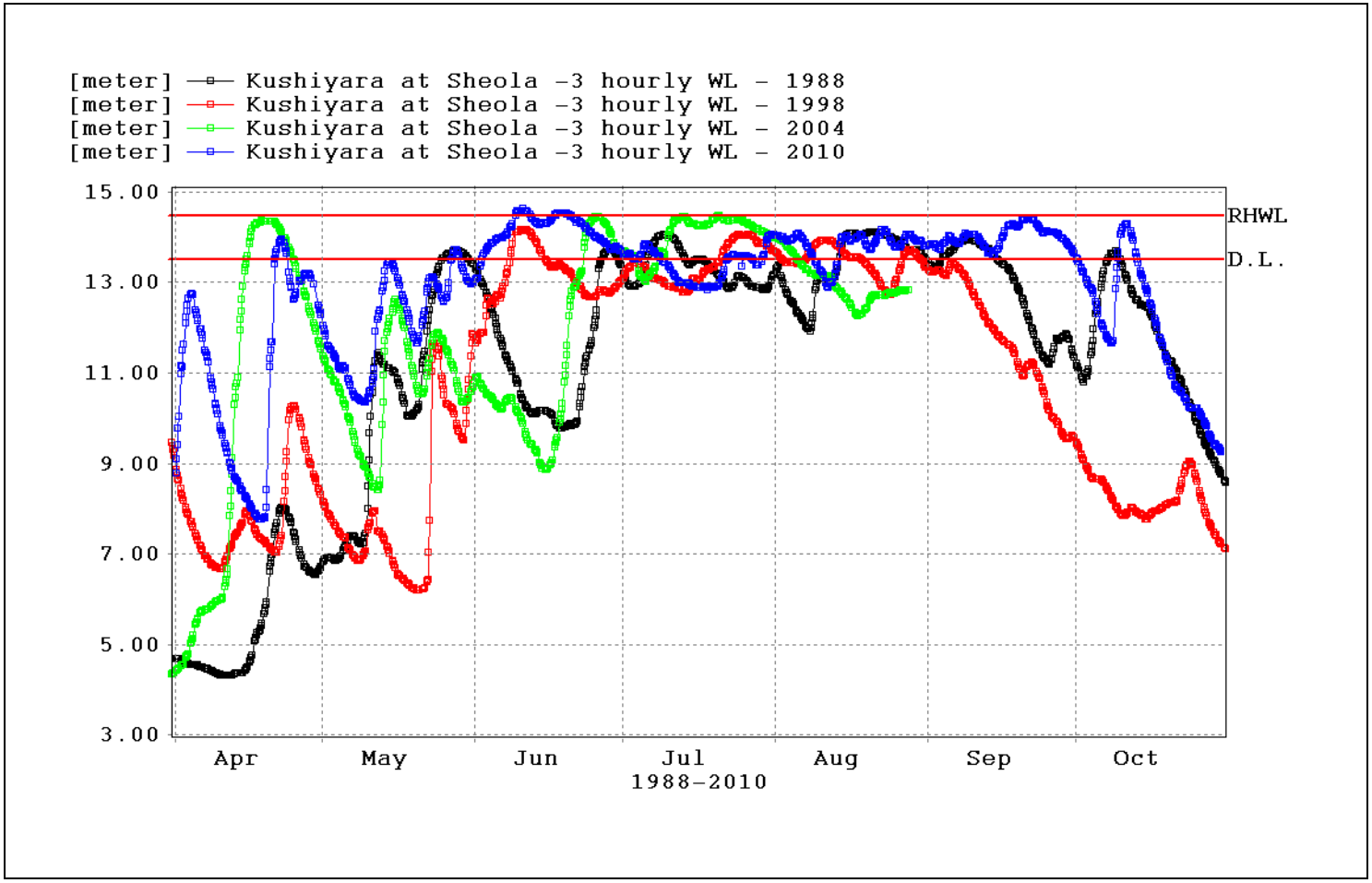


Figure 3.9: Comparison of Hydrographs (Kushiyara at Sheola)

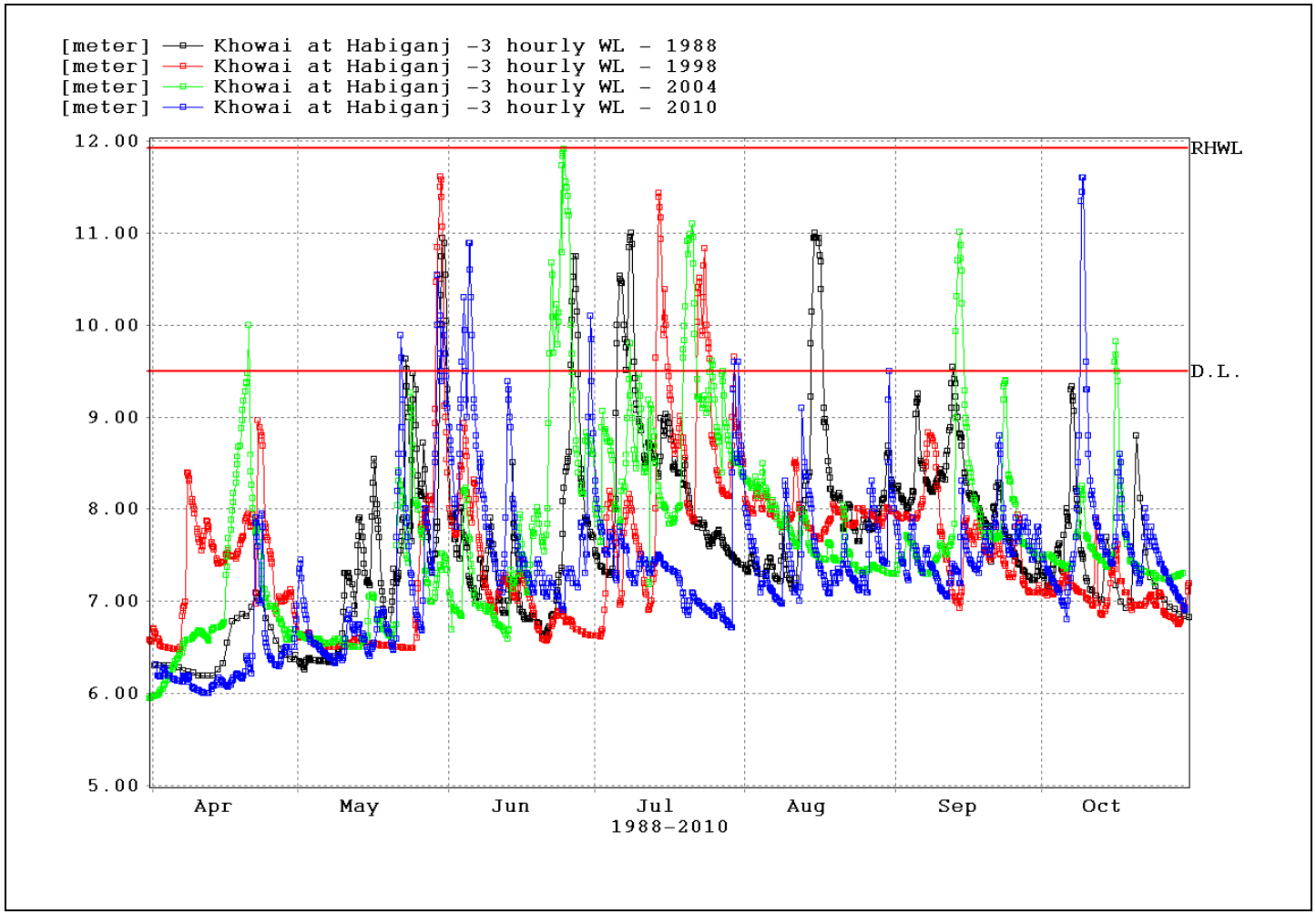


Figure 3.10: Comparison of Hydrographs (Khowai at Habiganj)

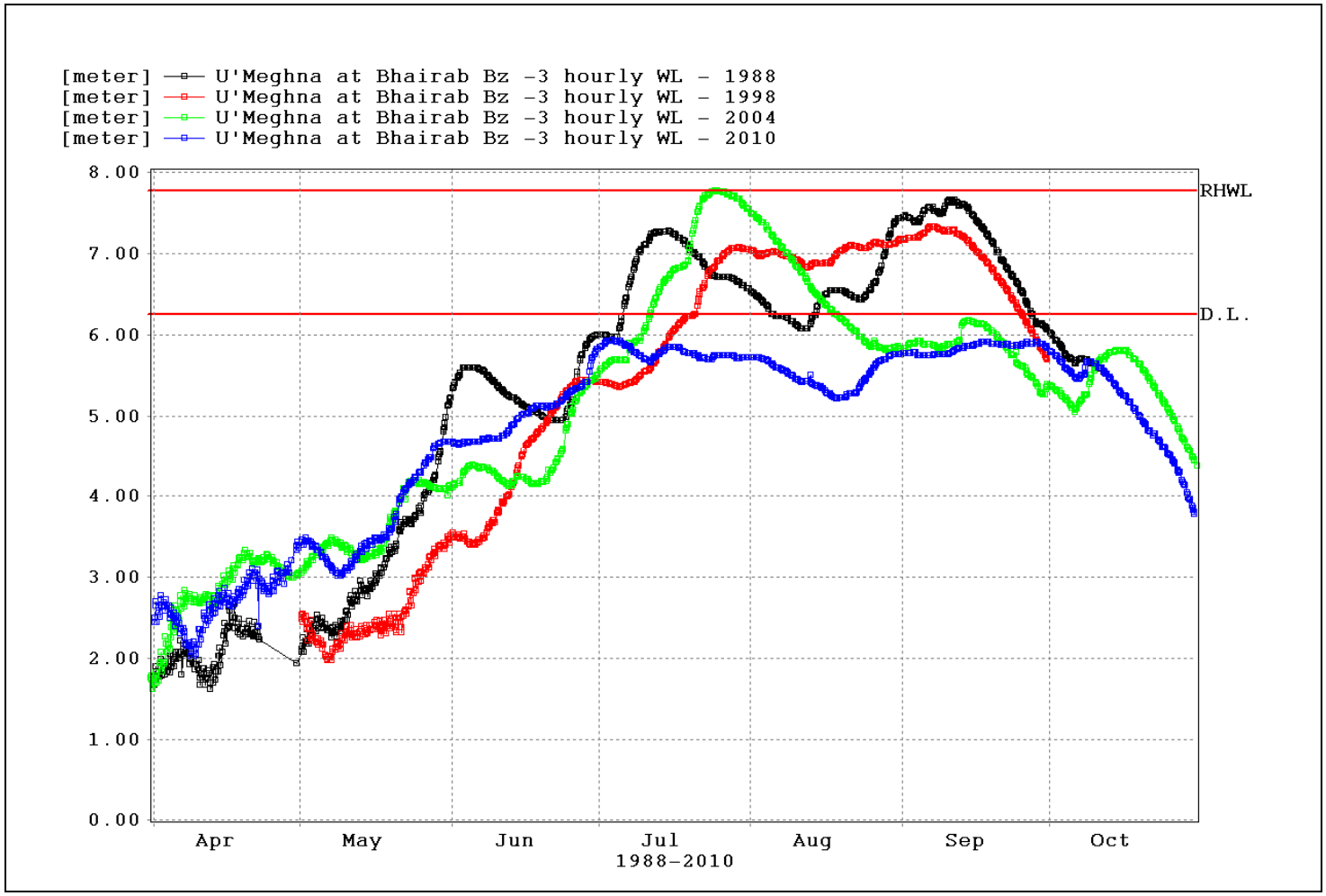


Figure 3.11: Comparison of Hydrographs (Meghna at Bhairab Bazar)

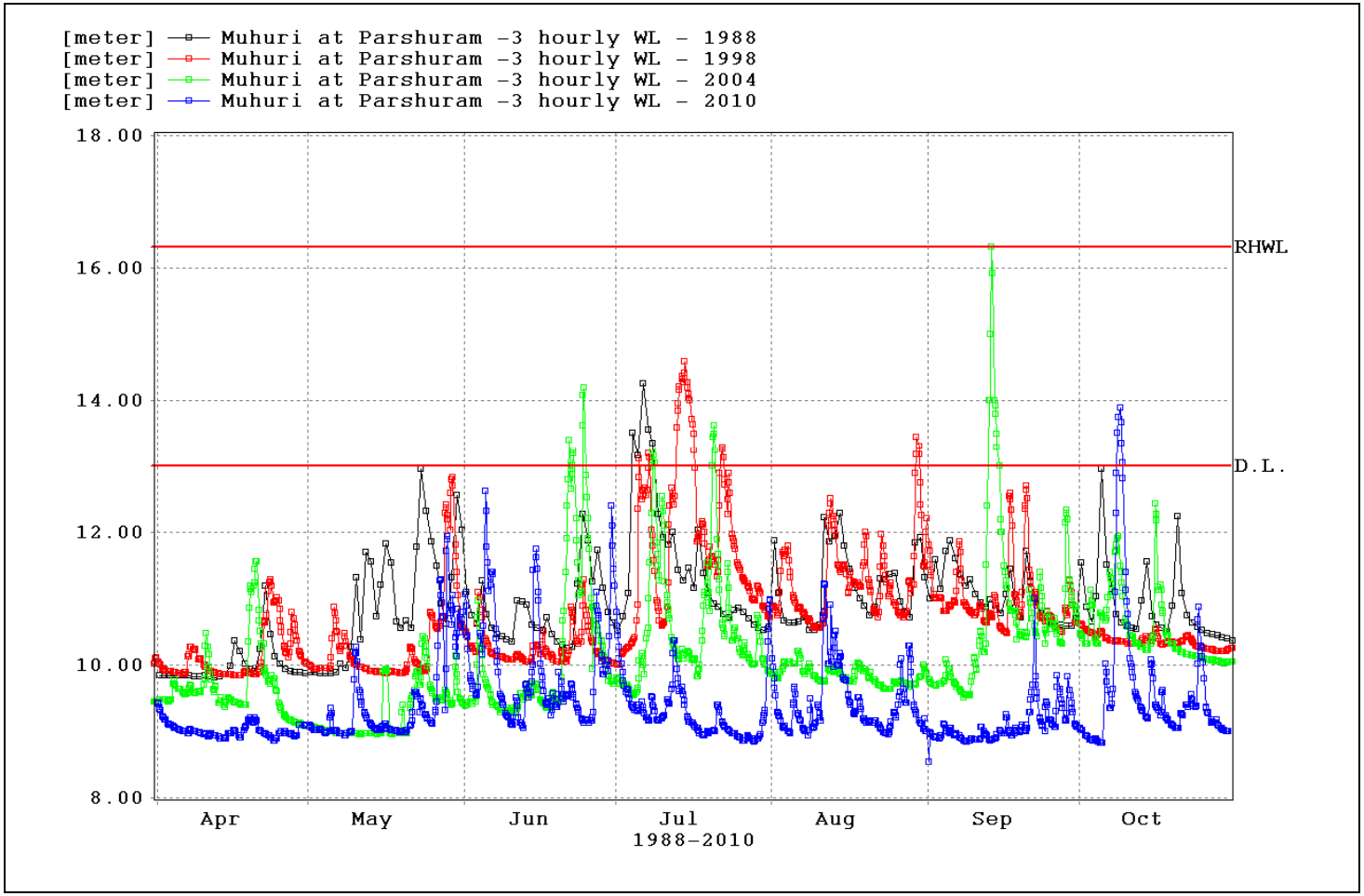


Figure 3.12: Comparison of Hydrographs (Muhuri at Parshuram)

CHAPTER 4: FORECAST EVALUATION, 2010

4.1 GENERAL

Flood Forecasting and Warning Centre (FFWC) of BWDB is mandated for flood forecasting early warning and its dissemination in Bangladesh. Flood forecasting models of FFWC are developed on MIKE 11, one-dimensional modeling software used for the simulation of WLs and discharges in the rivers and flood plains. Presently early warning on floods provides a lead time of 24, 48 and 72 hours. There are needs and expectations for increasing lead time forecast for cropping decisions, such as early harvesting, or to implement a contingency crop plan or protect infrastructure and preserve livelihoods.

The Climate Forecast Applications in Bangladesh (CFAB) project was supported by USAID/OFDA to develop and evaluate three tier overlapping forecast system with improved lead time during monsoon season 2003 and 2004, which showed a success in forecasting the discharges at Hardinge Bridge station of Ganges and Bahadurabad station of Brahmaputra rivers of Bangladesh. From March 2006 – June 2009, CARE-Bangladesh and United States Agency for International Development (USAID), Dhaka supported the program with an objective to technology transfer and capacity building for sustainable end-to-end generation and application through pilot projects at selected sites.

The project implemented with the active participation of key stakeholders in Bangladesh through a Steering Committee process. Membership in the CFAB Steering Committee includes the Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB), Department of Agriculture Extension (DAE), Disaster Management Bureau (DMB), Center for Environmental and Geographic Information Services (CEGIS), Institute of Water Modeling (IWM), and CARE Bangladesh. The Steering Committee meets periodically to review, monitor and guide the implementation of CFAB in Bangladesh.

4.2 EVALUATION CRITERIA OF FORECAST PERFORMANCE

Two statistical criteria considered for the performance evaluation of the model are as follows:

- Mean Absolute Error, MAE
- Co-efficient of Determination, r^2

4.2.1 MEAN ABSOLUTE ERROR, MAE

MAE is the mean of the absolute difference between *Observed* and *Forecast* levels as shown in the following equation:

$$MAE = \frac{\sum_{i=1}^{n} |x_i - y_i|}{n}$$

Where,

$x_1, x_2 \ldots\ldots x_n$ are *Observed* water levels

$y_1, y_2 \ldots\ldots y_n$ are *Forecast* water levels

n is the number of *Observed/Forecast* levels

4.2.2 CO-EFFICIENT OF DETERMINATION, R2

r^2 is the *Co-efficient of Determination* for the correlation of *Observed* and *Forecast* water levels and is given by the relation as show in the equation below:

$$r^2 = \frac{\left[\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})\right]^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2 \sum_{i=1}^{n} (y_i - \bar{y})^2}$$

Where,

$x_1, x_2 \ldots\ldots x_n$ are *Observed* water levels

$\bar{x}$ is the average of *Observed* water levels

$y_1, y_2 \ldots\ldots y_n$ are *Forecast* water levels

$\bar{y}$ is the average of *Forecast* water levels

n is the number of *Observed/Forecast* levels

4.3 PRE-DEFINED SCALES TO EVALUATE FORECAST PERFORMANCE

The forecast performances for the monsoon-2010 have been evaluated from the statistical components r^2 (*Co-efficient of Determination*) and *MAE* (*Mean Absolute Error*). Values of the above two components in their ideal case are generally assumed to be in the order of $MAE = 0$

$r^2 = 1$

Utilizing above two indicators, 5 category scales have been used to describe forecast performances. Stations having a minimum value of 0.9 for r^2 and a maximum value of 15 centimeter for *MAE* have been considered as "*Good*" performance. Table 4.1 presents the definition of scales used in the evaluation:

Table 4.1: Scales used for performance evaluation

Sl. No.	Scale	Value
1	*Good*	*MAE* <= 0.15 meter & r^2 >= 0.9
2	*Average*	*MAE* <= 0.2 meter & >0.15 meter and r^2 >= 0.7 & <0.9
3	*Not satisfactory*	*MAE* <= 0.3 meter & >0.2 meter and r^2 >= 0.4 & <0.7
4	*Poor*	*MAE* <= 0.4 meter& >0.3 meter and r^2 >= 0.3 & <0.4
5	*Very Poor*	*MAE* > 0.4 meter or r^2 < 0.3

Simulations were made for maximum 72 hours in the forecast period and forecasts were saved in the database at 24-hour and 48-hour and 72-hour intervals. Usually, the forecast quality gradually deteriorated with higher forecast intervals from the time of forecast. As lead time increases the forecast accuracy decreases. This means that forecasts are the best at 24-hour interval followed by 48-hour interval and then 72-hour interval. Figures from 4.4 to 4.15 show the comparison of observed and forecasted WL for 24, 48 and 72 hours. Result of the statistical analysis and performance on the basis of the aforesaid scale are presented in Tables 4.2, 4.3 and 4.4.

4.4 FORECAST STATISTICS AND MODEL PERFORMANCE, 2010

4.4.1 DETERMINISTIC FORECAST PERFORMANCE

For deterministic forecast, simulations were made for maximum 72 hours. The forecast quality gradually deteriorated where forecast intervals were moved further away from the time of forecast. Usually as lead time increases the accuracy (variation of forecast & observe value) decreases. This means that forecasts were the best at 24-hour interval (i.e. 24 hours/1-day lead time) followed by 48-hour interval and then 72-hour(3-days). Total 31 stations located within the model area (including some boundary stations) are evaluated. The forecast statistics along with their performance are provided in Tables 4.2 to 4.4 and in Figures 4.1 to 4.3.

Table 4.2: Statistics for 24- hour forecast performance

Sl. No.	Station	MAE (meter)	r^2	Performance
1	Aricha	0.05	0.97	Good
2	Bahadurabad	0.06	0.91	Good
3	Bhagyakul	0.04	0.96	Good
4	Bhairabbazar	0.03	0.93	Good
5	Bhusirbandar	0.36	0.40	Poor
6	Bogra	0.16	0.94	Average
7	Chakrahimpur	0.12	0.96	Good
8	Chilmari	0.08	0.90	Average

9	Demra	0.06	0.91	Good
10	Dhaka	0.06	0.91	Good
11	Goalondo	0.05	0.97	Good
12	Gorai-RB	0.07	0.97	Good
13	Hardinge-BR	0.07	0.98	Good
14	Jagir	0.05	0.94	Good
15	Jamalpur	0.08	0.94	Good
16	Kamarkhali	0.06	0.97	Good
17	Kaunia	0.15	0.64	Average
18	Mirpur	0.07	0.89	Good
19	Moulvibazar	0.26	0.41	Not satisfactory
20	Mymensingh	0.12	0.93	Good
21	Mohadevpur	0.29	0.90	Average
22	Naogaon	0.28	0.95	Average
23	Narayanganj	0.07	0.93	Good
24	Nayarhat	0.04	0.91	Good
25	Rajshahi	0.08	0.97	Good
26	Serajganj	0.04	0.93	Good
27	Sheola	0.18	0.94	Average
28	Sunamganj	0.08	0.90	Good
29	Sylhet	0.13	0.92	Good
30	Taraghat	0.07	0.94	Good
31	Tongi	0.04	0.91	Good

Table 4.3: Statistics for 48- hour forecast performance

Sl. No.	Station	MAE (meter)	r^2	Performance
1	Aricha	0.08	0.95	Good
2	Bahadurabad	0.14	0.85	Average
3	Bhagyakul	0.07	0.95	Good
4	Bhairabbazar	0.05	0.94	Good
5	Bhusirbandar	0.57	0.33	Poor
6	Bogra	0.30	0.86	Average
7	Chakrahimpur	0.24	0.91	Average
8	Chilmari	0.18	0.82	Average
9	Demra	0.09	0.89	Good
10	Dhaka	0.09	0.87	Good
11	Goalondo	0.09	0.94	Good
12	Gorai-RB	0.15	0.92	Good
13	Hardinge-BR	0.17	0.92	Good
14	Jagir	0.08	0.91	Good
15	Jamalpur	0.14	0.92	Good
16	Kamarkhali	0.10	0.92	Good
17	Kaunia	0.24	0.39	Poor
18	Mirpur	0.11	0.86	Average
19	Moulvibazar	0.34	0.30	Poor
20	Mymensingh	0.22	0.89	Average
21	Mohadevpur	0.48	0.80	Poor

22	Naogaon	0.53	0.88	Poor
23	Narayanganj	0.13	0.86	Good
24	Nayarhat	0.08	0.89	Good
25	Rajshahi	0.18	0.94	Good
26	Serajganj	0.10	0.90	Good
27	Sheola	0.39	0.85	Good
28	Sunamganj	0.18	0.78	Average
29	Sylhet	0.28	0.83	Poor
30	Taraghat	0.12	0.92	Good
31	Tongi	0.07	0.90	Good

Table 4.4: Statistics for 72- hour forecast performance

Sl. No.	Station	MAE (meter)	r^2	Performance
1	Aricha	0.13	0.91	Good
2	Bahadurabad	0.23	0.76	Average
3	Bhagyakul	0.10	0.91	Good
4	Bhairabbazar	0.08	0.93	Good
5	Bhusirbandar	0.77	0.25	Very Poor
6	Bogra	0.43	0.79	Poor
7	Chakrahimpur	0.37	0.83	Average
8	Chilmari	0.26	0.75	Poor
9	Demra	0.14	0.87	Good
10	Dhaka	0.12	0.85	Good
11	Goalondo	0.14	0.89	Good
12	Gorai-RB	0.24	0.86	Average
13	Hardinge-BR	0.27	0.86	Average
14	Jagir	0.10	0.90	Good
15	Jamalpur	0.21	0.89	Average
16	Kaunia	0.15	0.87	Average
17	Kamarkhali	0.27	0.30	Poor
18	Mirpur	0.14	0.84	Average
19	Moulvibazar	0.45	0.17	Very Poor
20	Mymensingh	0.31	0.85	Average
21	Mohadevpur	0.71	0.66	Poor
22	Naogaon	0.76	0.81	Average
23	Narayanganj	0.18	0.80	Average
24	Nayarhat	0.11	0.89	Average
25	Rajshahi	0.26	0.89	Average
26	Serajganj	0.19	0.83	Average
27	Sheola	0.58	0.73	Poor
28	Sunamganj	0.26	0.67	Not satisfactory
29	Sylhet	0.41	0.72	Poor
30	Taraghat	0.17	0.88	Average
31	Tongi	0.11	0.88	Good

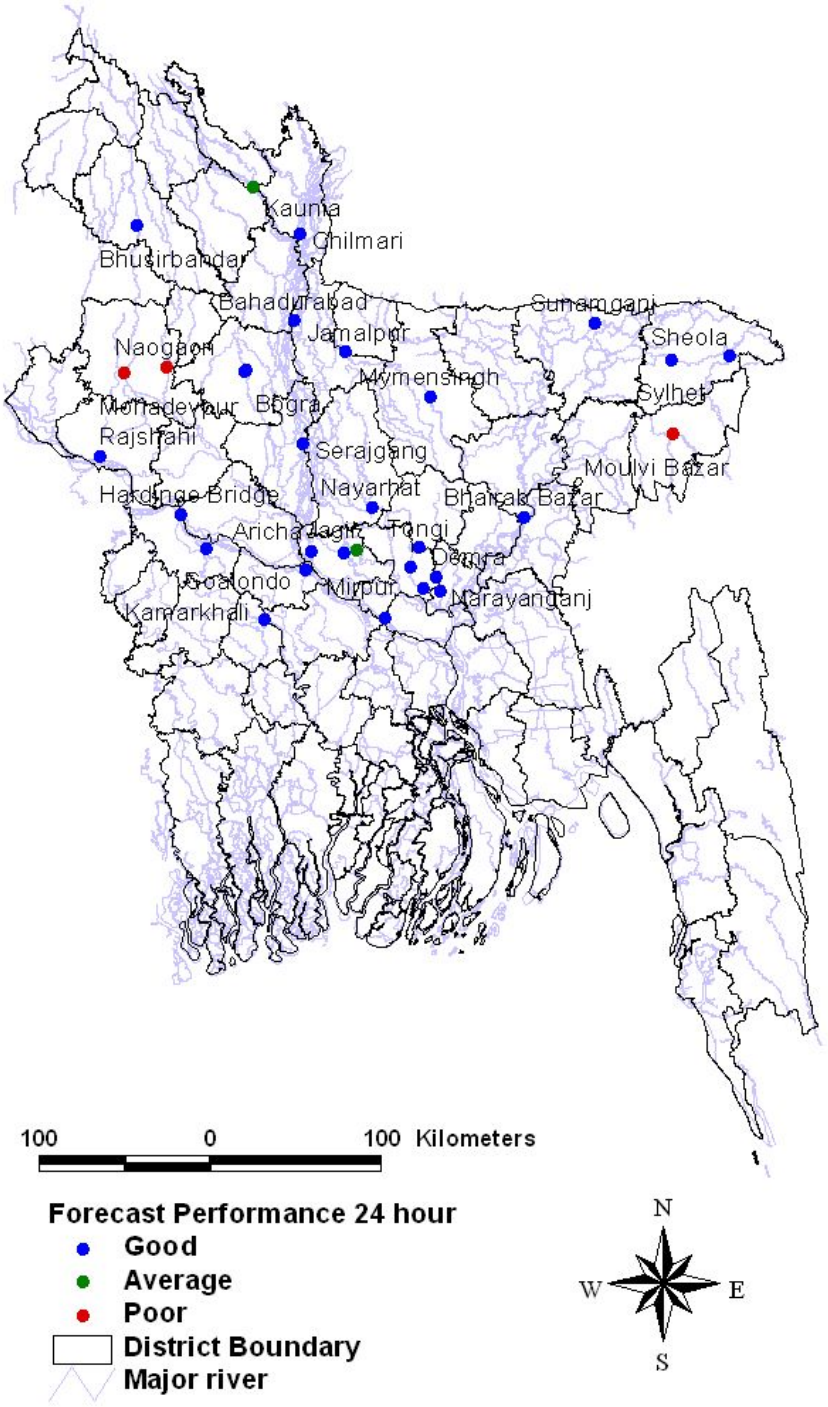


Figure 4.1: 24 hr Forecast Evaluation (Year, 2010)

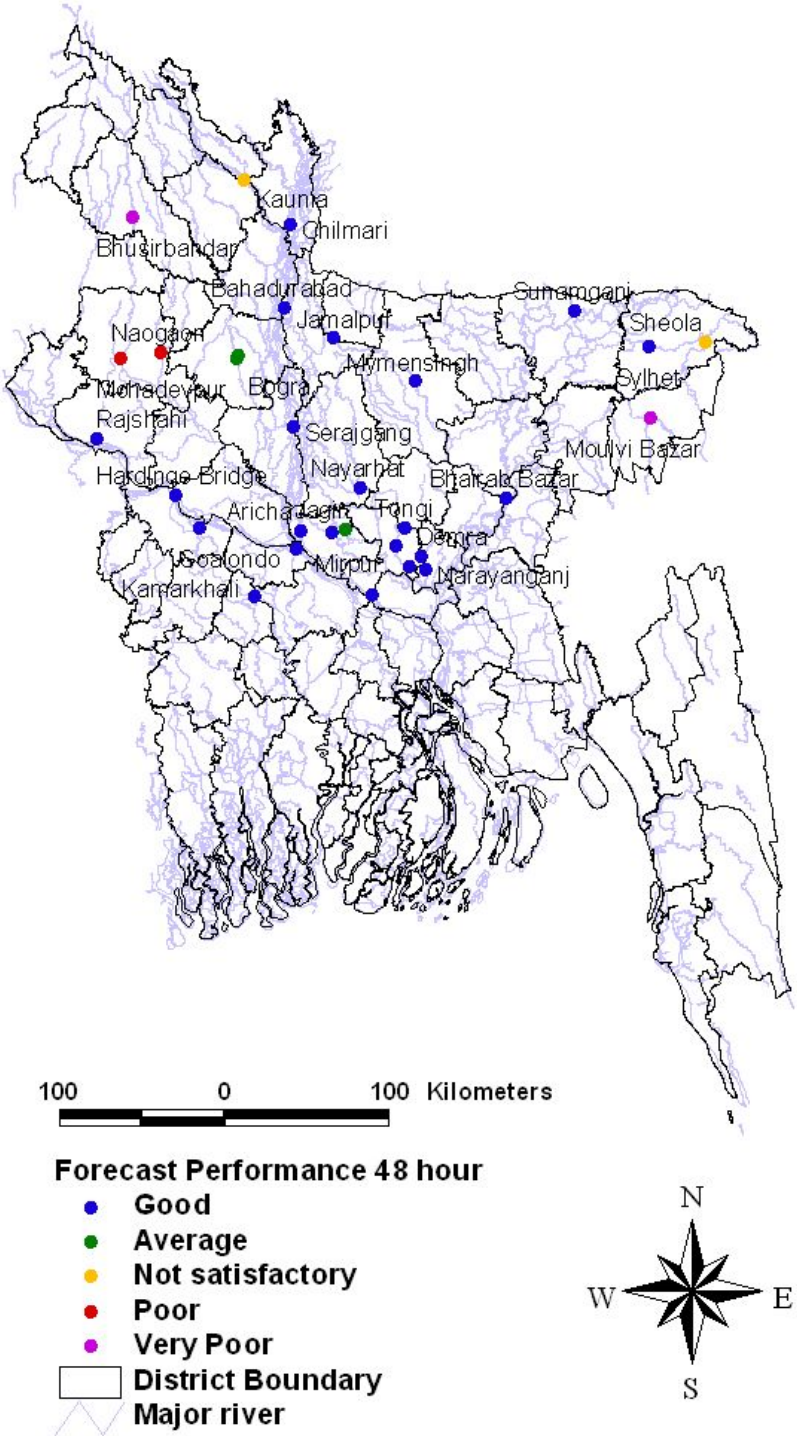


Figure 4.2: 48 hr Forecast Evaluation (Year, 2010)

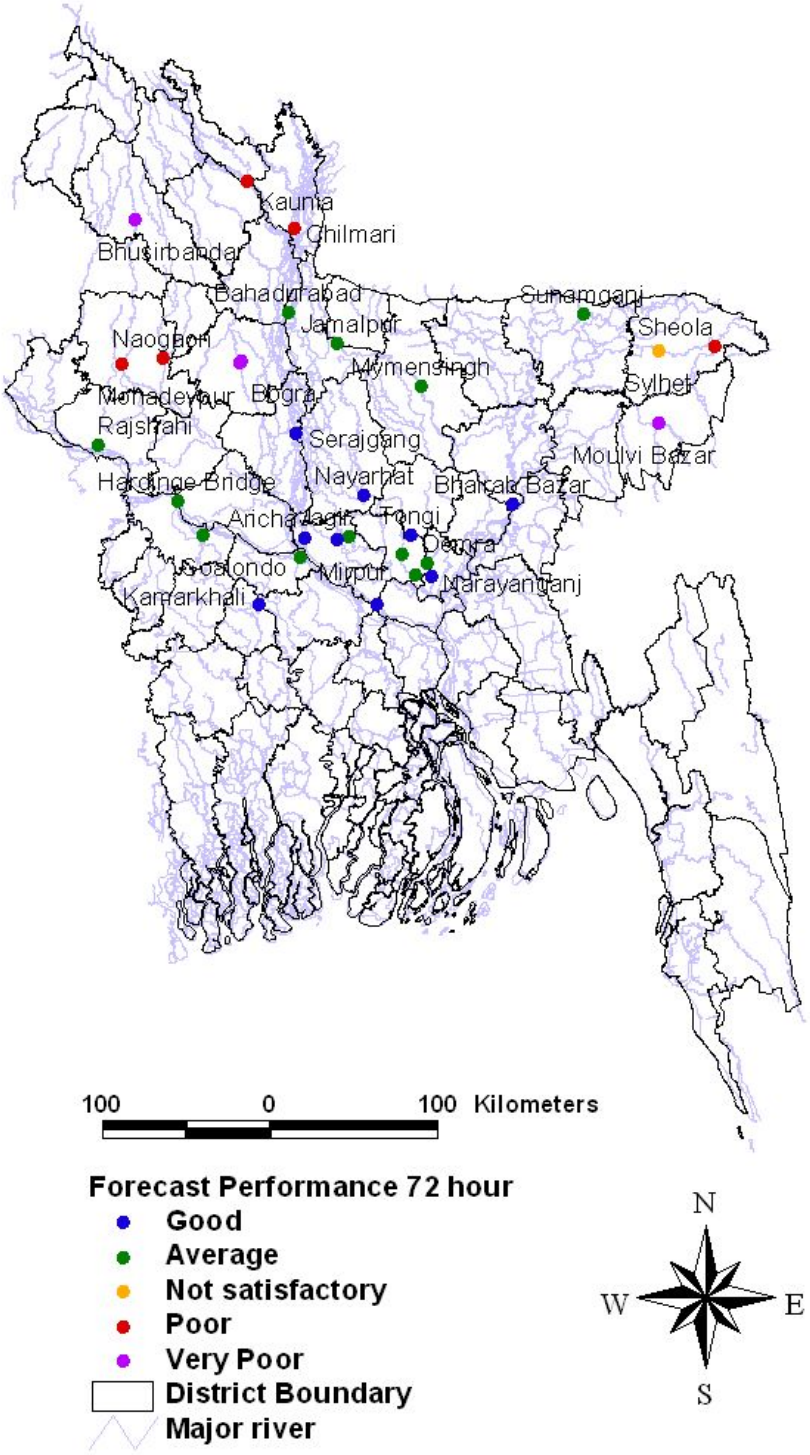


Figure 4.3: 72 hr Forecast Evaluation (Year, 2010)

4.4.2 Probabilistic (CFAN) Forecast Performance

CFAN (Climate Forecast Application Network) utilizes ECMWF weather prediction data in their model to generate 51 sets of discharge forecasts at Bahadurabad and Hardinge-Bridge on the Brahmaputra and the Ganges Rivers respectively. The updated FFWC model was taken for customization for real-time flood forecasting utilizing CFAN predictions. The customized FFWC model used for the flood forecasting of extended lead-time using climate forecast application data has been named CFAB-FFS (CFAB Flood Forecasting Study) model.

In addition to existing 24, 48 & 72 hrs deterministic forecast CFAN model generates 10 days lead-time probabilistic forecasts for mean, upper bound and lower bound WL at 18 locations listed below. The Mean Water Level forecast made from the mean discharge and the mean rainfall forecast of all 51 ensemble series. The Upper bound and Lower bound water corresponds to +1 standard deviation from the mean and -1 standard deviation from the mean respectively.

The statistics of forecast performance for the stations inside Bangladesh have been presented through Table 4.5 to Table 4.8. The plots of forecasts against measurements for Aricha and Serajganj stations during 3, 5, 7 and 10-day forecast periods have been shown through Figure 4.4 to Figure 4.10. These self-explanatory tables and figures indicate the performance forecasts at individual stations.

Table 4.5: 3-day Forecast Performance

Stations	Lower Bound			Mean			Upper Bound		
	MAE	RMAE	R2	MAE	RMAE	R2	MAE	RMAE	R2
Aricha	0.14	0.17	0.92	0.10	0.12	0.92	0.11	0.15	0.92
Bhagyakul	0.11	0.13	0.89	0.08	0.11	0.88	0.10	0.14	0.85
Bhairab Bazar	-	-	-	0.07	0.09	0.85	-	-	-
Demra	0.12	0.14	0.83	0.11	0.14	0.84	0.11	0.13	0.84
Dhaka	0.10	0.12	0.85	0.10	0.12	0.85	0.10	0.12	0.85
Goalondo	0.11	0.14	0.91	0.09	0.11	0.91	0.12	0.15	0.90
Gorai-RB	0.12	0.16	0.98	0.11	0.16	0.97	0.22	0.28	0.95
Kamarkhali	0.11	0.15	0.98	0.08	0.12	0.99	0.16	0.20	0.97
Mirpur	0.07	0.09	0.92	0.08	0.09	0.92	0.08	0.09	0.92
Mohadevpur	-	-	-	0.60	0.82	0.55	-	-	-
Moulvibazar	-	-	-	0.73	0.97	0.42	-	-	-
Naogaon	-	-	-	0.42	0.53	0.66	-	-	-
Serajganj	0.24	0.28	0.72	0.17	0.20	0.73	0.16	0.21	0.73
Sheola	-	-	-	0.33	0.65	0.34	-	-	-
Sherpur	-	-	-	0.11	0.16	0.58	-	-	-
Sunamganj	-	-	-	0.19	0.26	0.45	-	-	-
Sylhet	-	-	-	0.19	0.32	0.20	-	-	-
Tongi	0.08	0.10	0.89	0.08	0.10	0.89	0.08	0.10	0.89

Table 4.6: 5-day Forecast

Stations	Lower Bound			Mean			Upper bound		
	MAE	RMAE	R2	MAE	RMAE	R2	MAE	RMAE	R2
Aricha	0.22	0.25	0.86	0.14	0.17	0.83	0.20	0.25	0.73
Bhagyakul	0.17	0.20	0.01	0.12	0.15	0.71	0.19	0.23	0.01
Bhairab Bazar	-	-	-	0.10	0.13	0.71	-	-	-
Demra	0.16	0.19	0.73	0.16	0.19	0.73	0.15	0.18	0.74
Dhaka	0.12	0.15	0.76	0.12	0.15	0.75	0.13	0.16	0.74
Goalondo	0.19	0.22	0.84	0.13	0.17	0.78	0.22	0.27	0.63
Gorai-RB	0.20	0.29	0.92	0.20	0.27	0.90	0.36	0.46	0.76
Kamarkhali	0.18	0.23	0.95	0.17	0.23	0.93	0.29	0.38	0.86
Mirpur	0.09	0.12	0.86	0.10	0.12	0.86	0.11	0.13	0.86
Mohadevpur	-	-	-	0.84	1.11	0.13	-	-	-
Moulvibazar	-	-	-	0.91	1.14	0.42	-	-	-
Naogaon	-	-	-	0.60	0.73	0.29	-	-	-
Serajganj	0.35	0.41	0.62	0.23	0.27	0.56	0.23	0.31	0.41
Sheola	-	-	-	0.39	0.74	0.24	-	-	-
Sherpur	-	-	-	0.16	0.23	0.35	-	-	-
Sunamganj	-	-	-	0.26	0.33	0.21	-	-	-
Sylhet	-	-	-	0.27	0.43	.22	-	-	-
Tongi	0.11	0.14	0.79	0.12	0.14	0.79	0.12	0.14	0.79

Table 4.7: 7-day Forecast

Station	Lower Bound			Mean			Upper Bound		
	MAE	RMAE	R2	MAE	RMAE	R2	MAE	RMAE	R2
Aricha	0.27	0.31	0.82	0.16	0.20	0.76	0.28	0.34	0.56
Bhagyakul	0.22	0.25	0.74	0.14	0.18	0.62	0.25	0.31	0.17
Bhairab Bazar	-	-	-	0.13	0.17	0.60	-	-	-
Demra	0.20	0.24	0.59	0.21	0.24	0.60	0.21	0.24	0.61
Dhaka	0.13	0.17	0.70	0.14	0.18	0.69	0.16	0.20	0.66
Goalondo	0.23	0.27	0.78	0.15	0.20	0.71	0.31	0.36	0.40
Gorai-RB	0.25	0.33	0.89	0.23	0.31	0.86	0.48	0.59	0.61
Kamarkhali	0.25	0.32	0.91	0.18	0.26	0.91	0.40	0.50	0.75
Mirpur	0.11	0.14	0.80	0.11	0.15	0.78	0.13	0.17	0.77
Mohadevpur	-	-	-	1.06	1.29	0.30	-	-	-
Moulvibazar	-	-	-	0.91	1.16	0.26	-	-	-
Naogaon	-	-	-	0.75	0.89	0.14	-	-	-
Serajganj	0.40	0.46	0.55	0.25	0.31	0.47	0.30	0.38	0.29
Sheola	-	-	-	0.46	0.81	0.19	-	-	-
Sherpur	-	-	-	0.21	0.28	0.18	-	-	-
Sunamganj	-	-	-	0.31	0.42	0.06	-	-	-
Sylhet	-	-	-	0.32	0.48	0.03	-	-	-
Tongi	0.13	0.16	0.71	0.13	0.17	0.71	0.14	0.18	0.70

Table 4.8: 10-day Forecast

Station	Lower Bound			Mean			Upper Bound		
	MAE	RMAE	R2	MAE	RMAE	R2	MAE	RMAE	R2
Aricha	0.27	0.33	0.67	0.20	0.26	0.58	0.41	0.40	0.40
Bhagyakul	0.23	0.28	0.49	0.21	0.26	0.24	0.38	0.22	0.22
Bhairab Bazar	-	-	-	0.19	0.24	0.35	-	-	-
Demra	0.27	0.30	0.44	0.27	0.31	0.44	0.27	0.47	0.47
Dhaka	0.19	0.21	0.55	0.20	0.23	0.51	0.22	0.50	0.50
Goalondo	0.24	0.28	0.63	0.21	0.27	0.47	0.44	0.13	0.13
Gorai-RB	0.28	0.34	0.82	0.32	0.43	0.62	0.63	0.48	0.48
Kamarkhali	0.28	0.33	0.85	0.26	0.37	0.73	0.52	0.29	0.29
Mirpur	0.14	0.17	0.70	0.15	0.19	0.67	0.18	0.65	0.65
Mohadevpur	-	-	-	1.13	1.37	0.60	-	-	-
Moulvibazar	-	-	-	1.02	1.27	0.21	-	-	-
Naogaon	-	-	-	0.89	1.01	0.76	-	-	-
Serajganj	0.40	0.51	0.41	0.30	0.36	0.44	0.43	0.42	0.42
Sheola	-	-	-	0.56	0.89	0.18	-	-	-
Sherpur	-	-	-	0.26	0.35	0.06	-	-	-
Sunamganj	-	-	-	0.41	0.51	0.30	-	-	-
Sylhet	-	-	-	0.44	0.58	0.29	-	-	-
Tongi	0.16	0.20	0.60	0.17	0.22	0.57	0.20	0.57	0.57

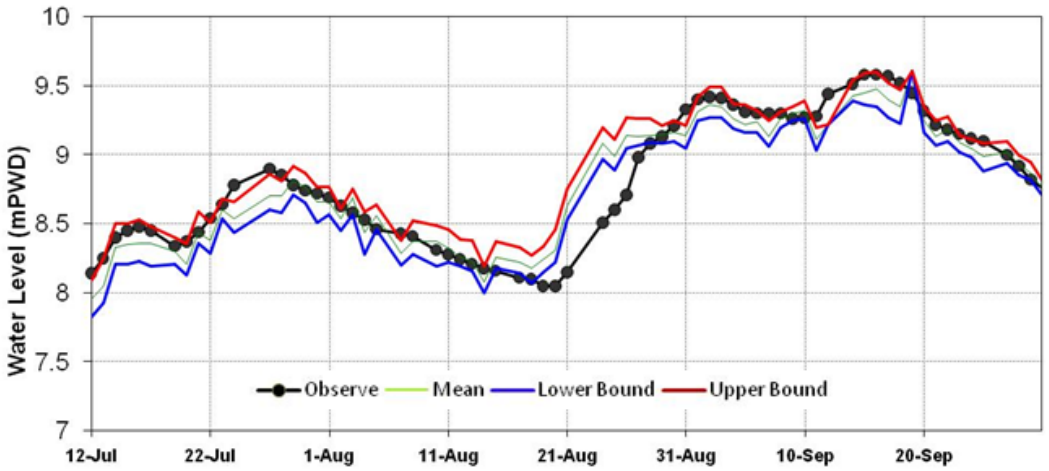


Figure 4.4: Aricha at the Jamuna River (3-day Forecast)

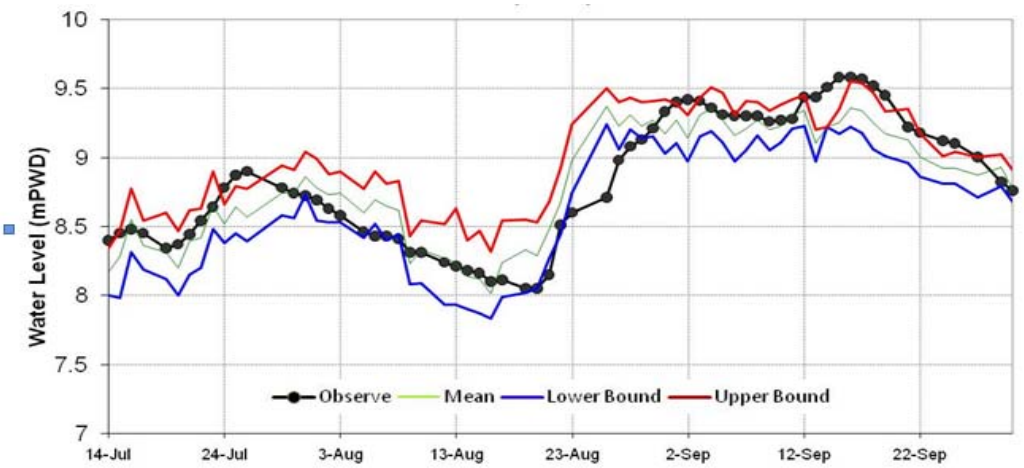


Figure 4.5-: Aricha at the Jamuna River (5-day Forecast)

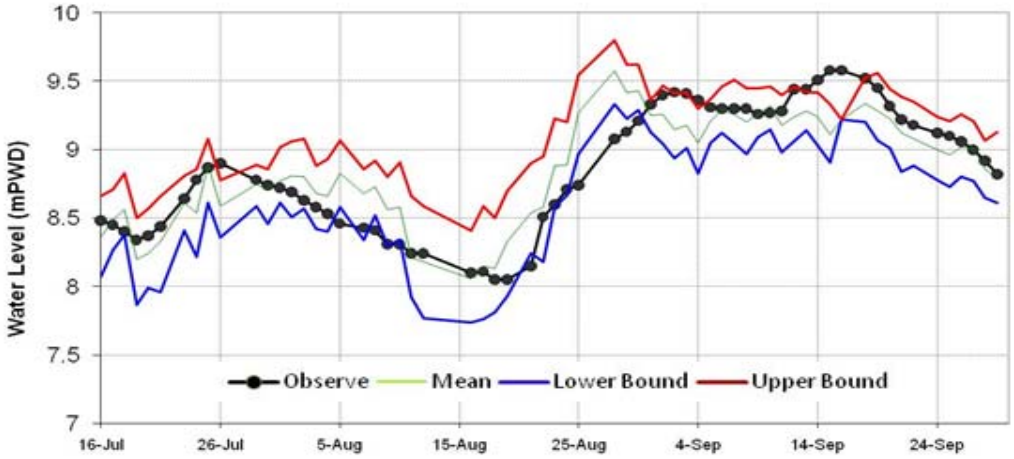


Figure 4.6: Aricha at the Jamuna River (7-day Forecast)

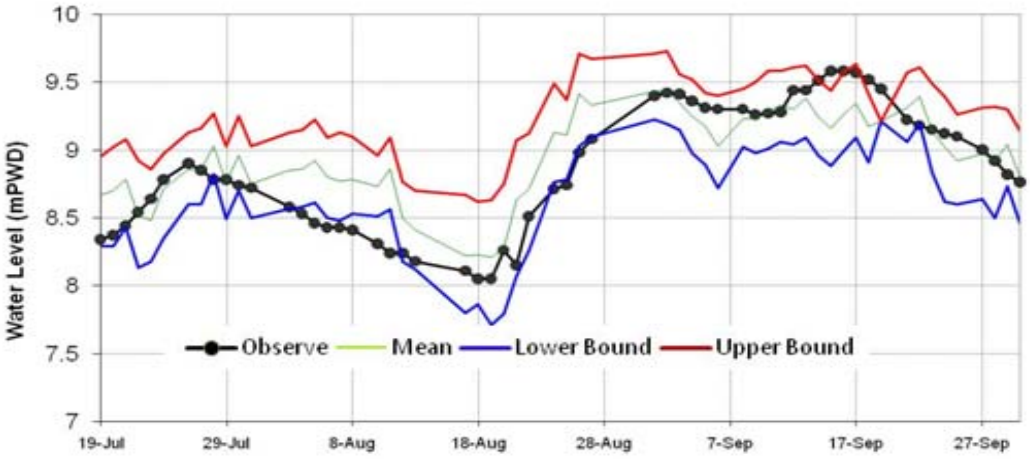


Figure 4.7: Aricha at the Jamuna River (10-day Forecast)

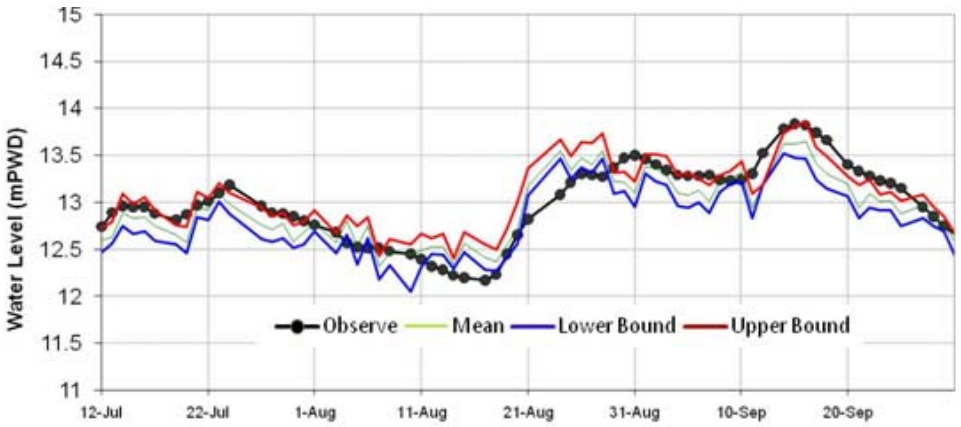


Figure 4.8: Serajganj at the Jamuna River (3-day Forecast)

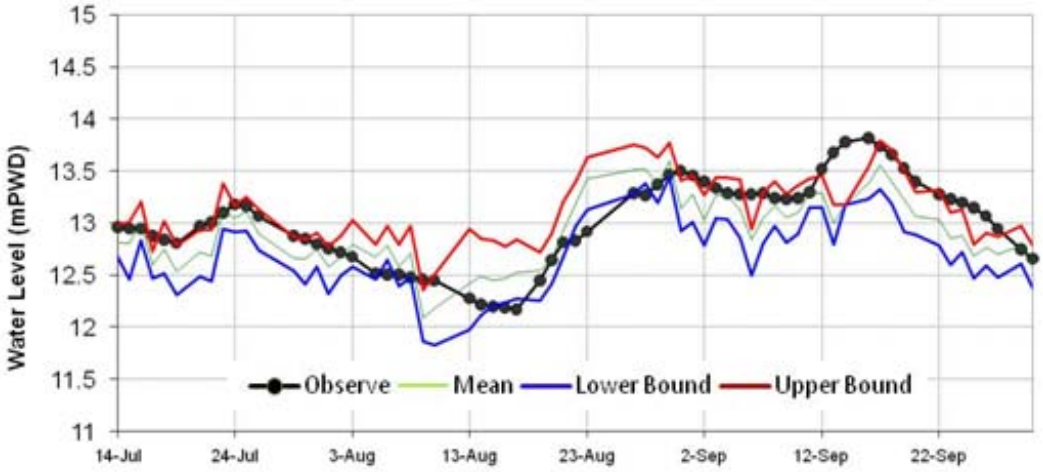


Figure 4.9: Serajganj at the Jamuna River (5-day Forecast)

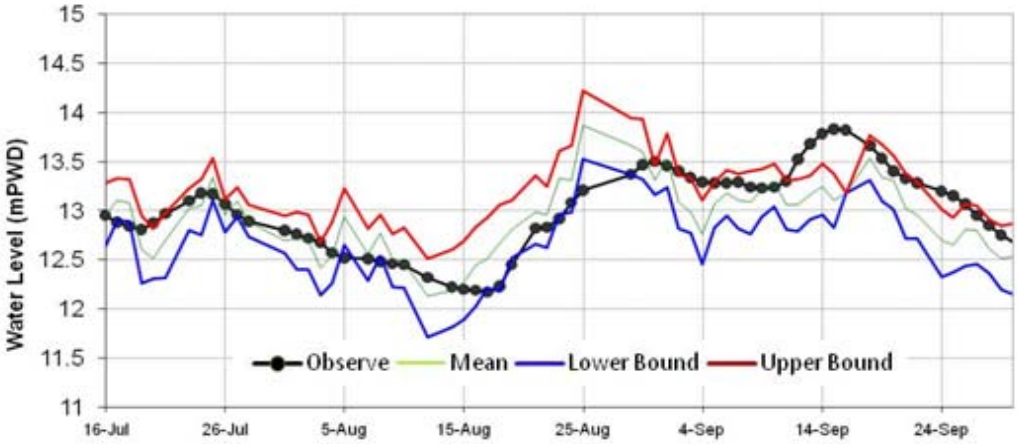


Figure 4.10: Serajganj at the Jamuna River (7-day Forecast)

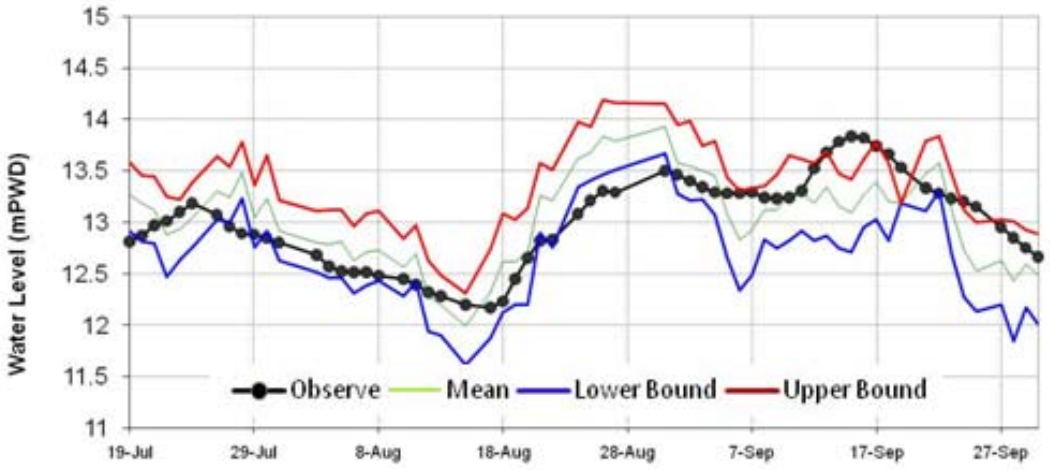


Figure 4.10: Serajganj at the Jamuna River (10-day Forecast)

CHAPTER 5: INUNDATION STATUS

The country as a whole experienced normal flooding during the flood season 2010. The low lying areas of Nilphamari, Lalmonirhat, Gaibandha, Jamalpur, Sherpur and Serajganj districts in the Brahmaputra Basin & Munshiganj, Manikgajn, Rajbari, Sariatpur, Madaripur and Fardipur districts in the Ganges Basin experienced short to medium duration of flooding during month of July, August and September. Along the Padma River, duration of WL remained above DL was 57-days iin Bhagyakul and 39-days in Goalondo. The Surma at Kanaighat(121-days), the Kushiyara at Amalshid(87-days), Sheola(113-days) and Sherpur(92-days) were above their respective DLs for prolong during in the flood season of 2010, longer then the previous flood years(1988 and 1998). As a result Sylhet, Sherpur and Moulvi Bazar experienced moderate flooding with longest duration during the monsoon-2010. The flooded area in the peak period of 15 September 2010 was 26,530 sq- km during the flood season of 2010.

In flood period, Flood Inundation Map for the whole country was developed at FFWC as a part of routine output. This was done by using MIKE 11 GIS, where the results were found from MIKE 11 Rainfall-Runoff and Hydrodynamic modelling simulation. In addition, River Situation Map was also developed in the FFWC. Flood inundation for whole country is a macro level product showing a general overview of flood situation of the whole country. A detail and authentic digital elevation map (DEM) shall improve significantly showing inundation status map. However, inundation status map of greater Dhaka city is more detail and precise. Sample of Flood Inundation Map and River Situation Map is presented in the following pages (Fig 5.11 and Fig 5.2).

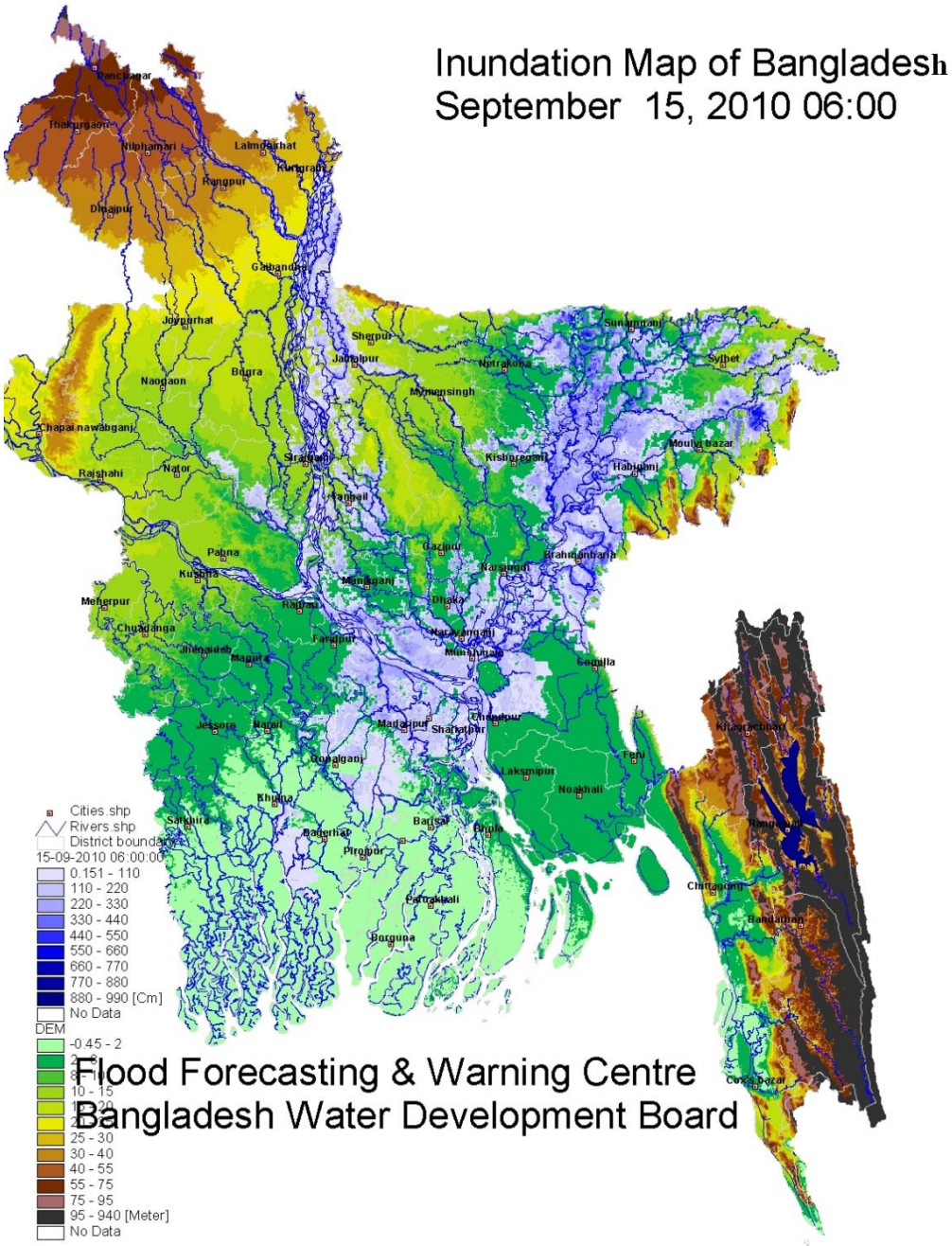


Figure 5.1: Flood Inundation Map of Bangladesh (September 10, 2010)

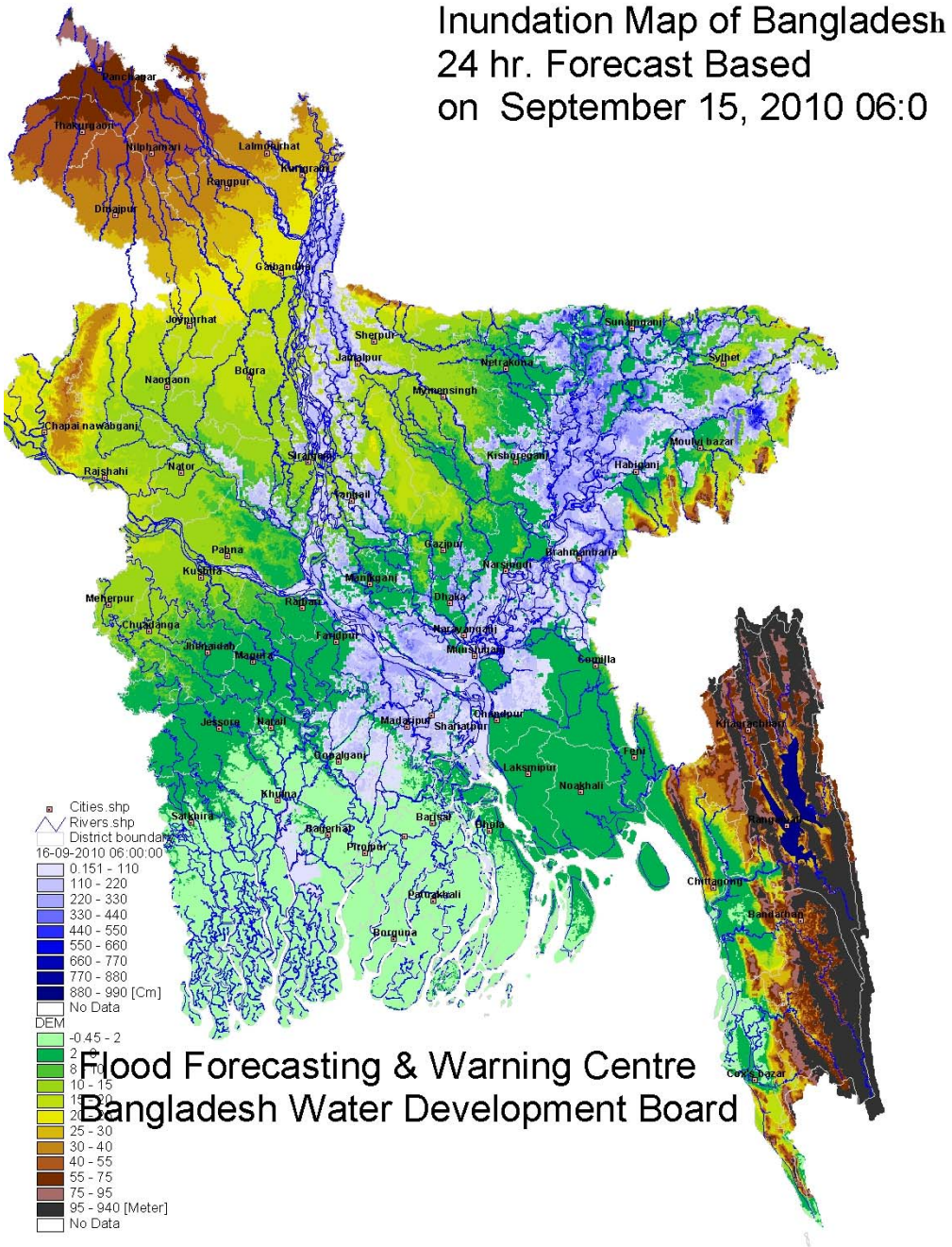


Figure 5.2: Flood Inundation Map of Bangladesh (24hr Forecast Based on 15 Sep 2010)

CHAPTER 6: CONCLUSIONS

The flood problem in Bangladesh is extremely complex. There are a number of reasons: the country is an active delta; it has extensive flood plains which surface water of about 1.7 million sq-km drains; and it has an extensive network of rivers and canals with flood plains. The country has an average annual rainfall of about 2300 mm, the range being 1500 mm in the west to over 5000 mm in the north-east. Floods occur in Bangladesh almost every year and devastating ones in every 5 to 10 years.

Floods are normal events in the deltaic plains of Bangladesh. Although the lifestyle of the people in Bangladesh is well adopted to flood phenomena, the damages due to inundation, riverbank erosion or breach of river structures, etc. still occur in various regions in every monsoon season. They often have disastrous consequences: major damage to infrastructure, great loss of property, human suffering and impoverishment of the poor.

The runoff from GBM catchments of 1.76 million sq-km passes through the intricate network of river systems of Bangladesh where only 7% area lies within the country. The characteristic of river varies from river to river and differs from region to region. Usually, in the Brahmaputra basin, flood begins in the late June while in the Ganges basin it starts from the second half of July. In the Meghna and south-eastern hill basins, flash flood occurs at the beginning of flood season.

As mandated, FFWC of BWDB monitored the flood situation from the very beginning of the flood season 2010. The FFWC has issued daily flood bulletin from May to October with a forecast lead-time of 24, 48 & 72hrs along with warning messages and flood inundation maps.

In addition to existing 24, 48 & 72 hrs deterministic forecast, FFWC issued 10 days lead-time probabilistic forecasts at 18 locations with the technical assistance of CFAN projects which utilizes ECMWF weather prediction data over the GBM basin to generate 51 sets of ensemble discharge forecasts at Bahadurabad and Hardinge-Bridge on the Brahmaputra and the Ganges Rivers respectively. The updated FFWC model was taken for customization for real-time flood forecasting utilizing CFAN predictions.

The FFWC also issued special type of flood bulletin during the critical time and tried to disseminate the whole situation to the people of the country through different mass media, news agencies and web site. The information has been used by various organizations: national and international disaster management operators, many Government agencies, NGOs and BWDB itself.

However, due to different shortcomings including limited upstream hydro-meteorological information, detail & accurate digital elevation model and limited technological development of the center itself, the services were fully not satisfactory to all corners. The forecast accuracy and lead time has been constrained by the lack of required data and rainfall forecast in upper catchments. Area-inundation forecast have been indicative, based on a coarse digital elevation model and old topographic maps. Information on flash flood was limited due to technological limitation and non-availability of the real time data at a much shorter interval than the usual.

The continued achievement of the Center is notable. It is trying hard to overcome the limitations and realities. Regional models need to have developed to provide regional flood forecasting and warning. Moreover, flood inundation map needs to develop further.

The FFWC of BWDB took the privileged to reflect the flood situation as accurate and reliable as possible. All these combined efforts may have played an effective role in minimizing people sufferings and damages of the infrastructures during the flood of 2010.

As a whole the flood of 2010 was fairly normal compare to devastating flood of 1987, 1988, 1998, 2004 and 2007. The maximum flooded area was 18% of the whole country (26,530 sq-km approximately).

In the Meghna basin due to excessive rainfall in the 2nd fortnight of April and 1st part of May generated onrush of inflow from the hilly region outside Bangladesh most of the rivers got higher water levels resulting flash flood of higher magnitude. This unusual high WL in the pre-monsoon(April-May) caused flesh floods in the entire North-Eastern region of Bangladesh resulted huge standing crop damage. Few of the stations of this basin (along Surma, Kushiyara rivers) exceeded previous record of duration of inundation/flooding. Flooding in the northern(along Jamuna-Brahmaputra river) and western part (along Ganges river) was shorter in duration and in the central part (along Padma river) duration was moderate.

The accuracy of flood forecasts issued by FFWC for monsoon Major River flood forecasting is around 92%, 83% & 75% for forecast of 24, 48 & 72 hrs respectively. Flood forecast model, the Super Model based on MIKE-11FF showed better performance in Brahmaputra and Ganges basins while in the flash flood areas, the model performance needs to improve further.

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