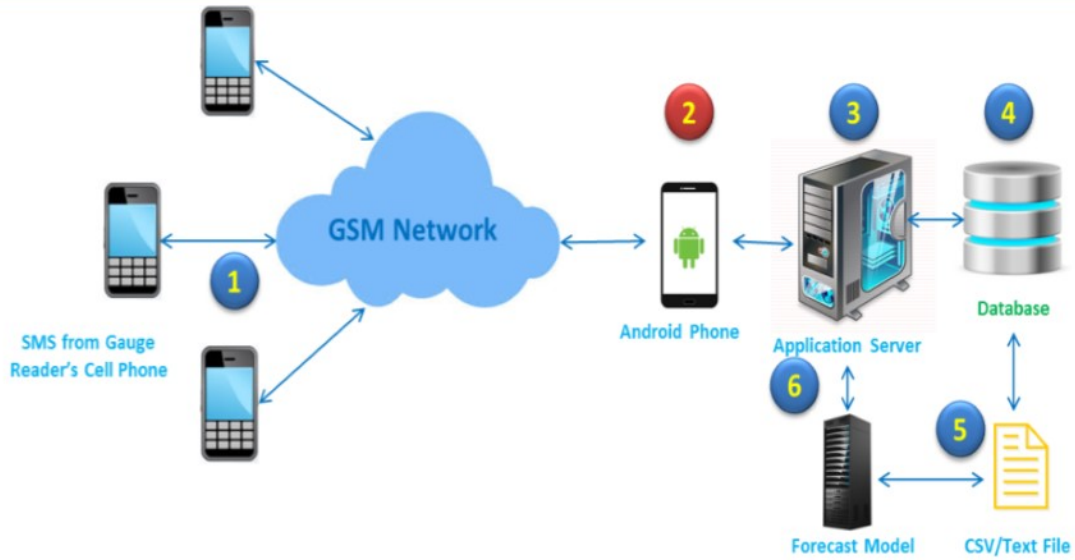
ANNUAL FLOOD REPORT 2015

SMS Solution



Flood Forecasting and 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, food security, poverty and almost every sector. In flood management, Bangladesh has been taken 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, following the Standing Orders for Disaster (SOD) of the Government of Bangladesh. The FFWC is acting as the focal point on flood forecasting and warning services in co-ordination with other ministries and agencies like BMD, DDM, DAE etc during the monsoon for flood disaster mitigation and management.

The objectives of flood forecasting and warning services are to enable and persuade people, community, agencies and organizations to be prepared for the flood and take necessary actions to increase safety and reduce or protect damages of lives and properties. Its goal is to alert the agencies, departments, communities and people to enhance their preparedness and to motivate vulnerable communities to undertake preparedness and protective measures.

The professionals of FFWC gratefully acknowledge the valuable advice and leadership of Director General, BWDB for his interest, continuous drive and suggestion. The valuable suggestions and encouragement provided by the ADG (Planning), Chief Engineer, Hydrology and Superintending Engineer, Processing & Flood Forecasting Circle, Hydrology, BWDB to improve the quality of works of the center.

The services of Flood Information Centers (FICs) established at the Division Offices of BWDB, Gauge Reader's, Wireless operators, local communities 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 and warning messages during flood 2015. A number of NGOs have been working in different areas for dissemination of the flood warning message generated by the FFWC at community and grass root level (Union and Village), this enables flood preparedness at local level.

With the support from the Comprehensive Disaster Management Programme, Phase-II (CDMP-II)(a UNDP initiative), under the Ministry of Disaster Management and Relief, following improvement and advancements have been made;

- Deterministic flood forecast lead time extended from 3-days to 5-days
- Structure based forecast for few BWDB projects and Dhaka-Mawa Highway
- Upgraded/updated easy to operate and more user friendly web-site with bangle flood warning message
- Flood warning dissemination through Interactive Voice Response(IVR) method using mobile phone(number 10941)
- Improved flood message display system in Bangla for the WAPDA Building
- Piloting Flash Flood Forecast in few stations of North Eastern zone.

Collaborative programmes with Regional Integrated Multi-hazard Early Warning System (RIMES), with financial support from USAID through CARE Bangladesh, the 10-daily probability based flood forecast has been strengthening.

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. One of 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 Flood Report-2015.

(Md. Sazzad Hossain)
Executive Engineer
Flood Forecasting & Warning Centre
BWDB, Dhaka.

Executive Summary

The characteristics of flood of 2015, is a representative one in respect of duration and magnitude. During the monsoon 2015, the flood was not severe one, duration was short in the north (along the Brahmaputra-Jamuna River) and short to moderate in the part of north east. Duration of flooding in the central part(along the Padma river) was moderate. Duration of flooding in the south west, in the part of Satkhira and Khulna districts was prolong, due to slow drainage or very low carrying capacity of rivers, specially Kobodak, Haribhanga & Shibsa river system. Water Level of Kobodak River at Jhikorgacha flowed above danger level for 100 days. As a whole, the monsoon 2015 was a normal flood year. The evaluation indicated that the accuracy of deterministic flood forecasts issued by FFWC is around 95.27%, 90.86%, 86.3%, 80.98% and 75.39% for 24hrs, 48hrs, 72 hrs, 96 hrs and 120 hrs respectively for the monsoon of 2015.

The country as a whole received 1.1% less rainfall than normal during the monsoon-2015 (May to October). The Brahmaputra, Ganges & Meghna received 13.71%, 0.2% and 10.5% less rainfall than the normal value respectively, while the South Eastern Hill basin received 18.8% more rainfall in the year of 2015. During the monsoon-2015 all the basins recorded more rainfall than their respective normal during August month. Basin wise monthly percent less(-) or more(+) rainfall than the normal is presented in the following table.

Month	Brahmaputra basin	Ganges basin	Meghna basin	South East Hill basin
May	-29.28	-54.68	-17.47	-17.47
June	6.58	8.59	-10.30	-10.30
July	-41.74	53.62	-12.04	-12.04
August	34.59	1.68	23.57	23.57
September	-3.98	-19.92	-12.93	-12.93
October	-76.83	-71.01	-76.66	-76.66

[BWDB Data 2015]

Professionals of the FFWC has been fully dedicated and committed to generate and disseminate flood forecasting and warning services on daily basis during the monsoon despite of limited resources, technology, short of logistics and lack of professional staff.

Notable improvents have been made during monsoon 2015 are extended lead time of flood forecsaat from 3-days to 5-days, structure based flood forecast for few projects, more user friendly-upgarded-easy to operate web-site with bangla flood warning message and mobile based dissemination system known as Interactive Voice Response (IVR).

During the monsoon-2015, maximum flooded area was 32% of the whole country (47,200 sq-km approximately). Some of the regions experienced river bank errosion and flash flood. The part of south west area flooded for prolong period.

List of Abbreviations

ADG	Additional Director General
ADPC	Asian Disaster Preparedness Centre
BWDB	Bangladesh Water development Board
BMD	Bangladesh Meteorological Department
CB	Cell Broadcast
CDMP	Comprehensive Disaster Management Programme
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
DDM	Department of Disaster Management
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
IVR	Interactive Voice Response
MAE	Mean Absolute Error
MoFDM	Ministry of Food and Disaster Management
MoWR	Ministry of Food Water Resources
NGO	Non-Government Organization
MSL	Mean Sea Level
RIMES	Regional Integrated Multi-hazard Early Warning System
SOD	Standing Order on Disaster
SSB	Single Site Band
SPARRSO	Space Research and Remote Sensing Organization
UNDP	United Nations Development Porgramme
USAID	United States Agency for International Development
WL	Water Level

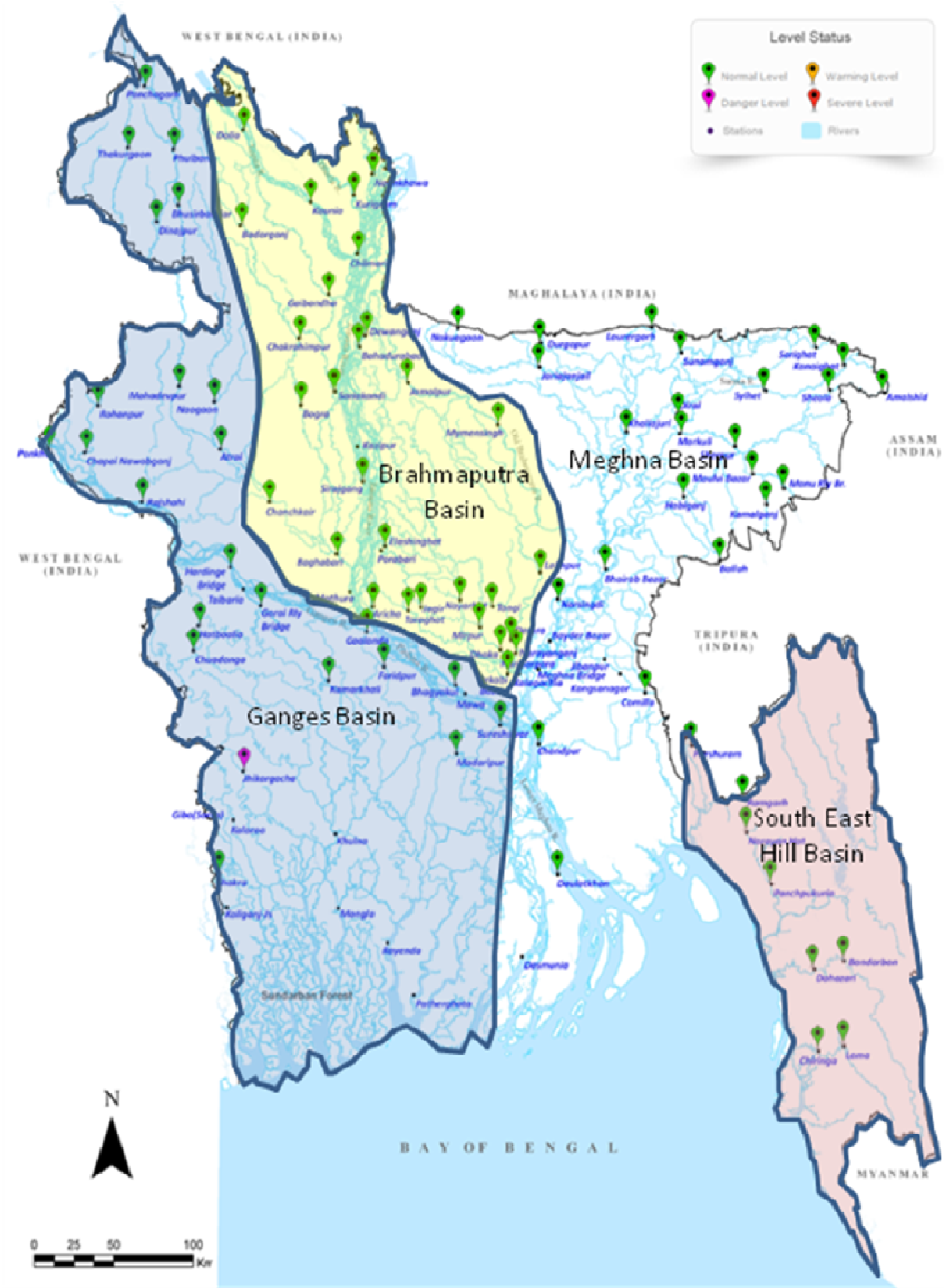

Figure 1 : Basin Map of Bangladesh with Water Level Gauge Stations

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 405 rivers including 57 transboundary rivers, among them 54 originated from India including three major rivers the Ganges, the Brahmaputra and the Meghna (*Ref. Bangladesher Nod Nodi, BWDB, August 2011*). 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 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, Sunamgonj 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 Karatoya-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 river course appears to have been taken place after a major earthquake and catastrophic flood 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 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 85 (73 previous and 12 added in 2015) 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, 96 and 120 hours at (38+16) 54 monitoring points, 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 at national level, weekly bulletin during dry season bulletin, monthly and annual flood reports. The Centre is responsible as a focal point in respect of flood from the month of April to November as per Government order for generating flood forecast & warning that are issued with the flood bulletin and also provide support services to DDM, BMD and SPARRSO during cyclonic disaster.

OUTPUTS of the FFWC

- **Rainfall Distribution Map.**
- **Daily Flood Bulletin & River situation summary**
- **Forecast bulletin & Hydrograph**
- **Warning message**
- **River situation map**
- **Special outlook**
- **Structure based flood forecast**
- **Countrywide coarse flood inundation map**
- **Dhaka city flood inundation map**
- **Comparison Hydrographs for various years**

Step by step development has been made in the flood forecasting and warning services in Bangadesh, started from 1972. Before 1990, forecast for six locations viz. Bahadurabad, Serajgonj, Aricha, Goalondo, Bhagyakul and Hardinge Bridge on the Padma – Brahmaputra –Jamuna river 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 flood affected area of Bangladesh, except coastal zone, the southern part. The Supermodel covers about 82,000 km^2 of entire country, except the coastal zone of the country. The area covered under the supermodel is

divided into 107 numbers of 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 is being done with a well-managed server based (Widows 2000) LAN–Operating System installed with desk top PCs at the FFWC.

Flood Forecasting & Warning Services: Brief History

1972 - FFWC Established under BWDB
- Real Time Flood Monitoring at 10 Stations/Points along the Brahmaputra, Ganges and Padma rivers
- Flood Forecast (FF) with few hours lead time at 6 points by Gauge Correlation along Brahmaputra and Padma rivers

1992 - MIKE11-FF Model Introduced
- FF with one day lead time at 16 points/locations

1995-96 - MIKE11 Super Model with GIS
- FF at 30 locations with lead time upto 2-days

2000-04 - Strengthening FFWS
- Expansion of FF areas coverage
- Flood monitoring covers entire country
- Improved accuracy and extend Lead Time upto 3-days
- Improved dissemination

2005-07 - Probabilistic medium range FF with lead time upto 10-days initiated at 18 points/locations

2007-09 - Further extension of FFWS
- Mike 11 Super Model with GIS introduced with flood ma generation facility
- FF at 38 locations on 21 Rivers upto 3-days Lead Time
- Flood Inundation Mapping
- Improvement of probabilistic medium range FF upto 10-days at 18 points

From 2012 - Strengthening and Improvement of FFWS
- FF at 54 locations on 29 rivers with Extended Lead Time upto 5-days
- Structure based FF for 4-selected projects upto 5-days lead time
- Probabilistic medium range FF lead time upto 10-days expanded at 38 locations
- Flash FF and Guidance initiated in North East and Jaliapalong, Coxs Bazar
- Improved and more user friendly web-site with Bangla language
- IVR system for dissemination based on mobile phone introduced
- Improved LAN and display

From 2014 – SMS based Digital Data Communication through Mobile Phone
- SMS based digital data communication between the FFWC and all the Gouge points under FFWS introduced since May 2014 replacing data collection and data communication by voice call. This reduces time, cost and error of data gathering and dissemination with improvement of forecast quality.
- Two Flood Bulletins in a day instead of One introduced since August 2015. The first Flood Bulletin prepared with Water Level (WL) of 09:00am (instead of 06:00am) and the Second one with WL of 03:00pm. Status of the day is prepared & disseminated showing the changes (Rising/Falling) of WL at Gauge points of the day indicating the change of flood situation
- Flood forecast SMS in Bangla sent to the Gauge Readers initiated since May 2015. The Gauge Readers of a particular Gauge point only receives WL Forecast of that point for next 1-Day and 5-Day.

1.4. OPERATIONAL STAGES BEFORE FORECAST MODEL RUN

Data Collection: The real time hydrological data (85 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 (24, 48, 72, 96 & 120hrs). 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. During monsoon (June to October) WL of few stations of upper catchments of Ganges, Brahmaputra, Teesta, Dharala and Barak rives has been received since 2010 from CWC India through e-mail. 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 about 30 to 40 minutes time to complete the calculations.

Daily forecast bulletin is prepared upto 5 days 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 organizations, 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. Interactive Voice Response (IVR) through mobile has been initiated since July 2011 through Teletalk and from 2015 all the mobile operators started the IVR.

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.

Mode of Dissemination

- E-mail
- Website
- Media, print & electronic
- Telephone, Mobile, Fax
- SMS to Gauge Readers
- Hard/print copy
- Lobby display
- (IVR) through mobile (no 10941)

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 kilometers 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 km²) 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 retard the drainage of floodwater into the sea and locally increase 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 2015, the flood was not a severe one and stayed for short duration in all the four basins, the Brahmaputra, the Ganges, the Meghna and South Eastern Hill Basin. In the South Western part of the country experienced prolong flooding in few stations, longer than the previous flood years, specially part of Khulna, Jessore and Satkhira districts. During the monsoon-2015 other flood affected districts (part of full, on the low-lying areas) are of Kurigram, Lalminiorhat, Gaibandha, Bogra, Rangpur, Serajgonj, Tangail, Jamalpur and Narayangonj, Munshigonj, Madaripur, Sariatpur, Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, Brahmmanbaria, Habigonj, Chittagong, Bandarban and Cox's Bazar. Percent of total area of Bangladesh affected by the flood are available since 1954 is presented in Table 1.1.

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	1976	28,300	19	**1998**	**1,00,250**	**68**
1955	50,500	34	1977	12,500	8	1999	32,000	22
1956	35,400	24	1978	10,800	7	2000	35,700	24
1960	28,400	19	1980	33,000	22	2001	4,000	2.8
1961	28,800	20	1982	3,140	2	2002	15,000	10
1962	37,200	25	1983	11,100	7.5	2003	21,500	14
1963	43,100	29	1984	28,200	19	2004	55,000	38
1964	31,000	21	1985	11,400	8	2005	17,850	12
1965	28,400	19	1986	6,600	4	2006	16,175	11
1966	33,400	23	1987	57,300	39	**2007**	**62,300**	**42**
1967	25,700	17	**1988**	**89,970**	**61**	2008	33,655	23
1968	37,200	25	1989	6,100	4	2009	28,593	19
1969	41,400	28	1990	3,500	2.4	2010	26,530	18
1970	42,400	29	1991	28,600	19	2011	29,800	20
1971	36,300	25	1992	2,000	1.4	2012	17,700	12
1972	20,800	14	1993	28,742	20	2013	15,650	10.6
1973	29,800	20	1994	419	0.2	2014	36,895	25
1974	52,600	36	1995	32,000	22	2015	47,200	32
1975	16,600	11	1996	35,800	24			

CHAPTER 2 : RAINFALL SITUATION

During the monsoon-2015 (May to Oct), the country experienced as a whole only 1.1% less rainfall than normal which can be considered as the normal rainfall situation in the monsoon period in Bangladesh. The Brahmaputra, Ganges & Meghna received 13.71%, 0.2% and 10.5% less rainfall than the normal value respectively, while the South Eastern Hill basin received 18.8% more rainfall in the year of 2015. Comparison of the basin and country average of normal and actual rainfall for the monsoon-2015 (May to October) is presented in the bar chart. Considering monthly value, all the basins recorded less rainfall than their respective normal during May-October period except the South Eastern Hill Region. The. Monthly normal and actual rainfall of all the basins and the country average are shown in Table 2.1.

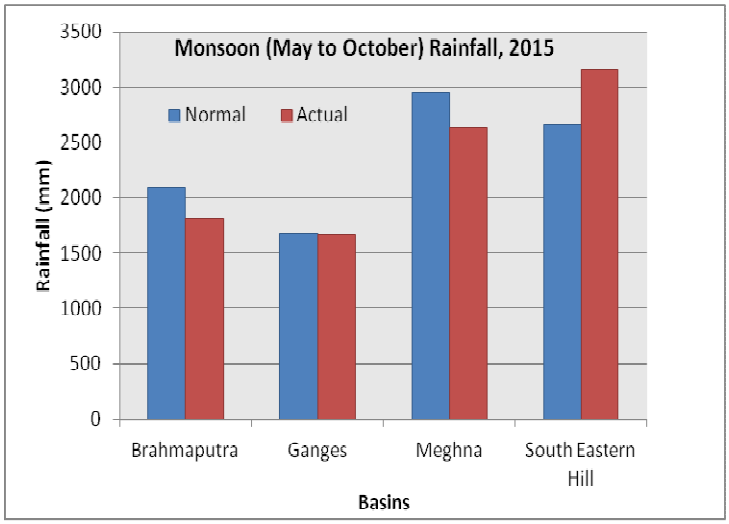

Table 2.1: Rainfall statistics for the monsoon 2015 over the four Basins

Month	Brahmaputra Basin(mm)		Ganges Basin(mm)		Meghna Basin(mm)		South Eastern Hill Basin(mm)		Monsoon average (mm)	
	Nor	Act	Nor	Act	Nor	Act	Nor	Act	Normal	Actual
May	315.4	223.04	191.8	86.92	491	405.2	290.4	61.79		
June	433.5	462.01	327	355.1	621	557.03	599.8	818.65		
July	496.1	289.02	397.8	611.1	650.5	572.2	728.5	1107.4		
Aug	339.7	457.2	337.8	343.48	537.9	664.66	536.9	583.44	2342.0	2317.2
Sept	353.4	339.34	298.7	239.2	449.2	391.1	317.9	453.69		
Oct	155.6	36.05	120.1	34.82	194.7	45.45	183.4	130.96		
Total	2094	1806.7	1673.2	1670.6	2944.3	2635.6	2656.9	3155.9		
%More / Less	13.71% less		0.2% less		10.5% less		18.8% more		1.1% less	

Rainfall situation of the country for the monsoon-2015(May to October) is described in the following sections.

2.1 MAY

The country, as a whole, experienced rainfall less than normal during the month of May 2015. All four basins, namely the Brahmaputra, the Ganges, the Meghna and the South-Eastern Hill Basin received

Important Rainfall Information for May 2015

Monthly Maximum at Sheola 731.0 mm

1-day maximum at Sheola: 135.0 mm

10-day maximum at Kanaighat: 502.0 mm

28.52%, 51.91%, 9.16% and 77.28% less rainfall than their monthly normal rainfall respectively. The summery of rainfall situation of the country during May 2015 is shown in the Table 2.2.

Table 2. 2 : **Summary of the rainfall situation during the month of May 2015**

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	18	17	12
Average Rainfall (mm) of the basin	**223.04**	**86.92**	**405.2**	**61.79**
%More(+)/Less(-) than the Normal:	**-28.52%**	**-51.91%**	**-9.16%**	**-77.28%**
Number of Stations above Normal Rainfall:	3	1	6	0
Highest 1-day Maximum Rainfall with Stations:	**Chilmari (128mm)**	**Dinajpur (95.0 mm)**	**Sheola (135mm)**	**Lama (103mm)**
Number of Rain Fed Flood* Stations:	0	0	6	0

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

In Brahmaputra basin, out of 13 rainfall monitoring stations, all the stations except Kurigram, Kaunia and Chilmari received less rainfall than their normal. The Basin received 28.52% less rainfall than their normal during the month May 2015.

In Ganges basin, out of 18 rainfall monitoring stations, all the stations except Dinajpur received less rainfall than their normal value of the month May 2015. At Sathkhira no rainfall is recorded for the month of May 2015. The basin as a whole received 51.91% less rainfall than the normal during the month of May-2015.

In the Meghna basin, out of 17 rainfall monitoring stations, 6 stations namely Sylhet, Sunamganj, Sheola, Sherpur, Lorergarh and Narsingdi received more rainfall than their normal value of the month. At Sherpur rainfall exceeds the previous maximum value in the month of May 2015. The Basin received 9.16% less rainfall than their monthly normal during the month.

In the South Eastern Hill basin, all the stations received less rainfall than their normal value of the month. In Noakhali, Teknaf and Swandip, no rainfall was recorded in the month of May 2015. The Basin received 77.28% less rainfall than their monthly normal during the month of May 2015.

Summary of the rainfall situation of the country is presented in Table 2.2. Considering 10-day maximum rainfall of 300 mm as a rain-fed flood index, as many as 6 stations were crossed the threshold value in this month in Meghna Basin. Those stations are Kanaighat, Sylhet, Sheola, Sunamganj, Lorergarh and Sherpur.

The Isohyets of the actual rainfall of the month of May-2015 is shown in the Figures 2.1.

2.2 JUNE

Important Rainfall Information for June, 2015
Maximum, at Cox's Bazar : 1551 mm
1-day maximum, at Cox's Bazar : 420 mm
10-day maximum, at Cox's Bazar : 1200 mm

The country, as a whole, recorded more rainfall than normal during the month of June-2015. the Brahmaputra basin, the Ganges basin the Meghna basin and the South Eastern Hill basins received 8.65%, 14. 89%, 4.59%, and 43.2% more rainfall than their respective monthly normal rainfall in the month of June 2015. The summery of the rainfall situation for June 2015 is shown in the Table 2.3.

Table 2. 3: Summary of the rainfall situation during the month of June 2015

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	18	17	12
Average Rainfall (mm) of the basin:	462.01	355.1	557.03	818.65
%More(+)/Less(-) than the Normal:	+8.65%	+14.89%	+4.59%	+43.2%
Number of Stations above Normal Rainfall:	8	10	7	9
Highest 1-day Maximum Rainfall with Stations:	**Dewanganj 250mm**	**Barisal 197 mm**	**Lorergarh 312 mm**	**Cox's Bazar 420 mm**
Number of Rain Fed Flood* Stations:	7	5	9	11

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

In Brahmaputra basin, out of 13 rainfall monitoring stations, 8 stations were recorded more rainfall than the monthly normal. The Basin received 8.65% more rainfall than their normal during the month June 2015.

10 out of 18 monitoring stations in the Ganges Basin were recorded rainfall above their monthly normal. One day maximum rainfall of 197 mm was recorded at Barisal. Ten day consecutive maximum rainfall of 581mm was recorded at Barisal. The Basin received 14.89% more rainfall than their monthly normal rainfall during the month of June 2015. In the district of Barisal, Patuakhali, Barguna, Naogoan and Kushtia were recorded above 300mm rainfall in Consecutive maximum rainfall which led to local flood in that part of Bangladesh in the month of June 2015.

In the Meghna basin, out of 17 rainfall monitoring stations, 10 stations were recorded less rainfall than the normal and 7 stations namely Sylhet, Sunamganj, Lorergarh, Nakuagaon, Chandpur and Narsingdi were recorded more rainfall than their respective monthly normal. One day maximum of 312 mm was recorded at Lorergarh and the 10-day consecutive maximum rainfall of 755mm recorded at Sunamganj. The Meghna basin as a whole received 4.59 % more rainfall than the normal rainfall during the month of June-2015. In the stations of Kanaighat, Sylhet, Sunamganj, Sheola, Sherpur, Durgapur, Lorergarh, Nakuagaon and Chandpur were recorded above 300mm rainfall in Consecutive maximum rainfall which led to flash flood in that North-Eastern part of Bangladesh in the month of June 2015.

In the South Eastern Hill basin, all rainfall monitoring stations received more rainfall than their normal rainfall for the month of June-2015 except Parshuram, Noakhali and Ramgarh. One day maximum of 420 mm was recorded at Cox's Bazar. The 10-day consecutive maximum rainfall of 1200 mm was also recorded at Cox's Bazar. The basin as a whole recorded 43.2% more rainfall than the normal rainfall during the month of June 2015. Total 10 stations in the country recorded 10-day consecutive rainfall more than 300mm which caused local flood in South Eastern part of Bangladesh.

Summary of the rainfall situation of the country is presented in the Table 2.3. Total 32 stations in the country recorded 10-day consecutive rainfall more than 300mm. The maximum 1-day rainfall of 420 mm and the 10-day consecutive maximum rainfall of 1200.0 mm was recorded at Cox's Bazar.

The Isohyets of the actual rainfall of the month of June-2015 are shown in the Figure 2.2.

2.3 JULY

Important Rainfall Information for July 2015
Maximum at Chittagong: 1600.0 mm
1-day maximum at Sunamganj: 360.0 mm
10-day maximum at Chittagong: 1093.0 mm

The country, as a whole, experienced rainfall more than normal during the month of July 2015 due to excessive rainfall in the Ganges and the South Eastern Hill Basin. The Brahmaputra and the Meghna basins received 40.4% and 9.5%, less rainfall while the Ganges and South Eastern Hill basin received 56.35% and 59.5% more rainfall than their respective monthly normal values. The Meghna basin, although received 9.5% less rainfall as a whole, some particular rainfall monitoring stations were recorded heavy rainfall. The summery of the rainfall situation of the country during the month of July 2015 is shown in the Table 2.4.

Table 2. 4: Summary of the rainfall situation during the month of July 2015

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	18	17	12
Average Rainfall (mm) of the basin:	289.02	611.1	572.2	1107.4
%More(+)/Less(-) than the Normal:	**-40.4%**	**+56.35%**	**-9.5%**	**+59.5%**
Number of Stations above Normal Rainfall:	1	15	5	9
Highest 1-day Maximum Rainfall with Stations:	Mymensingh **141.5 mm**	Jessore **223.8mm**	Sunamganj **360mm**	Chittagong **299 mm**
Number of Rain Fed Flood* Stations:	2	9	8	11
Name of Rain Fed Flood* Stations:		Jessore, Barisal	Sylhet, Sunamganj, Netrokona	Chittagong, Cox's Bazar

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

In Brahmaputra basin, all the stations received less rainfall than their normal except Dhaka station. The Basin received **40.4%** less rainfall than their normal during the month July 2015. Monthly 10-day maximum rainfall more than 300mm was recorded at Dhaka and Mymensingh.

In Ganges basin, all stations received more rainfall than their normal except three stations namely Panchagarh, Dinajpur and Mohadebpur. The basin as a whole received **56.35%** more rainfall than its normal during the month of July-2015. One day maximum rainfall of 223.8mm at Jessore and 10-day consecutive maximum rainfall of **633** mm was recorded at Barisal. 9 stations were recorded 10-day consecutive maximum rainfall more than 300mm which caused local flood in the month of July 2015.

In Meghna basin, all the stations recorded less rainfall than their normal value of the month except Sherpur, B. Baria, Comilla, Chandpur and Narsingdi. The Basin recorded 9.5 % less rainfall than their normal during the month of July 2015. One day maximum rainfall of 360 mm and ten day consecutive maximum rainfall of 637 mm were recorded at Sunamganj.

In South Eastern Hill basin, 9 stations received more rainfall than their normal rainfall. The basin as a whole received 59.5% more rainfall than its normal rainfall during the month of July 2015. One day maximum rainfall of 299 mm and 10-day consecutive maximum rainfall of 1093mm was recorded at Chittagong. This rainfall caused water logging and local flood at the area.

Summary of the country's rainfall situation is presented in Table 2.5. Total 30 out of 59 stations recorded more than 300 mm rainfall for 10-day consecutive maximum rainfall. Maximum 10-day rainfall recorded at Chittagong of 1093 mm. 1-day maximum rainfall recorded 360.0 mm in Sunamganj. Rain fed flood situation developed at Durpapur, Netrokona and Cox's Bazaar.

A map with isohyets of the actual rainfall of July-2015 is shown in the Figure 2.3.

2.4 AUGUST

Important Rainfall Information for August 2015
Maximum at Lorergarh: 2243 mm
1-day maximum at Lorergarh: 350 mm
10-day maximum at Lorergarh: 1451 mm

The intensity of rainfall in the Brahmaputra, the Ganges, the Meghna and the South Eastern Hill basin was moderately high at most of the places during the month of August 2015. The four hydrological basins Brahmaputra, Ganges, Meghna and South Eastern Hill basins received more rainfall than their respective monthly normal rainfall during the month of August, 2015. The Brahmaputra, the Ganges, the Meghna and the South Eastern Hill basin received 34.61%, 9.51%, 30.62% and 10.35% more rainfall than their respective normal rainfall of the month. Rainfall situation is summarized in the following table 2.5, where a brief description of the rainfall situation is described.

Table 2. 5: Summary of the rainfall situation during the month of August 2015

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	18	17	12
Basin average rainfall at August, 2015(mm):	457.2	343.48	664.66	583.44
%More(+)/Less(-) than Normal:	34.61%	9.51%	30.62%	10.35%
No. of Stations above Normal Rainfall:	8	9	12	7
Highest 1-day Maximum Rainfall Stations:	Chilmari (316 mm)	Dinajpur (178 mm)	Lorergarh (350 mm)	Lama (303 mm)
No of Rain Fed Flood* Stations:	5	4	7	6

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

The above table shows that 8 out of 13 rainfall monitoring stations in the Brahmaputra basin; 9 out of 18 rainfall stations in the Ganges basin; 12 out of 17 rainfall stations in the Meghna basin and 7 out 12 stations in South Eastern Hill the basin received more rainfall than their monthly normal rainfall. Among all monitoring stations, Lorergarh in the Meghna Basin is the daily highest rainfall recorded station.

The Table 2.5 shows that 5 stations in the Brhamaputra basin, 4 stations in Ganges basin, 7 stations in the Meghna Basin and 6 stations in the South Eastern Hill basin received more than 300 mm rainfall in consecutive 10-day period. It may be mentioned that 300 mm or more rainfall in consecutive 10-day period may cause rain fed flood in the locality.

In the month of August 2015, Rangpur and Chilmari stations in Brahmaputra basin and Lorergarh in Meghna Basin were recorded to cross the respective 30 years maximum rainfall records.

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The Isohyets of the actual rainfall of the month of August-2015 is shown in the Figure 2.4.

2.5 SEPTEMBER

Important Rainfall Information for September 2015
Maximum at Sylhet : 811.5 mm
1-day maximum at Lorergarh : 230.0 mm
10-day maximum at Sylhet : 462.0 mm

The country, as a whole, experienced 1.0% more rainfall than normal during the month of September 2015 due to the excessive rainfall in South Eastern Hill region. Among the four hydrological basins, the Brahmaputra, the Ganges and the Meghna basin received 3.98 %, 12.93% and 2.78% less rainfall while the South Eastern

Hill Basin received 28.8% more rainfall in the month of September 2015. Table 2.6 represents the summary of rainfall situation all through the country during the month of September 2015.

Table 2. 6: Summary of the rainfall situation during the month of September 2015

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	18	17	12
Basin average rainfall at September,2015(mm):	339.34	239.2	391.1	453.69
%More(+)/Less(-) than Normal:	-3.98 %	-12.93%	-2.78%	+28.8 %
No. of Stations above Normal Rainfall:	6	7	7	8
Highest 1-day Maximum Rainfall Stations:	Dalia (212mm)	C. Nawabganj (116.3mm)	Lorergarh (230 mm)	Cox's Bazar (218 mm)
No of Rain Fed Flood* Stations:	1	-	5	4

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

The above table shows that 6 out of 13 stations in the Brahmaputra, 7 out of 11 stations in the Ganges basin, 7 out of 11 stations in the Meghna and 8 out 11 stations in South Eastern Hill the basin received more rainfall than their monthly normal rainfall. Among all monitoring stations, Lorergarh in the Brahmaputra basin is the daily highest rainfall recipient station.

The table also shows that all the one station in the Brahmaputra basin, five stations in the Meghna basin and four stations in the South Eastern Hill basin received more than 300 mm rainfall in 10-day period. As a result, some parts of Sunamganj, Sylhet, Habiganj, Moulvibazar, Metrokona were affected by rain feed flood during the month of September 2015. It is to be mentioned here that 300 mm or more rainfall in 10-Day period may cause rain fed flood.

Two stations in South Eastern Hill basin, namely Ramgarh and Rangamati were recorded more rainfall than their previously recorded maximum cumulative rainfall in the month of September 2015.

The Isohyets of actual rainfall for September-2015 is shown in the Figure 2.5.

2.6 OCTOBER

All the four hydrological basins of the country received less rainfall than their monthly normal in October-2015. The Brahmaputra, the Ganges, the Meghna and the South Eastern Hill

Important Rainfall Information for October 2015

Monthly Maximum at Swandip : 299.0 mm

1 day maximum at Swandip: 164.5 mm

10 day maximum at Swandip: 299.0 mm

Basins received 76.68 %, 71.72%, 73.83% and 29.98% less rainfall than their monthly normal rainfall respectively during October-2015. At Swandip the 1-day maximum rainfall recorded 164.5 mm in October 2015. The summary of the rainfall for the month of October-2015 is presented in Table 2.7

Table 2. 7: Summary of Rainfall for the month of October-2015

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	18	17	12
Average Rainfall (mm) of the basin:	36.05	34.82	45.45	130.96
%More(+)/Less(-) than the Normal:	**76.68 % less**	**71.72 % less**	**73.83 % less**	**23.98 % less**
Number of Stations above Normal Rainfall:	-	1	1	4
Highest 1-day Maximum Rainfall with Stations:	Dhaka 79.0 mm	Barisal 46.0 mm	Kanaighat 67.0 mm	Sandwip 164.5 mm
Number of Rain Fed Flood* Stations:	0	0	0	0

*300 mm or more rainfall in consecutive 10 days impedes the drainage are likely to cause rain fed flood in the area.

In Brahmaputra basin, out of 13 rainfall monitoring stations, all stations recorded less rainfall than the normal and The Basin received 76.68% less rainfall than their normal during the month October 2015. Highest 1 day maximum rainfall of 79.0mm was recorded at Dhaka. At Rangpur Station, no rainfall recorded in the month of October-2015.

In Ganges basin, out of 18 rainfall monitoring stations, all stations except Faridpur recorded less rainfall than the normal rainfall of the month. The basin as a whole received 71.72% less rainfall than the normal during the month of October-2015.

In the Meghna basin, out of 17 rainfall monitoring stations, all stations except Chandpur were recorded less rainfall than the normal value of the month. The Basin received 73.83% less rainfall than their monthly normal during the month of October 2015.

In the South Eastern Hill basin, all rainfall monitoring stations except Bandarban, Lama, Swandip and Cox's Bazar were received less rainfall than their normal rainfall. The Basin as a whole recorded 23.98% less rainfall than the normal rainfall during the month October 2015.

A map with the Isohyets of actual rainfall for the month of October-2015 is shown in the Figure 2.6.

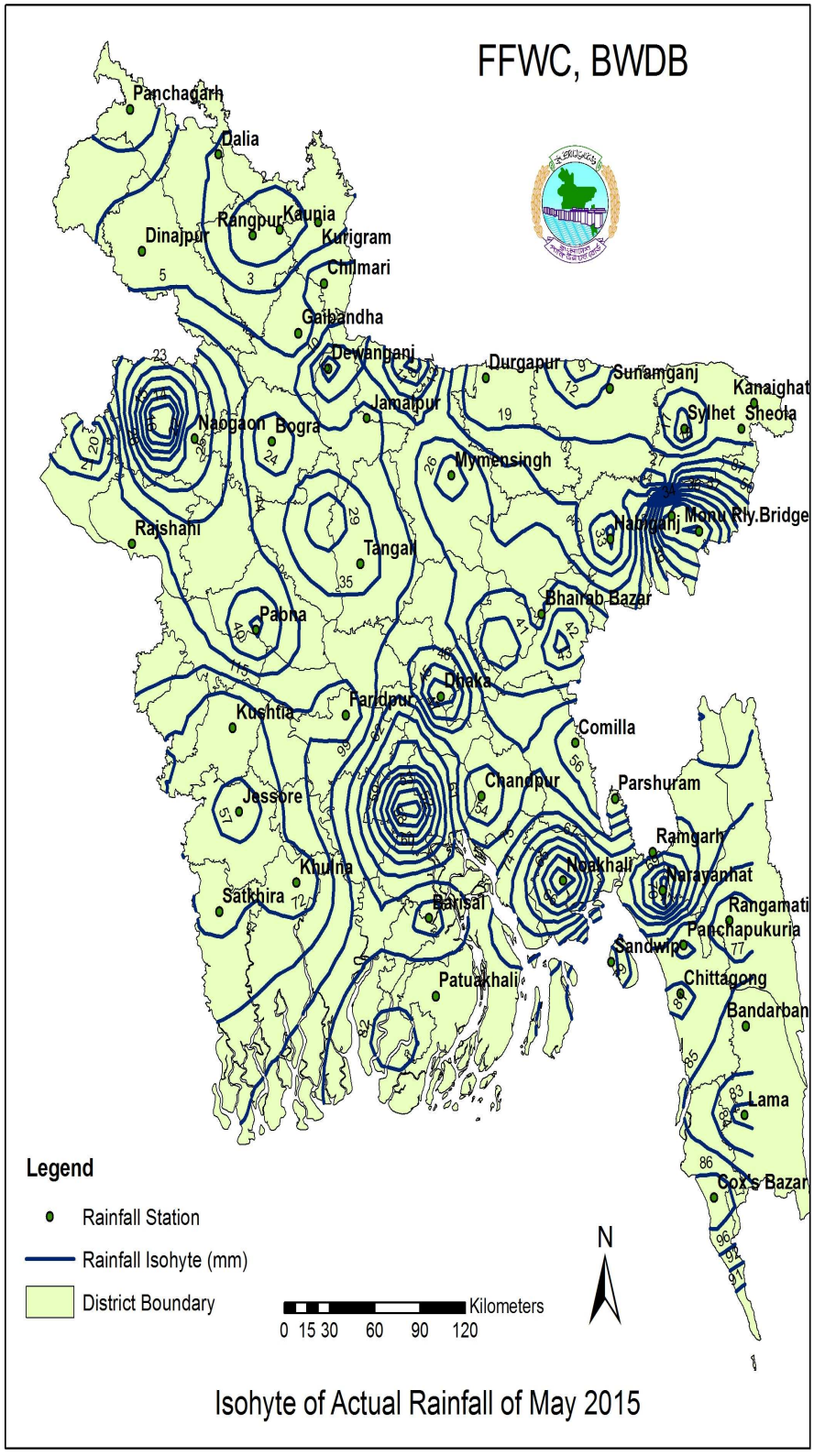


Figure 2.1 : Isohyets of Actual Rainfall (May 2015)

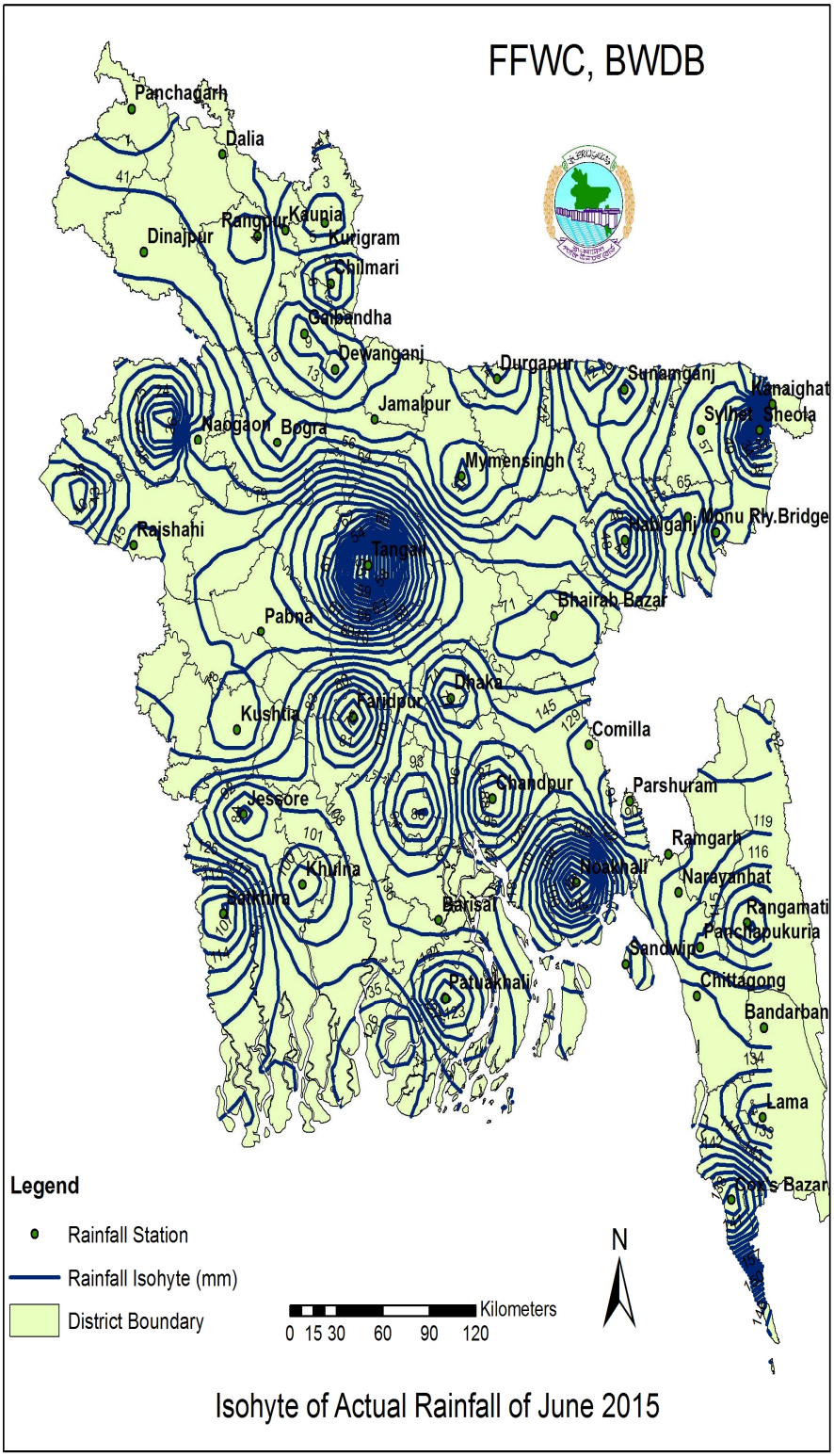


Figure 2.2 : Isohyets of Actual Rainfall (June 2015)

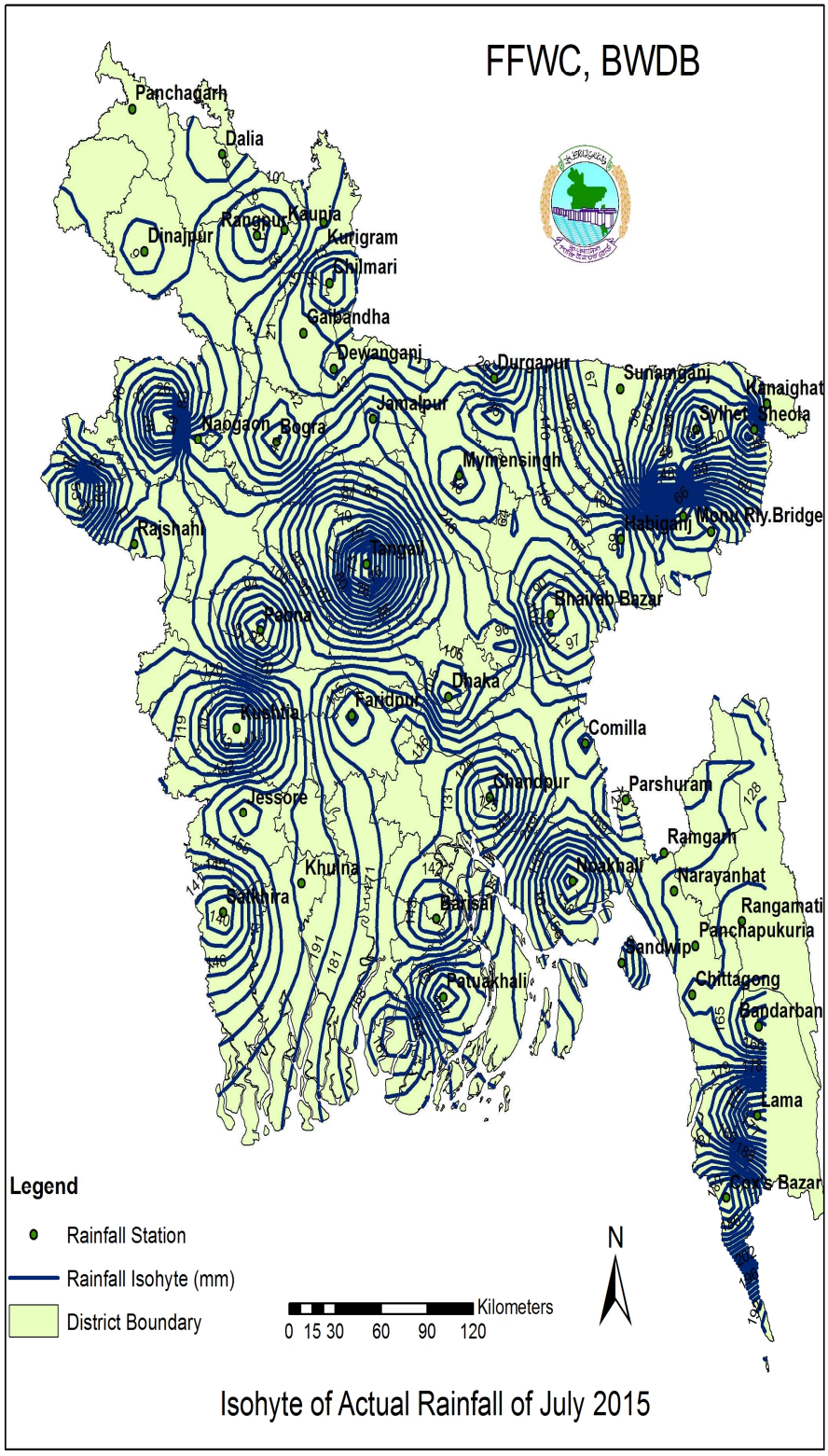


Figure 2.3 : Isohyets of Actual Rainfall (July 2015)

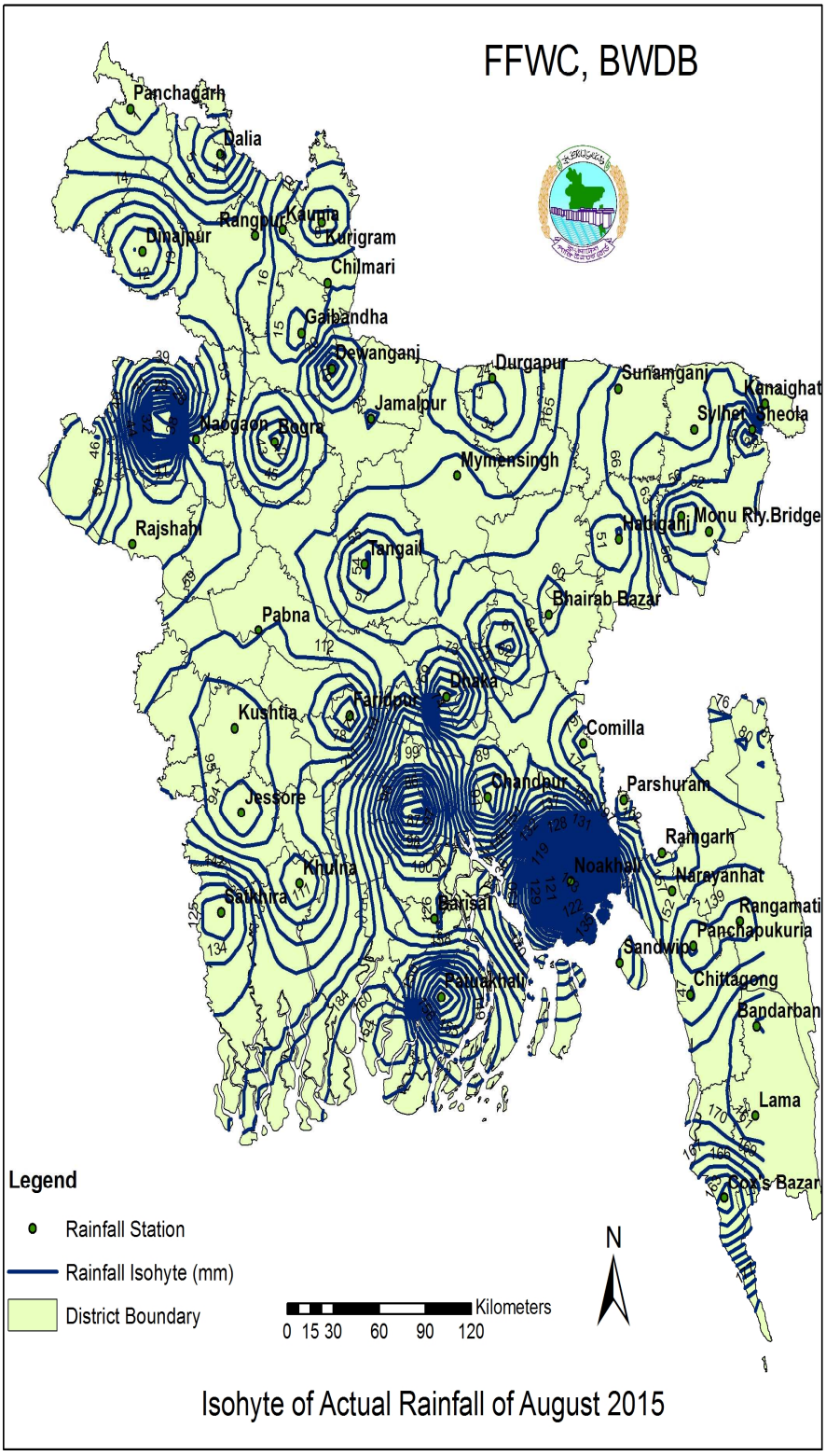


Figure 2.4 : Isohyets of Actual Rainfall (August 2015)

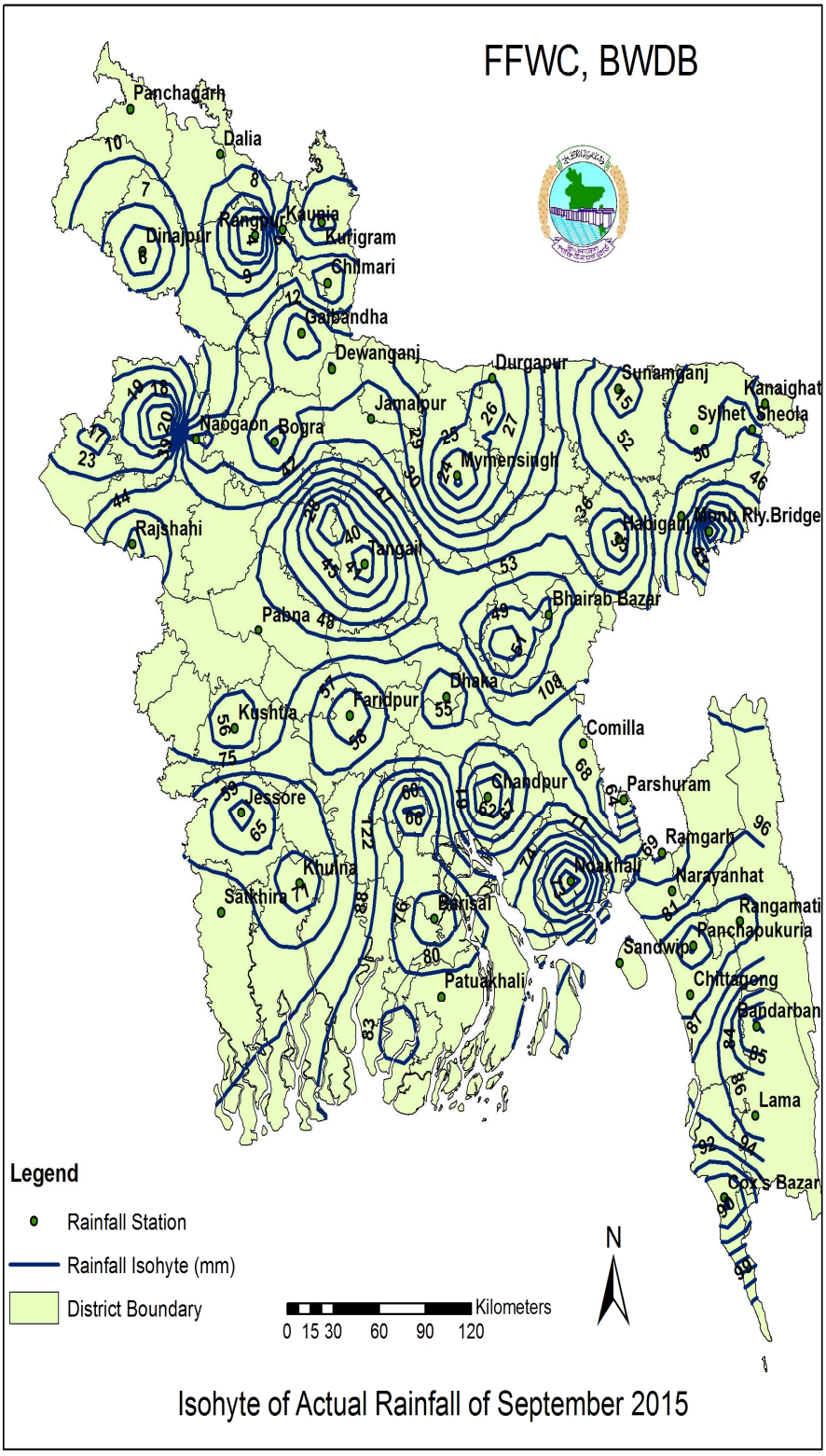


Figure 2.5 : Isohyets of Actual Rainfall (September 2015)

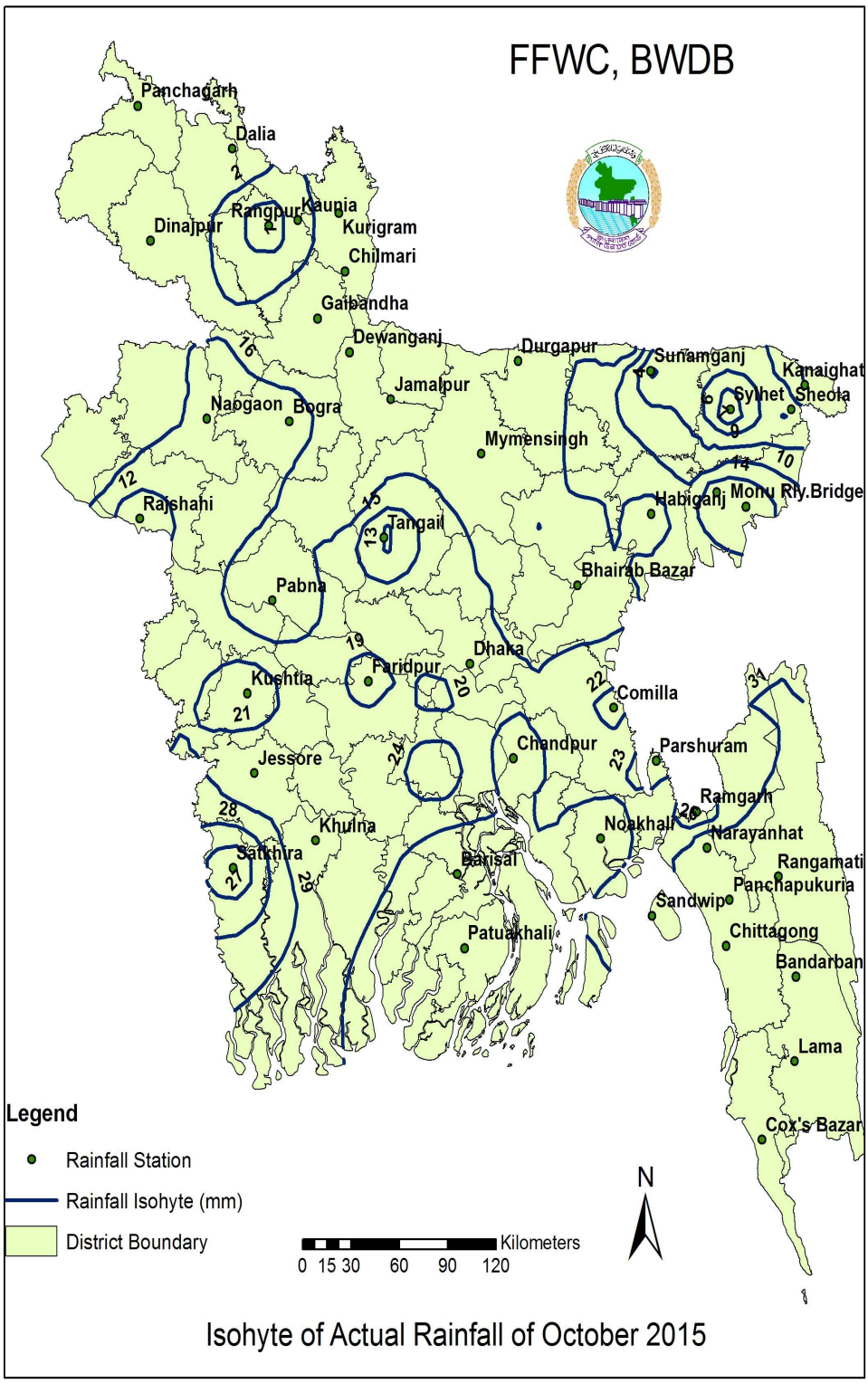


Figure 2.6 : Isohyets of Actual Rainfall (October 2015)

CHAPTER 3: RIVER SITUATION

During the monsoon 2015, the flood was not a severe one and stayed for medium duration in all the four basins, the Brahmaputra, the Ganges, the Meghna and South Eastern Hill Basin. The Brahmaputra and Meghna Basin first experienced the monsoon flood at the beginning of the second week of June 2015. The upper portion of Ganges Basin was not recorded as flood affected throughout the monsoon. Basin wise WL situation is described in the following sections.

3.1 THE BRAHMAPUTRA BASIN

Out of 28 Water Level (WL) monitoring stations in this basin, at 17 stations river WL was crossed their respective Danger Levels (DL). Water Level of Brhamaputra Basin started to rise from the second week of June 2015 for the first time in the monsoon and caused a medium duration of flood for this basin. In this monsoon Brahmaputra basin had experienced several peaks with two majors, which caused flood in this country in 2015. This flood situation lasted 1 to 24 days for the basin. As a result, low-lying areas of Kurigram, Lalminiorhat, Gaibandha, Bogra, Naogaon, Rangpur, Serajgonj, Tangail, Jamalpur and Narayangonj districts were flooded for short to medium period of flood. A comparative statement of WL for current year 2015 and historical events of 1988 and 1998 for the Brahmaputra Basin is shown in the Table 3.1. The details of the river situation in this basin are described in the following sections:

The Dharla at Kurigram

The WL of Dharla river at Kurigram registered its monsoon peak during the monsoon 2015, in 1st week of Septembert. It crossed the DL twice during the monsoon 2015 at the 3rd week of August and then again 1st day of September and flowed above DL for total 13 days. WL at Kurigram attained peak of 26.99mPWD on 2nd September at 12:00 hours, which was 49 cm above the DL (26.50 m).

The Teesta at Dalia and Kaunia

The Teesta river is flashy in nature. The WL of river Teesta showed several peaks during the monsoon both at Dalia and Kaunia. At Dalia WL crossed its DL mark for 4 times during the monsoon (1st in June, then also in July August and September), highest peak on 2nd July with peak of 52.85mPWD, which was 45cm above its DL (52.40m). At Dalia it flowed above DL for 13 days throughout the monsoon period. At Kaunia WL of the river Teesta did not cross the DL during the mosoon-2015, attained the peak of 29.11m on 2nd September which was 89cm below the DL(30.0m) at this point.

The Jamuneswari at Badargonj

The Jamuneswari at Badargonj crossed the DL in 23rd August and attained the peak of 32.44mPWD (DL 32.16m) on 24th August at 6:00 hours. During the whole monsoon this station was recorded with other several low peaks. Water level above DL was recorded for three days.

The Ghagot at Gaibandha

The WL of Ghagot river at Gaibandha crossed DL twice during the monsoon 2015, firstly in mid of June for two days and secondly in the beginning of the September for six days. It flowed above the DL for 8 days with peak of 22.33 m on 6th September, which was 63cm above its DL(21.70m).

The Korotoa at Chakrahimpur and Bogra

The WL of Ghagot river at Gaibandha crossed DL once during the monsoon 2015, from 24th August to 5th September for 12 days. It flowed above the DL for 12 days with peak of 20.69 m on 27th August, which was 54cm above its DL(20.15m). At Bogra point the Korotoa river did not cross its respective Danger Level with a peak flow of 14.54m on 6th September which was 178cm below the respective DL(16.32mPWD).

The Brahmaputra at Noonkhawa and Chilmari

The river Brahmaputra at Noonkhawa and Chilmari observed sharp rise and fall at several times. At Noonkhawa WL of the Brhamaputra river attained the peak of 26.89mPWD on 6th September at 09:00 hours, which was 36cm below the respective DL (27.25mPWD) at this point. At Chilmari, Water level crossed the Dl twice in this monsoon, firstly at 23th August to 25th August and Secondly 3rd September to 9th September. Water level crossed the rspective DL at 23rd August and continued to flow for three days up to 25th August and then it again crossed the DL at 2nd September 18:00 hours which continued to 9th September. At Chilmari, the water flowed above the DL for 10 days and the peak WL of the Brahmaputra river was recorded 24.44mPWD on the 6th September-2015, which was 44cm above its DL(24.00m).

The Jamuna at Bahadurabad, Sariakandi, Serajgonj and Aricha

The WL of river Jamuna at Bahadurabad, Sariakandi, Serajgonj & Aricha demonstrated similar trends as Brahmaputra at Noonkhawa and Chilmari. At Bahadurabad the Jamuna flowed above DL for 18 days with the peak of 20.19mPWD on 6th September, which is 69cm above the DL(19.50m) at this point. At this point Jamuna crossed its respective DL on 14th July for one day, then again crossed the DL on 22nd August and flowed till 28th August, 2015. Finally again it crossed the DL on 1st September and flowed till 10th September. At Sariakandi the Jamuna crossed the respective DL twice in this monsoon. At first it crossed the Dl on 13th July and flowed for 3 days till 15th July. Again it crossed DL on 22nd August and flowed above the DL for 21 days till 11th September. It flowed above for total 24 days, with a peak of 17.49mPWD on 6th September 12:00 hours, which was 79 cm above the DL (16.70 m). At Serajgonj the Jamuna flowed above DL from 22th August to 11th September for 21 days with peak of 14.13mPWD, on 7th September at 06:00hrs, which is 78cm above the DL(13.35m). At Aricha the WL of the Jamuna river crossed the DL with peak WL of 9.45mPWD on 27th August, which was 5cm above the DL(9.40m) and remained above DL for more than 2 days from 26th August 15:00 hours to 28th August 06:00 hours.

The Gur at Singra

The WL of river Atrai at Baghabari flowed above DL for 11 days from 1st September to 11th September 2015, with the peak of 12.87mPWD on 6th September, which is 22cm above the DL(12.65m) at this point.

The Atrai at Baghabari

The WL of river Atrai at Baghabari flowed above DL for 26 days, 15th July and 16th July and from 21st August to 13th September 2015, with the peak of 12.01mPWD on 7th September, which is 161cm above the DL(10.40m) at this point.

The Dhaleswari at Elashin

The WL of river Dhaleswari at Elashin flowed above DL for 24 days from 23th August to 15th September 2015, with the peak of 12.33mPWD on 8th Septembert, which is 193cm above the DL(10.40m) at this point.

The Old Brahmaputra at Jamalpur and Mymensingh

The WL of the Old Brahmaputra river at Jamalpur and Mymensingh showed rise and fall during the monsoon, but remained below the respective DLs at both the stations. At Jamalpur the peak WL recorded of 15.84mPWD on 9th September which is 116cm below the DL at this point(DL 17.0m). At Mymensingh the peak WL recorded was 11.19mPWD on 11th September, which was 131cm below the DL (12.5m) at this point.

The Lakhya at Lakhpur and Narayanganj

The WL of Lakhya river at Lakhpur and Narayanganj showed a similar trend to that of the Buriganga and crossed their respective DLs. The Lakhya river at Lakhpur crossed its respective DL 27th August and continued to flow above DL up to 17th September for 22 days. It attained its monsoon peak of 6.25mPWD 3rd September, which 45cm above the DL (DL 5.8m). Lakhya River at Narayanganj crossed its respective DL at 31st August 18:00 hours and continued to flow above DL up to 3rd September for 4 days. It attained its monsoon peak of 5.60mPWD 2nd September, which 10cm above the DL (DL 5.5m).

The Rivers around Dhaka

Stations near or around Dhaka city like Buriganga at Dhaka and the Turag at Mirpur attained the peak of the monsoon during the August and September in this year. all the river around Dhaka city flow Flowed below their respective DLs. The Buriganga at Dhaka, and the Balu at Demra recoded their highest peak of 5.2 mPWD (DL 6.0m) on 2nd September, 5.52m (DL 5.75m) on 2nd September 2015 respectively. The Turag at Mirpur did not cross its respective DL and flowed with a peak of 5.59 mPWD which is 35cm below the DL (5.94 mPWD).

The Kaliganga at Taraghat

The WL of Kaliganga river at Taraghat showed a trend similar to that of the Buriganga at Dhaka. The river at this station crossed the DL at 5th September and continued to flow

above DL up to 13th September for 9 days with peak of 8.75mPWD on 10th September, which was 35 cm above its DL(8.40 m) at Taraghat.

Comparative hydrographs for the year of 2015, 2007 & 2004 of few stations of the Brahmaputra basin are shown in Figures 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 3.10, 3.11, 3.12 and 3.13.

Table 3. 1 : Comparison of Water Level of 2015 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		
					2015	1998	1988	2015	98	88
1	Dharla	Kurigram	27.66	26.50	26.99	27.22	27.25	13	30	16
2	Teesta	Dalia	52.97	52.40	52.85	52.20	52.89	13	-	8
3	Teesta	Kaunia	30.52	30.00	29.11	29.91	30.43	-	-	38
4	Jamuneswari	Badargonj	33.00	32.16	32.44	33.00	32.80	3	6	5
5	Brahmaputra	Noonkhawa	28.10	27.25	26.89	27.35	NA	-	-	NA
6	Brahmaputra	Chilmari	25.06	24.00	24.44	24.77	25.04	10	22	15
7	Ghagot	Gaibandha	22.81	21.70	22.33	22.30	22.20	8	51	17
8	Jamuna	Bahadurabad	20.62	19.50	20.19	20.37	20.62	18	66	27
9	Jamuna	Serajgonj	15.12	13.35	14.13	14.76	15.12	21	48	44
10	Jamuna	Aricha	10.76	9.40	9.45	10.76	10.58	2	68	31
11	Old Br.putra	Jamalpur	18.00	17.00	15.84	17.47	17.83	-	31	8
12	Old Br.putra	Mymensingh	14.02	12.50	11.19	13.04	13.69	-	33	10
13	Buriganga	Dhaka	7.58	6.00	5.2	7.24	7.58	-	57	23
14	Lakhya	Narayangonj	6.71	5.50	5.6	6.93	6.71	-	71	36
15	Turag	Mirpur	8.35	5.94	5.59	7.97	NA	-	70	NA
16	Tongi Khal	Tongi	7.84	6.08	5.61	7.54	NA	-	66	NA

3.2 THE GANGES BASIN

In this basin out of 23 WL monitoring stations, 6 stations exceeded their respective DLs, during the monsoon 2015. The rivers flowed above DL are Little Jamuna at Naogaon for 3 days, Padma at Goalondo for 18 days, at Bhagyakul for 16 days and at Sureswar for 7 days and the Kobaddak River at Jhikargacha for 100 days. The low lying areas of Rajbari, Faridpur, Panchagr, Thakurgain, Dinajpur, Manikgonj, Munshigonj, Sariatpur and Noagaon districts was affected by normal flooding during the month of August and September for short ot medium periods. It may be mentioned that, a moderate duration of flooding situation was prevailing around the Bhagyakul and Goalundo. At Jhikargacha, due to local drainage problem, duration of flood became prolong to the people live there. All other rivers flowed below their respective DLs. A comparative statement of WL for 2015 and historical events of 1998 & 1988 for the Ganges Basin is shown in the Table 3.2. The details of the river WL situation in this basin are described below:

The Karatoa at Panchagarh

The karatoa river at Panchgarh showed a sharp rise and fall during the monsoon and didn't cross the DL with a peak flow of 69.85 mPWD at 1st September, which was 90 cm below the respective DL (70.75 m)

The Punarbhaba at Dinajpur

The WL of river Punarbhaba at Dinajpur showed sharp rise and fall during the monsoon, but did not cross the DL in the flood season of 2015. The peak WL of 32.47mPWD was recorded on 2nd September, which was 103cm below of its DL (33.50m).

The Tangon at Thakurgaon

The Tangon river is flashy in nature and showed various small peaks during the monsoon but never crossed its respective Danger Level with highest peak of 50.12mPWD on 31st August 6:00 hours, which was 28 cm below the Danger level (50.40 m).

The Upper Atrai at Bhusirbandar and Atrai at Modevpur

The WL of river Upper Atrai at Bhusirbandar (Upazila – Chirirbandar, District – Dinajpur) also showed similar trend of Punarbhaba, did not cross the DL. It had a peak value of WL 39.37mPWD on 2nd September at 06:00hour, which was 25cm below the DL(39.62m). The Atrai at Mohadevpur (Noagaon District) also flowed below the DL with peak of 18.22mPWD on 3rd September, which is 138cm below the DL(19.6m).

The Mohananda at Chapai-Nawabgonj

This river showed a gradual rise and fall in water level throughout the monsoon and did not cross the DL. It attained its peak of 19.98m on 28th August at 6:00 hours, which was 102cm below its DL (DL21.00m) at Chapai-Nawabgonj.

The Little Jamuna at Naogaon

The Little Jamuna river at crossed its respective Danger Level for 3 days, 23rd August to 25th August 2015, with highest peak of 15.35mPWD on 24th August 6:00 hours, which was 11 cm above the Danger level (15.24 m).

The Ganges/Padma at Pankha, Rajshahi and at Hardinge Bridge

The Ganges River at Pankha showed a gradual rise and fall in the whole season of flood in 2015 but did not cross the respective DL. At Pankha the peak of 21.19m was recorded during the day of 27th August, which was 131 cm below the DL (22.50m) at this point. At Rajshahi, the Ganges showed nearly similar trend as at Pankha and also flowed below its respective DL. It attained its peak of 17.30m on 22th August at 15:00 hours, which was 120cm below its DL (DL18.50m) at Rajshahi. At Hardinge Bridge, water level did not cross the respective Danger Level and it attained its peak of 13.75m on 28th August, which was 50 cm below its DL (14.25m) at this point.

The Ganges/ Padma at Goalundo

At Goalondo river WL started to rise in month of August, crossed its respective DL on 24th August and it flowed above the DL for 18 days from 24st August to 10th September

2015. The WL of the river Padma at Goalondo attained its yearly peak of 9.09mPWD on the 27th August, which was 44 cm above its DL (8.65m) at this point.

The Padma at Bhagyakul and Sureswar

The river Padma has tidal influence at this point. At Bhagyakul, the WL of river Padma crossed the DL on 25th August to 9th September for 16 days. The WL of the river attained its highest yearly peak water level of 6.54 mPWD on 28th August 18:00 hours, which was 24cm above the DL (6.30m) at Bhagyakul. The Padnma at Sureswar crossed the DL for 7 days in the month of August and September 2015. At sureswar point, the WL crossed the DL from 23th August to 29th August for 7 days. The WL of the river attained its highest yearly peak water level of 4.75 mPWD on 29th August, which was 30cm above the DL (4.45m) at Sureswar.

The Gorai at Gorai Railway Bridge and Kamarkhali

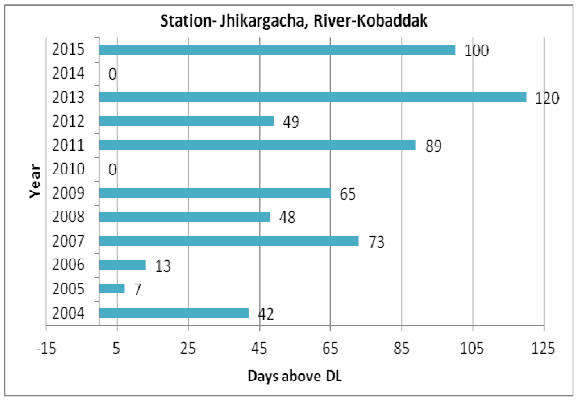
The WL of river Gorai at Gorai Railway Bridge and Kamarkhali showed steady rise during July to August in the monsoon-2015. The WL of river Gorai did not cross the DL at Gorai Railway Bridge. The WL of the river attained its highest yearly peak of 11.82 mPWD on 28th of August, which was 93cm below the DL (12.75m) at Gorai Rail Bridge. Gorai river at Kamarkhali did not cross the DL. The WL of the river attained its highest yearly peak of 7.89 mPWD on 29th of August, which was 31cm below the DL (8.20m) at Kamarkhali station.

The Arialkhan at Madaripur

At Madaripur the WL of the river Arialkhan showed similar trend of rise and fall of the river Padma. The WL of Arialkhan at Madaripur flowed below the DL. The WL attained its highest peak of 3.73 m on the 3rd of September, which was 34cm below the DL (4.17m) at Madaripur.

Kobodak at Jhikorgacha

A prolong flooding situation was prevailed along the Kobodak river from the second week of July to the middle of the October. At Jhikorgacha, the WL flowed above the DL for continuous 100 days with a peak of 4.85mPWD on 3rd October, which was 74cm above the DL(4.11m) at this point. As a result, part of Satkhira, Khulna and Jessore districts were flooded for prolong period.



This is due to the poor drainage condition and more rainfall in the region. At Jhikorgacha, the WL of river Kobodak crossed the DL on 10th July & remained above the DL till 17th of October. From the figure, it may be seen that, except 2010 and 2014, the Kobodak flowed above its DL at Jhikorgacha in every year since 2004.In this monsson the local flood at Jhikargacha lasted for more than three month.

Comparative hydrographs for few important stations for the year of 2015, 2007 & 2004 of the Ganges basin are shown in figures 3.14 to 3.20.

Table 3 2 : Comparison of Water Level of 2015 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		
					2015	1998	1988	2015	98	88
1	Punarbhaba	Dinajpur	34.40	33.50	32.47	34.09	34.25	-	3	4
2	Ganges	Pankha	22.97	22.50	21.19	24.14	NA	-	66	NA
3	Ganges	Rajshahi	20.00	18.50	17.30	19.68	19.00	-	28	24
4	Ganges	Hardinge Bridge	15.04	14.25	13.75	15.19	14.87	-	27	23
5	Padma	Goalundo	10.01	8.50	9.09	10.21	9.83	18	68	41
6	Padma	Bhagyakul	7.58	6.00	6.54	7.50	7.43	16	72	47
7	Gorai	Gorai Rail Bridge	13.65	12.75	11.82	13.45	13.65	-	25	25
8	Gorai	Kamarkhali	9.48	8.20	4.65	NA	NA	-	NA	NA
9	Arialkhan	Madaripur	5.80	4.17	3.73	NA	NA	-	NA	NA
10	Kobodak	Jhikorgacha	5.59	4.11	4.85	NA	NA	100	NA	NA

3.3 THE MEGHNA BASIN

Many rivers of this basin entered from the hilly catchment of India and are flashy in nature. Out of 25 WL monitoring stations in the Meghna basin, at 15 stations flowed above their respective DLs, these are Surma River at Kanaighat, Sylhet and Sunamganj, Kushyara River at Amalshid, Sheola and Sherpur, Sarigowain river at Sarighat, Khowai river at Habigonj and Bullah, Old Surma river at Derai, Bhugai river at Nakuagaon, Jadukata river at Lorergarh, Someswari river at Durgapur, Kangsha River at Jariajanjail and Titas river at Brahmanbaria for less than 2 days to 54 days. As a result, floods of short to moderate duration was experienced in the districts of Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, and Habigonj during the monsoon 2015.

Comparative statement of WL and days flowed above the DL for 2015 and historical events of 1998 and 1988 for this basin for selected stations are shown in Table 3.3.

The Surma at Kanaighat

As a flashy river, WL of the river Surma at Kanaighat (Sylhet district) showed several peaks during the monsoon-2015. WL flowed above its DL at Kanaighat during 1 day on 1st June, 1 days on 13th June, 23rd July to 28th July for 6 days and 19th August to 9th September for 22 days and flowed total more than 30 days above DL. It attained its highest peak of 14.85mPWD on 1st September at 18:00 hours, which was 165cm above the DL(13.20 m) at Kanaighat.

Surma at Sylhet

The WL of river Surma at Sylhet crossed the DL from 20th August to 7th September for 19 days and it showed the similar trend as Kanaighat. It attained the monsoon with peak WL of 11.76mPWD on 1st September 18:00 hours, which was 51cm above its DL (11.25m).

The Surma at Sunamgonj

The WL of the river Surma at Sunamgonj crossed the DL two times at 9th June to 18th June for 10 Days and 19th August to 8th September for 21 days in total 31 days in this monsoon-2015. The WL of Surma at Sunamgonj recorded its highest peak of 9.08mPWD on 20th August, which was 83cm above its DL (8.25m).

The Kushiyara at Amalshid, Sheola and Sherpur

The Kushiyara river at Amalshid, Sheola and Sherpur (Sylhet district) observed similar rise and fall trend throughout the monsoon 2015. At Amalshid water level of Kushiyara crossed the DL twice, firstly 22nd July to 27th July for 6 days and secondly from 21st August to 8th September for 19 days in to 25 days in this monsoon. At Amalshid, Kushiyara attained the peak flow of 17.49 mPWD on 28th August which was 165cm above the DL (15.85 mPWD). At Sheola it also crossed the DL twice, on 21st July to 28th July for 8 days and on 20th August to 9th September for 21 days in total 29 days in this monsoon and. It attained its highest peak of 14.49 mPWD on 27th August at 18:00hrs, which was 99 cm above its DL (13.50 m). At Sherpur the river flowed with a gradual rise and fall trend and didn't cross the DL with its yearly highest peak of 8.85mPWD on 29th August, which was 15cm below its DL (9.00 m).

The Sarigowain at Sarighat

As the flashy river the Sarighat on Saigowain river in Netrokona district, showed several peaks during the monsoon 2015 and crossed the respective DL for 5 times but remained above Dl for one day or less than one day. It attained monsoon highest peak of 13.55mPWD on 1st June at 18:00hours, which was 75cm above its DL (12.80 m).

The Manu at Manu Railway Bridge and Moulvi Bazar

As a flashy river, the WL of the river Manu at Manu Railway Bridge and at Moulvibazar observed several peaks during the monsoon-2015. The WL of Manu river did not cross the DL at Manu Railway Bridge with a peak flow of 17.56mPWD on 18th July, which is 44 cm below the DL(18.0mPWD). At Moulvibazar the WL of Manu didn't cross the DL, flowed with peak of 11.40mPWD on 18th July 18:00 hours, which was 35 cm below its DL(11.75m) at this point.

The Khowai at Habigonj and Bullah

As the flashiest river in Bangladesh, the Khowai at Habigonj showed several peaks during the monsoon 2015, The WL at Ballah crossed its DL 9 times once in June, twice in July, thrice in August and thrice in September. The WL recorded its yearly highest peak of 23.81 m on 17th July, which was 217 cm above its DL (21.64m). At Habiganj the WL of Khowai crossed the DL 2 times in the month of July and August and flowed above DL with peak of 10.2 m on 17th July at 15:00 hours, which is 70cm above the DL (9.50m).

The Dhalai at Kamalgonj

The WL of the flashy river Dhalai at Kamalganj didn't flow above its DL in this monsoon peak of 19.50mPWD on 19th August, which was 32 cm below its DL(19.82m) at this point.

The Old Surma at Derai

As the flashy river, the Derai on Old Surma crossed the DL from 23rd August at 9:00 hours to 15th September in the monsoon period with monsoon highest peak of 7.57mPWD on 4th September at 18:00hours, which was 57cm above its DL (7.0 m). It flowed above DL for 24 days in the month of August and September.

The Bhugai at Nakuagaon

As flashy river the Bhugai at Nakuagaon in Sherpur district recorded sharp rise & fall with several peaks during the monsoon 2015. It flowed above its DL 10 times in the monsoon once in May, forth times in June, twice in August and thrice in September in the monsoon 2015. It attained monsoon highest peak of 23.84mPWD at 16th June 18.00 hours, which was 144 cm above its DL (22.40m) at this point.

The Jadukata at Lorergarh

As the flashy river the lorergarh in Netrokona district, showed several peaks during the monsoon 2015, crossed its DL for three times, twice in August and once in September. First it crossed the DL from 18th August to 20th August for 3 days, then 30th August for two days and on 23rd September for one day, in total 6 days in this monsoon. It attained monsoon highest peak of 10.32mPWD on 31st August at 18:00hours, which was 179 cm above its DL (8.53 m).

The Someswari at Durgapur

As the flashy river the Durgapur in Netrokona district, showed several peaks during the monsoon 2015, crossed its DL for three times, twice in August and once in September. First it crossed the DL from 19th August to 21st August for 3 days, then 31st August for one day and on 23rd September for less than one day, in total 5 days in this monsoon. It attained monsoon highest peak of 14.16mPWD on 20th August at 18:00hours, which was 116 cm above its DL (13.0 m).

The Kangsha at Jariajanjail

As flashy river the Kangsha at Jariajanjail in Netrokona district showed several peaks during the monsoon 2015, crossed the DL four times and remained above DL for total 54 days in the monsoon period. It started to cross DL from 13th June to 1st July for 19 days, then from 4th July to 9th July for 6 days, again 20th August to 11th September for 23 days and 22nd September to 27th September for 6 days with a total 54 days of inundation. It attained its yearly highest peak of 11.10 mPWD on 22nd August at 6:00hours, which was 135cm above its DL (9.75m).

The Titas at Brahmanbaria

The Titas River at B. Baria point started to flow at above its DL for 23 days from 28th August to 19th September with monsoon peak of 6.11 mPWD on 5th September at 18:00hours, which was 61 cm above its DL(5.5 m) at this point.

Comparative hydrographs for few stations the year of 2015, 2007 & 2004 of rivers of the Meghna basin are shown in figures 3.21 to 3.36.

Table 3. 3: Comparison of Water Level of 2015 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		
					2015	1998	1988	15	98	88
1	Surma	Kanaighat	15.58	13.20	14.85	15.00	15.10	30	73	75
2	Surma	Sylhet	11.95	11.25	11.76	11.72	11.95	19	14	21
3	Surma	Sunamgonj	9.46	8.25	9.08	8.90	9.03	31	56	62
4	Kushiyara	Amalshid	18.28	15.85	17.49	17.60	17.50	25	54	65
5	Kushiyara	Sheola	14.60	13.50	14.49	14.14	14.09	29	37	80
6	Kushiyara	Sherpur	9.68	9.00	8.85	NA	NA	-	NA	NA
7	Jariajanjail	Kangsha	13.37	9.75	11.10	NA	NA	54	NA	NA
8	Manu	Manu RB	20.42	18.0	17.56	18.63	18.95	-	6	66
10	Manu	Moulvi Bazar	15.50	11.75	11.40	11.68	13.01	-	-	25
11	Khowai	Habiganj	12.00	9.50	10.2	11.44	11.06	2	8	14
12	Upper Meghna	Bhairab Bazar	7.66	6.25	6.14	7.33	7.66	-	68	68
13	Gumti	Comilla	13.56	11.75	11.02	12.79	11.80	-	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 WL of the monitoring rivers except Muhuri crossed their respective DLs several times throughout the monsoon-2015. As a result, a short duration flood occurred at Chittagong, Feni, Bandarban, Khagrachari, cox's Bazar, Rangamati districts during the monsoon 2015 and low lying areas of Chittagong, Bandarban and Cox's Bazar were slightly affected by the flood for very short duration. All other rivers of this basin flowed below their respective DLs. The details of WL of different river are described in following sections. A comparative statement of water level and days flowed above the DLs for the monsoon-2015 and historical events of 1998 and 1988 for this basin are shown in the Table 3.4.

The Muhuri at Parshuram

The Muhuri river in Feni, Noakhali district is a flashy one flowed above the DL for 2 days at 25th and 27th July, for 3 days at 20th, 21st and 31st of August and also 22nd September for 1 day (total 6 days above DL). It attained its highest peak 15.35m on 20th August, which was 235cm above its DL (13.00 m).

The Halda at Narayanhat

As it is a flashy river, the WL of the river Halda (a flashy river) at Narayanhat under Hathazari upzilla also showed several peaks during this monsoon. It crossed danger mark 5 times during the monsoon-2015, for 1 day on 24th June, for 3 days in 9th, 26th and 27th July,

for 4 days at 1st, 2nd, 23rd and 24th September (total 8 days above DL), with peak of 16.50 mPWD (monsoon peak) on 24th June, 125 cm above the DL(15.25 m) at Narayanhat.

The Halda at Panchpukuria

The river here observed several peaks like Narayanhat, but flowed below its DL during the monsoon 2015. At Panchpukuria it attained its highest peak of 7.33mPWD on 26th July at 6:00 hours, which was 49 cm below its DL (9.50 m).

The Sangu at Bandarban and Dohazari

It is a flashy river, showed several peaks. The river crossed the DL at Banarban for 5 times in this monsoon-2015. It crossed the DL, for 1 day at 26th June, for 3 days at 26th, 27th and 31st July and for 3 days at 1st , 2nd and 20th August (total 7 days above DL). At Bandarban the peak recorded was 17.45 mPWD on 27th July at 18:00 hours, which was 220 cm above its DL (15.25m). At Dohazari, the Sangu river crossed its respective DL 3 times, for 3 days from 25th June to 27th June, for 8 days from 26th July to 2nd August and for 2 days at 20th and 21st August in this monsoon. At Dohazari the highest peak was recorded 8.3m on 27th July at 06:00 hours, which was 130 cm above its danger mark (7.00 m) at this point.

Table 3. 4 : Comparison of Water Level of 2015 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		
					2015	98	88	2015	98	88
1	Muhuri	Parshuram	15.03	13.00	15.35	14.60	12.42	6	9	48
2	Halda	Narayanhat	18.05	15.25	16.50	16.57	NA	8	21	NA
3	Halda	Panchpukuria	11.55	9.50	7.33	10.44	10.05	-	4	6
4	Sangu	Bandarban	20.38	15.25	17.45	15.25	16.80	7	1	3
5	Sangu	Dohazari	9.05	7.00	8.3	7.42	NA	13	2	NA
6	Matamuhuri	Lama	15.45	12.25	14.11	13.05	12.18	7	2	-
7	Matamuhuri	Chiringa	6.83	5.75	7.4	6.85	NA	15	5	NA
8	Feni	Ramgarh	21.41	17.37	16.43	17.50	NA	-	1	NA

The Matamuhuri at Lama and Chiringa

The river observed several peaks DL in the monsoon-2015. At Lama, the Matamuhuri River crossed the DL for 5 times, for 2 days on 25th and 26th June, for 2 days on 26th and 27th July, for 1 day on 31st July, for 1 day on 1st August and finally for 1 day on 20th August (total 7 days in this monsoon). At Lama the peak recorded was 14.11 mPWD on 26th July at 12:00 hours, which was 186cm above its DL (12.25m). At Chiringa station the matamuhuri river crossed the DL 4 times; from 23th June to 28th June for 5 days, from 25th July to 1st August for 8 days, 20th August for 1 day and 1st September for 1 day (total 15 days in this monsoon). At Chiringa recorded highest peak of 7.4mPWD on 26th June at 12:00 hours, which was 165 cm above the DL (5.75 m) in this monsoon-2015.

The Feni at Ramgarh

The WL of river Feni at this point observed several peaks and flowed below its DL during the monsoon-2015. The highest peak WL attained by the river was 16.43 m on 26th July 6:00 hours , which was 94cm below its DL (17.37m) at this point.

Comparative hydrographs for the year of 2015, 2007 and 2004 of few stations of the South Eastern Hill Basin are shown in Figures 3.37 to 3.42.

3.5 RECORDED HIGHEST WATER LEVEL

The peak water level of all the water level monitoring stations under FFWC with the date during the monsoon 2015 is shown in the following table.

Table 3.5: Recorded Peak Water Level with Date during the monsoon 2015

SL No	River name	Station	Peak WL-2015 (m)	Date
	BRAHMAPUTRA BASIN			
1	DHARLA	KURIGRAM	26.99	2/9/2015
2	TEESTA	DALIA	52.85	2/7/2015
3	TEESTA	KAUNIA	29.11	2/9/2015
4	JAMUNESWARI	BADARGANJ	32.44	24/8/2015
5	GHAGOT	GAIBANDHA	22.33	6/9/2015
6	KARATOA	CHAK RAHIMPUR	20.69	27/8/2015
7	KARATOA	BOGRA	14.54	6/9/2015
8	BRAHMAPUTRA	NOONKHAWA	26.89	6/9/2015
9	BRAHMAPUTRA	CHILMARI	24.44	6/9/2015
10	JAMUNA	BAHADURABAD	20.19	6/9/2015
11	JAMUNA	SARIAKANDI	17.49	6/9/2015
12	JAMUNA	SERAJGONJ	14.13	7/9/2015
13	JAMUNA	ARICHA	9.45	27/8/2015
14	GUR	SINGRA	12.87	6/9/2015
15	ATRAI	BAGHABARI	12.01	7/9/2015
16	DHALESWARI	ELASIN	12.33	8/9/2015
17	OLD BRAHMAPUTRA	JAMALPUR	15.84	9/9/2015
18	OLD BRAHMAPUTRA	MYMENSINGH	11.19	11/9/2015
19	LAKHYA	LAKHPUR	6.25	3/9/2015
20	BURIGANGA	DHAKA	5.2	2/9/2015
21	BALU	DEMRA	5.52	2/9/2015
22	LAKHYA	NARAYANGONJ	5.60	2/9/2015
23	TURAG	MIRPUR	5.59	2/9/2015
24	TONGI KHAL	TONGI	5.61	4/9/2015
25	KALIGANGA	TARAGHAT	8.75	10/9/2015
26	DHALESWARI	JAGIR	8.35	11/9/2015
27	DHALESWARI	REKABI BAZAR	5.19	2/9/2015
28	BANSHI	NAYARHAT	5.84	12./9/2015
GANGES BASIN				
29	KARATOA	PANCHAGARH	69.85	1/9/2015
30	PUNARBHABA	DINAJPUR	32.47	2/9/2015
31	ICH-JAMUNA	PHULBARI	28.7	24/8/2015
32	TANGON	THAKURGAON	50.12	31/8/2015
33	UPPER ATRAI	BHUSIRBANDAR	39.37	2/9/2015
34	MOHANANDA	ROHANPUR	20.55	6/9/2015
35	MOHANANDA	CHAPAI-NAWABGANJ	19.98	28/8/2015
36	LITTLE JAMUNA	NAOGAON	15.35	24/8/2015
37	ATRAI	MOHADEBPUR	18.22	3/9/2015

SL No	River name	Station	Peak WL-2015 (m)	Date
38	GANGES	PANKHA	21.19	27/8/2015
39	GANGES	RAJSHAHI	17.30	27/8/2015
40	GANGES	HARDINGE BRIDGE	13.75	28/8/2015
41	PADMA	GOALONDO	9.09	27/8/2015
42	PADMA	BHAGYAKUL	6.54	28/8/2015
43	PADMA	SURESWAR	4.75	29/8/2015
44	GORAI	GORAI RAIL BRIDGE	11.82	28/8/2015
45	GORAI	KAMARKHALI	4.65	29/8/2015
46	ICHAMATI	SAKRA	3.52	2/9/2015
47	MATHABHANGA	CHUADANGA	9.06	10/8/2015
48	MATHABHANGA	HATBOALIA	11.53	29/8/2015
49	KOBADAK	JHIKORGACHA	4.85	3/8/2015
50	KUMAR	FARIDPUR	5.15	4/9/2015
51	ARIALKHAN	MADARIPUR	3.73	3/9/2015
52	KIRTONKHOLA	BARISAL	2.89	5/8/2015
MEGHNA BASIN				
53	SURMA	KANAIGHAT	14.85	1/9/2015
54	SURMA	SYLHET	11.76	1/9/2015
55	SURMA	SUNAMGONJ	9.08	20/8/2015
56	KUSHIYARA	AMALSHID	17.49	28/8/2015
57	KUSHIYARA	SHEOLA	14.49	27/8/2015
58	KUSHIYARA	SHERPUR	8.85	29/8/2015
59	KUSHIYARA	MARKULI	7.96	1/9/2015
60	SARIGOWAIN	SARIGHAT	13.55	1/6/2015
61	MANU	MANU RAILY BRIDGE	17.56	18/7/2015
62	MANU	MOULVI BAZAR	11.40	18/7/2015
63	KHOWAI	BALLAH	23.81	17/7/2015
64	KHOWAI	HABIGONJ	10.2	20/7/2015
65	DHALAI	KAMALGONJ	19.50	19/8/2015
66	OLD SURMA	DERAI	7.57	4/9/2015
67	BAULAI	KHALIAJURI	7.21	4/9/2015
68	BHUGAI	NAKUAGAON	23.84	16/6/2015
69	JADUKATA	LORERGARH	10.32	31/8/2015
70	SOMESWARI	DURGAPUR	14.16	20/8/2015
71	KANGSHA	JARIAJANJAIL	11.10	22/8/2015
72	TITAS	B. BARIA	6.11	5/9/2015
73	MEGHNA	BHAIRAB BAZAR	6.14	4/9/2015
74	MEGHNA	NARSINGDI	5.50	4/9/2015
75	GUMTI	COMILLA	11.02	11/9/2015
76	GUMTI	DEBIDDAR	7.78	23/9/2015
77	MEGHNA	CHANDPUR	4.54	30/8/2015
	SOUTH EASTERN HILL BASIN			
78	MUHURI	PARSHURAM	15.35	20/8/2015
79	HALDA	NARAYAN HAT	16.50	24/6/2015
80	HALDA	PANCHPUKURIA	7.33	26/7/2015
81	SANGU	BANDARBAN	17.45	27/7/2015
82	SANGU	DOHAZARI	8.30	27/7/2015
83	MATAMUHURI	LAMA	14.11	26/7/2015
84	MATAMUHURI	CHIRINGA	7.40	26/6/2015
85	FENI	RAMGARH	16.43	26/7/2015

Table 3. 6: Recorded Historical Highest Water Level with Date

Sl. No.	River	Station	Danger Level (m)	Recorded highest WL (m) before 2015 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	Serajgonj	13.35	15.12 (30.08.88)	-
8	Jamuna	Aricha	9. 40	10.76 (02.09.88)	-
9	Old Brhamaputra	Jamalpur	17.00	18.00 (31.07.54)	-
10	Old Brhamaputra	Mymensingh	12.50	13.71(1.09.88)	-
11	Buriganga	Dhaka	6.00	7.58 (04.09.68)	-
12	Lakhya	Narayangonj	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	15.58(26.06.12)	-
24	Surma	Sylhet	11.25	12.44 (19.07.04)	-
25	Surma	Sunamgonj	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)	-
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	Habigonj	9.50	12.00 (18.06.07)	-
31	Someswari	Durgapur	13.00	15.5(23.09.2014)	-
32	Upper Meghna	Bhairab Bazar	6.25	7.78 (24.07.04)	-
33	Gumti	Comilla	11.75	13.56 (23.07.93)	-
34	Muhuri	Parshuram	13.00	16.33 (13.09.04)	-
35	Halda	Narayanhat	15.25	19.30 (13.08.99)	-
36	Halda	Panchpukuria	7.00	12.54(27.06.03)	-
37	Sangu	Bandarban	15.25	20.7 (12.07.97)	-
38	Sangu	Dohazari	5.75	9.05	-
39	Matamuhuri	Lama	12.25	15.46 (12.08.99)	-
40	Matamuhuri	Chiringa	5.75	7.03 (10.07.97)	-
41	Feni	Ramgarh	17.37	21.42 (11.07.68)	-

WL - Water Level

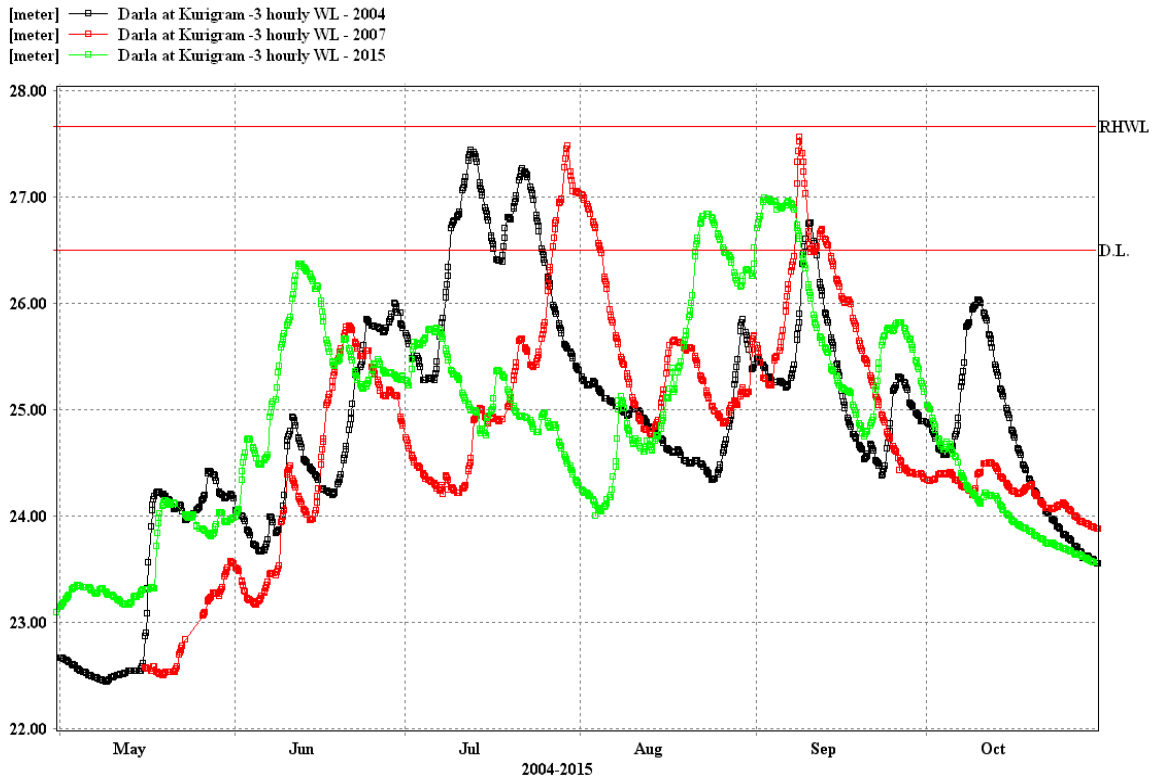


Figure 3.1: Comparison of Hydrograph on Dharla at Kurigram

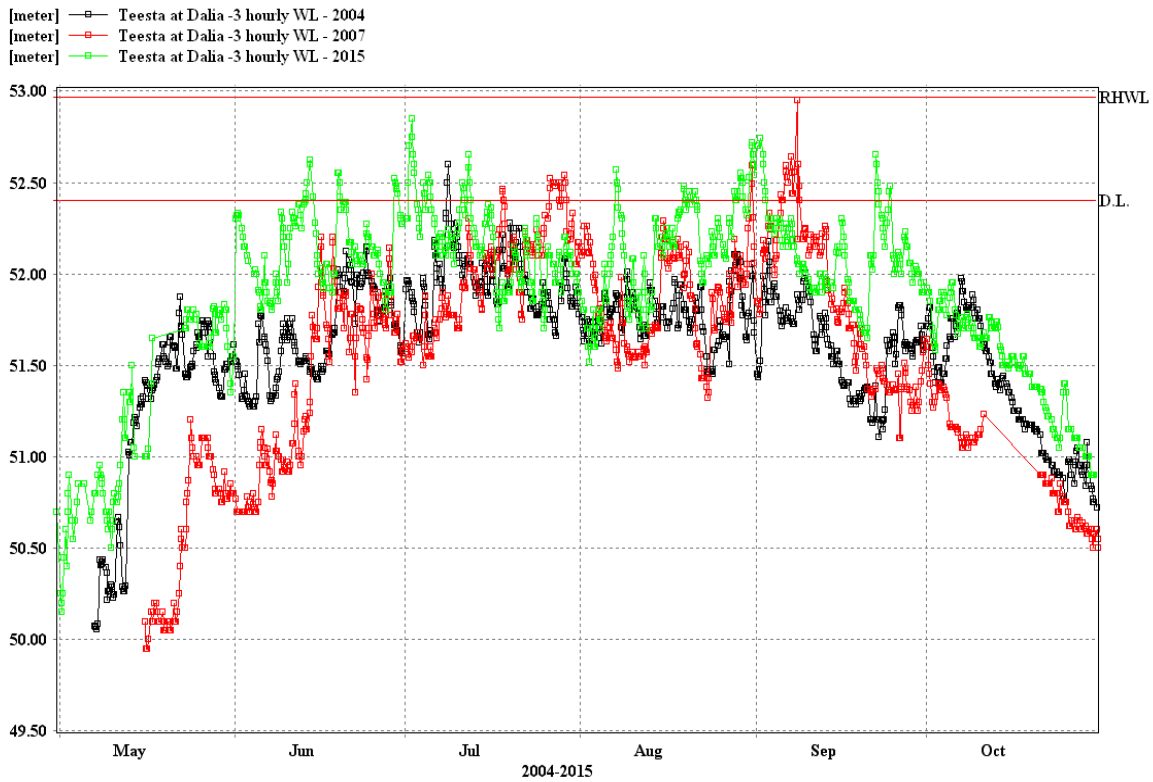


Figure 3.2: Comparison of Hydrograph on Teesta at Dalia

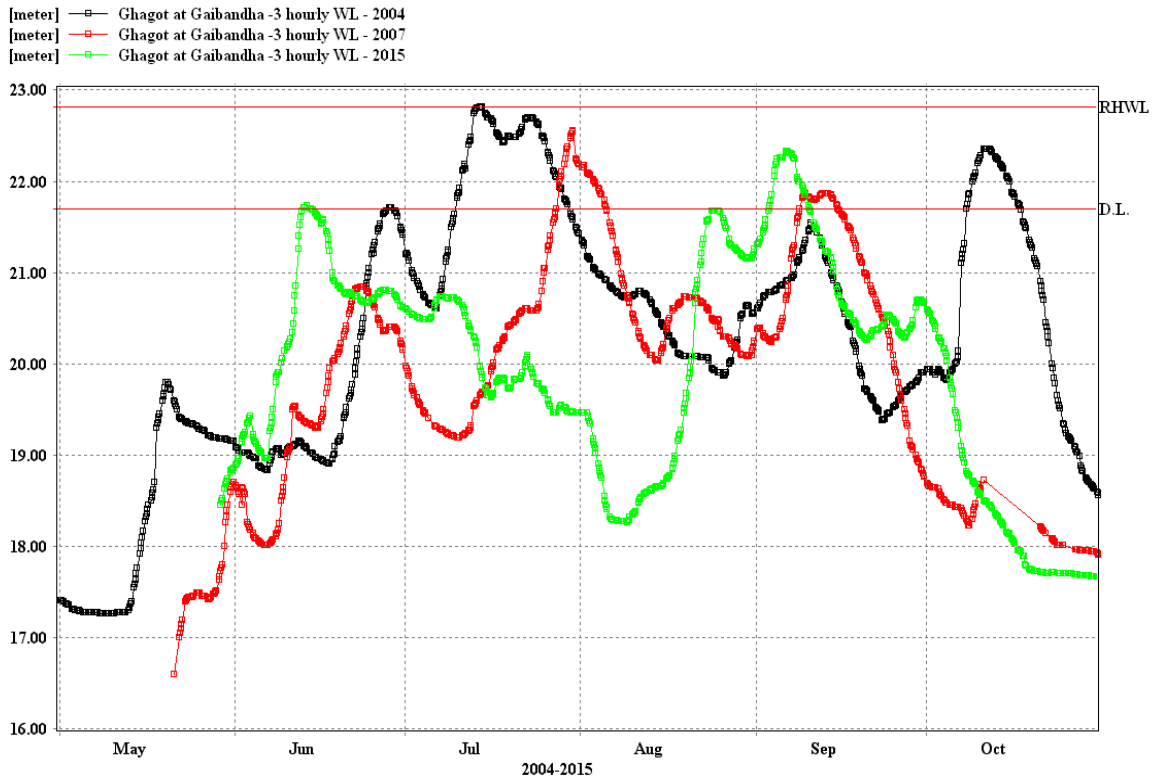


Figure 3.3: Comparison of Hydrograph on Ghagot at Gaibandha

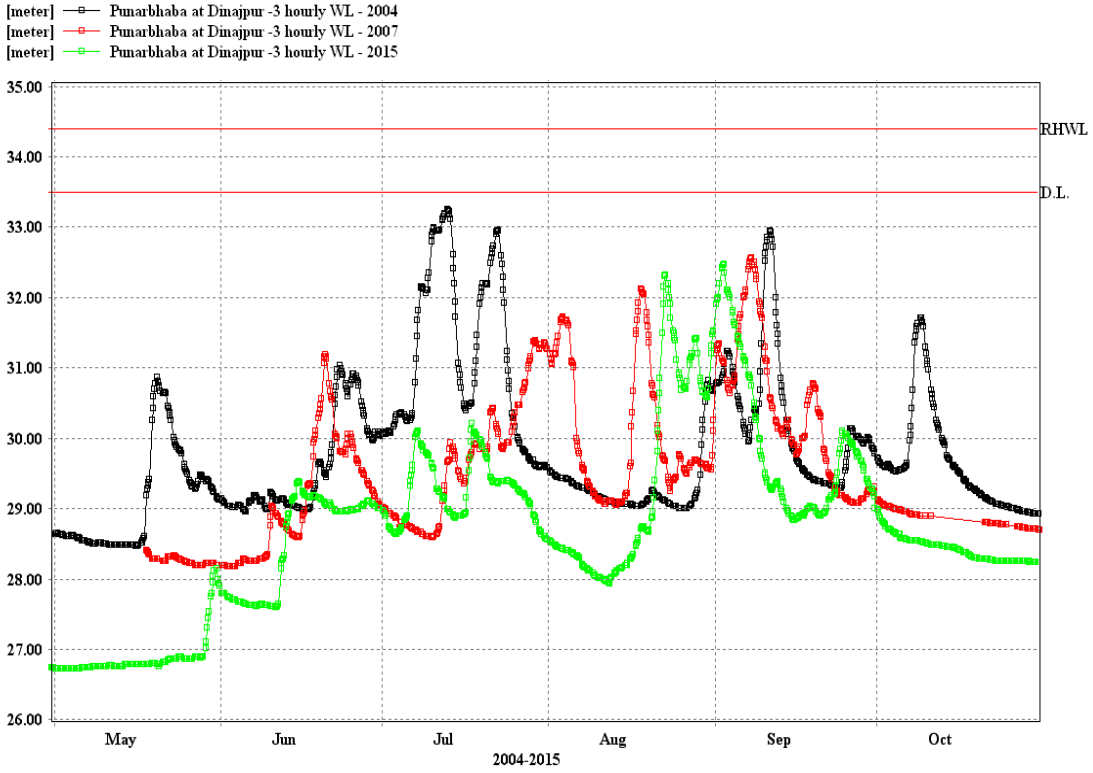


Figure 3.4: Comparison of Hydrograph on Punurbhoba at Dinajpur

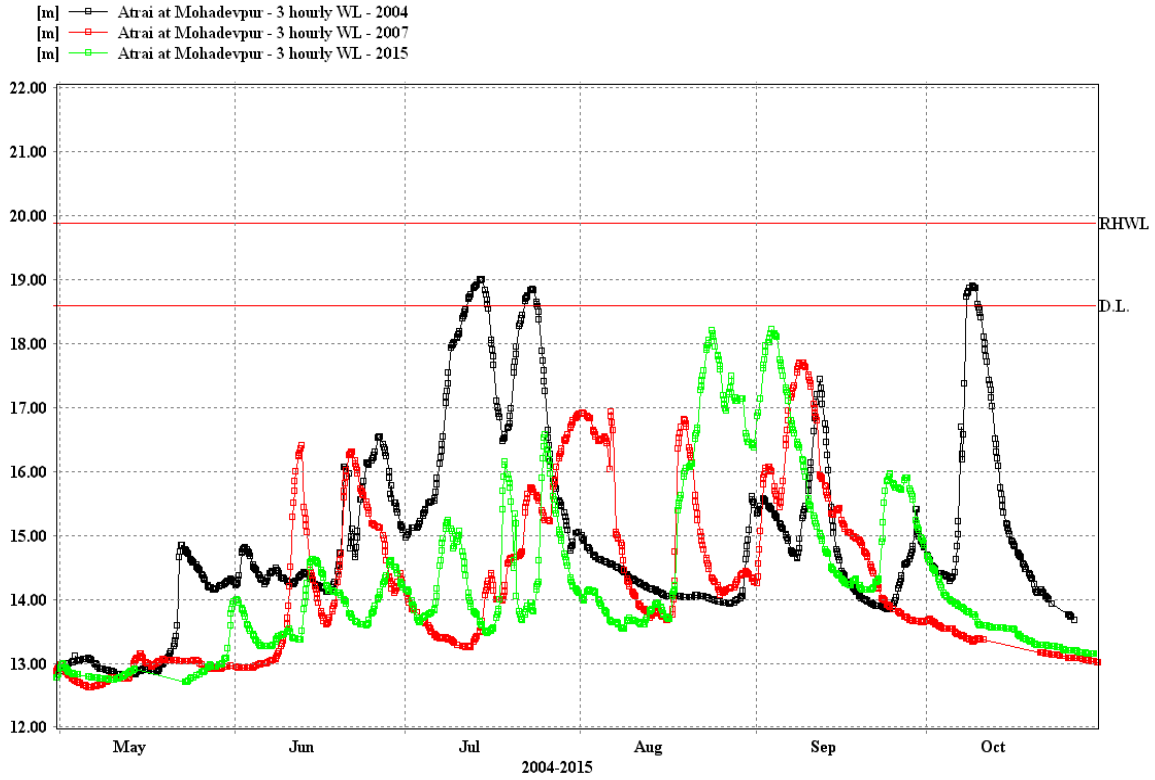


Figure 3.5: Comparison of Hydrograph on Atrai at Mohadevpur

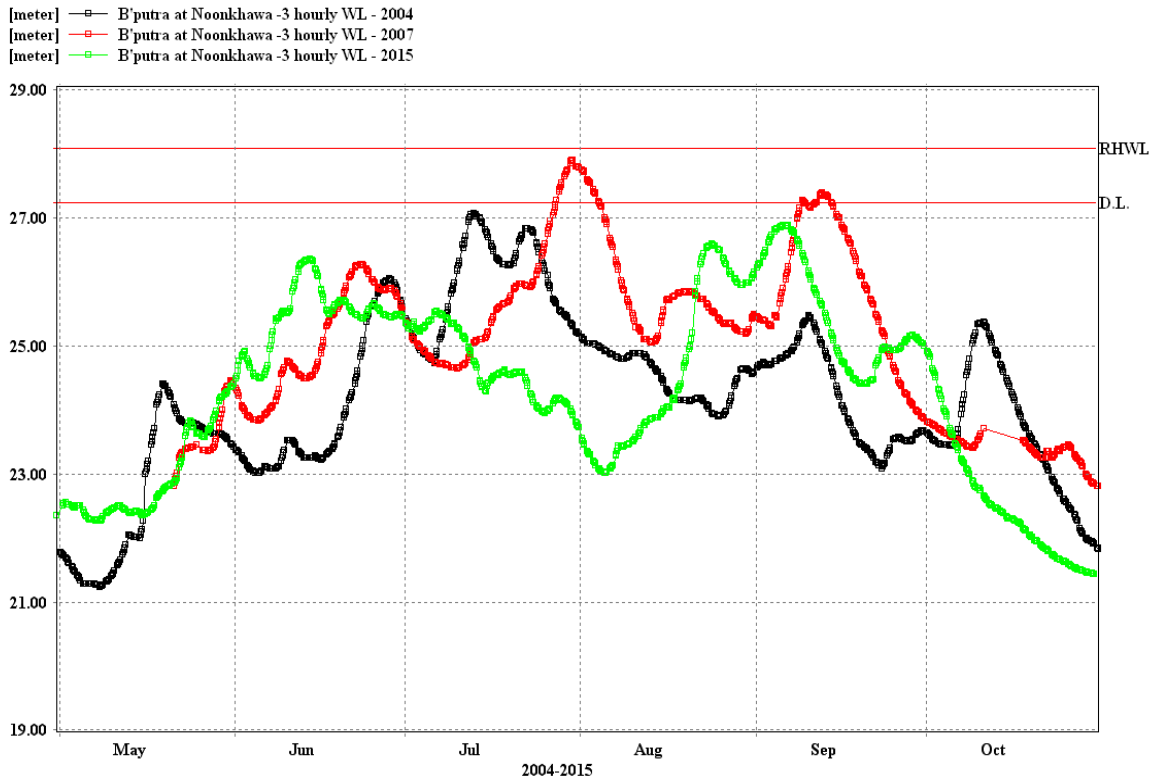


Figure 3.6: Comparison of Hydrograph on Brahmaputra at Noonkhawa

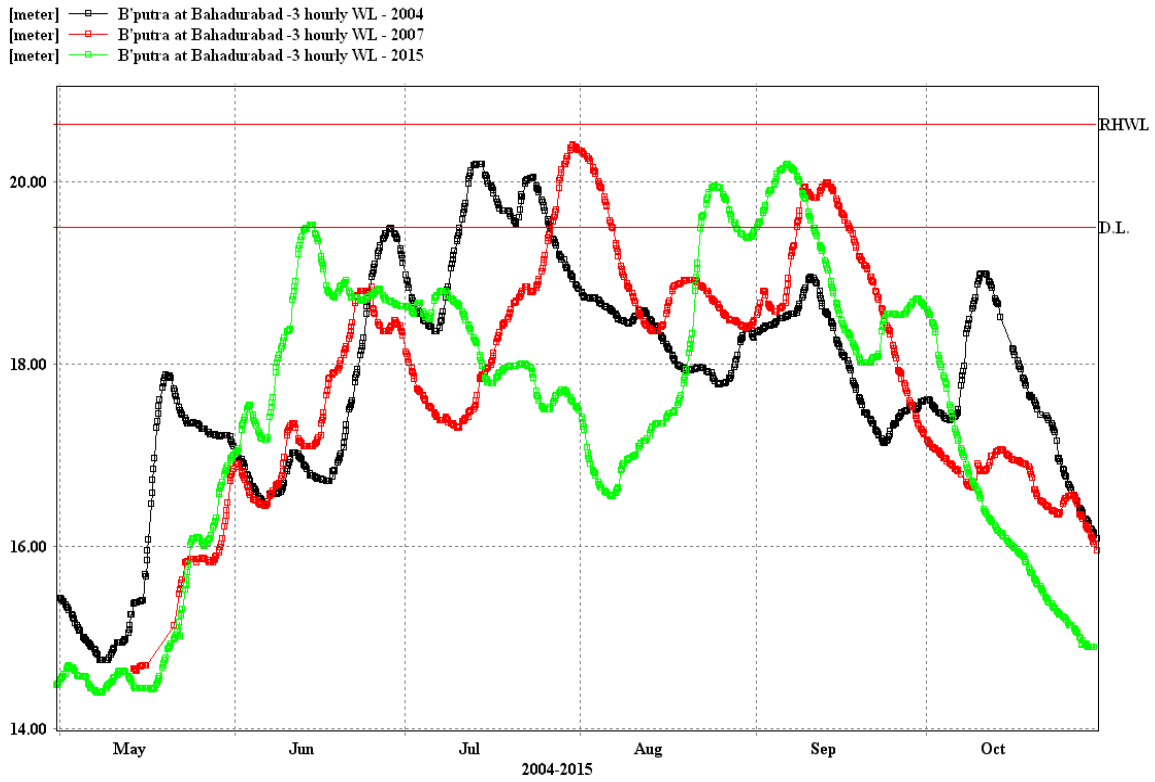


Figure 3.7: Comparison of Hydrograph on Brahmaputra at Bahadurabad

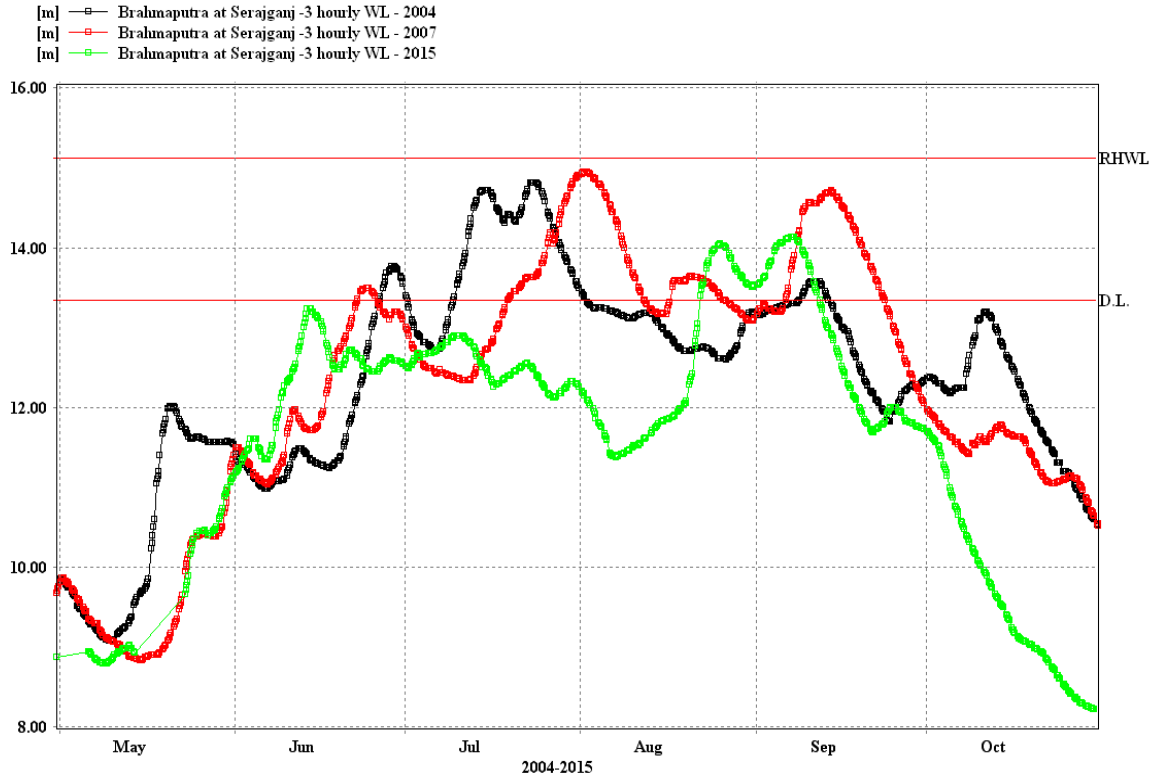


Figure 3.8: Comparison of Hydrograph on Jamuna at Serajgonj

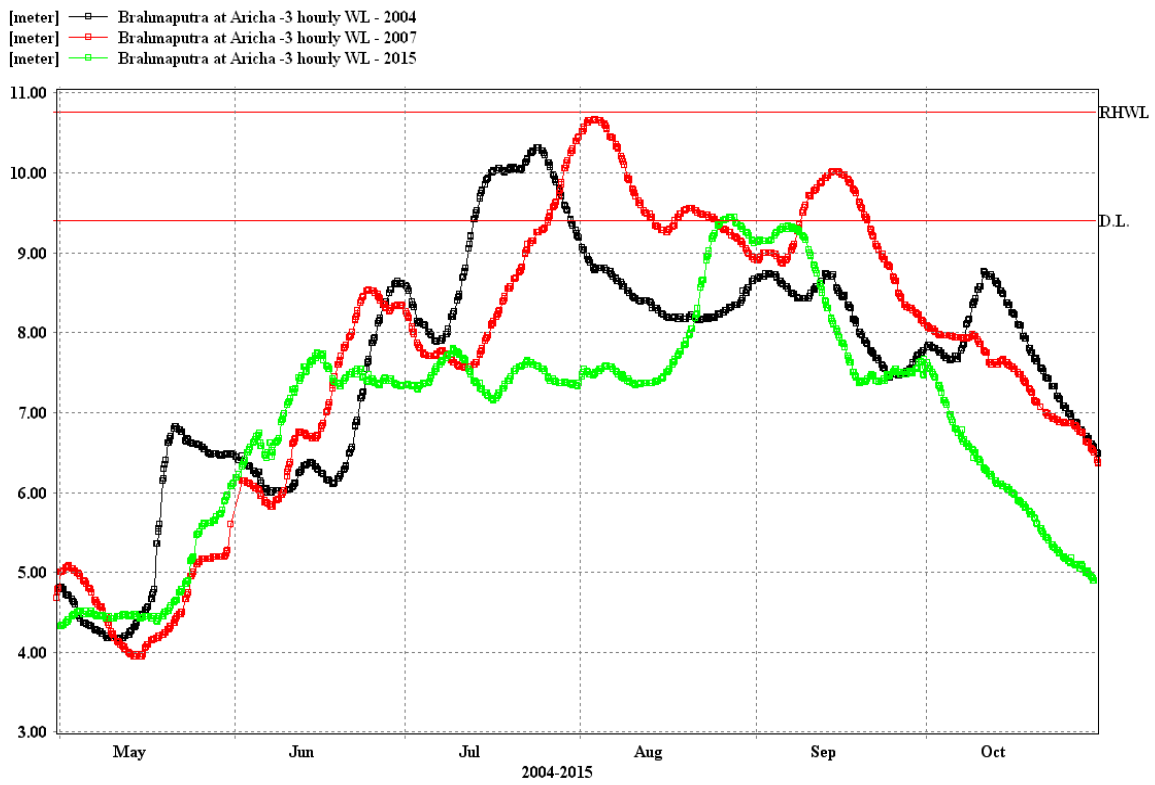


Figure 3.9: Comparison of Hydrograph on Jamuna at Aricha

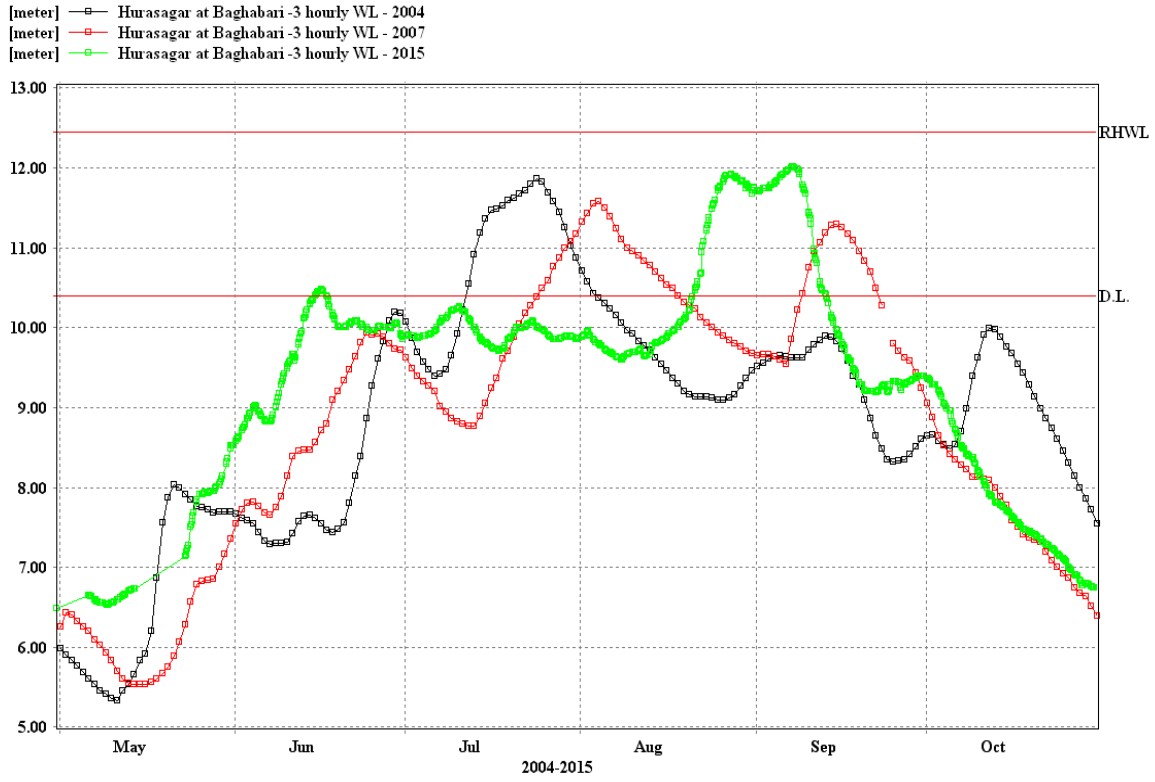


Figure 3.10: Comparison of Hydrograph on Atrai at Baghabari

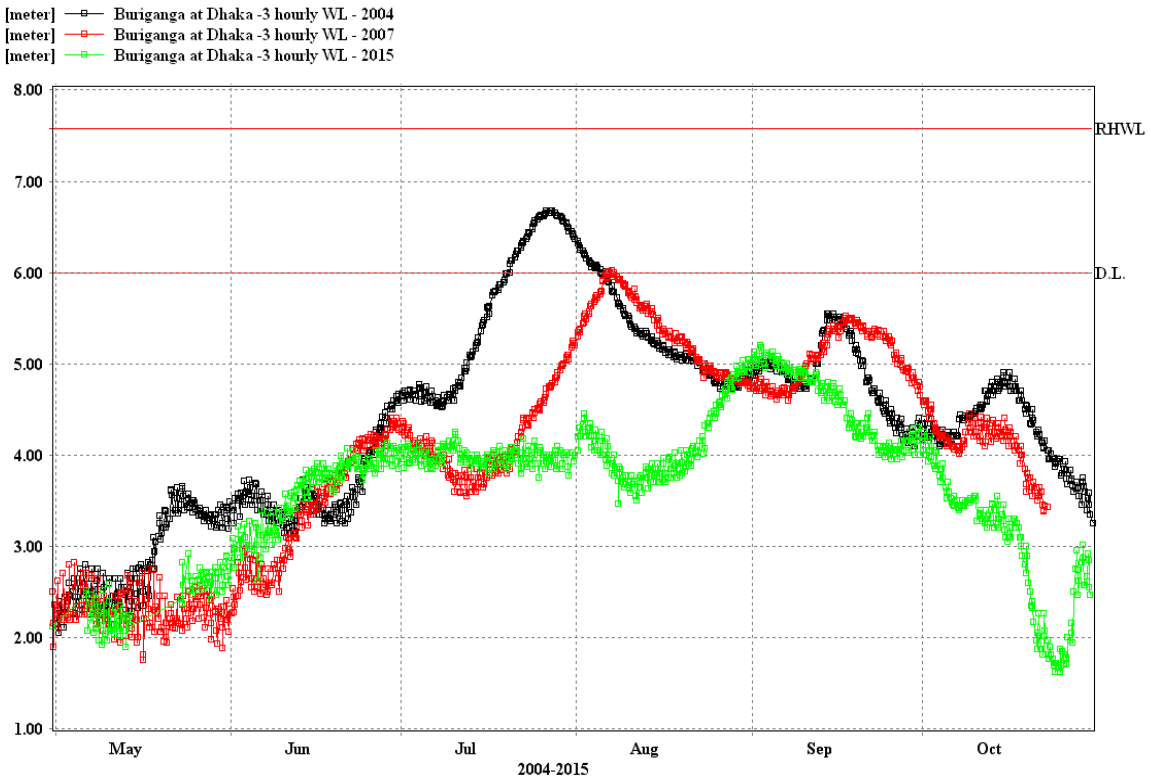


Figure 3.11 : Comparison of Hydrograph on Buriganga at Dhaka (Milbarak)

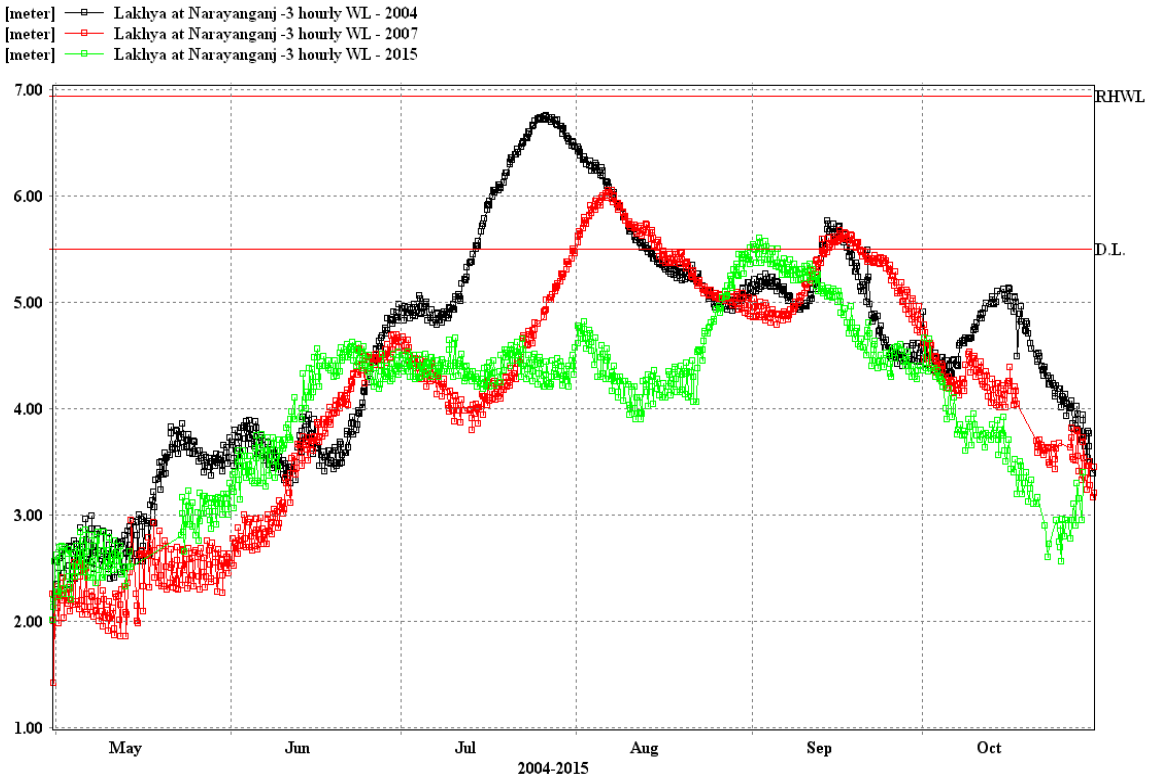


Figure 3.12: Comparison of Hydrograph on Lakhya at Narayangonj

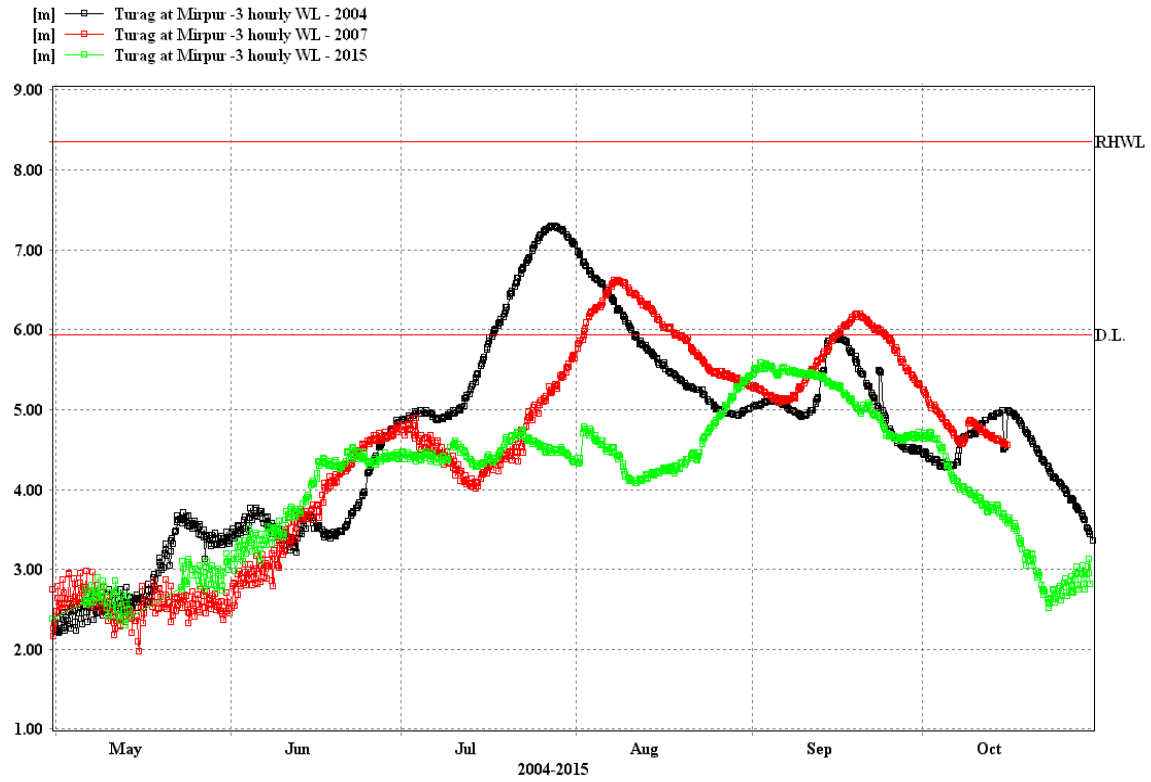


Figure 3.13 : Comparison of Hydrograph on Turag at Mirpur

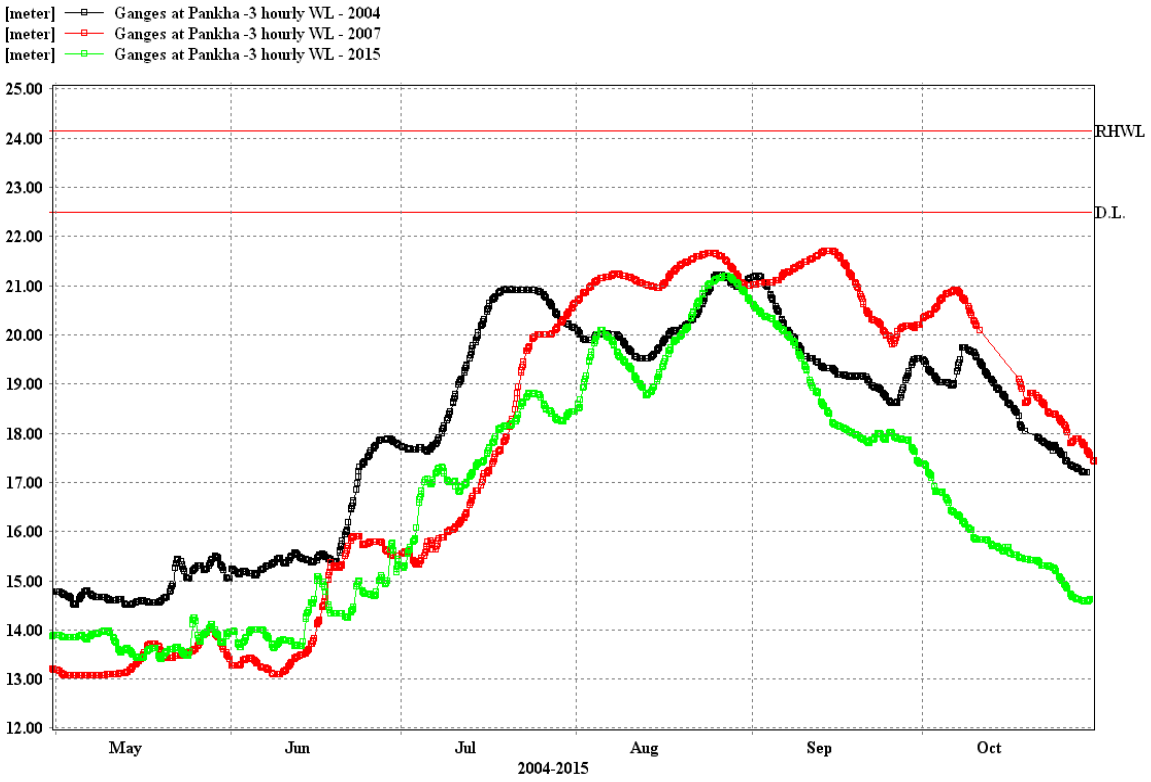


Figure 3.14: Comparison of Hydrograph on Ganges at Pankha

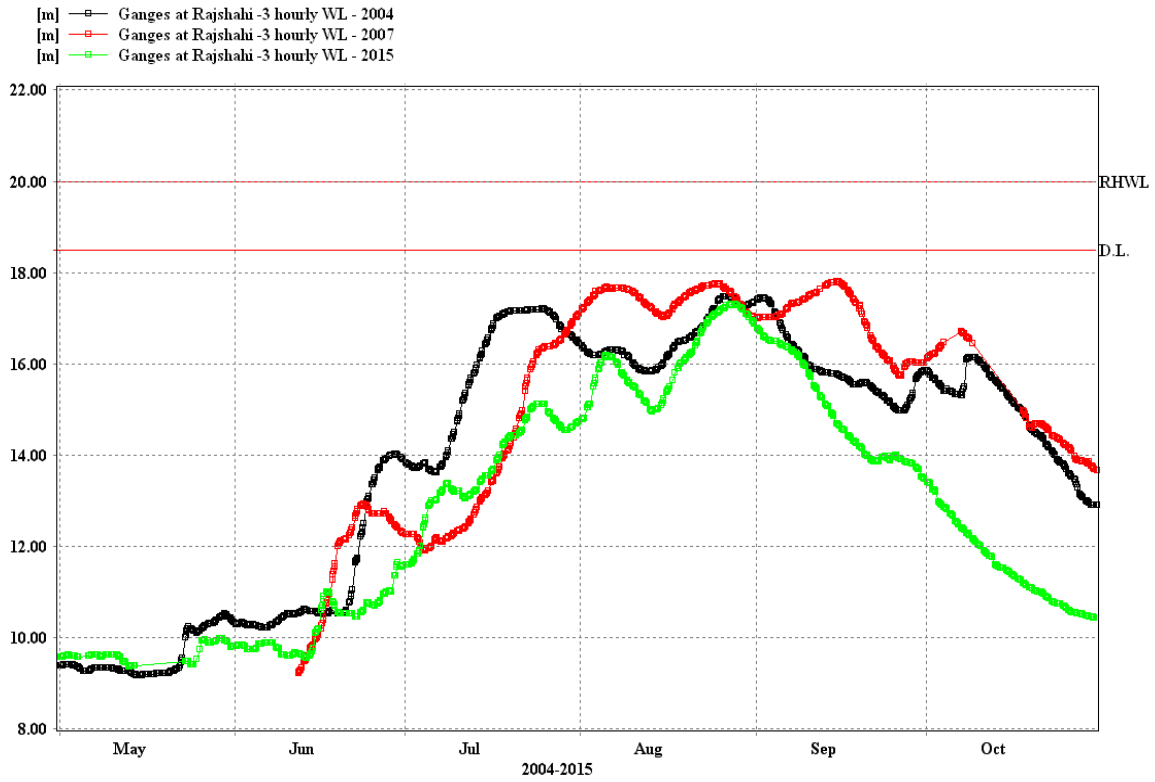


Figure 3.15: Comparison of Hydrograph on Ganges at Rajshahi

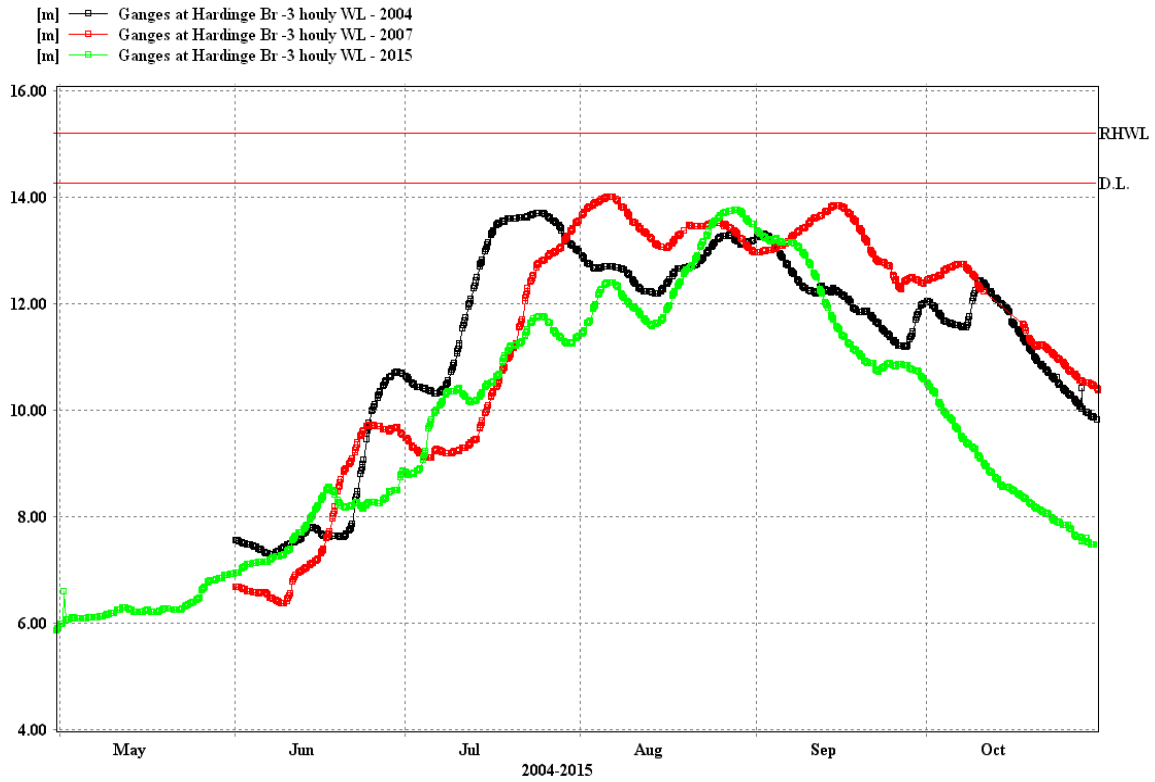


Figure 3.16: Comparison of Hydrograph on Ganges at Hardinge Bridge

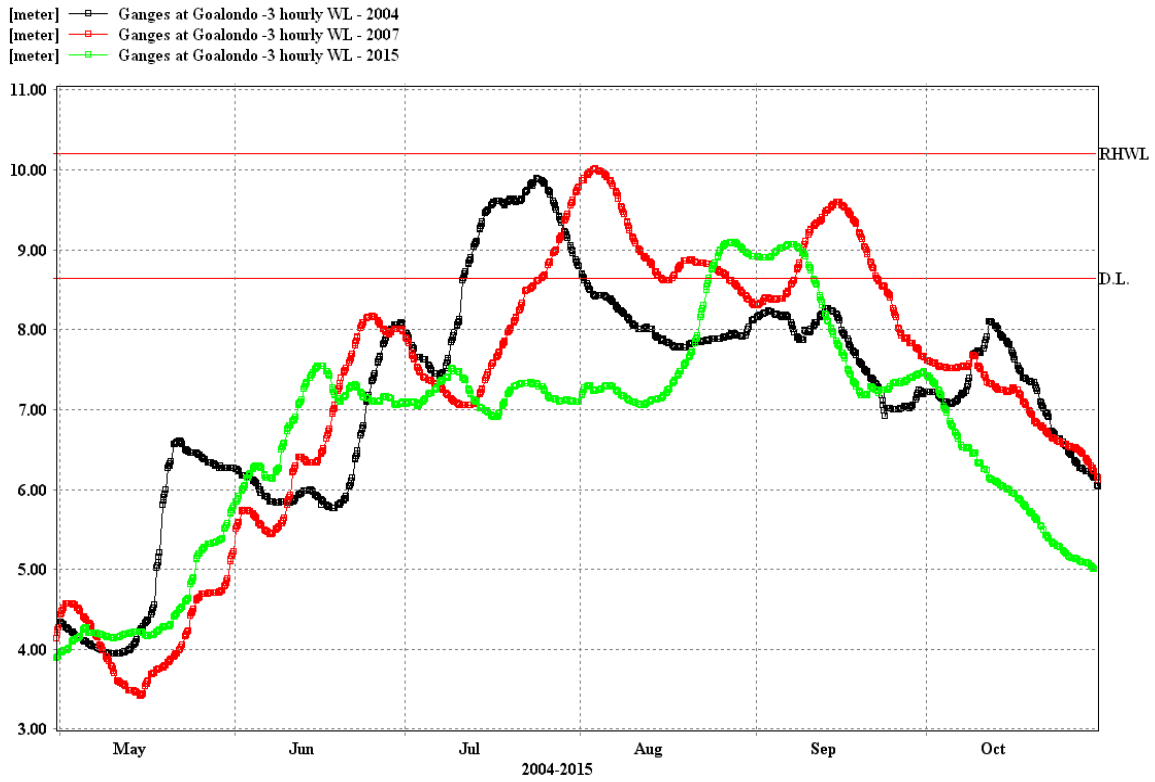


Figure 3.17: Comparison of Hydrograph on Padma at Goalondo

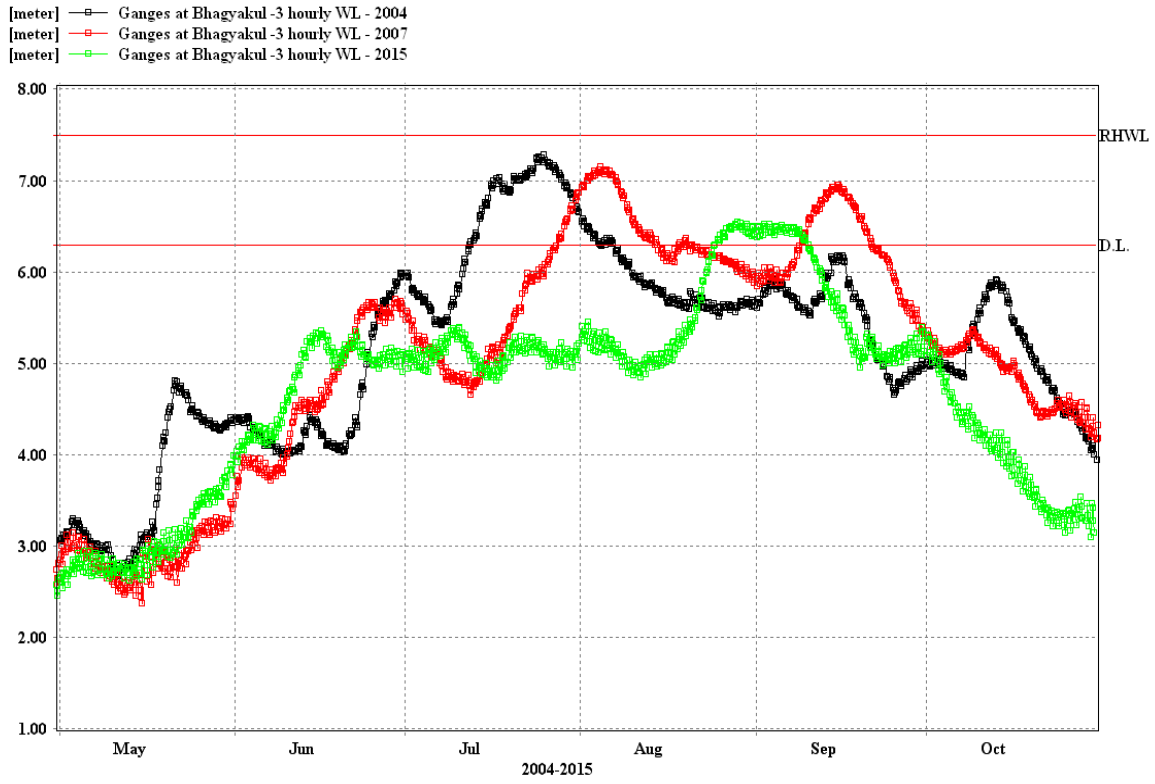


Figure 3.18: Comparison of Hydrograph on Padma at Bhagyakul

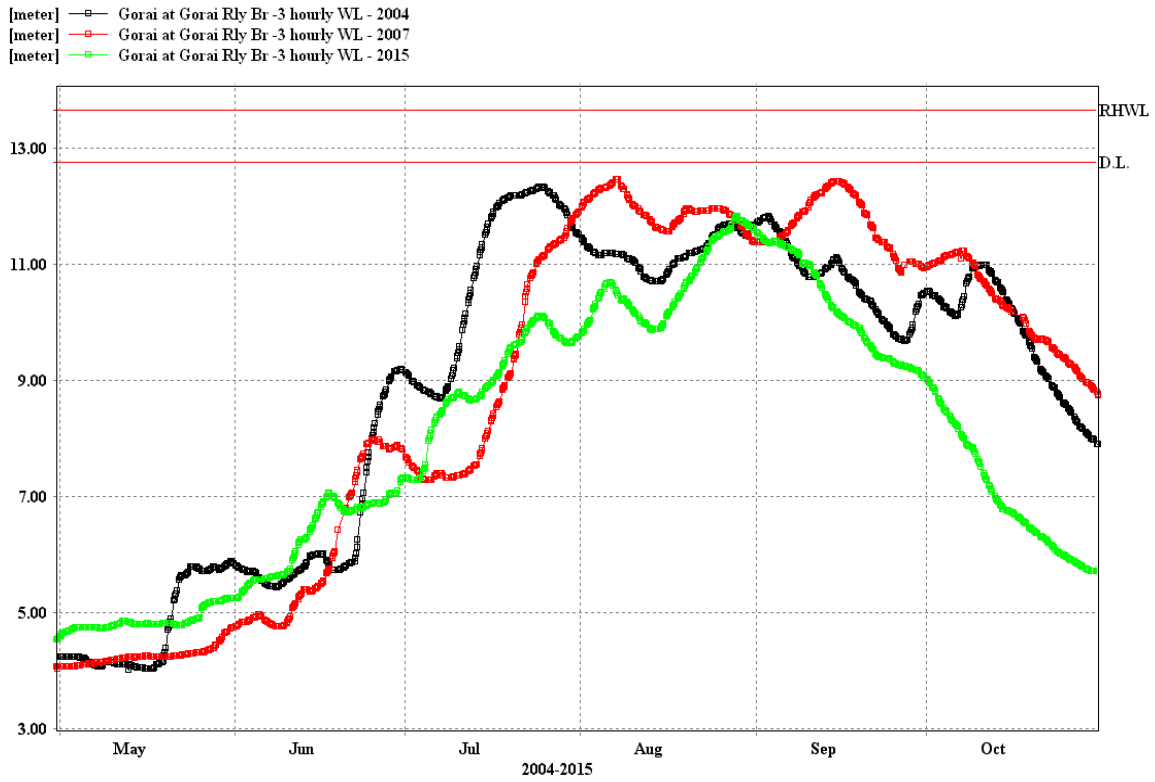


Figure 3.19: Comparison of Hydrograph on Gorai at Gorai Railway Bridge

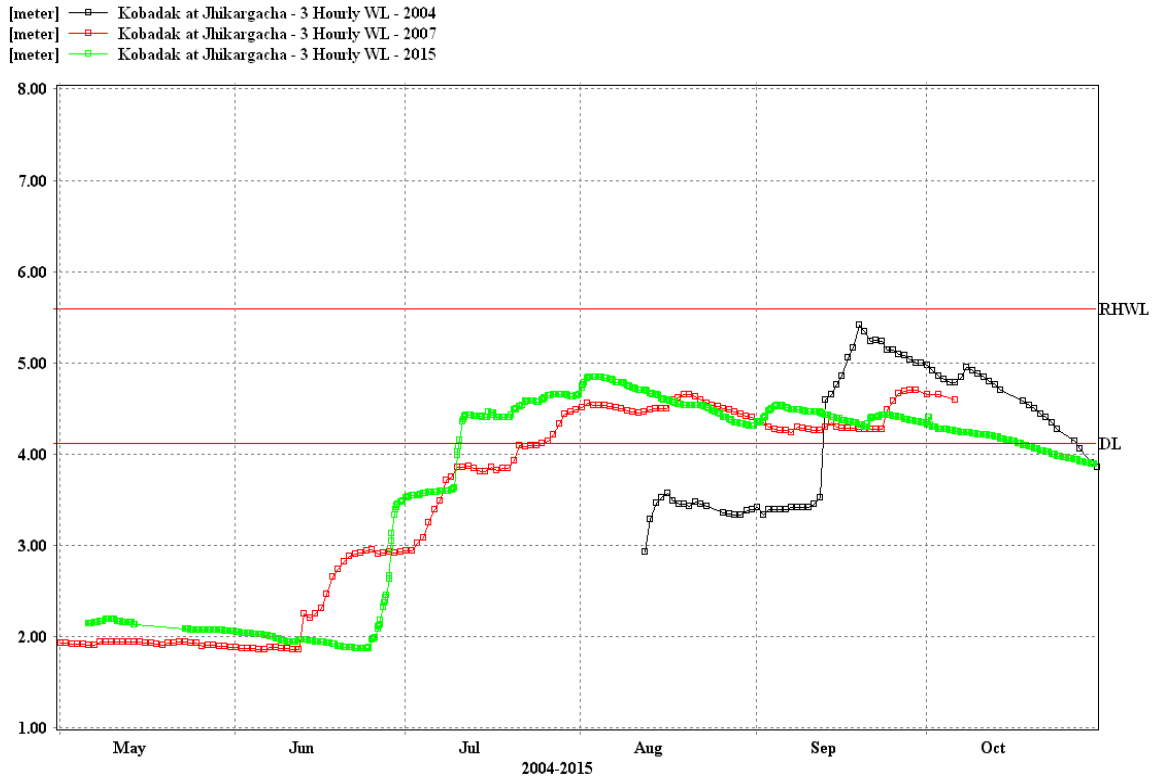


Figure 3. 20: Comparison of Hydrograph on Kobodak at Jhikorgacha

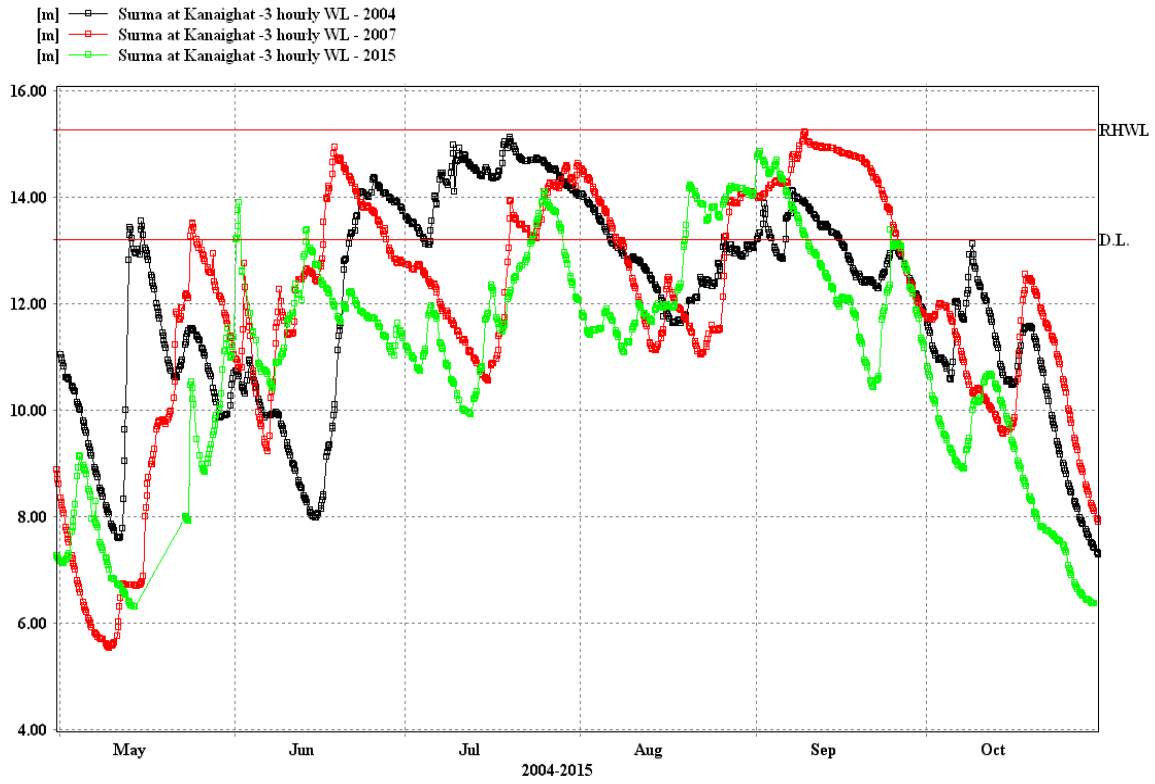


Figure 3.21: Comparison of Hydrograph on Surma at Kanaighat

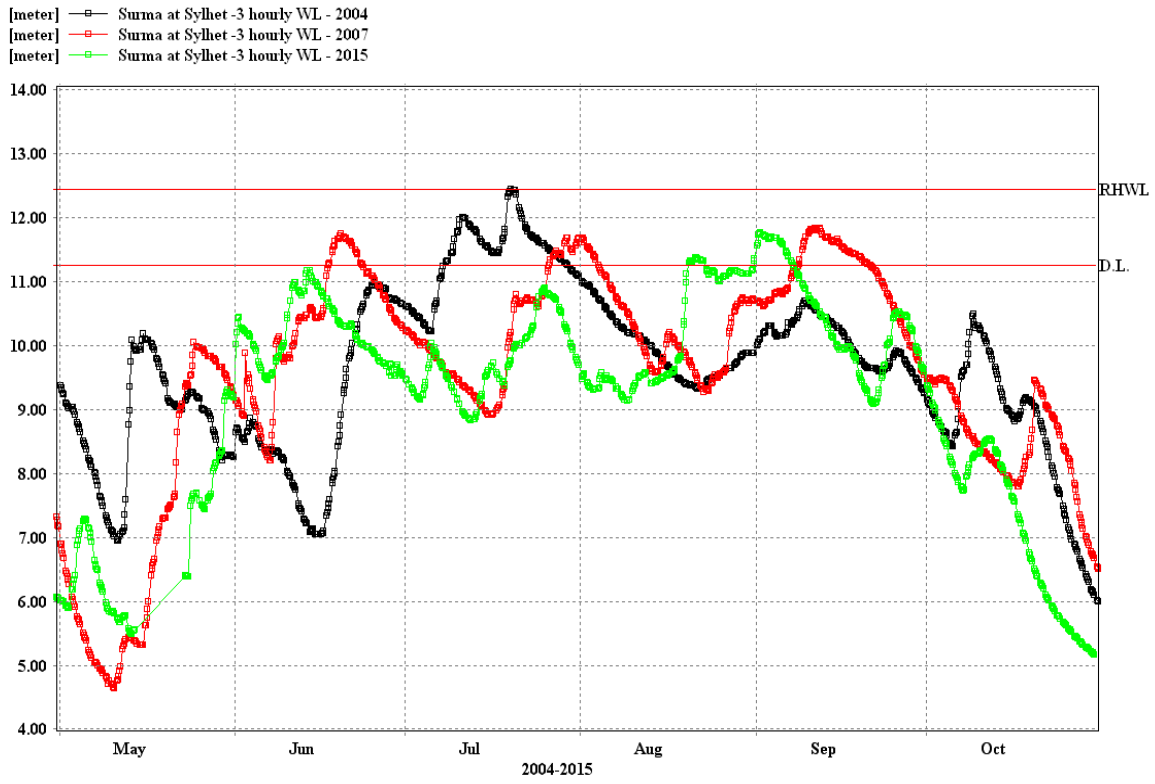


Figure 3.22: Comparison of Hydrograph on Surma at Sylhet

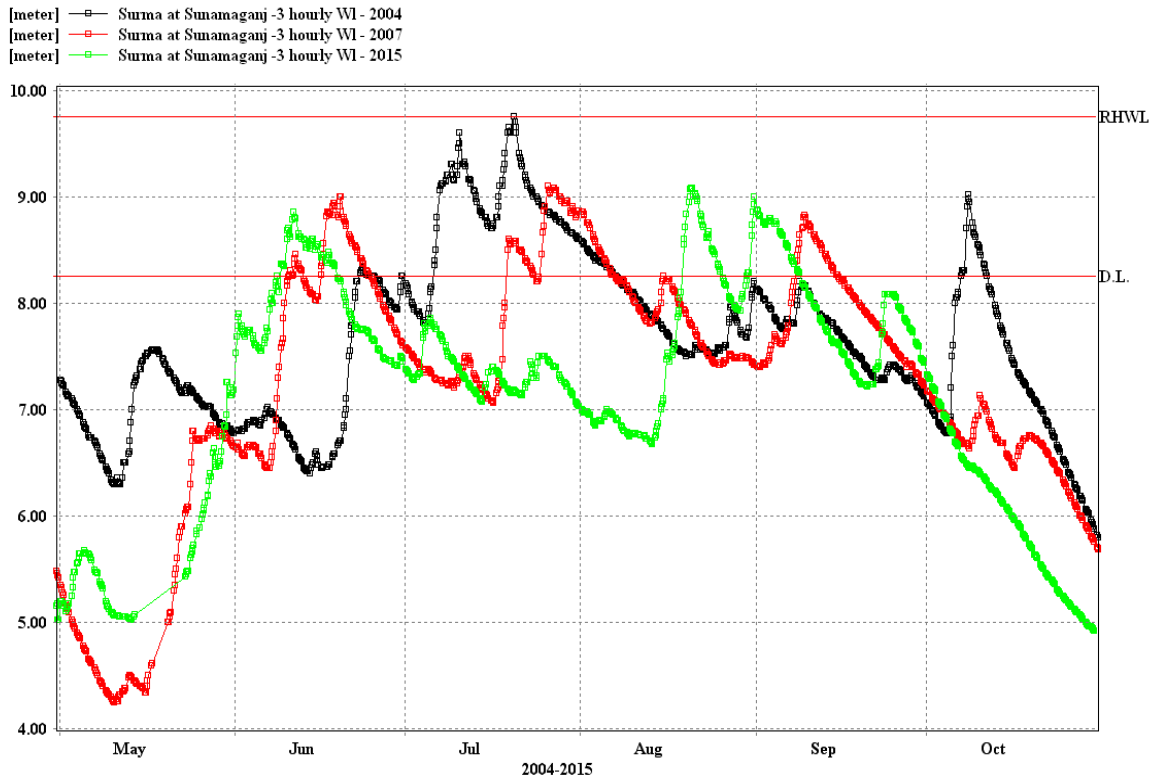


Figure 3.23: Comparison of Hydrograph on Surma at Sunamganj

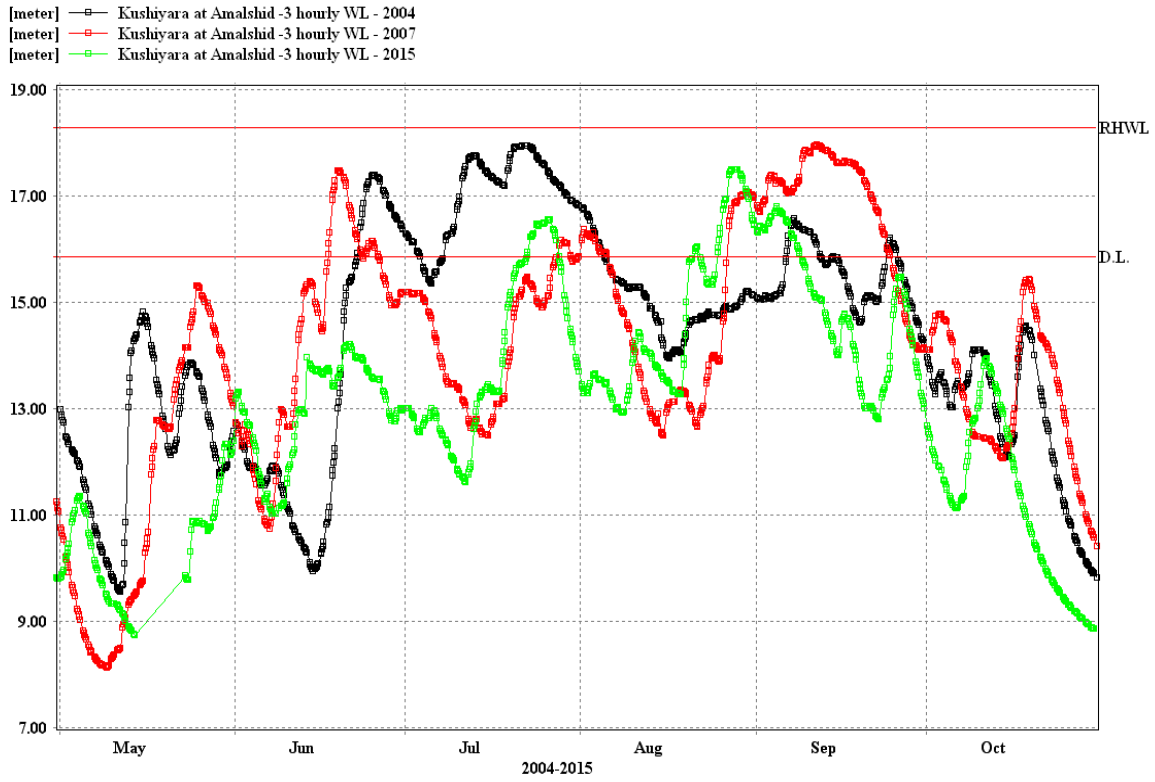


Figure 3.24: Comparison of Hydrograph on Kushiyara at Amalshid

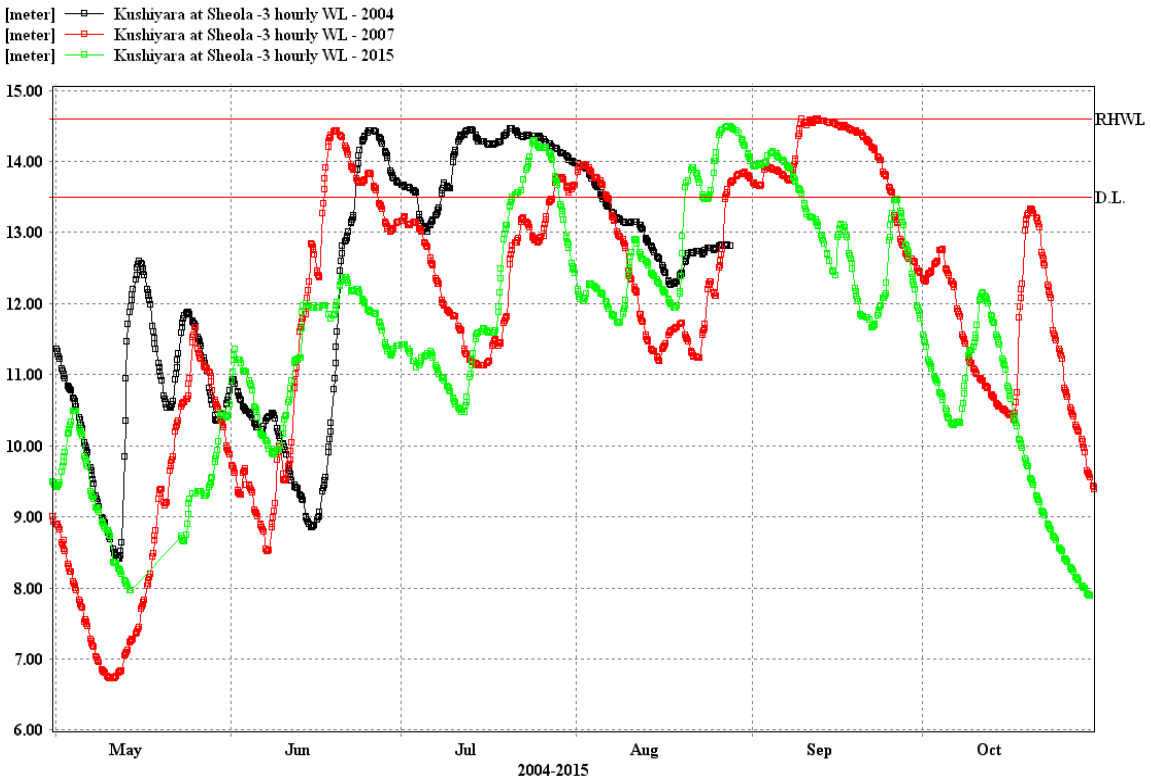


Figure 3.25: Comparison of Hydrograph on Kushiyara at Sheola

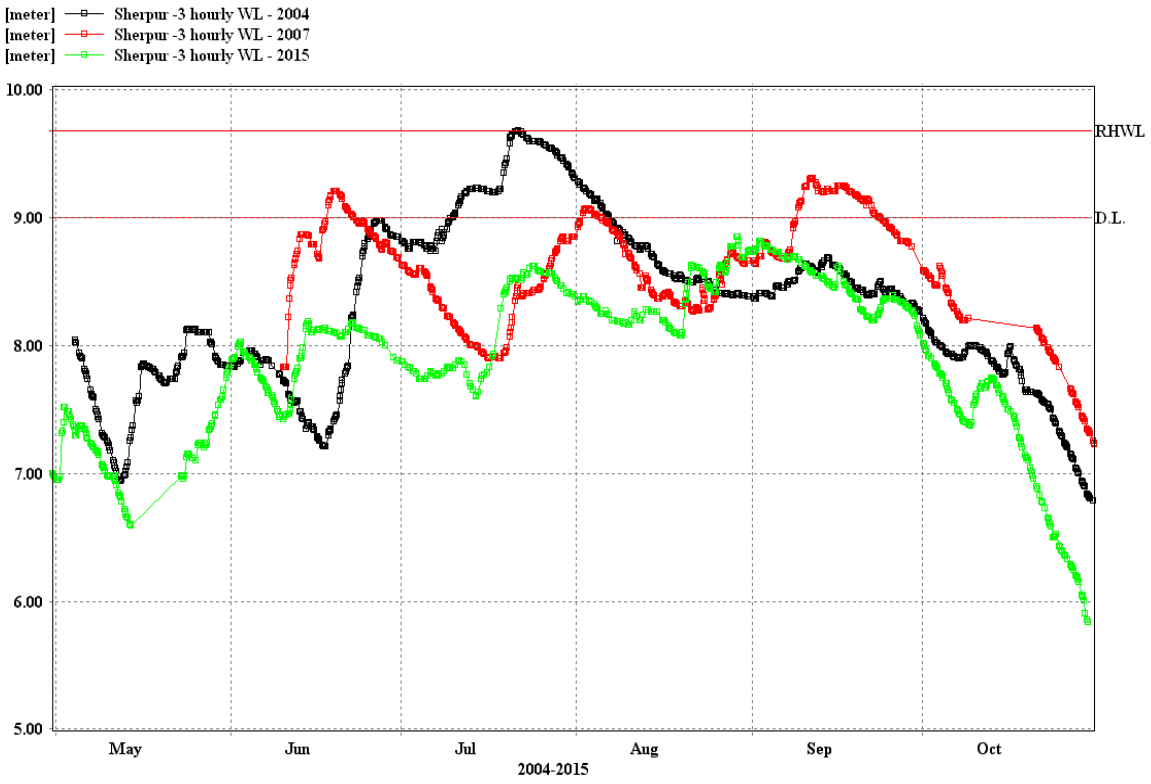


Figure 3.26: Comparison of Hydrograph on Kushiyara at Sherpur

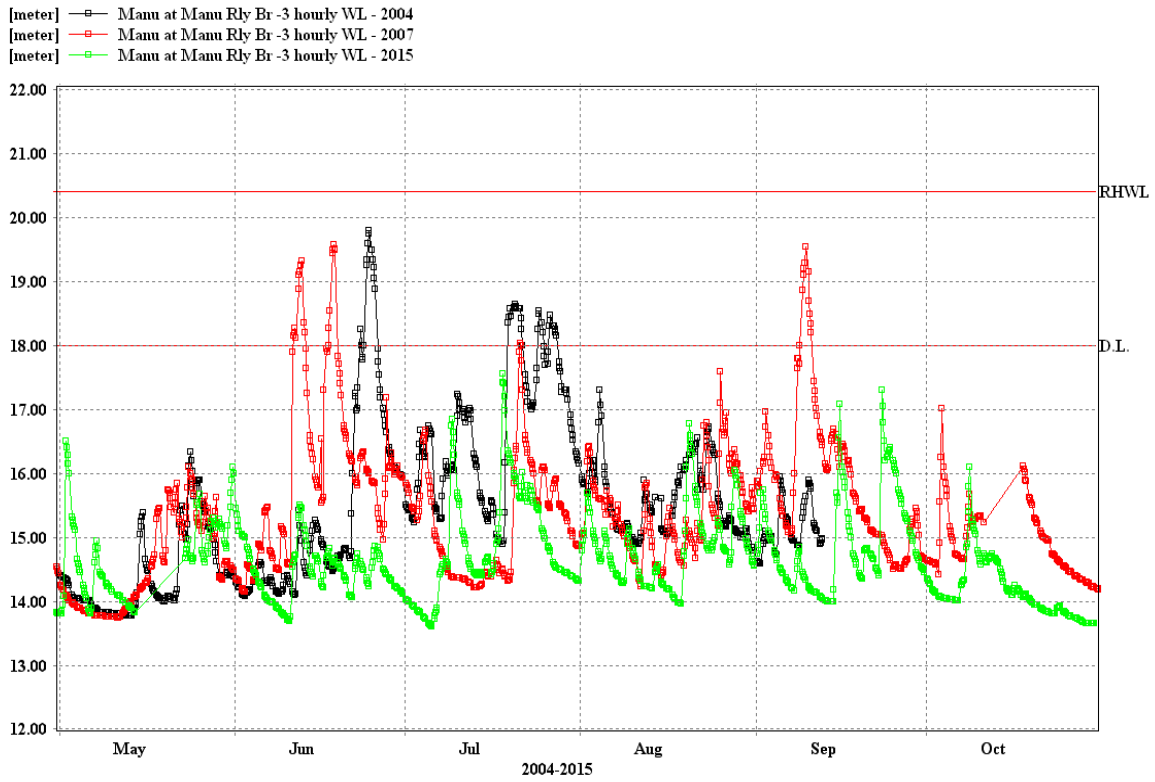


Figure 3.27: Comparison of Hydrograph on Manu at Manu Rail Bridge

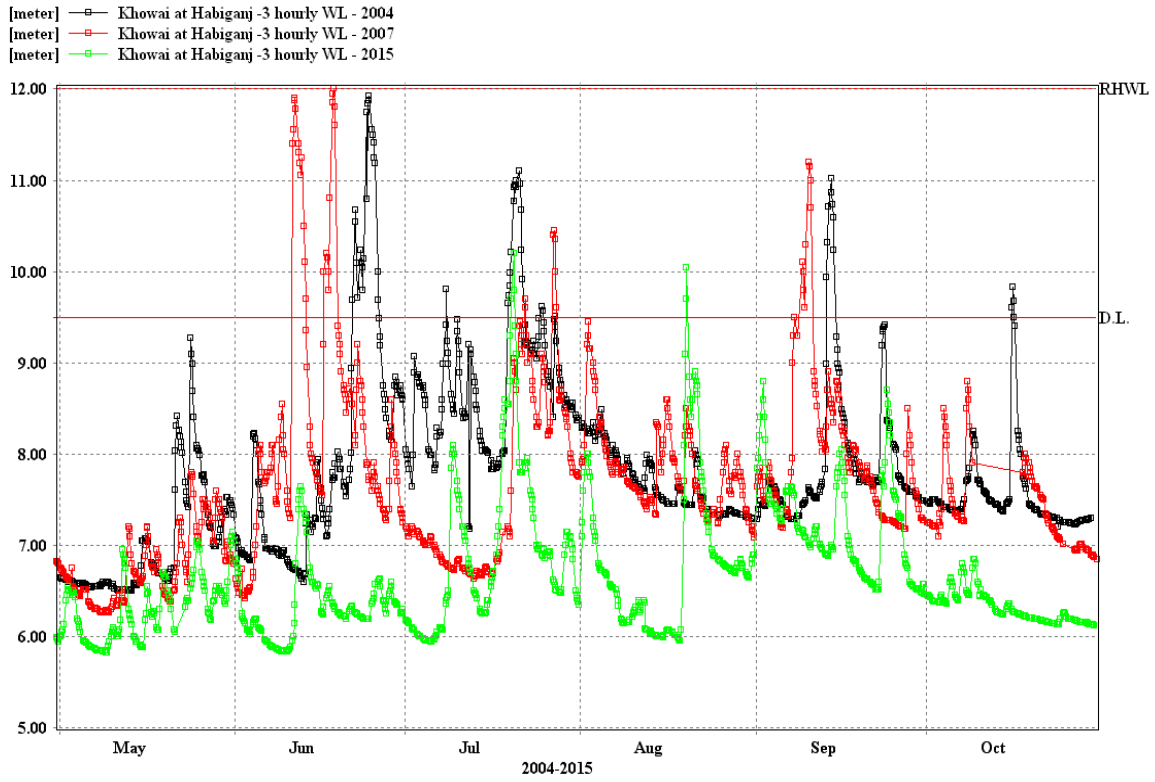


Figure 3.28: Comparison of Hydrograph on Khowai at Habigonj

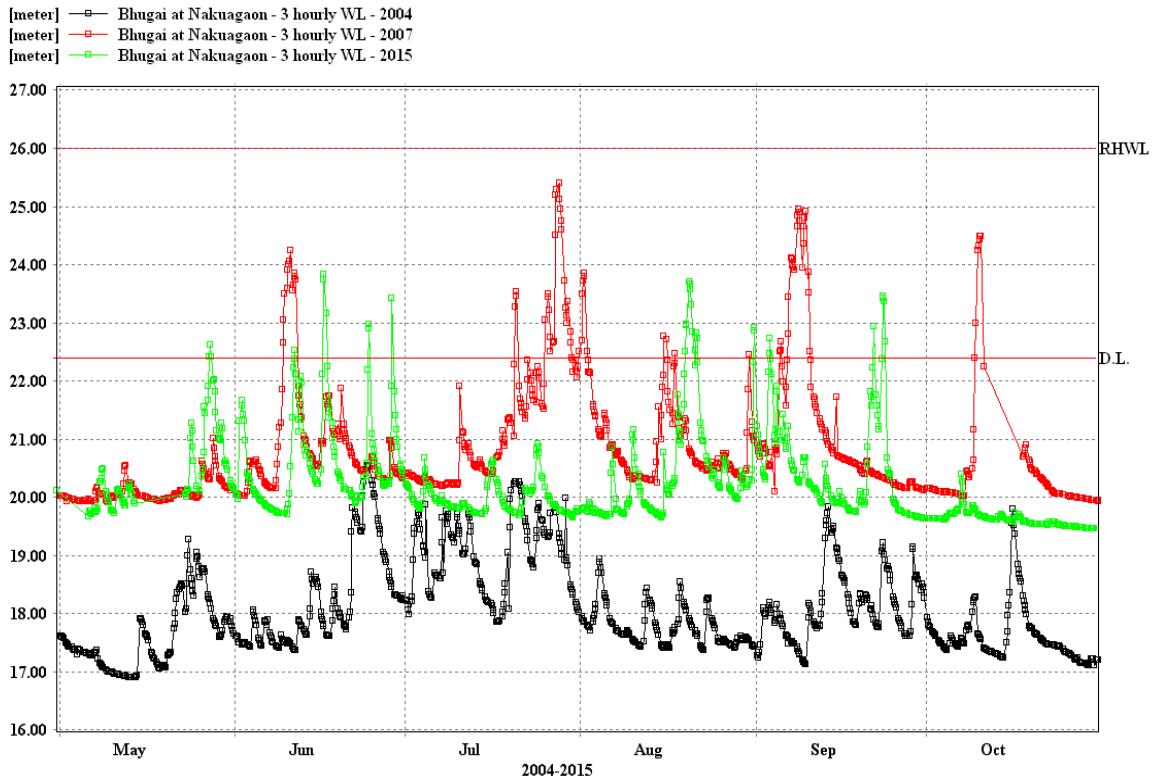


Figure 3.29: Comparison of Hydrograph on Bhugai at Nokuagaon

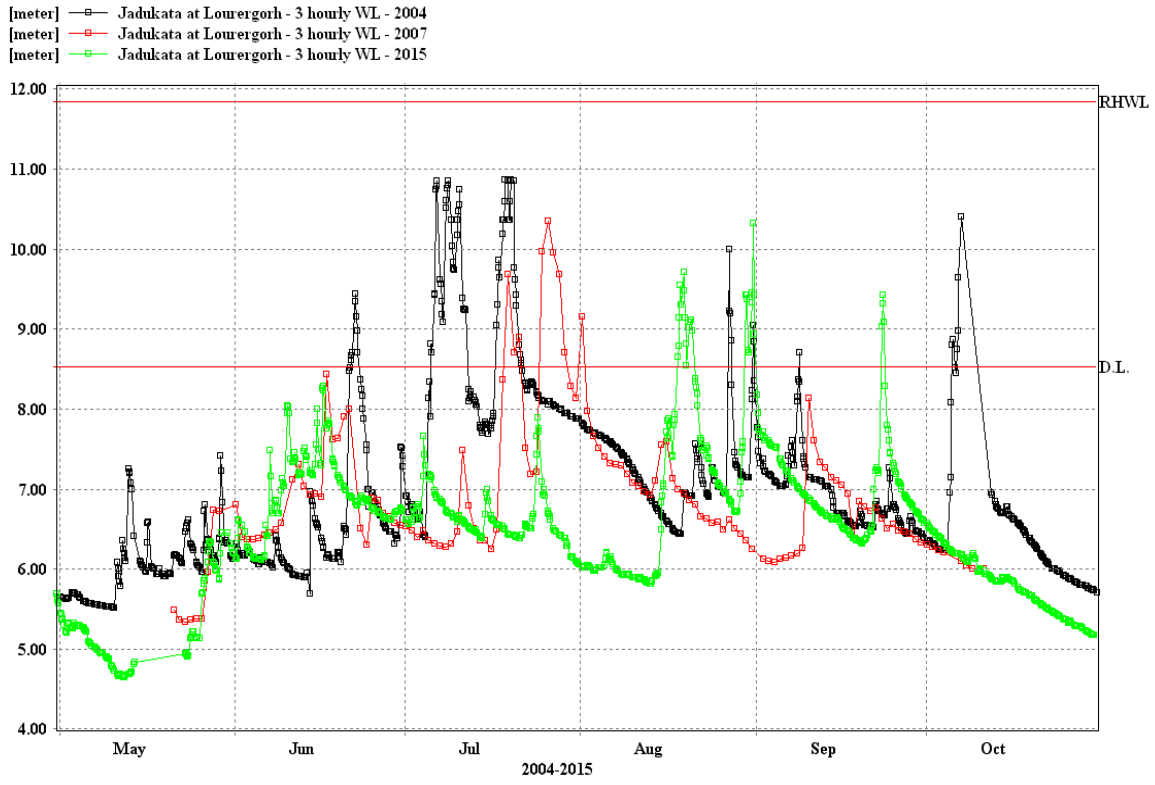


Figure 3.30: Comparison of Hydrograph on Jadukata at Lorergarh

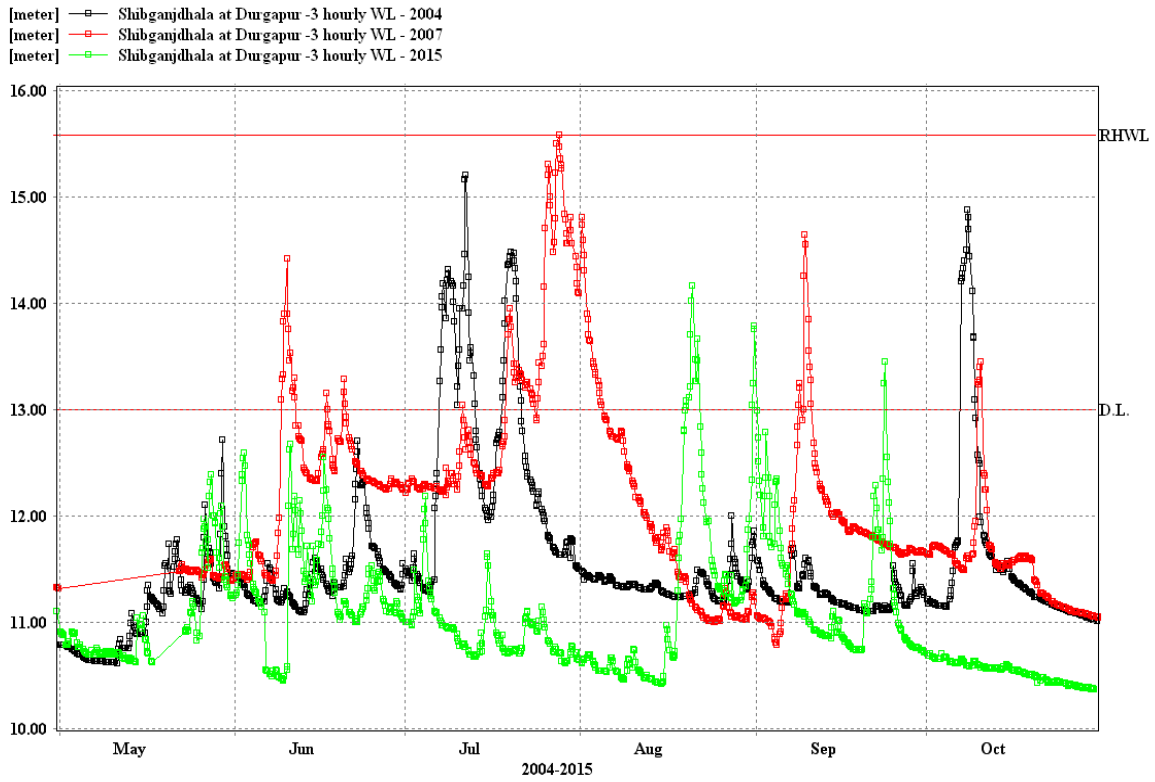


Figure 3.31: Comparison of Hydrograph on Someswari at Durgapur

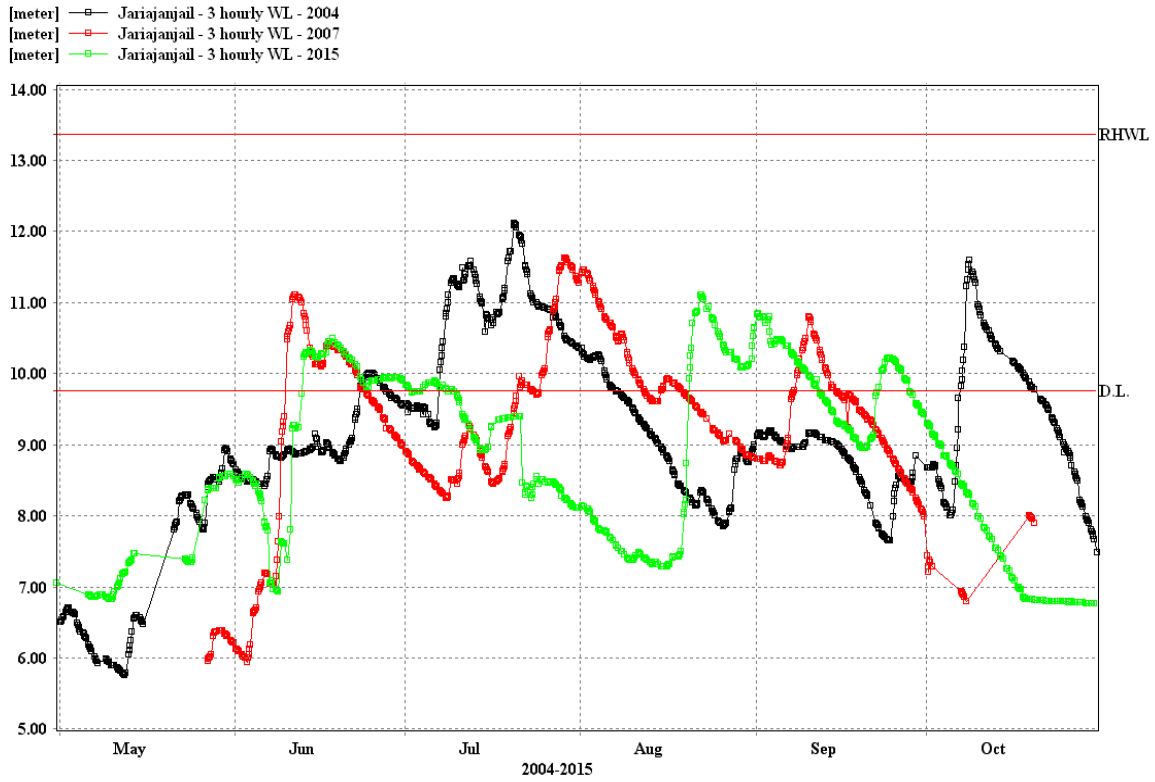


Figure 3.32: Comparison of Hydrograph on Kangsha at Jariajanjail

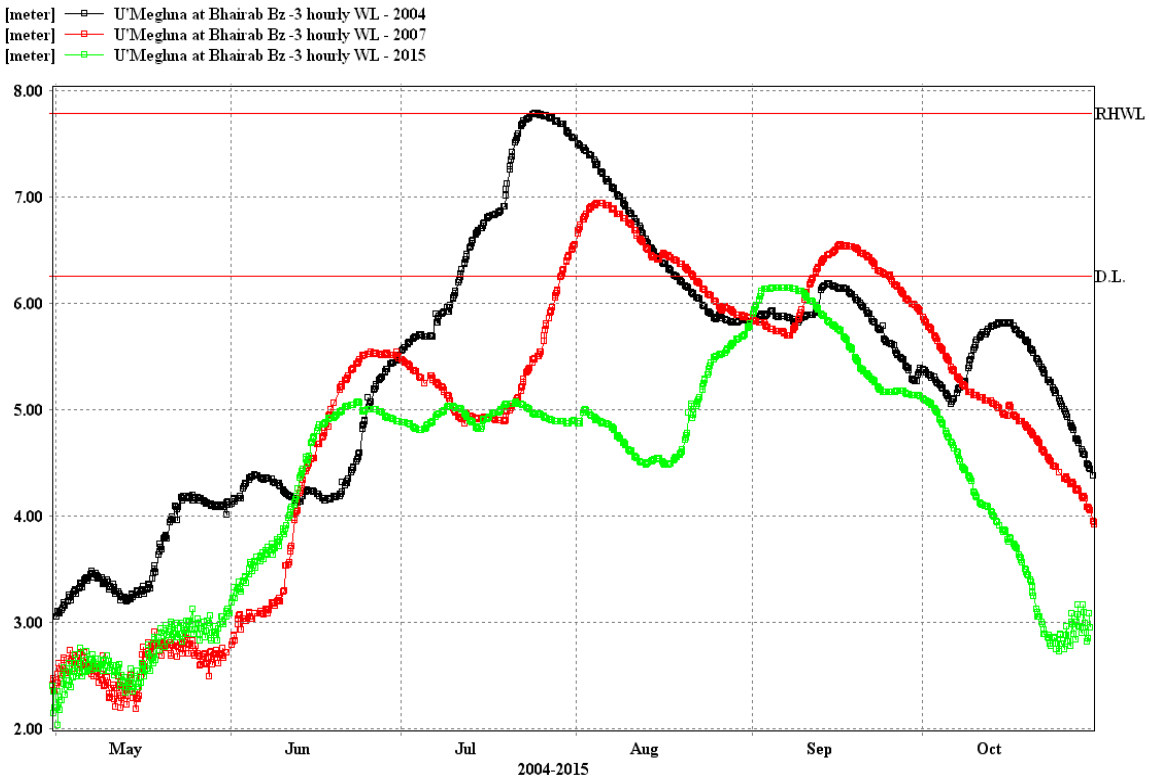


Figure 3.33: Comparison of Hydrograph on Upper Meghna at Bhairab Bazar

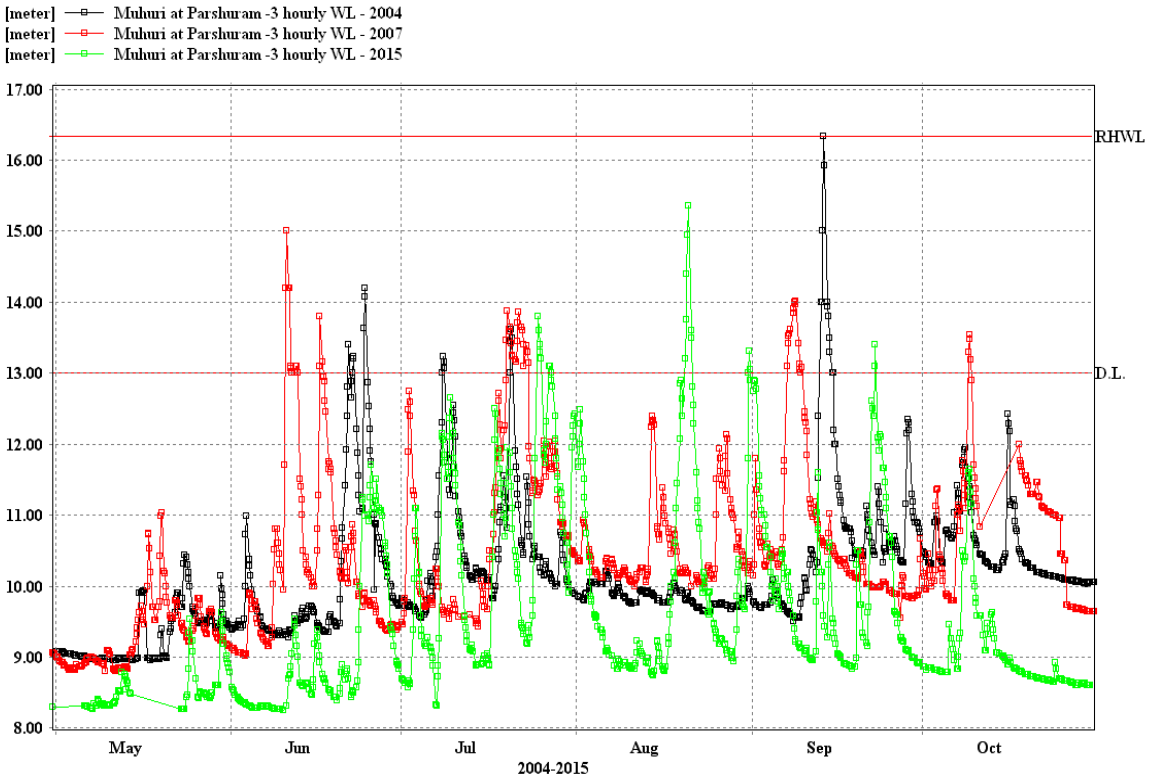


Figure 3.34: Comparison of Hydrograph on Muhuri at Parshuram

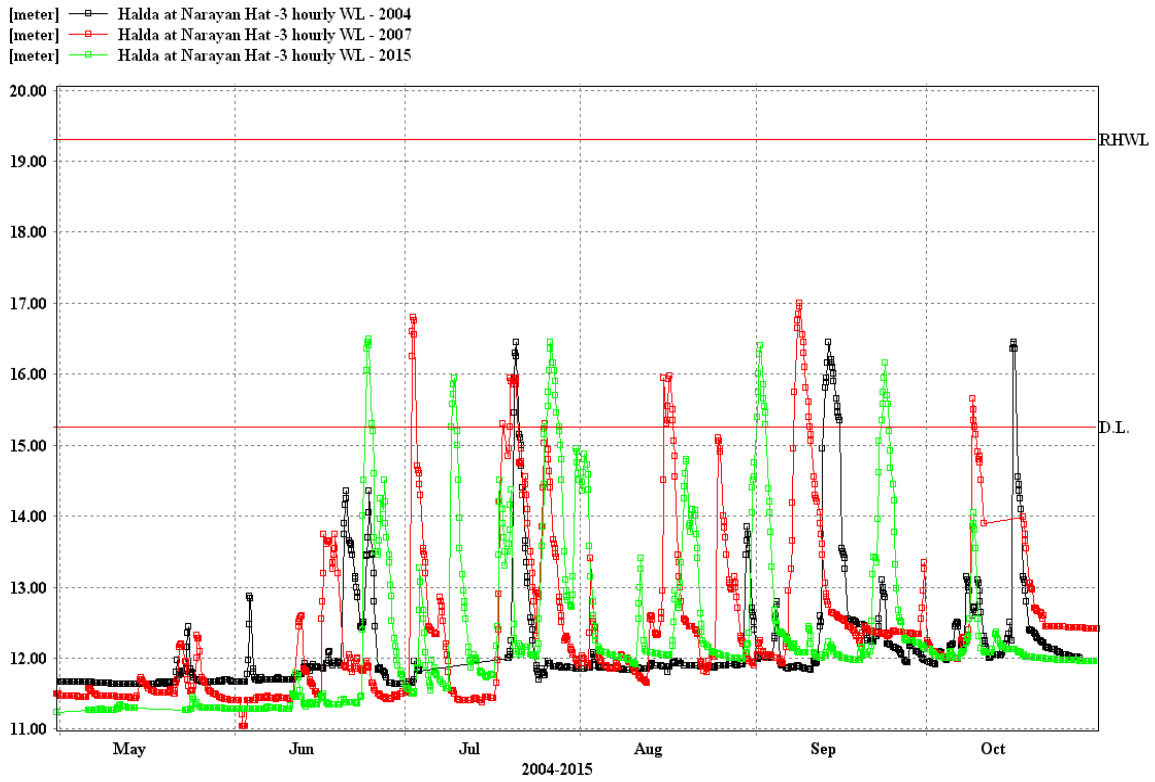


Figure 3.35 : Comparison of Hydrograph on Halda at Narayanhat

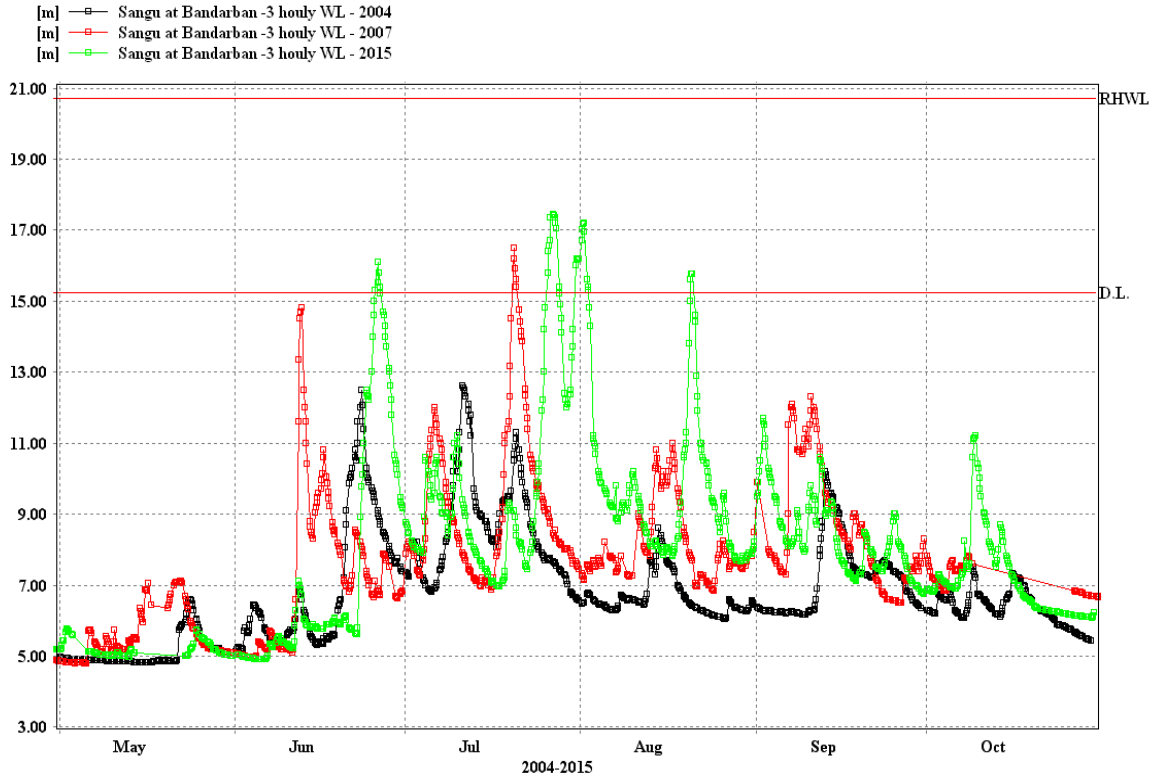


Figure 3.36: Comparison of Hydrograph on Sangu at Bandarban

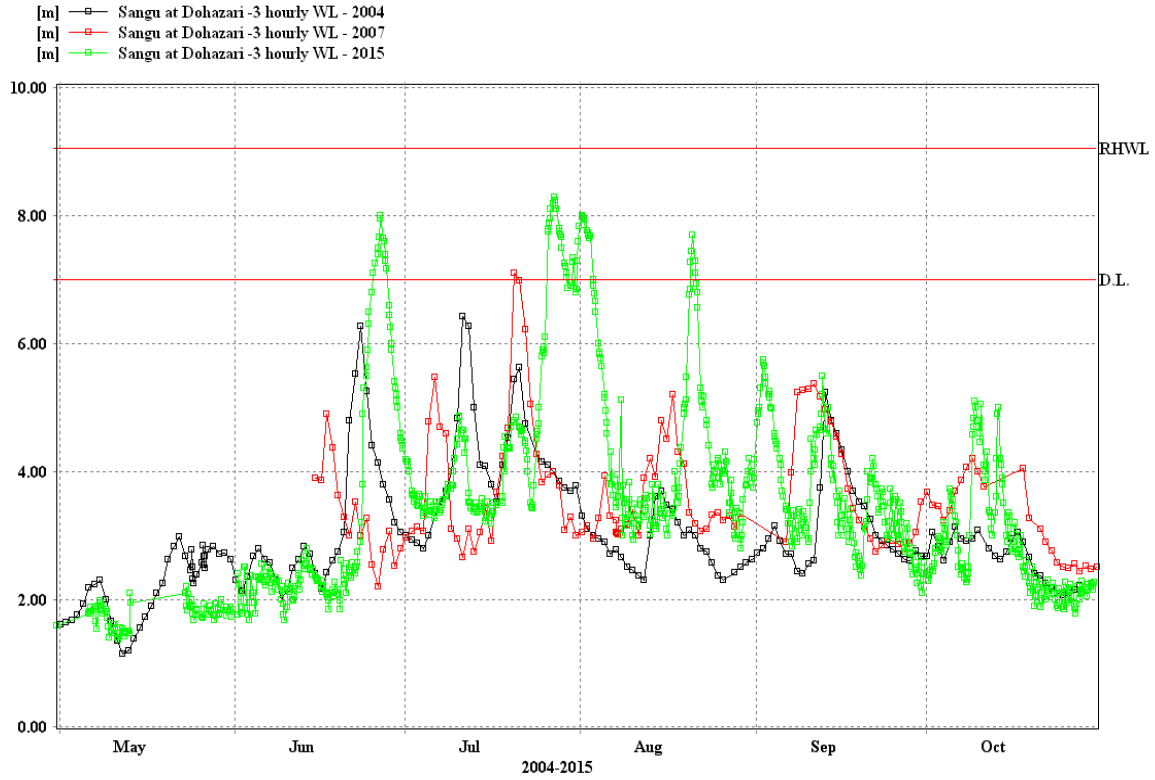


Figure 3.37: Comparison of Hydrograph on Sangu at Dohazari

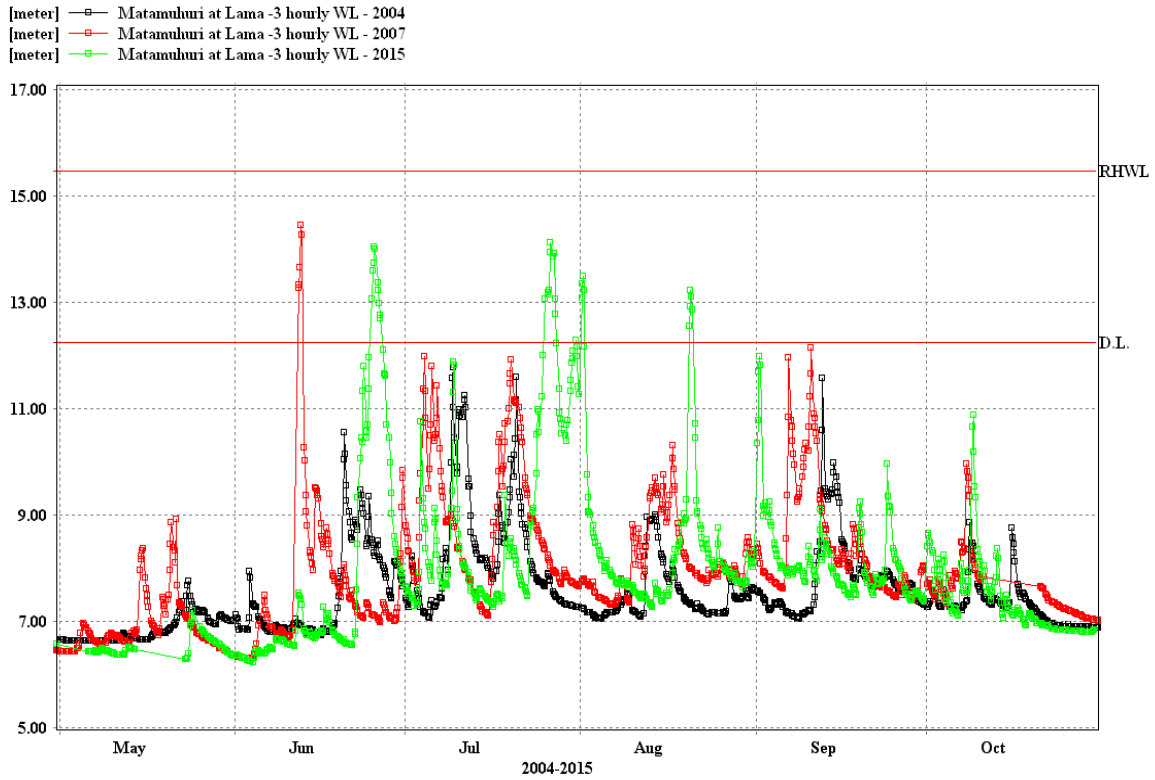


Figure 3.38: Comparison of Hydrograph on Matamuhuri at Lama

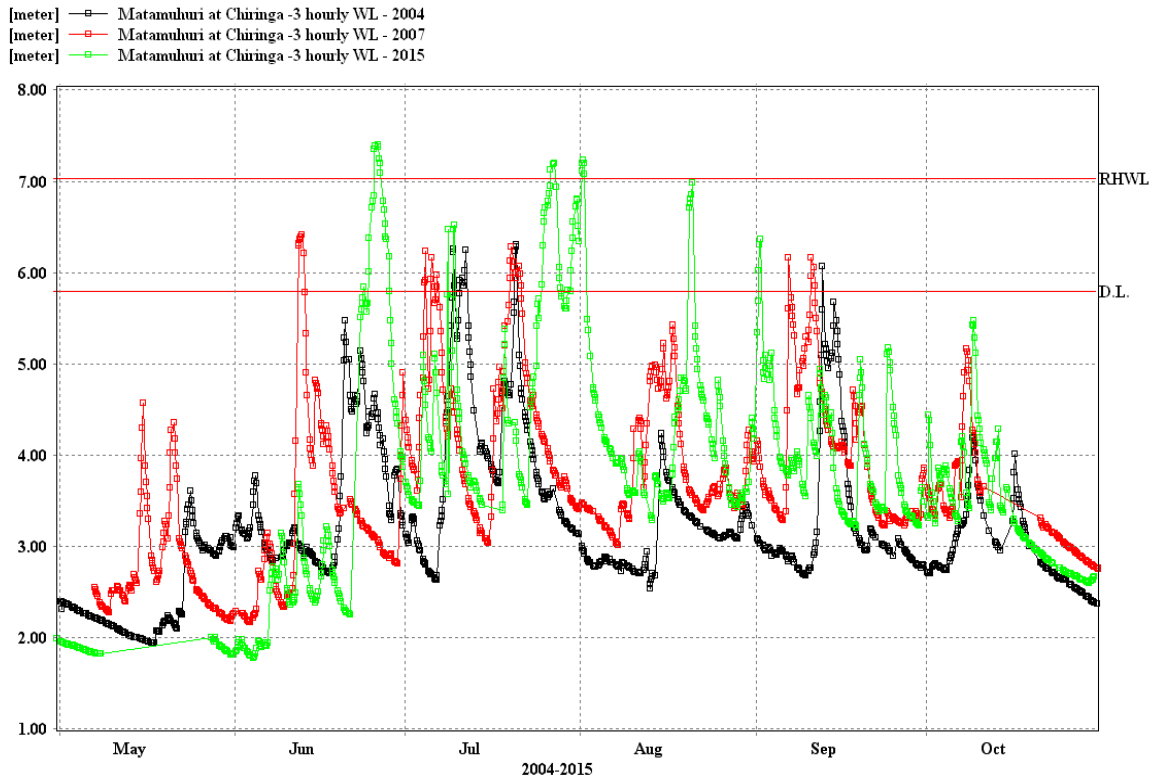


Figure 3.39: Comparison of Hydrograph on Matamuhuri at Chiringa

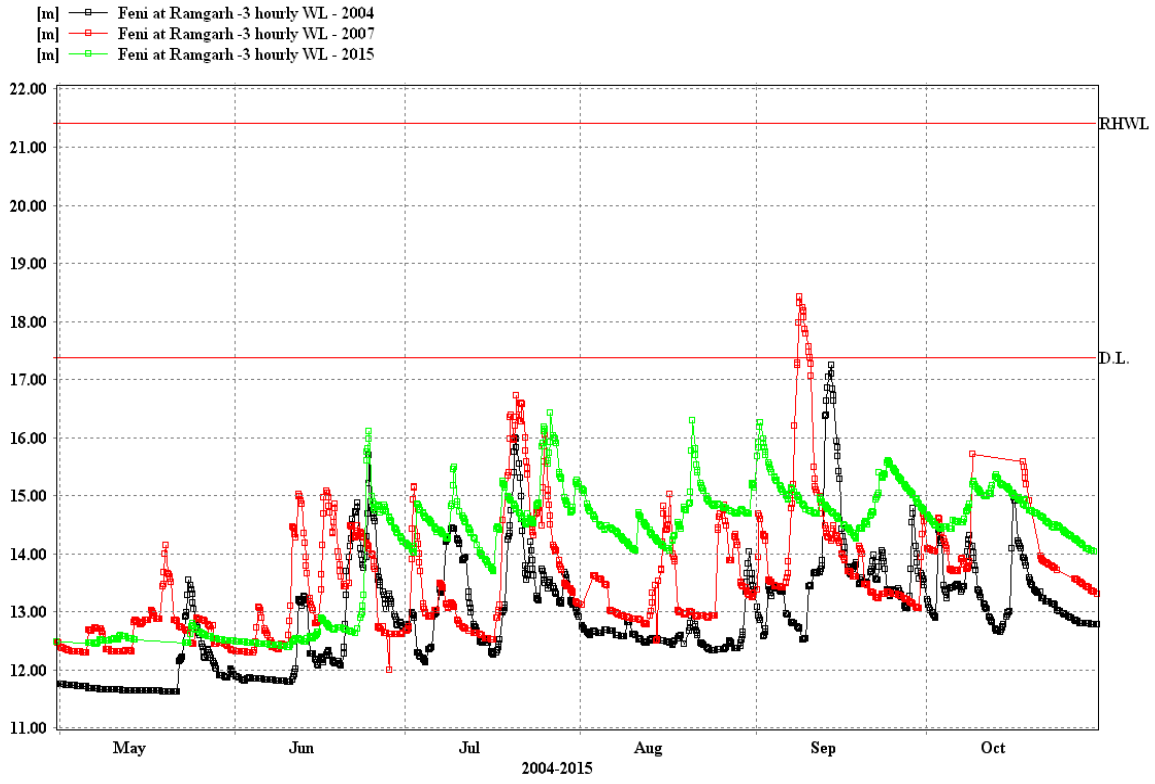


Figure 3.40: Comparison of Hydrograph on Feni at Ramgarh

CHAPTER 4: FORECAST EVALUATION, 2015

4.1 GENERAL

Flood Forecasting and Warning Centre (FFWC) of BWDB is mandated for preparation of flood forecasting, early warning and its dissemination in Bangladesh (BWDB Act-2000). Flood forecasting models of FFWC are developed on MIKE 11, one-dimensional modeling software used for the simulation of WLs and discharges in the river network and flood plains. The existing 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. A research initiative has been started from July 2011 to increase lead time for deterministic flood forecast up to 5 days (up to 120 hours) from existing 3-days and to extend the Flood Forecast to few selected BWDB projects with support from CDMP-II under Ministry of Food and Disaster Management (MoFDM) (from middle of 2012 renamed as Ministry of Disaster Management and Relief). 5-days extended lead time flood forecast has been generated and disseminated on regular basis since June 2015.

The Climate Forecast Applications in Bangladesh (CFAB) project was supported by USAID/OFDA to develop and evaluate three tire 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 stations 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.

Medium range 10-day lead time probability based flood forecast to a limited number of places (only 18 points) on experimental basis has been initiated under the project. After the termination of the support from the USAID-CARE, this has been continued with technical support from the RIMES. Another initiative has been started from July 2012 to expand the number of points for medium range 10-day lead time probability based flood forecast to increase the area coverage along with long range seasonal flood forecast at 5-places on experimental basis with support from USAID through CARE-Bangladesh under SHOURHARDO-II programme with technical partner RIMES.

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, r^2

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-2015 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 4.1 to 4.3 are shown 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 Table 4.2, Table 4.3 and Table 4.4.

4.4 FORECAST STATISTICS AND MODEL PERFORMANCE, 2015

4.4.1. Deterministic forecast performance

For deterministic forecast, simulations were made for maximum 120 hrs. 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 hrs/1-day lead time) followed by 48-hrs interval and then 72-hrs(3-days). Total 43 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 4.6 and in Figures 4.1 to 4.5. From the tables it may be seen that the forecast performance was 95.27% (MAE 8.38%), 90.86% (MAE 14.56%), 86.29% (MAE 20.43%), 80.98% (MAE 26.09%) and 75.39% (MEA 31.29%) accurate for 24hrs, 48hrs ,72 hrs, 96hrs and 120hrs respectively for the monsoon of 2015.

Table 4. 2: Statistics for 24- hour forecast performance

Sl. No.	Station	MAE (m)	r^2	Performance-24hr
1	Aricha	0.05	0.99	Good
2	Baghabari	0.05	0.99	Good
3	Bahadurabad	0.07	0.99	Good
4	Bhagyakul	0.06	0.99	Good
5	Bhairab Bazar	0.03	1.00	Good
6	Bogra	0.10	0.97	Good
7	Chakrahimpur	0.14	0.98	Good
8	Chapai Nawabganj	0.10	1.00	Good
9	Chilmari	0.07	0.98	Good
10	Demra	0.06	0.98	Good
11	Derai	0.04	0.98	Good
12	Dhaka	0.07	0.97	Good
13	Elashinghat	0.05	0.99	Good
14	Goalondo	0.05	0.99	Good
15	Gorai Rly Bridge	0.05	1.00	Good
16	Hardinge Br	0.05	1.00	Good
17	Jagir	0.12	0.98	Good
18	Jamalpur	0.10	0.98	Good
19	Kamarkhali	0.05	1.00	Good
20	Kaunia	0.24	0.42	Not Satisfactory
21	Khaliajuri	0.03	0.99	Good
22	Kurigram	0.12	0.95	Good
23	Lakhpur	0.11	0.78	Good
24	Markuli	0.05	0.89	Good
25	Mirpur	0.06	0.98	Good
26	Mohadevpur	0.22	0.92	Not Satisfactory
27	Moulvi Bazar	0.22	0.66	Not Satisfactory
28	Mymensingh	0.10	0.99	Good
29	Naogaon	0.11	0.98	Good
30	Narayanganj	0.08	0.95	Good
31	Narsingdi	0.05	0.98	Good
32	Nayerhat	0.06	0.97	Good
33	Rajshahi	0.09	1.00	Good
34	Sariakandi	0.05	0.99	Good
35	Serajganj	0.06	0.99	Good
36	Sheola	0.17	0.96	Average
37	Sherpur-Sylhet	0.06	0.94	Good
38	Singra	0.06	1.00	Good
39	Sunamganj	0.08	0.97	Good
40	Sureswar	0.07	0.96	Good
41	Sylhet	0.10	0.96	Good
42	Taraghat	0.06	0.99	Good
43	Tongi	0.05	0.99	Good

Table 4.3: Statistics for 48- hour forecast performance

Sl. No.	Station	MAE (m)	r^2	Performance-48hr
1	Aricha	0.08	0.98	Good
2	Baghabari	0.08	0.98	Good
3	Bahadurabad	0.14	0.95	Good
4	Bhagyakul	0.09	0.96	Good
5	Bhairab Bazar	0.06	0.99	Good
6	Bogra	0.20	0.91	Not Satisfactory
7	Chakrahimpur	0.26	0.94	Not Satisfactory
8	Chapai Nawabganj	0.21	0.99	Not Satisfactory
9	Chilmari	0.15	0.94	Average
10	Demra	0.10	0.93	Good
11	Derai	0.07	0.96	Good
12	Dhaka	0.11	0.92	Good
13	Elashinghat	0.08	0.98	Good
14	Goalondo	0.08	0.98	Good
15	Gorai Rly Bridge	0.10	1.00	Good
16	Hardinge Br	0.11	0.99	Good
17	Jagir	0.13	0.98	Good
18	Jamalpur	0.17	0.96	Average
19	Kamarkhali	0.08	1.00	Good
20	Kaunia	0.32	0.25	Very Poor
21	Khaliajuri	0.06	0.97	Good
22	Kurigram	0.20	0.89	Average
23	Lakhpur	0.15	0.71	Average
24	Markuli	0.07	0.80	Good
25	Mirpur	0.10	0.94	Good
26	Mohadevpur	0.38	0.83	Poor
27	Moulvi Bazar	0.36	0.42	Poor
28	Mymensingh	0.18	0.96	Average
29	Naogaon	0.20	0.95	Average
30	Narayanganj	0.12	0.90	Good
31	Narsingdi	0.10	0.95	Good
32	Nayerhat	0.11	0.95	Good
33	Rajshahi	0.19	0.99	Average
34	Sariakandi	0.11	0.97	Good
35	Serajganj	0.10	0.97	Good
36	Sheola	0.33	0.87	Poor
37	Sherpur-Sylhet	0.09	0.88	Good
38	Singra	0.10	0.99	Good
39	Sunamganj	0.18	0.86	Average
40	Sureswar	0.13	0.87	Good
41	Sylhet	0.21	0.89	Not Satisfactory
42	Taraghat	0.10	0.98	Good
43	Tongi	0.09	0.95	Good

Table 4.4: Statistics for 72- hour forecast performance

Sl. No.	Station	MAE (m)	r^2	Performance-72hr
1	Aricha	0.12	0.96	Good
2	Baghabari	0.11	0.96	Good
3	Bahadurabad	0.22	0.90	Not Satisfactory
4	Bhagyakul	0.13	0.93	Good
5	Bhairab Bazar	0.09	0.97	Good
6	Bogra	0.30	0.83	Not Satisfactory
7	Chakrahimpur	0.38	0.87	Poor
8	Chapai Nawabganj	0.32	0.97	Poor
9	Chilmari	0.24	0.87	Not Satisfactory
10	Demra	0.13	0.88	Good
11	Derai	0.09	0.93	Good
12	Dhaka	0.13	0.88	Good
13	Elashinghat	0.11	0.96	Good
14	Goalondo	0.12	0.97	Good
15	Gorai Rly Bridge	0.16	0.99	Average
16	Hardinge Br	0.20	0.99	Average
17	Jagir	0.16	0.97	Average
18	Jamalpur	0.22	0.93	Not Satisfactory
19	Kamarkhali	0.12	0.99	Good
20	Kaunia	0.36	0.27	Very Poor
21	Khaliajuri	0.10	0.92	Good
22	Kurigram	0.29	0.79	Not Satisfactory
23	Lakhpur	0.21	0.61	Not Satisfactory
24	Markuli	0.09	0.71	Good
25	Mirpur	0.13	0.91	Good
26	Mohadevpur	0.49	0.77	Very Poor
27	Moulvi Bazar	0.44	0.30	Very Poor
28	Mymensingh	0.26	0.93	Not Satisfactory
29	Naogaon	0.28	0.91	Not Satisfactory
30	Narayanganj	0.15	0.85	Good
31	Narsingdi	0.14	0.90	Good
32	Nayerhat	0.15	0.91	Good
33	Rajshahi	0.31	0.97	Poor
34	Sariakandi	0.19	0.92	Average
35	Serajganj	0.15	0.93	Good
36	Sheola	0.48	0.76	Very Poor
37	Sherpur-Sylhet	0.12	0.81	Good
38	Singra	0.14	0.97	Good
39	Sunamganj	0.26	0.74	Not Satisfactory
40	Sureswar	0.16	0.81	Average
41	Sylhet	0.30	0.78	Poor
42	Taraghat	0.14	0.96	Good
43	Tongi	0.12	0.90	Good

Table 4. 5: Statistics for 96- hour forecast performance

Sl. No.	Station	MAE (m)	r^2	Performance-96hr
1	Aricha	0.17	0.93	Average
2	Baghabari	0.17	0.92	Average
3	Bahadurabad	0.30	0.83	Not Satisfactory
4	Bhagyakul	0.18	0.89	Average
5	Bhairab Bazar	0.12	0.95	Good
6	Bogra	0.36	0.79	Poor
7	Chakrahimpur	0.49	0.80	Very Poor
8	Chapai Nawabganj	0.41	0.96	Very Poor
9	Chilmari	0.34	0.78	Poor
10	Demra	0.17	0.81	Average
11	Derai	0.11	0.91	Good
12	Dhaka	0.16	0.83	Average
13	Elashinghat	0.15	0.93	Good
14	Goalondo	0.16	0.94	Average
15	Gorai Rly Bridge	0.24	0.98	Not Satisfactory
16	Hardinge Br	0.28	0.97	Not Satisfactory
17	Jagir	0.17	0.96	Average
18	Jamalpur	0.28	0.89	Not Satisfactory
19	Kamarkhali	0.17	0.98	Average
20	Kaunia	0.41	0.20	Very Poor
21	Khaliajuri	0.13	0.86	Good
22	Kurigram	0.37	0.68	Poor
23	Lakhpur	0.24	0.56	Not Satisfactory
24	Markuli	0.11	0.63	Good
25	Mirpur	0.17	0.86	Average
26	Mohadevpur	0.61	0.68	Very Poor
27	Moulvi Bazar	0.50	0.14	Very Poor
28	Mymensingh	0.31	0.90	Poor
29	Naogaon	0.39	0.84	Poor
30	Narayanganj	0.15	0.84	Average
31	Narsingdi	0.18	0.86	Average
32	Nayerhat	0.18	0.86	Average
33	Rajshahi	0.42	0.95	Very Poor
34	Sariakandi	0.27	0.84	Not Satisfactory
35	Serajganj	0.21	0.87	Not Satisfactory
36	Sheola	0.59	0.67	Very Poor
37	Sherpur-Sylhet	0.15	0.73	Good
38	Singra	0.18	0.96	Average
39	Sunamganj	0.33	0.62	Poor
40	Sureswar	0.19	0.76	Average
41	Sylhet	0.38	0.68	Poor
42	Taraghat	0.19	0.94	Average
43	Tongi	0.16	0.84	Average

Table 4. 6: Statistics for 120- hour forecast performance

Sl. No.	Station	MAE (m)	r^2	Performance-120hr
1	Aricha	0.22	0.89	Not Satisfactory
2	Baghabari	0.22	0.86	Not Satisfactory
3	Bahadurabad	0.36	0.74	Poor
4	Bhagyakul	0.23	0.83	Not Satisfactory
5	Bhairab Bazar	0.15	0.92	Good
6	Bogra	0.39	0.77	Poor
7	Chakrahimpur	0.58	0.72	Very Poor
8	Chapai Nawabganj	0.49	0.94	Very Poor
9	Chilmari	0.41	0.67	Very Poor
10	Demra	0.20	0.75	Not Satisfactory
11	Derai	0.13	0.87	Good
12	Dhaka (Mill Barrack)	0.19	0.79	Average
13	Elashinghat	0.20	0.89	Average
14	Goalondo	0.20	0.89	Average
15	Gorai Rly Bridge	0.30	0.96	Poor
16	Hardinge Br	0.36	0.96	Poor
17	Jagir	0.20	0.94	Not Satisfactory
18	Jamalpur	0.34	0.84	Poor
19	Kamarkhali	0.23	0.97	Not Satisfactory
20	Kaunia	0.46	0.14	Very Poor
21	Khaliajuri	0.17	0.78	Average
22	Kurigram	0.44	0.57	Very Poor
23	Lakhpur	0.28	0.52	Not Satisfactory
24	Markuli	0.12	0.52	Good
25	Mirpur	0.20	0.82	Not Satisfactory
26	Mohadevpur	0.77	0.55	Very Poor
27	Moulvi Bazar	0.58	0.05	Very Poor
28	Mymensingh	0.35	0.87	Poor
29	Naogaon	0.45	0.79	Very Poor
30	Narayanganj	0.17	0.81	Average
31	Narsingdi	0.20	0.82	Not Satisfactory
32	Nayerhat	0.22	0.81	Not Satisfactory
33	Rajshahi	0.52	0.93	Very Poor
34	Sariakandi	0.35	0.76	Poor
35	Serajganj	0.28	0.78	Not Satisfactory
36	Sheola	0.66	0.58	Very Poor
37	Sherpur-Sylhet	0.17	0.64	Average
38	Singra	0.21	0.95	Not Satisfactory
39	Sunamganj	0.39	0.50	Poor
40	Sureswar	0.20	0.72	Not Satisfactory
41	Sylhet	0.43	0.60	Very Poor
42	Taraghat	0.24	0.92	Not Satisfactory
43	Tongi	0.20	0.78	Average

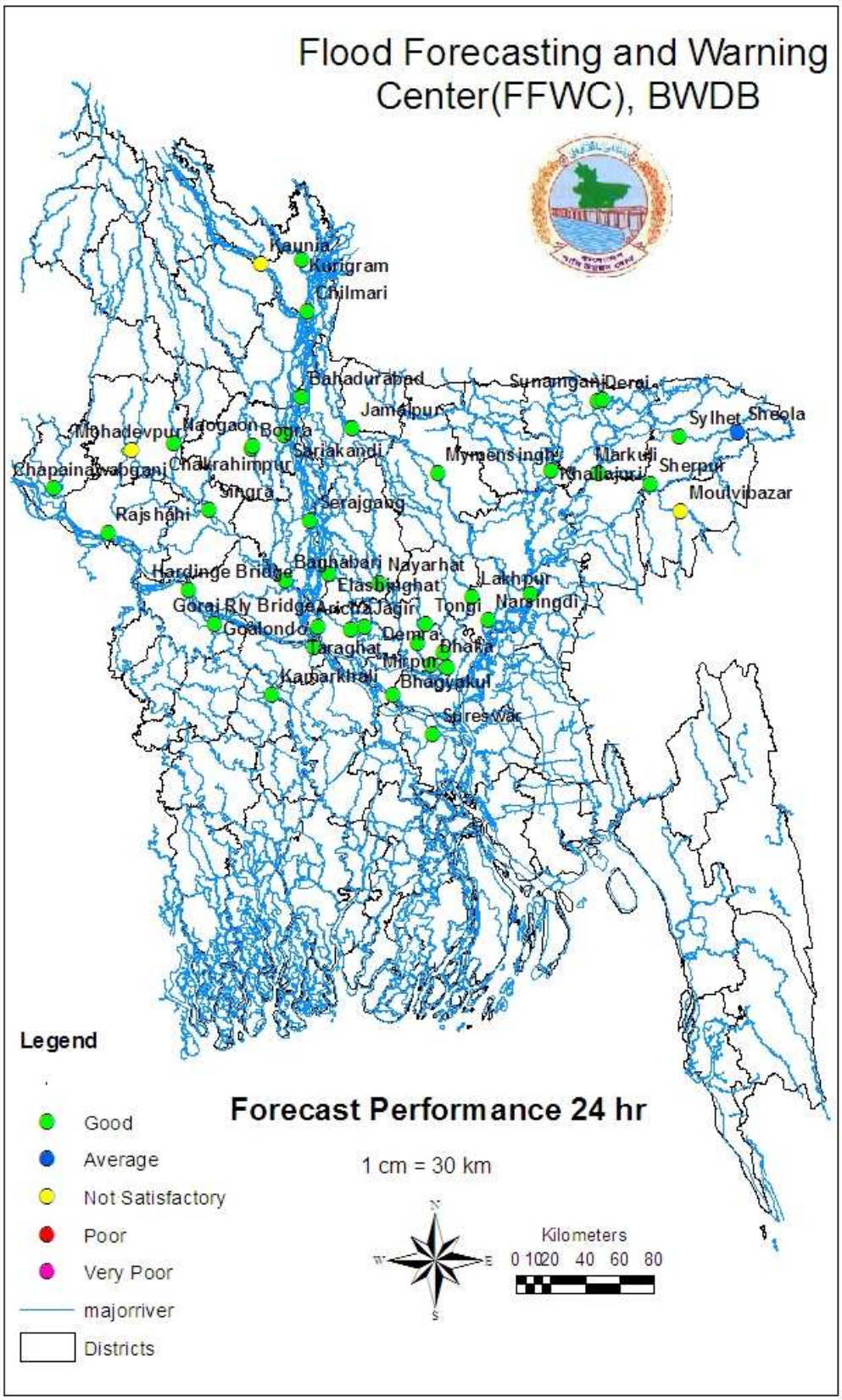


Figure 4.1 : 24 hr Forecast Evaluation (Year, 2015)

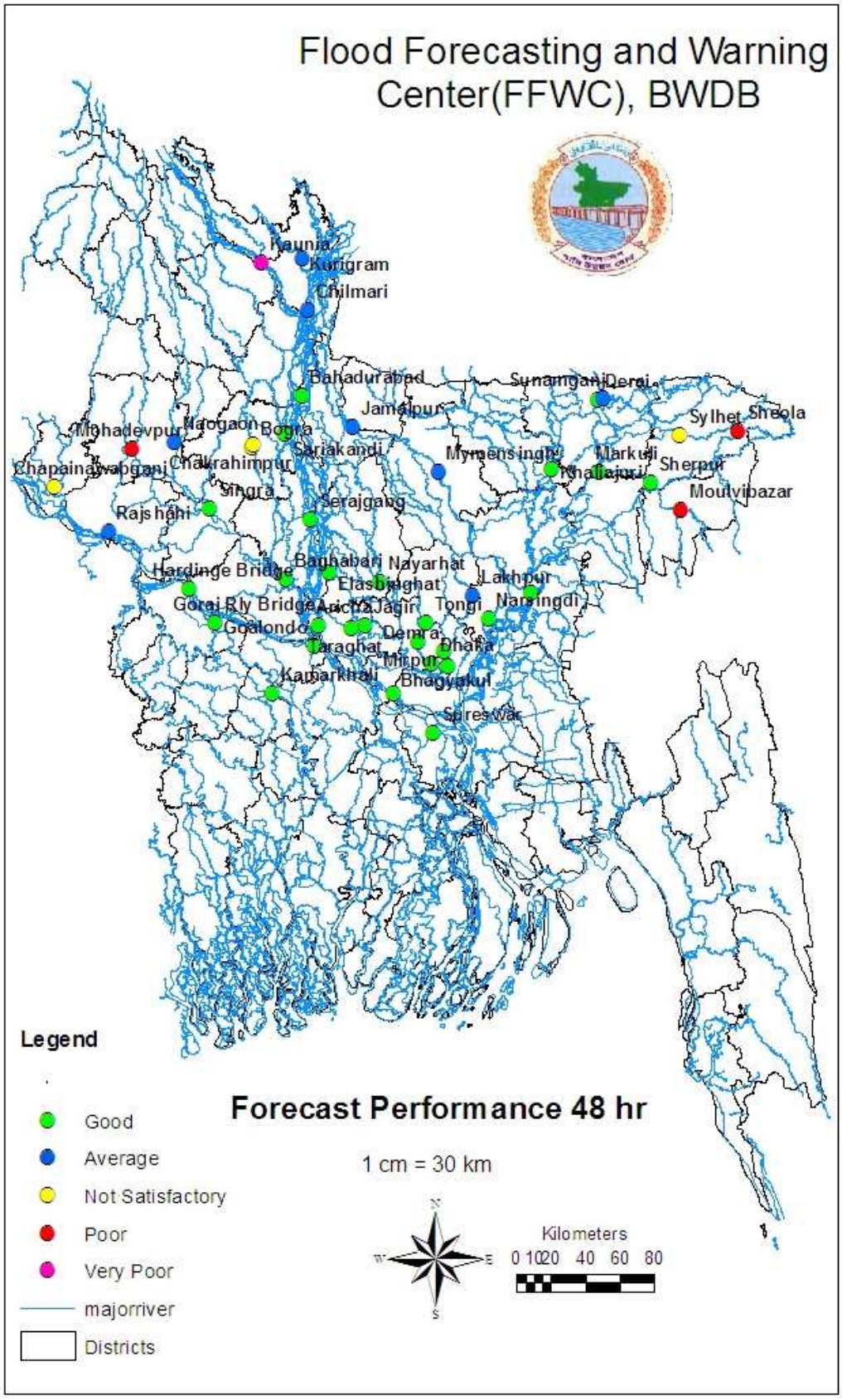


Figure 4.2 : 48 hr Forecast Evaluation (Year, 2015)

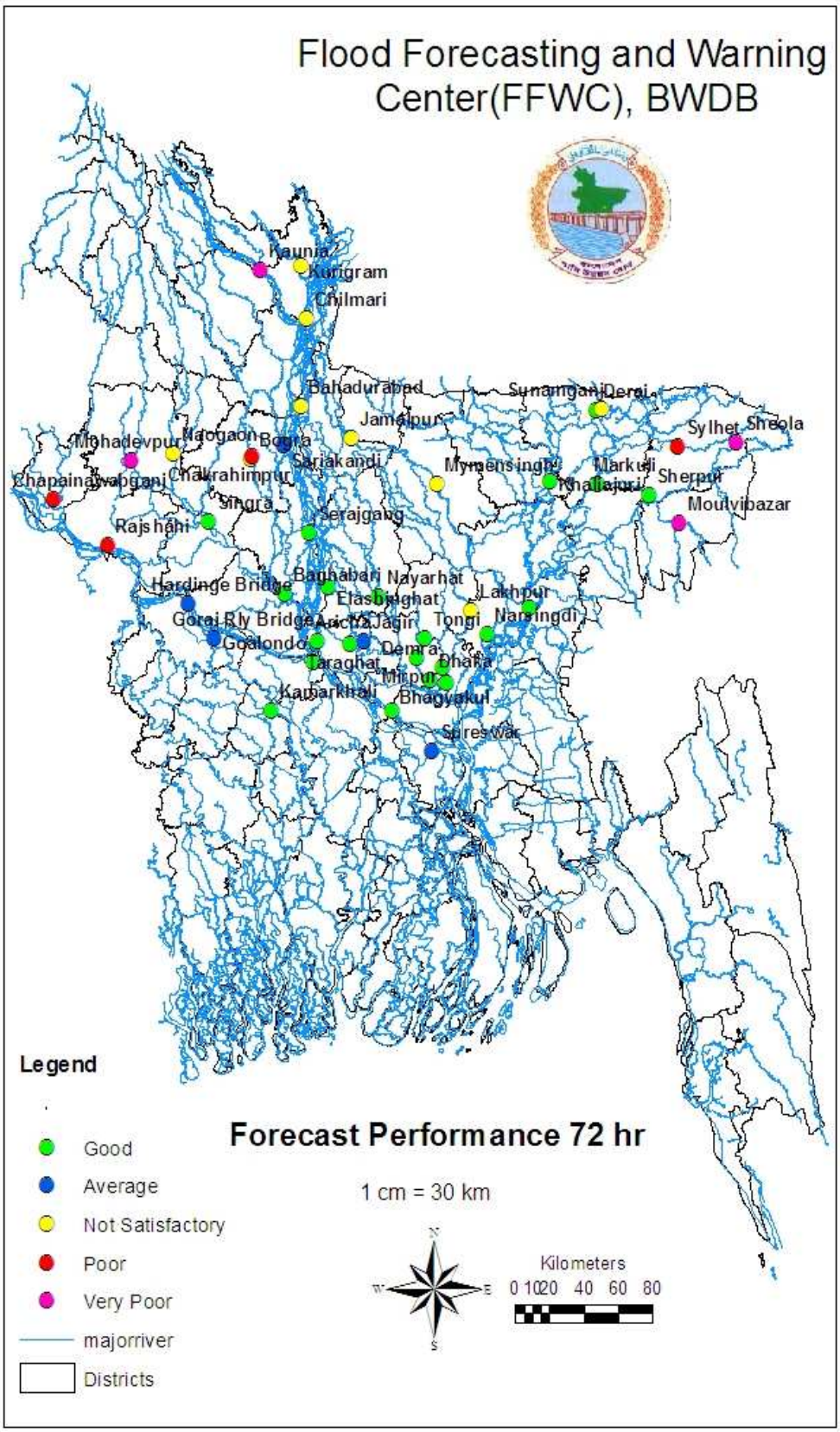


Figure 4.3 : 72 hr Forecast Evaluation (Year, 2015)

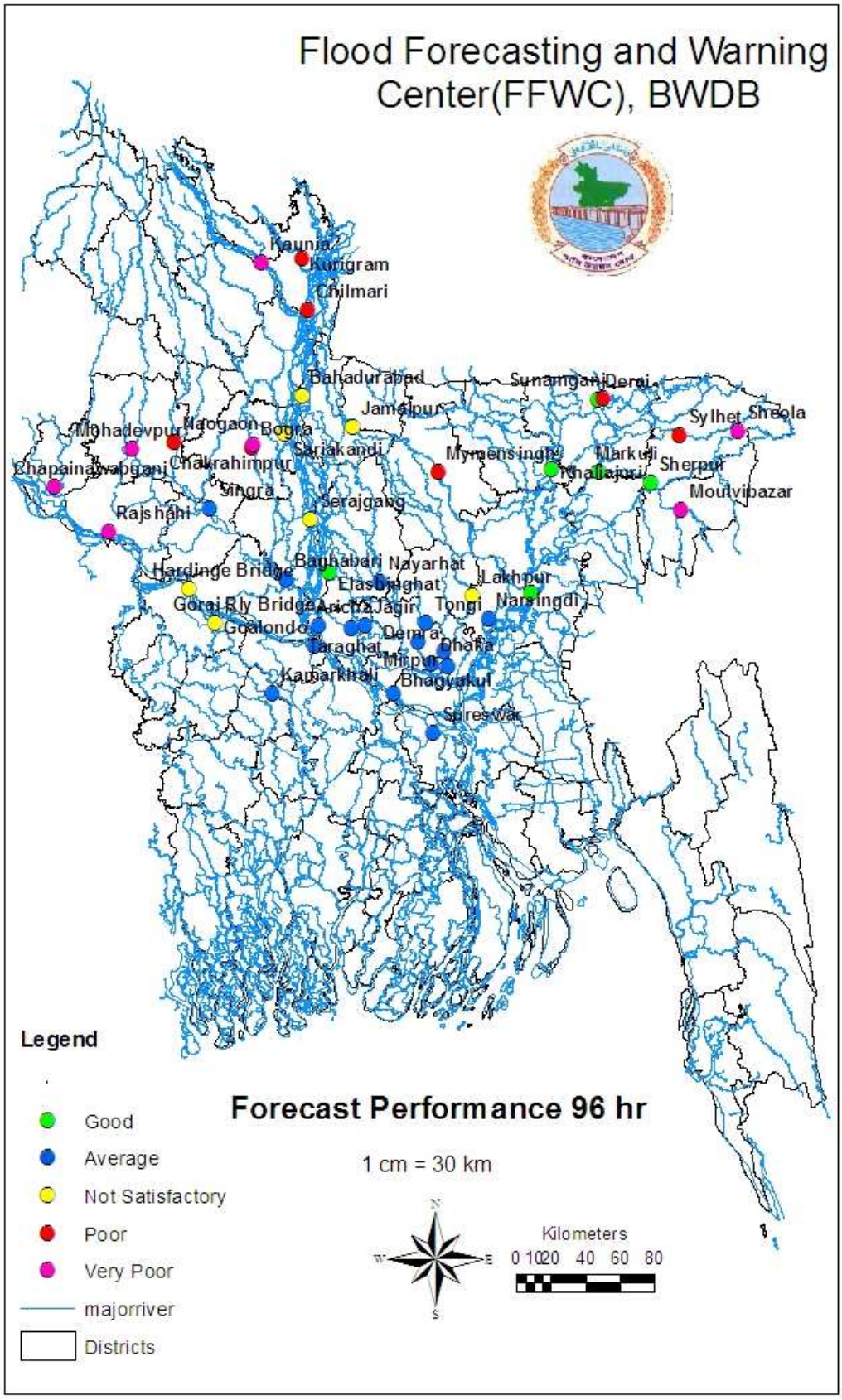


Figure 4.4 : 96 hr Forecast Evaluation (Year, 2015)

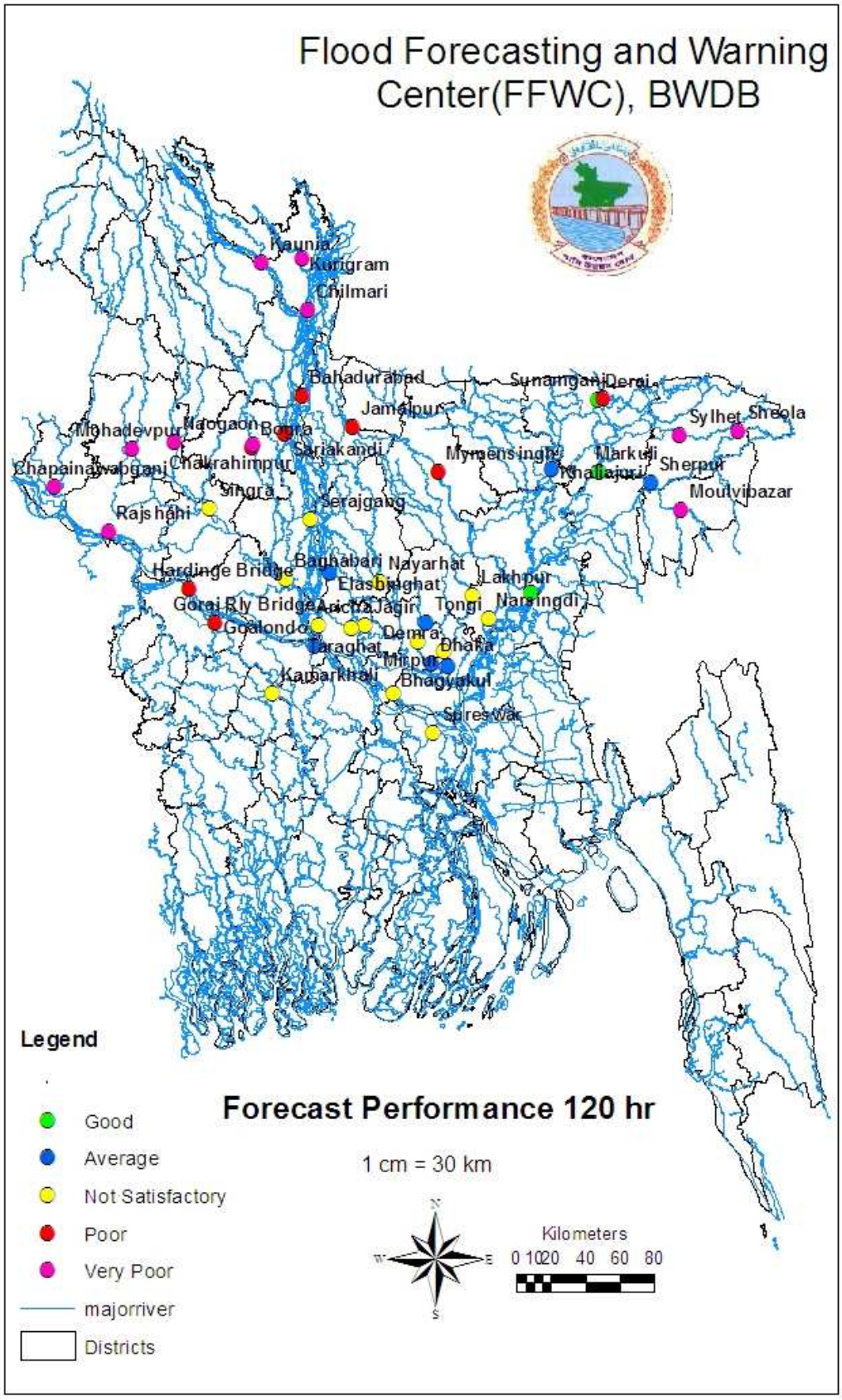


Figure 4.5 : 120 hr Forecast Evaluation (Year, 2015)

4.4.2 Medium Range (upto 10-days) Probabilistic Forecast Performance

CFAN (Climate Forecast Application Network) utilizes ECMWF (European Centre for Medium-Range Weather Forecasts) weather prediction data in their model to generate 51 sets of ensemble discharge forecasts data on the Brahmaputra at Bahadurabad and on the Ganges at Hardinge-Bridge in Bangladesh. 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 (medium range upto 10-days) using climate forecast application data has been named CFAB-FFS (CFAB Flood Forecasting Study) model.

In addition to existing 24, 48, 72, 96 & 120 hrs deterministic forecast, CFAN model generates medium range 10 days lead-time probabilistic forecasts for mean, upper bound and lower bound WL at 37 locations listed below on experimental basis. 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 based on the MAE, RMSE and r^2 at different time-scale up to 10 days for the 37 number of stations under FFWC system have been presented through Table 4.5 to Table 4.8.

Table 4. 7 : Performance of 3-day Probabilistic Forecast

	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
Stations	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2
Aricha	0.26	0.32	0.92	0.17	0.24	0.92	0.18	0.27	0.90
Baghbari	0.22	0.27	0.92	0.20	0.26	0.92	0.20	0.27	0.92
Bahadurabad	0.55	0.69	0.76	0.37	0.47	0.81	0.34	0.47	0.77
Bhagyakul	0.22	0.29	0.86	0.16	0.24	0.85	0.19	0.27	0.82
Bhairab Bz	0.13	0.23	0.86	0.13	0.23	0.85	0.13	0.23	0.85
Chandpur	0.33	0.39	0.37	0.33	0.39	0.37	0.33	0.39	0.37
Demra	0.16	0.20	0.85	0.16	0.20	0.85	0.17	0.21	0.84
Dhaka	0.16	0.20	0.85	0.16	0.21	0.84	0.17	0.22	0.82
Dirai	0.29	0.36	0.76	0.29	0.36	0.76	0.29	0.36	0.76
Elashinghat	0.39	0.47	0.85	0.28	0.37	0.87	0.23	0.35	0.86
Faridpur	0.12	0.16	0.94	0.12	0.16	0.94	0.12	0.16	0.94
Goalondo	0.26	0.32	0.92	0.18	0.24	0.91	0.19	0.27	0.89
Gorai Rly. Br	0.34	0.43	0.96	0.29	0.37	0.96	0.44	0.55	0.94
Hardinge Br	0.42	0.52	0.95	0.36	0.49	0.94	0.61	0.77	0.92
Jagir	0.11	0.16	0.98	0.11	0.15	0.98	0.11	0.15	0.98
Jamalpur	0.31	0.45	0.84	0.29	0.47	0.84	0.30	0.53	0.81
Kamarkhali	0.24	0.29	0.97	0.22	0.29	0.97	0.34	0.42	0.96
Kanaighat	0.59	0.84	0.63	0.59	0.84	0.63	0.59	0.84	0.63

Kazipur	0.43	0.55	0.83	0.31	0.41	0.85	0.30	0.41	0.83
Madaripur	0.21	0.27	0.70	0.20	0.26	0.71	0.20	0.28	0.68
Mawa	0.18	0.24	0.89	0.14	0.21	0.88	0.16	0.24	0.85
Mirpur	0.13	0.16	0.90	0.13	0.16	0.90	0.14	0.17	0.89
Mohadevpur	0.56	0.78	0.68	0.56	0.78	0.68	0.56	0.78	0.68
Moulvibazar	0.52	0.72	0.35	0.52	0.72	0.35	0.52	0.72	0.35
Mymensingh	0.29	0.44	0.87	0.29	0.44	0.87	0.29	0.45	0.87
Naogaon	0.31	0.39	0.90	0.31	0.39	0.90	0.31	0.39	0.90
Narayanganj	0.17	0.20	0.81	0.17	0.21	0.81	0.17	0.21	0.80
Narsingdi	0.12	0.14	0.92	0.12	0.14	0.92	0.12	0.14	0.92
RekabiBazar	0.13	0.18	0.86	0.15	0.19	0.85	0.15	0.19	0.85
Sariakandi	0.46	0.58	0.83	0.31	0.41	0.85	0.29	0.38	0.84
Serajganj	0.44	0.53	0.82	0.30	0.38	0.84	0.28	0.36	0.82
Sheola	0.55	0.88	0.66	0.55	0.88	0.66	0.55	0.88	0.66
Sherpur	0.17	0.30	0.67	0.17	0.30	0.67	0.17	0.30	0.67
Sunamganj	0.26	0.36	0.75	0.26	0.36	0.75	0.26	0.36	0.75
Sureshwar	0.27	0.33	0.65	0.24	0.31	0.64	0.25	0.31	0.63
Sylhet	0.37	0.55	0.67	0.37	0.55	0.67	0.37	0.55	0.67
Tongi	0.12	0.15	0.87	0.13	0.15	0.87	0.13	0.16	0.85

Table 4. 8: Performance of 5-day Probabilistic Forecast

	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
Stations	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2
Aricha	0.45	0.60	0.71	0.30	0.40	0.75	0.34	0.44	0.73
Baghbari	0.37	0.49	0.77	0.33	0.43	0.79	0.34	0.45	0.78
Bahadurabad	0.79	0.97	0.64	0.52	0.68	0.62	0.51	0.66	0.58
Bhagyakul	0.39	0.52	0.63	0.28	0.38	0.62	0.33	0.43	0.57
Bhairab Bz	0.19	0.29	0.78	0.20	0.29	0.78	0.20	0.29	0.77
Chandpur	0.48	0.56	0.04	0.48	0.56	0.04	0.48	0.56	0.04
Demra	0.24	0.29	0.71	0.24	0.30	0.71	0.25	0.32	0.69
Dhaka	0.22	0.28	0.74	0.22	0.29	0.72	0.23	0.32	0.68
Dirai	0.44	0.55	0.54	0.44	0.55	0.54	0.44	0.55	0.54
Elashinghat	0.62	0.79	0.68	0.40	0.53	0.73	0.32	0.43	0.74
Faridpur	0.19	0.23	0.88	0.19	0.23	0.88	0.19	0.23	0.88
Goalondo	0.46	0.61	0.71	0.31	0.40	0.73	0.38	0.47	0.69
Gorai Rly. Br	0.60	0.80	0.87	0.46	0.59	0.89	0.67	0.86	0.86
Hardinge Br	0.72	0.98	0.82	0.58	0.78	0.85	0.92	1.15	0.81
Jagir	0.22	0.27	0.96	0.18	0.23	0.96	0.17	0.21	0.95
Jamalpur	0.52	0.68	0.72	0.47	0.65	0.70	0.45	0.69	0.69
Kamarkhali	0.44	0.59	0.89	0.39	0.51	0.90	0.58	0.73	0.87
Kanaighat	0.78	1.08	0.42	0.78	1.08	0.42	0.78	1.08	0.42
Kazipur	0.69	0.87	0.66	0.48	0.63	0.66	0.47	0.59	0.66
Madaripur	0.34	0.43	0.53	0.29	0.38	0.50	0.28	0.39	0.46
Mawa	0.33	0.43	0.70	0.25	0.34	0.68	0.30	0.40	0.63

Mirpur	0.17	0.21	0.84	0.18	0.21	0.83	0.19	0.23	0.82
Mohadevpur	0.73	0.94	0.51	0.73	0.94	0.51	0.73	0.94	0.51
Moulvibazar	0.64	0.90	0.11	0.64	0.90	0.11	0.64	0.90	0.11
Mymensingh	0.42	0.56	0.80	0.42	0.58	0.79	0.42	0.63	0.77
Naogaon	0.38	0.50	0.83	0.38	0.50	0.83	0.38	0.50	0.83
Narayanganj	0.21	0.25	0.74	0.21	0.26	0.73	0.23	0.28	0.72
Narsingdi	0.19	0.23	0.81	0.19	0.23	0.81	0.19	0.23	0.81
RekabiBazar	0.18	0.24	0.78	0.21	0.26	0.75	0.21	0.26	0.75
Sariakandi	0.73	0.91	0.65	0.48	0.64	0.65	0.45	0.58	0.65
Serajganj	0.72	0.89	0.55	0.47	0.60	0.59	0.40	0.52	0.59
Sheola	0.66	0.95	0.54	0.66	0.95	0.54	0.66	0.95	0.54
Sherpur	0.23	0.37	0.47	0.23	0.37	0.47	0.23	0.37	0.47
Sunamganj	0.39	0.51	0.56	0.39	0.51	0.56	0.39	0.51	0.56
Sureshwar	0.39	0.48	0.40	0.33	0.42	0.36	0.34	0.46	0.31
Sylhet	0.48	0.68	0.51	0.48	0.68	0.51	0.48	0.68	0.51
Tongi	0.18	0.22	0.73	0.19	0.23	0.71	0.20	0.25	0.68

Table 4. 9: Performance of 7-day Probabilistic Forecast

	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
Stations	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2
Aricha	0.63	0.81	0.58	0.40	0.51	0.60	0.49	0.59	0.54
Baghbari	0.54	0.70	0.61	0.44	0.58	0.62	0.47	0.60	0.60
Bahadurabad	0.91	1.09	0.64	0.57	0.73	0.60	0.59	0.74	0.50
Bhagyakul	0.54	0.68	0.50	0.35	0.46	0.48	0.45	0.54	0.40
Bhairab Bz	0.23	0.34	0.70	0.23	0.34	0.70	0.24	0.35	0.69
Chandpur	0.53	0.63	0.00	0.53	0.63	0.00	0.53	0.63	0.00
Demra	0.29	0.36	0.62	0.30	0.38	0.60	0.32	0.41	0.59
Dhaka	0.27	0.34	0.67	0.26	0.34	0.65	0.29	0.38	0.62
Dirai	0.51	0.66	0.42	0.51	0.66	0.42	0.51	0.66	0.42
Elashinghat	0.82	1.01	0.56	0.53	0.67	0.58	0.45	0.57	0.54
Faridpur	0.24	0.28	0.82	0.24	0.28	0.82	0.24	0.28	0.82
Goalondo	0.64	0.81	0.57	0.41	0.52	0.56	0.53	0.64	0.48
Gorai Rly. Br	0.83	1.07	0.81	0.57	0.72	0.81	0.78	0.99	0.77
Hardinge Br	0.99	1.29	0.74	0.73	0.95	0.73	1.05	1.32	0.68
Jagir	0.37	0.44	0.91	0.28	0.34	0.92	0.23	0.29	0.91
Jamalpur	0.73	0.93	0.56	0.62	0.83	0.56	0.61	0.83	0.55
Kamarkhali	0.64	0.84	0.81	0.50	0.63	0.82	0.72	0.89	0.77
Kanaighat	0.89	1.15	0.32	0.89	1.15	0.32	0.89	1.15	0.32
Kazipur	0.85	1.09	0.58	0.58	0.76	0.57	0.59	0.71	0.53
Madaripur	0.44	0.56	0.43	0.33	0.43	0.41	0.34	0.44	0.37
Mawa	0.46	0.58	0.52	0.32	0.42	0.50	0.42	0.51	0.43
Mirpur	0.23	0.28	0.77	0.23	0.27	0.76	0.24	0.30	0.74
Mohadevpur	0.81	1.02	0.39	0.81	1.02	0.39	0.81	1.02	0.39
Moulvibazar	0.75	0.98	0.07	0.75	0.98	0.07	0.75	0.98	0.07

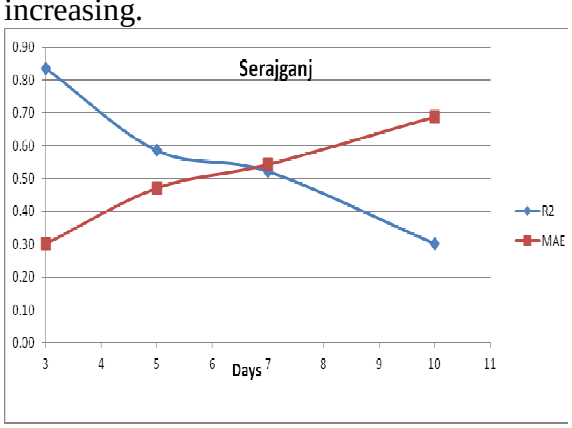
Mymensingh	0.51	0.64	0.74	0.50	0.65	0.74	0.50	0.70	0.72
Naogaon	0.46	0.62	0.71	0.46	0.62	0.71	0.46	0.62	0.71
Narayanganj	0.26	0.32	0.62	0.27	0.33	0.62	0.30	0.37	0.60
Narsingdi	0.23	0.28	0.73	0.23	0.28	0.73	0.23	0.28	0.73
RekabiBazar	0.23	0.31	0.71	0.28	0.33	0.67	0.28	0.33	0.67
Sariakandi	0.89	1.10	0.61	0.58	0.73	0.59	0.57	0.70	0.53
Serajganj	0.90	1.07	0.52	0.54	0.69	0.52	0.52	0.65	0.45
Sheola	0.77	1.05	0.39	0.77	1.05	0.39	0.77	1.05	0.39
Sherpur	0.27	0.39	0.34	0.27	0.39	0.34	0.27	0.39	0.34
Sunamganj	0.46	0.59	0.47	0.46	0.59	0.47	0.46	0.59	0.47
Sureshwar	0.46	0.57	0.31	0.37	0.47	0.27	0.41	0.52	0.21
Sylhet	0.57	0.75	0.42	0.57	0.75	0.42	0.57	0.75	0.42
Tongi	0.22	0.27	0.61	0.23	0.28	0.59	0.25	0.31	0.56

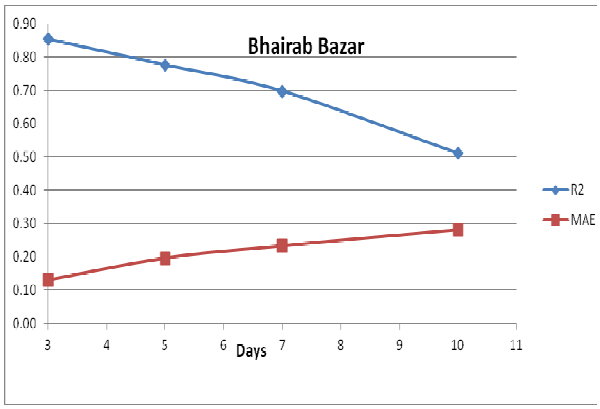
Table 4. 10: Performance of 10-day Probabilistic Forecast

	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
Stations	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2	MAE (m)	RMSE (m)	R2
Aricha	0.87	1.06	0.42	0.50	0.65	0.40	0.59	0.71	0.30
Baghbari	0.73	0.92	0.48	0.55	0.72	0.46	0.58	0.74	0.41
Bahadurabad	1.03	1.37	0.33	0.73	0.96	0.33	0.75	0.90	0.32
Bhagyakul	0.70	0.85	0.42	0.41	0.54	0.33	0.54	0.63	0.17
Bhairab Bz	0.27	0.43	0.52	0.28	0.44	0.51	0.31	0.46	0.49
Chandpur	0.45	0.56	0.03	0.45	0.56	0.03	0.45	0.56	0.03
Demra	0.34	0.45	0.49	0.37	0.48	0.48	0.42	0.54	0.46
Dhaka	0.34	0.43	0.56	0.33	0.41	0.51	0.40	0.49	0.46
Dirai	0.60	0.84	0.21	0.60	0.84	0.21	0.60	0.84	0.21
Elashinghat	1.10	1.27	0.47	0.70	0.86	0.42	0.50	0.66	0.37
Faridpur	0.29	0.33	0.77	0.29	0.33	0.77	0.29	0.33	0.77
Goalondo	0.87	1.05	0.44	0.49	0.65	0.38	0.65	0.76	0.23
Gorai Rly. Br	1.11	1.46	0.68	0.73	0.93	0.70	0.95	1.17	0.62
Hardinge Br	1.29	1.74	0.57	0.91	1.18	0.60	1.26	1.56	0.49
Jagir	0.54	0.62	0.86	0.40	0.47	0.85	0.32	0.39	0.83
Jamalpur	0.90	1.16	0.40	0.76	0.99	0.39	0.80	1.01	0.37
Kamarkhali	0.87	1.17	0.70	0.63	0.80	0.70	0.84	1.04	0.62
Kanaighat	0.99	1.20	0.21	0.99	1.20	0.21	0.99	1.20	0.21
Kazipur	1.07	1.36	0.40	0.72	0.96	0.38	0.73	0.88	0.35
Madaripur	0.53	0.66	0.43	0.35	0.46	0.37	0.43	0.50	0.24
Mawa	0.60	0.72	0.47	0.38	0.50	0.38	0.50	0.59	0.22
Mirpur	0.28	0.34	0.70	0.26	0.32	0.68	0.28	0.37	0.64
Mohadevpur	0.85	1.07	0.28	0.85	1.07	0.28	0.85	1.07	0.28
Moulvibazar	0.66	0.84	0.09	0.66	0.84	0.09	0.66	0.84	0.09
Mymensingh	0.63	0.82	0.65	0.58	0.78	0.64	0.62	0.82	0.62
Naogaon	0.66	0.84	0.48	0.66	0.84	0.48	0.66	0.84	0.48
Narayanganj	0.31	0.38	0.53	0.33	0.40	0.50	0.39	0.48	0.46
Narsingdi	0.27	0.34	0.63	0.27	0.34	0.63	0.27	0.34	0.63

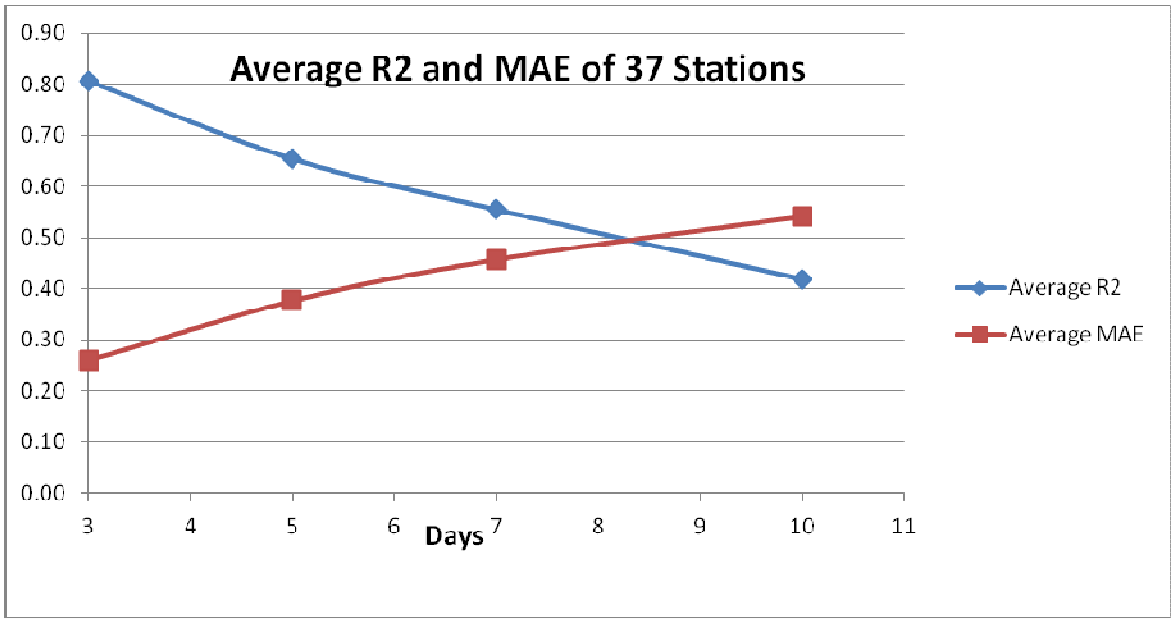
RekabiBazar	0.30	0.38	0.63	0.35	0.41	0.53	0.35	0.41	0.53
Sariakandi	1.09	1.39	0.38	0.73	0.96	0.35	0.72	0.88	0.32
Serajganj	1.10	1.35	0.33	0.69	0.88	0.30	0.61	0.76	0.26
Sheola	0.90	1.15	0.23	0.90	1.15	0.23	0.90	1.15	0.23
Sherpur	0.34	0.44	0.16	0.34	0.44	0.16	0.34	0.44	0.16
Sunamganj	0.53	0.73	0.22	0.53	0.73	0.22	0.52	0.73	0.22
Sureshwar	0.50	0.60	0.39	0.36	0.45	0.28	0.44	0.53	0.14
Sylhet	0.68	0.86	0.21	0.68	0.86	0.21	0.68	0.86	0.21
Tongi	0.27	0.32	0.50	0.27	0.34	0.47	0.31	0.40	0.43

Following charts showing the MAE and r^2 plots for the Serajganj and Bhairabbazar for monsoon 2015, indicated that as the longer the lead tie, the r^2 is reducing and MAE increasing.





Average of MAE and r^2 of all the 18 probability based flood forecast stations plot also indicating the variability of the Forecast & Observe is increasing with the increasing lead time.



CHAPTER 5 : INUNDATION STATUS

Flood inundation is a phenomenon that results from overtopping or overflowing of flood water to the river banks. In our country, this situation at a particular place occurs when the river water level exceeds the danger level of that particular place. During normal flooding, it is expected and observed that flood plain alone the major rivers becomes inundated and after that flood water progressively enters the adjacent residential and commercial areas depending upon the severity of flood. In the year 2015 monsoon, the country as a whole experienced slightly above normal flooding, but it did not prolonged to severe condition.

The flood during 2015 stayed for short (1-day) to medium duration (24-days) in all the four basins, the Brahmaputra, the Ganges, the Meghna and South Eastern Hill Basin, except Jhikorgacha on Kobodak of the south west part of the country. The South Western part of the country experienced prolong flooding in few stations longer than the previous flood years, specially part of Khulna, Jessore and Satkhira districts, the most affected Upozillas are Keshobpur, Kalaroa, Tala, Monirumpur and Satkhira Sadar. Water Level at Jhikorgacha on Kobodak was flowed above the danger level for continuous 100 days. During the monsoon-2015 there was less flash flood in the North-Eastern part and South-Eastern part of the country.

Out of 28 Water Level (WL) monitoring stations in the Brahmaputra basin, at 17 stations WL was crossed and remained over the respective DLs that caused short to medium duration flood. This year (2015) flood hit this basin twice; first arrived at 2nd week of June for short duration and later comparatively big flood during last week of August which was prolonged 3 weeks. The significant stations that were above and remained over DLs are Dharala at Kurigram for 13 days, Teesta at Dalia for 13 days, Brahmaputra at Chilmari for 10 days, Ghagot at Gaibandha for 8 days, Jamuna at Bahadurabad for 18 days, Sariakandi for 24 days, Serajgonj 21 days, Atrai at Baghabari 26 days, Gur at Singra for 11 days, Dhaleswari at Elasin ghat for 24 days and Shitalakya at Lakhpur for 22 days and at Narayanganj for 4 days, Kaliganga at Taraghat for 9 days and Dhaleswari at Jagir for 4 daya during months of June, August and September. As a result, low-lying areas of Kurigram, Lalminiorhat, Gaibandha, Bogra, Rangpur, Serajgonj, Tangail, Jamalpur Natore and Narayangonj districts were experienced short to medium duration flooding.

In the Ganges basin out of 23 WL monitoring stations, at 6 stations river exceeded their respective DLs during monsoon 2015, these are Goalondo, Sureswar and Bhagyakul on Padma, Little Jamuna on Naogaon and Jhikorgacha on Kobodak during the monsoon 2015. The WLs of river Padma at Goalondo and Bhagyakul were flowed for 18 and 16 days above DL respectively. The low lying areas of Faridpur, Manikgonj, Munshigonj, and Sariatpur districts were affected by normal to moderate intensity flooding during end of the month of September. Prolonged flooding situation was prevailing in part of Satkhira, Khulna and Jessore districts due to lack of very poor drainage condition along with very high rainfall during August-September period. The WL of Kobodak river at Jhikorgacha flowed above the DL for continuous 100 days. Flood caused immense suffering of the people of the locality.

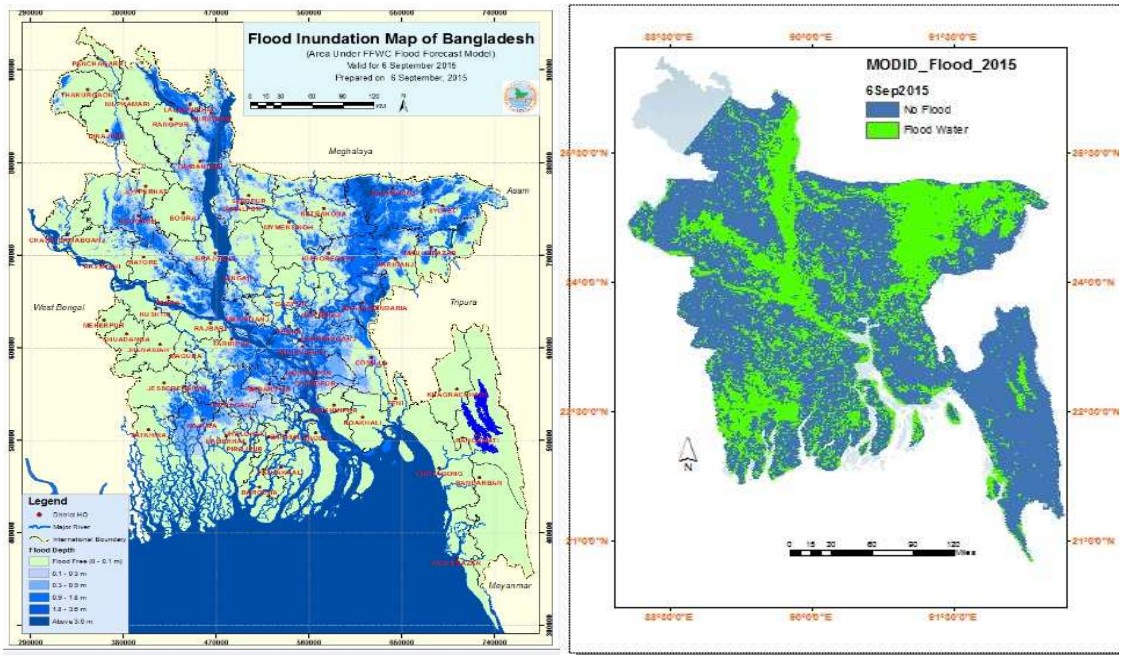
Out of 25 WL monitoring stations in the Meghna basin, at 15 stations water flowed above their respective DLs resulting floods for different duration which started from mid-June and continued to the middle of September. These are Kanaighat, Sylhet, Derai and Sunamgonj stations on Surma River; Amalshid and Sheola on Kushyara River; Habigonj and Bullah on Khowai river, Sarighat at Sarigowen river; Lorergarh on Jadukata river; Durapur at Someswari, Jariajanjail at Kangsha, Brahmanbaria on Titas and Nakuakaon on Bhugai. Among them, in Kanaighat (30 days), Sunamgonj (31 days), Amalshid (25 days), Sheola (29 days), Derai (24 days) and Jariajanjail (54 days) stations, water flowed above their respective danger levels for duration of 3 weeks or more during August-September period. As a result, moderate intensity floods were observed in the districts of Sylhet, Sunamgonj, Netrokona, Sherpur, and Habigonj during the monsoon 2015.

In the South Eastern Hill basin, all the monitoring water level stations crossed the danger level several times during July-September period due to intense monsoon rainfall and effect of low pressure of weather in Bay of Bengal during monsoon 2015. Excessive rainfall during last week of month June, a short duration flash flood hit the basin during first week of July. Later during the month of July and August, subsequent pressure of heavy rainfall caused arrival of short duration flash flood for about 5 times at 6 stations - Parshuram (Muhuri), Narayanhat (Halda river), Bandarban (Sangu), Dohazari (Sangu), Chiringa (Matamuhuri) and Lama (Matamuhuri). As a result, some areas of Chittagong, Feni, Bandarban and Cox's Bazar were severely affected. The highest water level at chiringa station in Matamuhuri River in 2015 monsoon crossed the recoded highest level in previous years.

Like other previous years, this year also FFWC generated model based nationwide and Dhaka city area inundation map. Flood map has been generated from FFWC Flood Forecasting Model output results file found from MIKE 11 FF Rainfall-Runoff and Hydrodynamic modeling simulation using customized MIKE 11 GIS model as a routine activity during monsoon period. Here, Digital Elevation Model (DEM) having 300 m spatial resolution collected from Survey of Bangladesh (SoB) long ago is used with MIKE 11 GIS tool. This is to mention here that flood peak arrived several times in 2015 which was attenuated during the first week of September. It was observed from monitoring that peak water level attained in Brahmaputra river on 1st September, in Ganges river on, in Padma river on the last of August and in Upper Meghna river on the last of August. FFWC observed total number of 26 flood monitoring stations above danger level at 01 September, 2015 which was the peak condition for this monsoon. Similar situation continued for next few days with severity in some places alone the bank of Jamuna river. Figure shows the observed inundation map for 3rd of September and then 24, 48, 72, 96 and 120 hours forecasted inundation maps. This map (on 3rd September) calculates inundation area 47000 sq-km which is 32% of the total country area and this is the maximum inundation area found in this flood season. This inundation area excludes the permanent water body i.e. rivers, lakes, haors, ponds etc. To calculate the permanent water body is also a crucial issue. Some literature reviews and remote sensing based analysis depicts that there are approximately 6-8% permanent water body exist in Bangladesh.

Flood inundation for whole country is a macro level product showing a general overview of flood situation of the whole country due to coarse resolution DEM. A detail, authentic and finer resolution DEM shall significantly improve generation of inundation map even in the local level.

One of the limitations of this map that none of the flood map output has been verified and so some obvious errors have been observed. One method currently in practice in operational flood forecasting is the verification of inundation map using satellite imagery. FFWC flood inundation map for peak condition of 2015 flood was verified with moderate resolution (500 m) MODIS (Source: NASA) data which is found free of cost and easily downloadable from internet. Due to non-availability of daily product, MODIS data of 6th September, 2015 was used in this case and compared with the FFWC flood map of 6th September, 2015. This is a gross comparison of inundation for whole country area. FFWC model based map shows inundation of about 27% of total country area whereas MODIS calculated 28% area, both of which have good agreement specially in detecting inundation areas at Central, North-central, North and North-eastern part of the country. Yet there is some spatial variability in South-central and south-western part i.e. coastal regions. FFWC present flood model domain does not cover coastal part, so model result is not appropriate for inundation analysis or verification of that part.



FFWC MIKE 11 FF Flood super model was developed decade ago. After that, catchment characteristics, river morphology and climatology had been changed significantly which were not incorporated in the model. That's why current inundation map explores underestimation as well as overestimation in some places. A total updating of model set up alone with latest version of MIKE software are needed to overcome this problem.

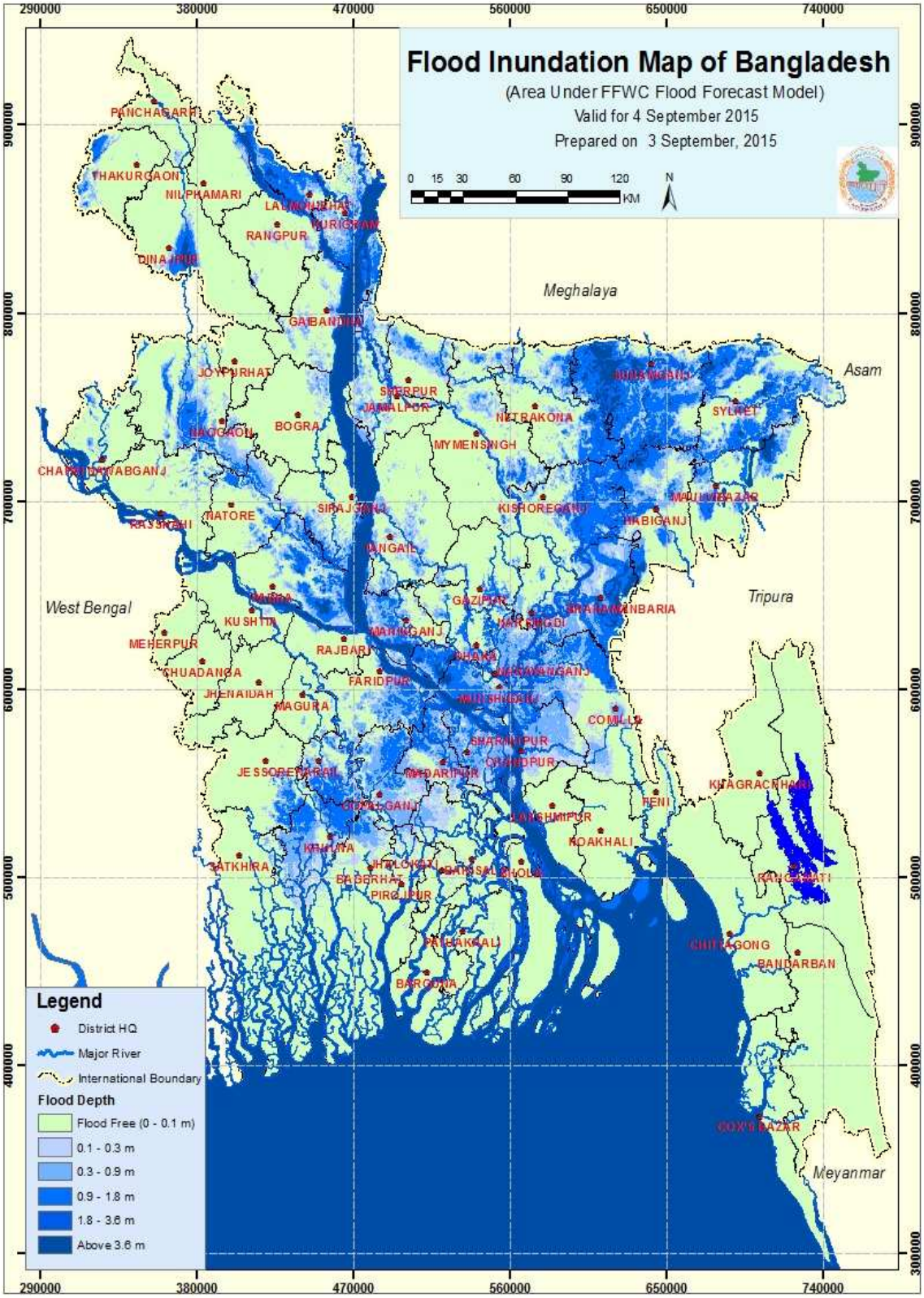


Figure 5.1 : Flood Inundation Map of Bangladesh (24hr Forecast Based on 3 September 2015)

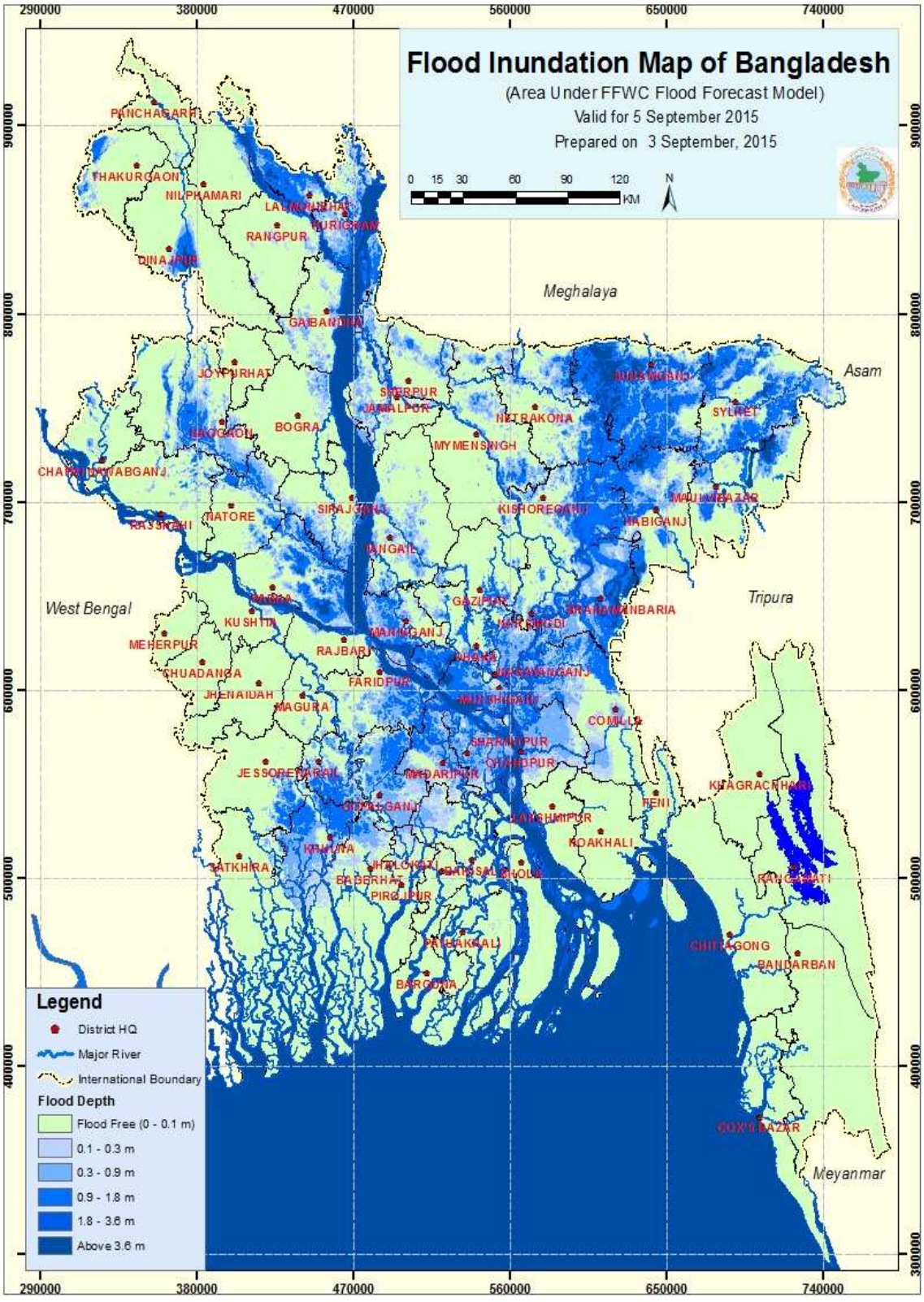


Figure 5.2 : Flood Inundation Map of Bangladesh (48hr Forecast Based on 3 September 2015)

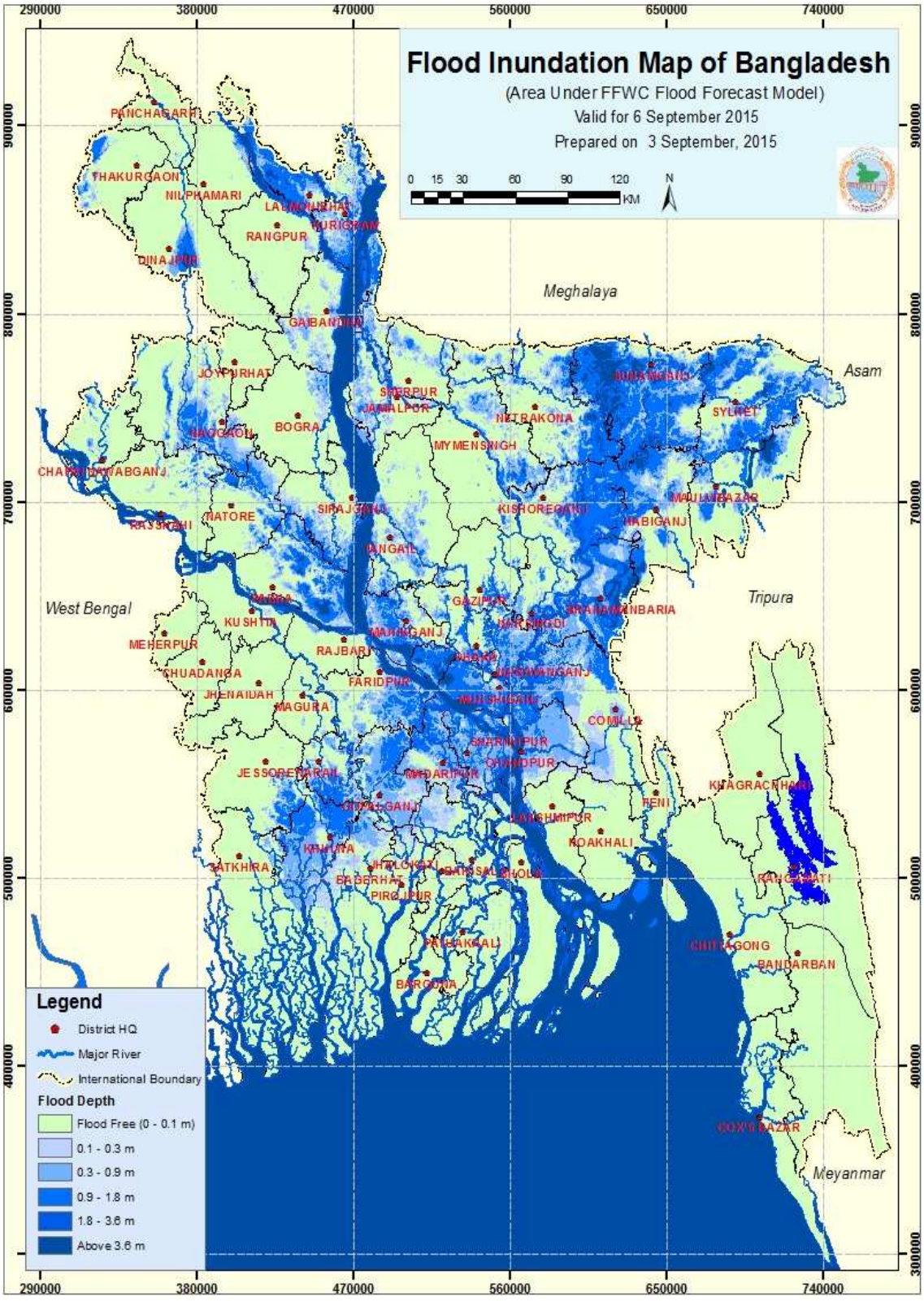


Figure 5.3: Flood Inundation Map of Bangladesh (72hr Forecast Based on 3 September 2015)

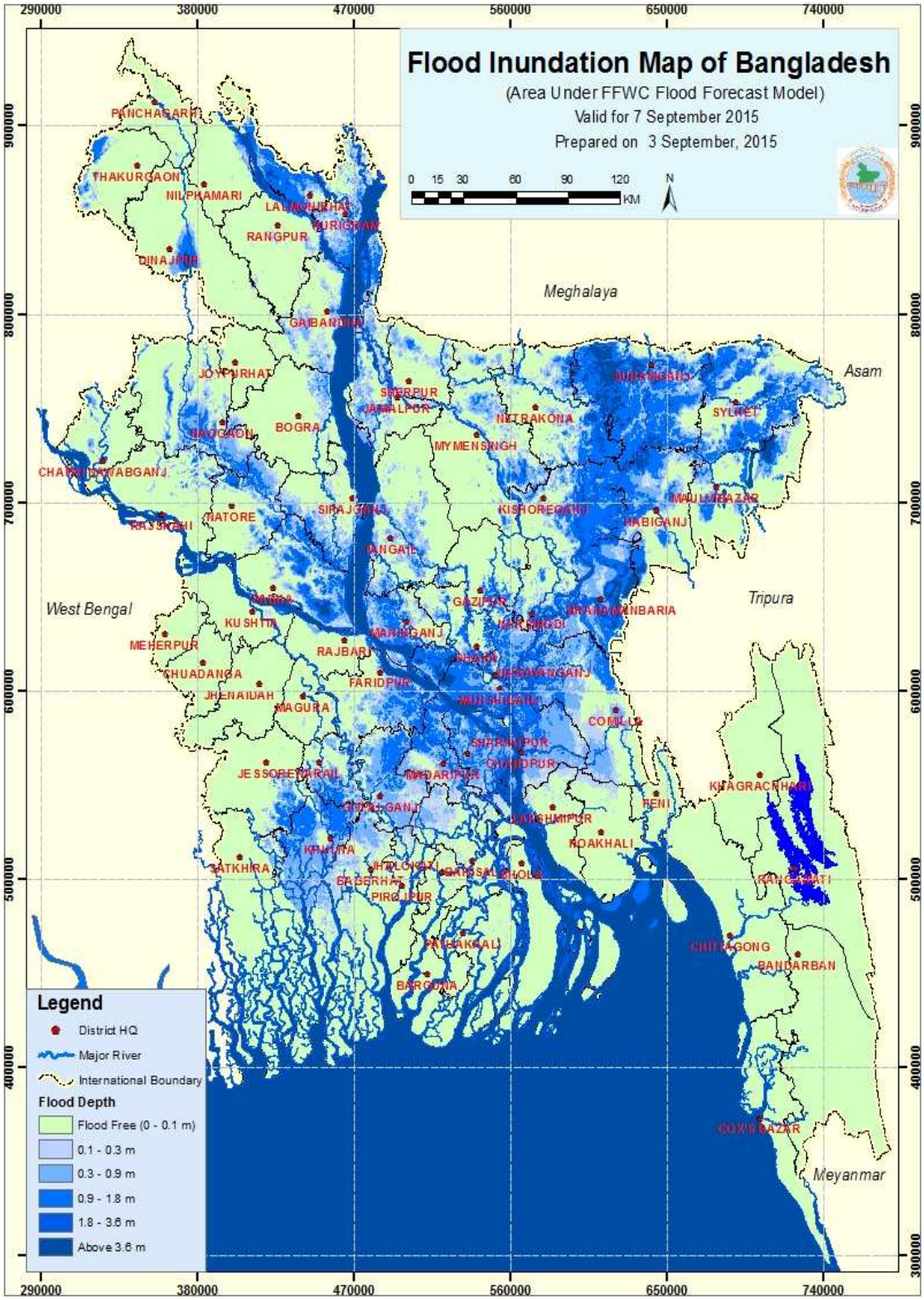


Figure 5.4 : Flood Inundation Map of Bangladesh (96hr Forecast Based on 3 September 2015)

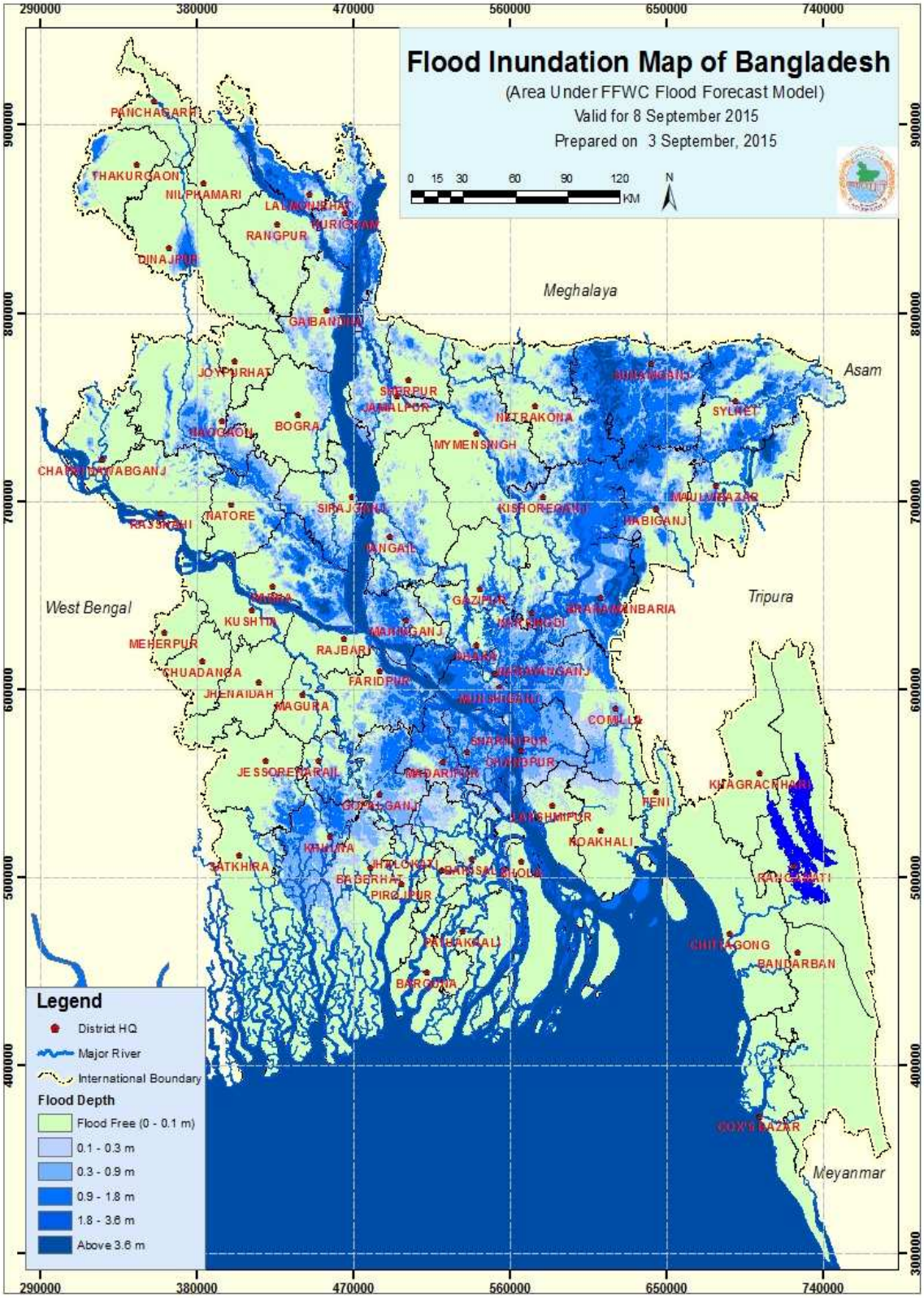


Figure 5.5 : Flood Inundation Map of Bangladesh (120hr Forecast Based on 3 September 2015)

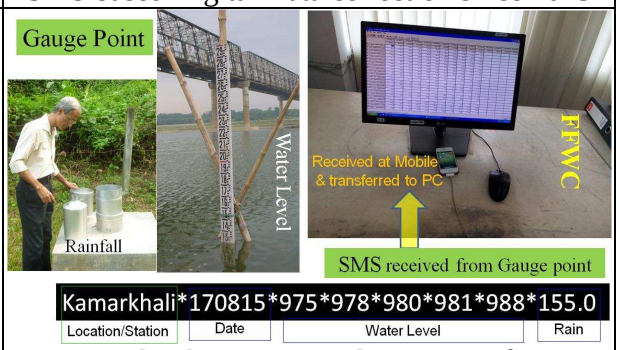
CHAPTER 6: RESEARCH AND DEVELOPMENT

6.1 Establishment of Digital Data Communication Network

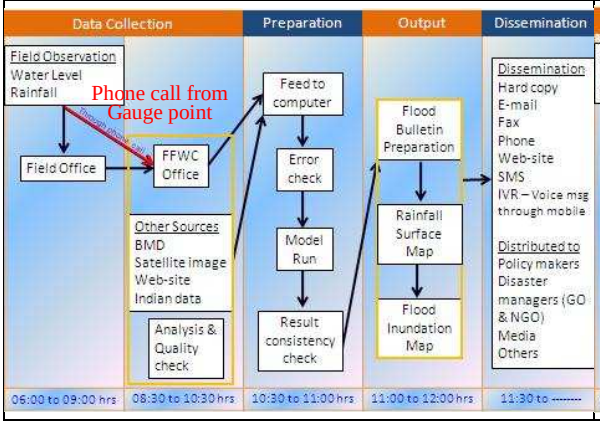
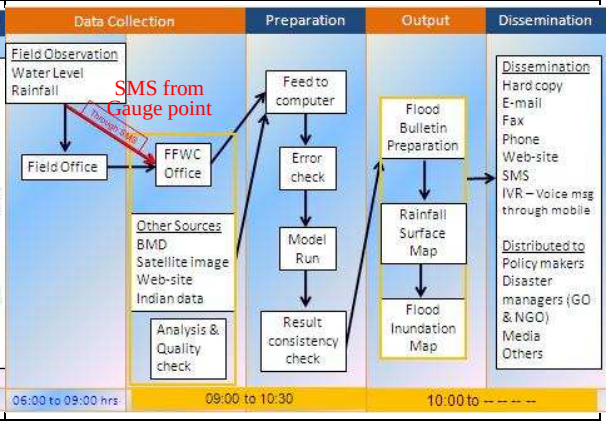
In 2015, one of the most important FFWC activities was the introduction and establishment of a digital data communication system between field level data collection point (the Gauge Point) and the FFWC office, BWDB, Dhaka. This means the transmission of river water level and rainfall data through mobile SMS as shown in Figure by the gauge readers to FFWC as well as sending forecast message from FFWC to the same gauge readers instead of mobile voice calls. During the entire 2015 monsoon period, this system was practiced and almost established. Under a MoU between FFWC, BWDB and Islamic Relief, Bangladesh, a 2-year project titled "Attune FFWC Flood Forecasting and Dissemination System by Mobile SMS and Database Development through Multi Stakeholder Engagement" with financial assistance from UKAiD and technical support from Institute of Water Modeling (IWM) , this mobile based data communication system with necessary customization of FFWC MIKE 11 Flood model was installed to ease data transmission system and avoid human errors.

Figure 6.1: Data sending to FFWC office by Mobile voice call

Till 2014 monsoon, the data collection system of the FFWC from the Gauge Points (both Water Level (WL) and Rainfall) based on the mobile phone call ie Voice Call. From morning 08:30 the Gauge Readers reported the WL data (5-WL data, 3hrly interval, 06:00hrs current day and 09:00hrs, 12:00hrs, 15:00hrs and 18:00hrs of the previous day) and one rainfall data at the FFWC. Two persons at the FFWC receiving the phone call from all the Gauge Points during 08:30 to 10:30 hrs, hearing the data through mobile phone writing at the data register of the FFWC, BWDB, Dhaka. Data from the each stations/points has been written under the particular stations/gauge points and specific column with WL data of 5-times or Rainfall data of one time. Then the data has been punched at the PC using keyboard from the register. That manual system of data collection at FFWC was cumbersome and hard working and need 4 to 5 hours. SMS based Digital Data collection and communication system between Gauge Point and FFWC has been installed from May 2015, at the beginning of the monsoon. The Data collection system at the FFWC, BWDB is illustrated in the photos below.

Data collection system at FFWC	
Based on Phone call, the Manual system, till 2014	SMS based Digital Data collection since 2015
	 Data sent by the Gauge readers in specific format. Gauge readers trained. This activity supported by the UKaid and IR,B

The daily Flood Forecasting and Waning Activity is illustrated below with Manual system of data collection, practiced till 2014 and with introduction of the SMS based digital data collection system. About two hours time saved for data collection, bulletin preparation and model simulation, thus dissemination could be started 2-hours earlier.

Flood Forecasting and Waning Activity	
Based on Phone call, the Manual system, till 2014	SMS based Digital Data collection since 2015
	

With introduction of the SMS based digital data collection system at the FFWC, following advantages/benefits has been achieved;

- Error of daily data reduced significantly.
- Cost of data collection reduced significantly, because instead of Voice Call Charge, SMS charge is applicable.
- Data collection/communication is more dependable, not affected by call drop, low or bad quality signal.
- Gauge readers not need to wait for getting the FFWC mobile number free at the time of data communication during 08:30 to 10:30am.
- Much easy both for the Gauge Readers and at FFWC professionals.
- Time of data collection and data management reduced about two hours

Before operatinoalise the system, the Gauge Readers and the supervising staff/officers of the Hydrology, BWDB working for the FFWC System has been trained. This activity is supported by the UKaid through IR,B. Under this new system of data collection, the Gauge Readers need to send data by SMS through a particular format twice a day. First time during 09:00 to 09:30 am with WL data (3-data 18:00hrs WL data of the previous day, 06:00hrs and 09:00hrs WL data of the current day in cm along with Rainfall data of the day in mm (if the station record and FFWC Bulletin report Rainfall at that location). The data received at a mobile set at the FFWC. The 2nd SMS sent by the Gauge Readers during 13:00 to 15:30 pm with WL data of 12:00hrs and 15:00 hrs of the day(current day). Two SMS received at the FFWC converted into data file and entered in PC/Model input after appropriate Quality check and necessary corrections once in the morning by 10:00am and again by 16:00 pm. Necessary apps for mobile and SMS data conversion has been developed by the IWM engaged by the IRB with support from the UKaid. IRB has been providing logistics and equipment support for the training and equip Gauge Readers. For this all the stations/points reported at the FFWC Flood Bulletin has been assigned a THREE letter unique STATION_ID (Table -4.1).
Sample of the SMS is described below.

The 1st SMS sent from the Chilmari station on 1 May 2015 morning (by 09:30am), this station has both WL and Rainfall data.

SMS	Explanation
Chl*010515*1990*1996*1997*0.0	Chl – Station ID for the Chilmari station 010515- date 1st May 2015 6-digit date format 1990 WL at Chilmari in cm, 19.90mPWD on 30 April-2015 (previous day) 18:00hrs. 1996 WL at Chilmari in cm, 19.96mPWD on 01 May-2015 (current day) 06:00hrs. 1997 WL at Chilmari in cm, 19.97mPWD on 01 May-2015 (current day) 09:00hrs. 0.0 Rainfall of the day recorded at Chilmari in mm 01 May-2015 * item separator

The 2nd SMS sent from the Chilmari station on 1 May 2015 afternoon (by 15:30pm).

SMS	Explanation
Chl*010515*1999*2000	Chl – Station ID for the Chilmari station 010515- date 1st May 2015 6-digit date format 1999 WL at Chilmari in cm, 19.99mPWD on 01 May-2015 (current day) 12:00hrs. 2000 WL at Chilmari in cm, 20.00mPWD on 01 May-2015 (current day) 15:00hrs. * item separator

The 1st SMS sent from the Noonkhawa station on 1 May 2015 morning (by 09:30am), this station has WL data only, no Rainfall data.

SMS	Explanation
Noo*010515*2237*2245*2248	Noo – Station ID for the Noonkhawa station 010515- date 1st May 2015 6-digit date format 2237 WL at Chilmari in cm, 22.37Mpwd on 30 April-2015 (previous day) 18:00hrs. 2245 WL at Chilmari in cm, 22.45mPWD on 01 May-2015 (current day) 06:00hrs. 2248 WL at Chilmari in cm, 22.48mPWD on 01 May-2015 (current day) 09:00hrs. * item separator

The 2nd SMS sent from the Noonkhawa station on 1 May 2015 afternoon (by 15:30pm).

SMS	Explanation
Noo*010515*2250*2254	Noo – Station ID for the Noonkhawa station 010515- date 1st May 2015 6-digit date format 2250 WL at Chilmari in cm, 22.50mPWD on 01 May-2015 (current day) 12:00hrs. 2254 WL at Chilmari in cm, 22.54mPWD on 01 May-2015 (current day) 15:00hrs. * item separator

Stations with only Rainfall, the SMS sent from Rangpur with rainfall data only (no WL data). Need to send only one SMS in a day morning by 09:00hrs. Ran_R is the station ID for Rangpur and R indicated the rainfall data.

Ran_R*010515*0.0

If at a particular day the Rainfall at Rangpur recorded 271.5mm on 12 August 2015, the SMS format is

Ran_R*120815*271.5

All the related gauge Readers, the supervising staff and Officers and the Hydrological Measurement Divisions has been provided the list of the STATION ID for SMS purpose.

Table 6.1: List of Stations/Points with stations ID for SMS and Type of Data

Brahmaputra Basin

SL. No.	Station name	Initial_Station	River Name	District	Measurement Division	Measurement Sub-Division	Data
1	Kurigram	Kur	Dharla	Kurigram	NMD	Dinajpur	WL & RF
2	Dalia	Dal	Teesta	Rangpur	NMD	Dinajpur	WL & RF
3	Kaunia	Kau	Teesta	Rangpur	NMD	Dinajpur	WL & RF
4	Badargonj	Bad	Jamuneswari	Rangpur	NMD	Dinajpur	WL & RF
5	Gaibandha	Gai	Ghagot	Gaibandha	NMD	Dinajpur	WL & RF
6	Chalkrahimpur	Chk	Karatoa	Bogra	NMD	Dinajpur	WL & RF
7	Bogra	Bog	Karatoa	Bogra	NMD	Rajshahi	WL & RF
8	Noonkhawa	Noo	Brahmaputra	Kurigram	NMD	Dinajpur	WL & RF
9	Chilmari	Chl	Brahmaputra	Kurigram	NMD	Dinajpur	WL & RF
10	Bahadurabad	Bah	Jamuna	Jamalpur	NEMD	Mymensing	WL & RF
11	Sariakandi	Sar	Jamuna	Bogra	NMD	Rajshahi	WL
12	Serajgonj	Ser	Jamuna	Serajgonj	NMD	Pabna	WL & RF
13	Aricha	Ari	Jamuna	Manikgonj	NEMD	Dhaka	WL
14	Singra	Sin	Gur	Natore	NMD	Rajshahi	WL
15	Baghabari	Bag	Atrai	Serajgonj	NMD	Pabna	WL
16	Elasin	Ela	Dhaleswari	Tangail	NEMD	Mymensing	WL
17	Jamalpur	Jam	Old Brahmaputra	Jamalpur	NEMD	Mymensing	WL& RF
18	Mymensingh	Mym	Old Brahmaputra	Mymensingh	NEMD	Mymensing	WL & RF
19	Lakhpur	Lak	Lakhya	Gazipur	NEMD	Dhaka	WL
20	Dhaka	Dha	Buriganga	Dhaka	NEMD	Dhaka	WL & RF
21	Demra	Dem	Balu	Dhaka	NEMD	Dhaka	WL
22	Narayangonj	Nag	Lakhya	Narayangonj	NEMD	Dhaka	WL
23	Mirpur	Mir	Turag	Dhaka	NEMD	Dhaka	WL
24	Tongi	Ton	Tongi Khal	Gazipur	NEMD	Dhaka	WL
25	Taraghat	Tar	Kaligaga	Manikgonj	NEMD	Dhaka	WL
26	Jagir	Jag	Dhaleswari	Manikgonj	NEMD	Dhaka	WL
27	Rekabibazar	Rek	Dhaleswari	Manikgonj	NEMD	Dhaka	WL
28	Naryarhat	Nay	Banshi	Manikgonj	NEMD	Dhaka	WL

Ganges Basin

29	Panchagarh	Pag	Karatoa	Dinajpur	NMD	Dinajpur	WL & RF
30	Dinajpur	Din	Punarbhaba	Dinajpur	NMD	Dinajpur	WL & RF
31	Phulbari	Phu	Ichamoti Jamuna	Dinajpur	NMD	Dinajpur	WL& RF
32	Thakurgaon	Tha	Tangon	Dinajpur	NMD	Dinajpur	WL& RF
33	Bhusirbandar	Bhu	Upper Atrai	Dinajpur	NMD	Dinajpur	WL& RF
34	Rohanpur	Roh	Mohananda	Chapai Nawabg	NMD	Rajshahi	WL & RF
35	Chapai Nawabgonj	Cha	Mohananda	Chapai Nawabg	NMD	Rajshahi	WL & RF
36	Naogaon	Nao	Little Jamuna	Naogaon	NMD	Rajshahi	WL & RF
37	Mohadebpur	Moh	Atrai	Naogaon	NMD	Rajshahi	WL & RF
38	Pankha	Pan	Ganges	Chapai Nawabg	NMD	Rajshahi	WL
39	Rajshahi	Raj	Ganges	Rajshahi	NMD	Rajshahi	WL & RF
40	Hardinge Bridge	Har	Ganges	Pabna (Issordi)	NMD	Pabna	WL
41	Goalundo	Goa	Padma	Rajbari	SWMD	Faridpur	WL
42	Bhagyakul	Bha	Padma	Munsignoj	NEMD	Dhaka	WL & RF
43	Sureswar	Sur	Padma	Madaripur	NEMD	Dhaka	WL
44	Gorai Rly Bridge	Gor	Gorai	Kushtia	NMD	Pabna	WL
45	Kmarkhali	Kma	Gorai	Magura	SWMD	Faridpur	WL
46	Sakra	Sak	Ichamati	Satkhira	SWMD	Khulna	WL
47	Chuadanga	Chu	Matabhanga	Chuadanga	SWMD	Jessore	WL
48	Hatboalia	Hat	Mathabhanga	Chuadanga	SWMD	Jessore	WL
49	Jhikargacha	Jhi	Kobadak	Jessore	SWMD	Jessore	WL
50	Faridpur	Far	Kumar	Faridpur	SWMD	Faridpur	WL & RF
51	Madaripur	Mad	Arialkhan	Madaripur	SWMD	Faridpur	WL & RF

Meghna Basin

SL. No.	Station name		River Name	District	Measurement Division	Measurement Sub-Division	Data
52	Kanaighat	Kan	Surma	Sylhet	NEMD	Sylhet	WL & RF
53	Sylhet	Syl	Surma	Sylhet	NEMD	Sylhet	WL & RF
54	Sunamgonj	Sun	Surma	Sunamgonj	NEMD	Sylhet	WL & RF
55	Amalshid	Ama	Kushiyara	Sylhet	NEMD	Sylhet	WL
56	Sheola	She	Kushiyara	Sylhet	NEMD	Sylhet	WL & RF
57	Markuli	Mar	Kushiyara	Habighonj	SEMD	Brahmmanbaria	WL
58	Sherpur	Shr	Kushiyara	Sherpur	NEMD	Sylhet	WL & RF
59	Sarighat	Sag	Sarigowain	Sylhet	NEMD	Sylhet	WL
60	Manu Rly Bridge	Man	Manu	Moulvi Bazar	NEMD	Sylhet	WL & RF
61	Moulvi Bazar	Mou	Manu	Moulvi Bazar	NMED	Sylhet	WL & RF
62	Ballah	Bal	Khowai	Habigonj	SEMD	Brahmmanbaria	WL
63	Habigonj	Hab	Khowai	Habigonj	SEMD	Brahmmanbaria	WL & RF
64	Kamalgonj	Kam	Dhalai	Moulavi Bazar	NEMD	Sylhet	WL & RF
65	Derai	Der	Old Surma	Sunamgonj	NEMD	Sylhet	WL
66	Khaliajuri	Kha	Baulai	Netrokona	SEMD	Brahmmanbaria	WL
67	Nakuagaon	Nak	Bhugai	Mymensingh	NEMD	Mymensingh	WL & RF
68	Lorergarh	Lor	Jadukata	Sunamgonj	NEMD	Sylhet	WL & RF
69	Durgapur	Dur	Someswari	Mymensingh	NEMD	Mymensingh	WL & RF
70	Jariajangail	Jar	Kangsha	Mymensingh	NEMD	Mymensingh	WL & RF
71	B. Baria	Bba	Titas	Brahmmanbaria	SEMD	Brahmmanbaria	WL & RF
72	Bhairab Bazar	Bhb	Meghna	Kishorgonj	SEMD	Brahmmanbaria	WL & RF
73	Narshingdi	Nar	Meghna	Dhaka	NEMD	Dhaka	WL & RF
74	Comilla	Com	Gumti	Comilla	SEMD	Comilla	WL & RF
75	Debidder	Deb	Gumti	Comilla	SEMD	Comilla	WL
76	Chandpur	Chn	Meghna	Chandpur	SEMD	Comilla	WL & RF

South Eastern Basin

SL. No.	Station name		River Name	District	Measurement Division	Measurement Sub-Division	Data
77	Parshuram	Par	Muhuri	Feni	SEMD	Comilla	WL & RF
78	Naryanhat	Nat	Halda	Chittagonj	SEMD	Chittagong	WL & RF
79	Panchpukuria	Pak	Halda	Chittagonj	SEMD	Chittagong	WL & RF
80	Bandarban	Ban	Sangu	Chittagonj	SEMD	Chittagong	WL & RF
81	Dohazari	Doh	Sangu	Chittagonj	SEMD	Chittagong	WL
82	Lama	Lam	Matamuhuri	Bandarban	SEMD	Chittagong	WL & RF
83	Chiringa	Chi	Matamuhuri	Cox's Bazar	SEMD	Chittagong	WL
84	Ramgarh	Ram	Feni	Feni	SEMD	Chittagong	WL & RF

Stations with Rainfall data only

SL. No.	Station name		District	Measurement Division	Measurement Sub-Division	Data
1	Rangpur	Ran_R	Rangpur	NMD	Dinajpur	Rain
2	Dewangonj	Dew_R	Jamalpur	NEMD	Mymensing	Rain
3	Dhaka	Dha_R	Dhaka	NEMD	Dhaka	Rain
4	Tangail	Tan_R	Tangail	NEMD	Mymensingh	Rain
5	Pabna	Pab_R	Pabna	NMD	Pabna	Rain
6	Kushtia	Kus_R	Kushtia	NMD	Pabna	Rain
7	Jessore	Jes_R	Jessore	SWMD	Jessore	Rain
8	Khulna	Khu_R	Khulna	SWMD	Khulna	Rain
9	Satkhira	Sat_R	Satkhira	SWMD	Khlna	Rain
10	Barisal	Bar_R	Barisal	SWMD	Barisal	Rain
11	Patuakhali	Pat_R	Patuakhali	SWMD	Barisal	Rain
12	Barguna	Bgu_R	Barguna	SWMD	Barisal	Rain
13	Noakhali	Noa_R	Noakhali	SEMD	Comilla	Rain
14	Rangamati	Rng_R	Rangamati	SEMD	Chittagong	Rain
15	Chittagong	Ctg_R	Chittagong	SEMD	Chittgong	Rain
16	Cox's Bazar	Cob_R	Cox's Bazar	SEMD	Chittagong	Rain
17	Teknaf	Tek_R	Cox's Bazar	SEMD	Chittagong	Rain

Sending Flood Forecast to the Gauge Readers in Bangla SMS

After entering all the data in the Model, simulation is made and then numerical WL forecast or Flood Forecast upto 5-days lead time for 54 points/stations is ready. With introduction of SMS based data communication, the station wise Flood Forecast for day-1 and Day-5 is sent to the respective Gauge Readers in Bangla, sample is shown below. The mobile apps is developed such a way that, the Gauge Reader of the Serajgonj point/station only received the Flood Forecast SMS in Bangla for the Serajgonj station only, so that he/she can disseminate it locally. This system of SMS sending in Bangla to the Gauge Point enhances the local level dissemination of the Flood Forecast or Flood Early Warning. This is the first time a Gauge Reader able to know the WL situation (Rise or Fall in cm) upto next 5-days at his point.

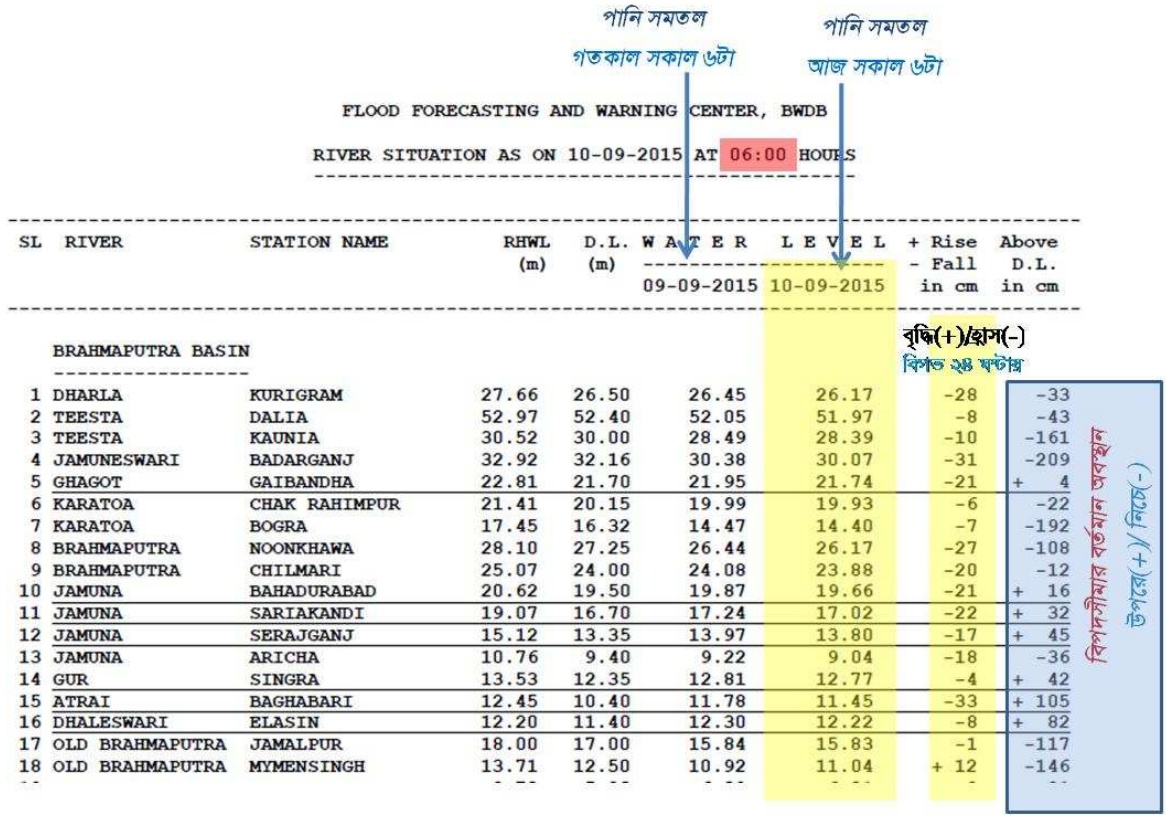
Searjgonj*150815* ১দিনে পানি ২০সেমি কমবে, ৫দিনে পানি ৭২সেমি কমবে

Activities and status of the SMS based digital data communication system

No	Activity	Date/time
1	Memorandum of Understanding (MoU) signed between BWDB & IRB	21/05/2014
2	Inception Workshop	18/06/2014
3	Distribution of Mobile sets	Distribution of 103 mobile sets to the designated gauge readers (102) of all measurement points in connection with Flood Forecasting and Warning System and FFWC office (1) completed. Training and Mobile sets distribution was completed in the presence of Executive engineers of concerned measurement divisions of the Hydrology, Executive Engineer of FFWC, BWDB, professionals of IWM and Islamic relief, Bangladesh. In cases the Chief Engineer Hydrology, Chief Engineer, Zones of BWDB, respective, SE hydrology SE and XEN/SDE of O&M offices were also presented.
4	Distribution of Safety Equipments (Rain-coat, Umbrella, Torch light, Gumboot and Life Jacket)	Distribution to the designated gauge readers (102) of all measurement points in connection with Flood Forecasting and Warning System. Safety Equipments distribution was completed in the presence of Executive engineers of concerned measurement divisions of the Hydrology, Executive Engineer of FFWC, BWDB, professionals of IWM and Islamic relief, Bangladesh. In cases the Chief Engineer Hydrology, Chief Engineer, Zones of BWDB, respective, SE hydrology SE and XEN/SDE of O&M offices were also presented.
5	System Set up	System Set up completed before monsoon 2015. This includes installation of application software having Android apps, SQL database for storing SMS data, customization of Flood watch database for receiving sms input and generate forecast message. Troubleshooting process is ongoing. The system is operationalized in FFWC, BWDB
6	Capacity Building	Intensive training had been provided to all gauge readers including their supervisors i.e. TCO, TPO, SO, SAE etc in connection with Flood Forecasting and Warning System for sending water level and rainfall data in a specified format by mobile sms two times in a day during monsoon. In this programs, field level staffs and their supervising officers were receive training to send sms by mobile phone and on how to disseminate forecast message by the same mobile phone to local community. FFWC professionals has also been received training on database management with SQL i.e. data receiving through mobile sms, error check, upgrade and finally store to Flood Watch database.

6.2 Introduction of Two Flood Bulletins in a Day

FFWC since its inception had been practiced one flood bulletin in a day with WL of 06:00hrs of the respective stations/points. Example of a Flood Bulletin with WL is given below.



পানি সমতল
গতকাল সকাল ৬টা

পানি সমতল
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FLOOD FORECASTING AND WARNING CENTER, BWDB

RIVER SITUATION AS ON 10-09-2015 AT 06:00 HOURS

SL	RIVER	STATION NAME	RHWL (m)	D.L. (m)	WATER LEVEL 09-09-2015	WATER LEVEL 10-09-2015	+ Rise - Fall in cm	Above D.L. in cm
	BRAHMAPUTRA BASIN						বৃদ্ধি(+)/হ্রাস(-) বিগত ২৪ ঘন্টায়	
1	DHARLA	KURIGRAM	27.66	26.50	26.45	26.17	-28	-33
2	TEESTA	DALIA	52.97	52.40	52.05	51.97	-8	-43
3	TEESTA	KAUNIA	30.52	30.00	28.49	28.39	-10	-161
4	JAMUNESWARI	BADARGANJ	32.92	32.16	30.38	30.07	-31	-209
5	GHAGOT	GAIBANDHA	22.81	21.70	21.95	21.74	-21	+ 4
6	KARATOA	CHAK RAHIMPUR	21.41	20.15	19.99	19.93	-6	-22
7	KARATOA	BOGRA	17.45	16.32	14.47	14.40	-7	-192
8	BRAHMAPUTRA	NOONKHAWA	28.10	27.25	26.44	26.17	-27	-108
9	BRAHMAPUTRA	CHILMARI	25.07	24.00	24.08	23.88	-20	-12
10	JAMUNA	BAHADURABAD	20.62	19.50	19.87	19.66	-21	+ 16
11	JAMUNA	SARIAKANDI	19.07	16.70	17.24	17.02	-22	+ 32
12	JAMUNA	SERAJGANJ	15.12	13.35	13.97	13.80	-17	+ 45
13	JAMUNA	ARICHA	10.76	9.40	9.22	9.04	-18	-36
14	GUR	SINGRA	13.53	12.35	12.81	12.77	-4	+ 42
15	ATRAI	BAGHABARI	12.45	10.40	11.78	11.45	-33	+ 105
16	DHALESWARI	ELASIN	12.20	11.40	12.30	12.22	-8	+ 82
17	OLD BRAHMAPUTRA	JAMALPUR	18.00	17.00	15.84	15.83	-1	-117
18	OLD BRAHMAPUTRA	MYMENSINGH	13.71	12.50	10.92	11.04	+ 12	-146

বিপদসীমার বর্তমান অবস্থান (-)ঋণাত্মক/(+)ধনাত্মক

Example of Flood Bulletin with Rainfall situation is given below.

RAINFALL SITUATION AS ON 28-08-2015 (IN MM)

SL NO	STATION	MAXIMUM FOR AUGUST	NORMAL FOR AUGUST	RAINFALL FOR 2015 26-08	27-08	28-08	MONTHLY CUMULATIVE (UPTO 28-08-2015)
	BRAHMAPUTRA BASIN						
1	KURIGRAM	876.6	340.1	0.0	0.0	0.0	501.3
2	DALIA	1247.5	516.0	34.0	8.0	0.0	521.1
3	KAUNIA	745.0	406.2	0.0	0.0	0.0	768.5
4	RANGPUR	608.0	340.8	0.0	0.0	0.0	683.8
5	CHILMARI	834.4	327.6	6.5	0.0	0.0	760.5
6	DEWANGANJ	617.0	338.3	3.0	5.0	3.0	394.0
7	GAIBANDHA	528.3	236.4	0.0	0.0	0.0	229.5
8	SERAJGANJ	540.6	257.2	17.0	3.7	0.0	144.8
9	BOGRA	734.0	297.3	0.0	0.0	0.0	246.0
10	JAMALPUR	914.4	367.9	0.0	9.0	0.0	220.0
11	MYMENSINGH	1008.3	396.1	1.5	1.0	0.0	266.8
12	DHAKA	484.5	304.8	0.0	9.5	0.0	317.5
13	TANGAIL	706.5	286.7	0.0	0.0	0.0	149.7
	GANGES BASIN						
14	PANCHAGARH	1341.3	524.9	31.5	36.5	48.0	581.5
15	DINAJPUR	891.4	349.7	28.2	42.5	0.0	461.2
16	PABNA	639.0	264.0	0.0	5.0	0.0	174.5
17	NAOGAON	690.5	265.7	0.0	0.0	0.0	126.2
18	MOHADEBPUR	663.2	276.4	22.5	0.0	0.0	255.4
19	KUSHTIA	767.2	260.3	0.0	0.0	1.6	230.9
20	RAJSHAHI	453.0	242.8	0.0	0.0	0.0	124.0

Example of Flood Bulletin with Forecast upto 5 day is given below.

EXPERIMENTAL 5 Days Forecast (24, 48, 72, 96 & 120 Hrs), FFWC, BWDB
Supported by CDMP-II

SL NO	River	Station	D.L.	Today	24-hrs forecast	24-hrs +Rise -fall	24-hrs +above -below D.L.	48-hrs forecast	48-hrs +Rise -fall	48-hrs +above below D.L.	72-hrs forecast	72-hrs +Rise -fall	72-hrs +above -below D.L.	96-hrs forecast	96-hrs +Rise -fall	96-hrs +above -below D.L.	120-hrs forecast	120-hrs +Rise -fall	120-hrs +above -below D.L.
				01-09	02-09	02-09	02-09	03-09	03-09	03-09	04-09	04-09	04-09	05-09	05-09	05-09	06-09	06-09	06-09
				6:00 AM	6:00 AM	6:00 AM	6:00 AM	6:00 AM	6:00 AM	6:00 AM	6:00 AM	6:00 AM	6:00 AM	6:00 AM	6:00 AM	6:00 AM	6:00 AM	6:00 AM	6:00 AM
			(meter)	(meter)	(meter)	(cm)	(cm)	(meter)	(cm)	(cm)	(meter)	(cm)	(cm)	(meter)	(cm)	(cm)	(meter)	(cm)	(cm)
1	Atrai	Mohadevpur	18.59	16.86	17.14	+28	-145	17.63	+49	-96	17.84	+22	-75	17.81	-3	-78	17.69	-12	-90
2	Atrai	Atrai	13.72	-	13.57	-	-15	13.70	+13	-2	13.85	+14	+13	13.96	+11	+24	14.04	+8	+32
3	Atrai	Singra	12.65	12.67	12.76	+9	+11	12.88	+11	+23	13.01	+13	+36	13.12	+11	+47	13.21	+9	+56
4	Karatoa-Atrai-GGH	Baghabari	10.40	11.71	11.77	+6	+137	11.85	+8	+145	11.91	+7	+151	11.97	+5	+157	12.02	+5	+162
5	Little Jamuna	Naogaon	15.24	14.84	15.04	+20	-20	15.21	+16	-3	15.36	+15	+12	15.46	+10	+22	15.48	+2	+24
6	Karatoya	Chakrahimpur	20.15	20.22	20.23	+1	+8	20.28	+5	+13	20.32	+5	+17	20.34	+2	+19	20.34	0	+19
7	Karatoya	Bogra	16.32	14.42	14.16	-26	-216	13.84	-32	-248	13.64	-20	-268	13.66	+2	-266	13.78	+11	-254
8	Teesta	Kaunia	30.00	28.97	29.07	+10	-93	29.14	+7	-86	29.20	+6	-80	29.26	+6	-74	29.32	+6	-69
9	Ghagot	Gaibandha	21.70	21.31	21.36	+5	-34	21.41	+5	-29	21.46	+5	-24	21.51	+5	-19	21.56	+5	-14
10	Dharla	Kurigram	26.50	26.70	26.77	+7	+27	26.83	+6	+33	26.88	+5	+38	26.94	+5	+44	26.99	+5	+49
11	Brahmaputra	Chilmari	24.00	23.78	23.87	+9	-13	23.94	+7	-6	24.00	+6	0	24.06	+6	+6	24.12	+6	+12
12	Jamuna	Bahadurabad	19.50	19.50	19.62	+12	+12	19.70	+8	+20	19.76	+6	+26	19.82	+5	+32	19.88	+6	+38
13	Jamuna	Sariakandi	16.70	16.88	17.02	+14	+32	17.10	+8	+40	17.16	+6	+46	17.22	+5	+52	17.27	+6	+57
14	Jamuna	Kazipur	14.85	-	14.62	-	-23	14.71	+9	-14	14.78	+7	-7	14.83	+5	-2	14.88	+5	+3
15	Jamuna	Serajganj	13.35	13.54	13.68	+14	+33	13.79	+11	+44	13.87	+8	+52	13.93	+6	+58	13.99	+6	+64
16	Jamuna	Porabari	12.27	-	11.72	-	-55	11.82	+10	-45	11.90	+8	-37	11.95	+6	-32	12.01	+6	-26
17	Jamuna	Aricha	9.40	9.15	9.18	+3	-23	9.23	+6	-17	9.28	+5	-12	9.32	+4	-8	9.36	+4	-4

SMS based Digital Data collection and communication system between Gauge Point and FFWC has been installed from May 2015, at the beginning of the monsoon. With the advantages of easy of data transmission and data management, saving time and cost, reducing error, Two Flood Bulletins in a day has been prepared and disseminate from the middle of August. The 1st Flood Bulletin, Morning Bulletin, of the day with 09:00hrs WL and the 2nd (Afternoon) Bulletin with 15:00 hours WL has been prepared. In the Morning Bulletin 09:00 hrs WL (in m) of previous day and current day is given in column 3 and 4. Change of 24hrs WL in cm of all the points is indicated in the 5th column and in the last column status of WL (at 09:00hrs) above (+) or below (-) with respect to the Danger Level is indicated in cm. In the afternoon Bulletin 3rd and 4th column presents the WL (in m) of 09:00hrs and 15:00hrs of the day. The 5th column indicated the change of WL from 09:00 to 15:00hrs of the day and the last column indicated the status of WL at 15:00hrs above (+) or below (-) with respect to the Danger Level is indicated in cm. Total 85 WL and 59 Rainfall stations of four Hydrological Basins has been covered under the FFWC system.

Steps; summary of the activities carried out at FFWC with Two Flood Bulletins in a day.

Tome	Activity
09:00hrs to 09:30hrs	• Gauge Readers from all the Gauge points sent SMS to the mobile set at FFWC in a particular format. The SMS contains the WL of 18:00hrs of the previous day, 06:00hrs and 09:00 hrs of the current day along with Rainfall data of the current day. • If any missing stations, FFWC professionals collect it.
09:30hrs to 10:00hrs	• Received data through SMS has been converted to txt file • Transferred the txt file data into PC. • Data quality check carried out, make necessary corrections. • Corrected data taken/transferred as input for preparation of Flood Bulletin and model simulation. • Boundary estimation/computation has been carried out.
10:00hrs to 10:30hrs	• Prepared the 1st Flood Bulletin of the day • Model run/simulation for forecast

	• Dissemination started and continue for rest of the day
15:00hrs to 15:30hrs	• SMS received at FFWC from all the Gauge Points in a particular format with WL of 12:00hrs and 15:00 hrs of the current day. • If any missing stations, FFWC professionals collect it.
15:30hrs to 16:00hrs	• Received data through SMS has been converted to txt file • Transferred the txt file data into PC. • Data quality check carried out, make necessary corrections. • Corrected data taken/transferred as input for preparation of the 2nd Flood Bulletin of the day and model simulation. Prepared the 2nd Flood Bulletin of the day • Model run/simulation for forecast • Dissemination started and continue for rest of the day

Example of two flood bulletins in a day is given below.

FLOOD FORECASTING AND WARNING CENTRE
RIVER SITUATION AS ON 10-09-2015 AT **09:00 HOURS**

Morning Bulletin

SL	RIVER	STATION NAME	RHWL (m)	D.L. (m)	WATER LEVEL 09-09-2015	WATER LEVEL 10-09-2015	+ Rise - Fall in cm	Above D.L. in cm
	BRAHMAPUTRA BASIN				পানিসমতল সকাল ৯টা গতকাল	আজ	হ্রাস -/+বৃদ্ধি	বিপদসীমার উপরে/নীচে
1	DHARLA	KURIGRAM	27.66	26.50	26.42	26.14	-28	-36
2	TEESTA	DALIA	52.97	52.40	52.05	51.95	-10	-45
3	TEESTA	KAUNIA	30.52	30.00	28.47	28.39	-8	-161
4	JAMUNESWARI	BADARGANJ	32.92	32.16	30.34	30.02	-32	-214
5	GHAGOT	GAIBANDHA	22.81	21.70	21.93	21.71	-22	+ 1
6	KARATOA	CHAK RAHIMPUR	21.41	20.15	19.98	19.92	-6	-23
7	KARATOA	BOGRA	17.45	16.32	14.47	14.39	-8	-193
8	BRAHMAPUTRA	NOONKHAWA	28.10	27.25	26.41	26.14	-27	-111
9	BRAHMAPUTRA	CHILMARI	25.07	24.00	24.06	23.86	-20	-14
10	JAMUNA	BAHADURABAD	20.62	19.50	19.85	19.64	-21	+ 14
11	JAMUNA	SARIAKANDI	19.07	16.70	17.23	17.00	-23	+ 30
12	JAMUNA	SERAJGANJ	15.12	13.35	13.96	13.78	-18	+ 43
13	JAMUNA	ARICHA	10.76	9.40	9.20	9.04	-16	-36
14	GUR	SINGRA	13.53	12.35	12.80	12.77	-3	+ 42
15	ATRAI	BAGHABARI	12.45	10.40	11.76	11.43	-33	+ 103
16	DHALESWARI	ELASIN	12.20	11.40	12.30	12.21	-9	+ 81
17	OLD BRAHMAPUTRA	JAMALPUR	18.00	17.00	15.84	15.83	-1	-117
18	OLD BRAHMAPUTRA	MYMENSINGH	13.71	12.50	10.92	11.06	+ 14	-144

FLOOD FORECASTING AND WARNING CENTRE
RIVER SITUATION AS ON 10-09-2015 AT **15:00 HOURS**

Afternoon Bulletin

SL	RIVER	STATION NAME	RHWL (m)	D.L. (m)	WATER LEVEL 10-09-2015 9.00 AM	WATER LEVEL 10-09-2015 3.00 PM	+ Rise - Fall in cm	Above D.L. in cm
	BRAHMAPUTRA BASIN				পানিসমতল আজ সকাল ৯টা	বিকাল ৩টা	হ্রাস -/+বৃদ্ধি	বিপদসীমার উপরে/নীচে
1	DHARLA	KURIGRAM	27.66	26.50	26.14	26.07	-7	-43
2	TEESTA	DALIA	52.97	52.40	51.95	51.90	-5	-50
3	TEESTA	KAUNIA	30.52	30.00	28.39	28.36	-3	-164
4	JAMUNESWARI	BADARGANJ	32.92	32.16	30.02	29.93	-9	-223
5	GHAGOT	GAIBANDHA	22.81	21.70	21.71	21.68	-3	-2
6	KARATOA	CHAK RAHIMPUR	21.41	20.15	19.92	19.88	-4	-27
7	KARATOA	BOGRA	17.45	16.32	14.39	14.37	-2	-195
8	BRAHMAPUTRA	NOONKHAWA	28.10	27.25	26.14	26.07	-7	-118
9	BRAHMAPUTRA	CHILMARI	25.07	24.00	23.86	23.80	-6	-20
10	JAMUNA	BAHADURABAD	20.62	19.50	19.64	19.59	-5	+ 9
11	JAMUNA	SARIAKANDI	19.07	16.70	17.00	16.94	-6	+ 24
12	JAMUNA	SERAJGANJ	15.12	13.35	13.78	13.73	-5	+ 38
13	JAMUNA	ARICHA	10.76	9.40	9.04	8.97	-7	-43
14	GUR	SINGRA	13.53	12.35	12.77	12.76	-1	+ 41
15	ATRAI	BAGHABARI	12.45	10.40	11.43	11.37	-6	+ 97
16	DHALESWARI	ELASIN	12.20	11.40	12.21	12.18	-3	+ 78
17	OLD BRAHMAPUTRA	JAMALPUR	18.00	17.00	15.83	-	-	-
18	OLD BRAHMAPUTRA	MYMENSINGH	13.71	12.50	11.06	11.10	+ 4	-140

A summary of the WL changes at the points/stations flowing above DL is prepared and disseminated, example given in the table. In a particular day, at 09:00hrs (morning) 7 points/stations and at 15:00hrs 6 points/stations flowed above their respective DLs. The WL of all the stations showing falling trend except one steady. It is uploaded in the web-site with Title “Status of the Day”.

ষ্টেশন/স্থান	নদ-নদীর নাম	বিপদসীমার উপরে/নীচে		দিনের পরিবর্তন
		সকাল ৯টা	বিকাল ৩টা	
বাঘাবাড়ি	আত্রাই	+১	-৪	হ্রাস
এলাসিন	ধলেশ্বরী	+৩৯	+৩৬	হ্রাস
তারাঘাট	কালিগঙ্গা	+২৮	+১৬	হ্রাস
জাগির	ধলেশ্বরী	+৪	+২	হ্রাস
ঝিকরগাছা	কপোতাক্ষ	+৩২	+৩২	স্থিতিশীল
দিরাই	পুরাতন সুরমা	+১৩	+১২	হ্রাস
ব্রাহ্মণবাড়িয়া	তিতাস	+৪০	+৩৮	হ্রাস

6.2 Application of Remote Sensing in Flood Risk Reduction

ICHARM (International Center for Water Hazard and Risk Management) a chartered center engaged in management of flood related disaster management, has a long term collaboration with BWDB in enhancing the capacity of flood early warning and river erosion control through research and experiment. It is now trying to find ways on how to better co-operate BWDB in solving the flood related issues. ICHARM developed a new technology which relates the water level with inundation area for a particular flood vulnerable area and verification of inundation areas with remote sensing data. This experiment was performed during 2015 flood with a latest equipment – UAV (Unmanned Air Vehicle) drone which a latest addition in arial photogrammetric and capable of capturing wide area high resolution scene with short time interval and better accuracy than satellite based data.

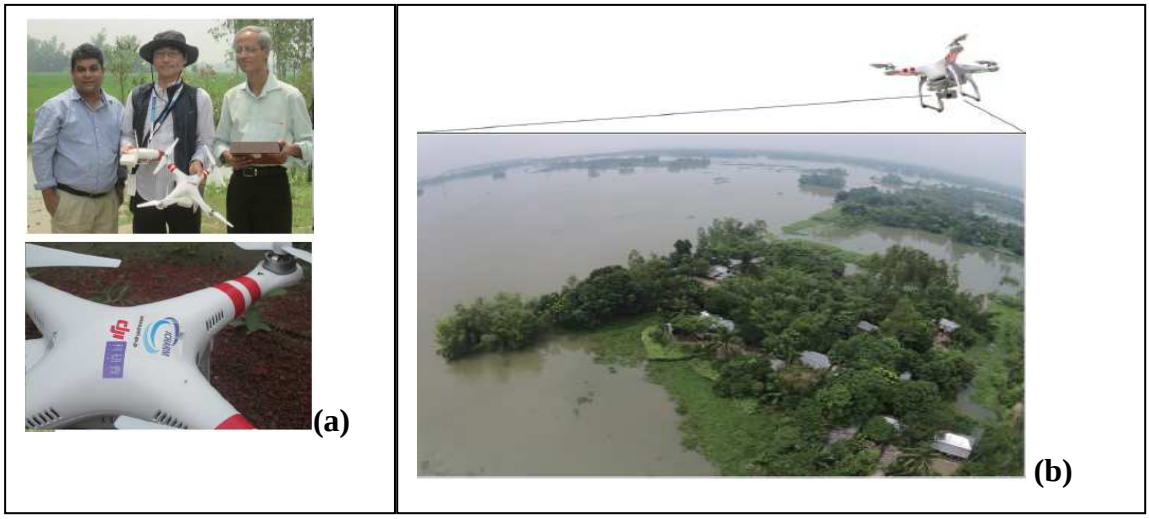

Figure 6.3: (a) Field visit of FFWC professionals and ICHARM staff with UAV Drone , (b) A UAV photo showing a town and rice fields flooded in Serajgonj District

Two senior researchers from ICHARM, Japan visited the flood affected areas of Bangladesh, discussed with the various stakeholders including FFWC in September, 2015 during the time of peak flooding of this monsoon and they did investigation and ground truth in some selected flood vulnerable areas in Serajgonj, Munshigonj and Sunamgonj districts using UAV drone.

The main application of drone measurement is rapid identification of flood hazard areas within short time which is useful for verification of flood inundation map. This technology is not only useful in determining flood hazard areas but also identifying crop inundation or damaged crop areas for a specific area which can be further useful in preparing crop damage map.

6.3 Extended Flood Forecast Lead Time

With financial support from the Comprehensive Disaster Management Program, phase-II (CDMP-II), FFWC-BWDB initiated a research work in collaboration of Institute of Water Modeling (IWM) as consultant to extend deterministic flood forecasting lead time up to 5-days(120 hrs) from 3-days (72hrs). The CDMP-II program is lead by the Ministry of Disaster Management and Relief with financial support from a consortium of

Development Partners lead by the UNDP and others are Australian Aid, European Union, Norwegian Embassy, SIDA and UK Aid. A part of financial contribution of CDMP-II program has been utilizing for strengthening of FFWC, BWDB. Under the approved Project Implementation Plan (PIP), the CDMP-II supported activity entitled "Strengthening Flood Forecasting and Warning Centre's Early Warning Capacity" started since June 2011. During the September-October 2012 (end of last year monsoon) the 5-days lead time deterministic flood forecast was generated on daily basis in the Brahmaputra basin and performance was evaluated. The lead time of the flood forecasting has been extended by using the Ganges-Brahmaputra-Meghna (GBM) basin model. This GBM basin model is capable of generating the flows of major trans-boundary rivers using meteorological data of the basin as input. Rainfall measurement data and forecasts/ prediction are available in the web-site. Water level data at limited number of sites from upstream gauges inside India is also available during flood period (June to October). The gauge data (measured) along with measured and forecasted/predicted rainfall data has been utilized to generate the major inflows and thus extended deterministic flood forecast lead time up to 5-days has been generated at 54 numbers of flood forecasting points/stations. From the beginning of the monsoon (June 2015) 24hr, 48hr, 72hr, 96hr and 120 hours (up to 5-days) lead time deterministic flood forecast & warning has been generated and disseminated on daily basis. Initial evaluation indicated that up to the 3rd day the forecast performance is satisfactory. At the 4th (96 hours) and 5th day (120 hours), the forecast is acceptable but the performance need to be improved further. Improvement and fine tuning of the model specially in improving the forecast quality of 4^{th} and 5^{th} days will continue before commencement of the next monsoon 2016. A sample flood bulletin up to 5-days lead time flood forecast at 54 points is presented in **Annex-1**. Two more days lead time, from 3-days (72 hours) to 5-days (120 hours), is a major achievement for the Flood Forecasting and Warning Services (FFWS) of the country.

Another component of the Research on Prediction modeling is "Structure Based Flood Forecast" for selected BWDB projects. Based on the extended 5- days deterministic flood forecast, structure based flood forecast for selected projects (i) Brahmaputra Right Embankment(BRE) (ii) Dhaka-Mawa Road, (iii) Pabna Irrigation and Rural Development Project (PIRDP) and (iv) Meghna-Dhonagoda Irrigation Project (MDIP) has been generated and disseminated from July 2013 on experimental basis (location map Fig A.3). The output of the Structure Based Flood Forecast for 24, 48, 72, 96 and 120 hours for the PIRDP is shown in the **Annex-2.** This is more localized flood forecasting system from point based forecast to along the structure (embankment and road) water level profile for observed and forecast for next 5-days. The quality of this product has also been improved than last monsoon which is expected to continue in coming monsoon.

6.4 Flash Flood Forecast for North East Part

Experimental flash flood forecast has been generated and disseminated through e-mail and FFWC website (www.ffwc.gov.bd) during April-May period (period of threat for disaster) for the North East region. Flood forecast is produced with lead time of 2 days at 13 stations. The initial evaluation for the forecast during April May period indicated good performance and acceptable. Further improvement is in progress and will be tested in the next season during April May 2015. A bulletin of Experimental Flash Flood forecast is shown in the **Annex-3**.

CHAPTER 7: CONCLUSIONS

The flood problem in Bangladesh is extremely complex. The country is an active delta; it has numerous networks of rivers, canals and coast creeks with extensive flood plains through which surface water of about 1.7 million sq-km drains annually. The annual average rainfall of about 2300 mm, the range varies from about 1500 mm in the north-west to over 5000 mm in the north-east.

Floods are normal monsoon phenomena in the deltaic plains of Bangladesh. Although the livelihood of the people in Bangladesh is well adapted to normal monsoon flood, the damages due to inundation, riverbank erosion or breach of embankment, etc. still occur in various regions in almost every monsoon. They often have disastrous consequences: major damage to infrastructure, great loss of property, crops, cattle, poultry etc, human suffering and impoverishment of the poor. With every major flood in Bangladesh, food security and poverty situation adversely affected.

The runoff from GBM catchments of about 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. The part of Meghna, North and South-Eastern Hill basins is vulnerable to flash flood at the beginning or even pre-monsoon causing loss of standing crops and source of hardship for the population.

As mandated, FFWC of BWDB under Ministry of Water Resources monitored the flood situation during the monsoon and also beyond the monsoon if situation demand. The FFWC has issued daily flood bulletin from May to October with a forecast lead-time of 24hrs, 48hrs and 72hrs, 96 hrs and 120 hrs(upto 5 days) along with warning messages and flood inundation maps. The extend deterministic flood forecast lead time upto 5-days from 3-days, experimental flash flood forecast on pilot basis for Natrokona, Sunamgonj and Sylhet districts and expand the deterministic flood forecast to few selected BWDB projects known as structure based flood forecast upto 5 days lead time initiated with financial support from Comprehensive Disaster Management Programme (Phase–II), CDMP-II under Ministry of Disaster Management and Relief. Also 16 new flood forecasting points has been added in the system. These are the new efforts to make more localized flood forecast. Further improvement is needed for these initiatives/outputs.

Updated/improved more user friendly web-site has been in operation since June-2015 (beginning of monsoon) with the financial support of CDMP-II. The upgraded web-site having easy to operate menu and Bangla language option is added with flood warning message in Bangla. Improvement of the web-site is on-going.

In addition to deterministic flood forecasts upto 5-days lead time, FFWC issued medium range upto 10-days lead-time probabilistic forecasts at 18 locations in experimental basis with the technical support from RIMES utilizing ECMWF weather prediction data over

the GBM basin to generate 51 sets of ensemble discharge forecasts on the Brahmaputra at Bahadurabad and on the Ganges rivers at Hardinge-Bridge. Technical support from the RIMES (Regional Integrated Multi-hazard Early Warning System) is recognized for preparing and providing the medium range 10-day lead time probabilistic flood forecast in Bangladesh on experimental basis. The updated FFWC model was taken for customization for real-time flood forecasting utilizing CFAN predictions.

The special type of flood bulletin has been issued during the critical time and disseminate through different mass media, news agencies, fax, e-mail, web-site and IVR through mobile phone. The IVR system using mobile is a new way of dissemination started from July 2011, in cooperation of DDM, anyone can call 10941 number from any mobile oprator and hear a short voice message on flood warning in Bangla. The information has been used by various communities and 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 (DEM) and limited technological development of the center itself, the services were fully not satisfactory to all corners. Area-inundation forecast have been indicative, based on a coarse DEM 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 FFWC 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 2015.

As a whole the flood of 2015 was fairly normal compare to devastating flood of 1987, 1988, 1998, 2004 and 2007. The maximum flooded area was 32% of the whole country (47,200 sq-km approximately).

Evaluation indicated that, the accuracy of deterministic flood forecasts issued by FFWC for monsoon-2015 on Major River is around 95.27%, 90.86%, 86.29%, 80.98% and 75.39% accurate for 24hrs, 48hrs, 72hrs, 96hrs and 120hrs lead time 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.

Annex-1

EXPERIMENTAL 5 Days Forecast (24, 48, 72, 96 & 120 Hrs), FFWC, BWDB

Supported by CDMP-II

SL NO	River	Station	D.L. (meter)	Today 01-09 6:00 AM (meter)	24-hrs forecast 02-09 6:00 AM (meter)	24-hrs +Rise -fall 02-09 6:00 AM (cm)	24-hrs +above -below D.L. 02-09 6:00 AM (cm)	48-hrs forecast 03-09 6:00 AM (meter)	48-hrs +Rise -fall 03-09 6:00 AM (cm)	48-hrs +above below D.L. 03-09 6:00 AM (cm)	72-hrs forecast 04-09 6:00 AM (meter)	72-hrs +Rise -fall 04-09 6:00 AM (cm)	72-hrs +above -below D.L. 04-09 6:00 AM (cm)	96-hrs forecast 05-09 6:00 AM (meter)	96-hrs +Rise -fall 05-09 6:00 AM (cm)	96-hrs +above -below D.L. 05-09 6:00 AM (cm)	120-hrs forecast 06-09 6:00 AM (meter)	120-hrs +Rise -fall 06-09 6:00 AM (cm)	120-hrs +above -below D.L. 06-09 6:00 AM (cm)
1	Atrai	Mohadevpur	18.59	16.86	17.14	+28	-145	17.63	+49	-96	17.84	+22	-75	17.81	-3	-78	17.69	-12	-90
2	Atrai	Atrai	13.72	-	13.57	-	-15	13.70	+13	-2	13.85	+14	+13	13.96	+11	+24	14.04	+8	+32
3	Atrai	Singra	12.65	12.67	12.76	+9	+11	12.88	+11	+23	13.01	+13	+36	13.12	+11	+47	13.21	+9	+56
4	Karatoa-Atrai-GGH	Baghabari	10.40	11.71	11.77	+6	+137	11.85	+8	+145	11.91	+7	+151	11.97	+5	+157	12.02	+5	+162
5	Little Jamuna	Naogaon	15.24	14.84	15.04	+20	-20	15.21	+16	-3	15.36	+15	+12	15.46	+10	+22	15.48	+2	+24
6	Karatoya	Chakrahimpur	20.15	20.22	20.23	+1	+8	20.28	+5	+13	20.32	+5	+17	20.34	+2	+19	20.34	0	+19
7	Karatoya	Bogra	16.32	14.42	14.16	-26	-216	13.84	-32	-248	13.64	-20	-268	13.66	+2	-266	13.78	+11	-254
8	Teesta	Kaunia	30.00	28.97	29.07	+10	-93	29.14	+7	-86	29.20	+6	-80	29.26	+6	-74	29.32	+6	-69
9	Ghagot	Gaibandha	21.70	21.31	21.36	+5	-34	21.41	+5	-29	21.46	+5	-24	21.51	+5	-19	21.56	+5	-14
10	Dharla	Kurigram	26.50	26.70	26.77	+7	+27	26.83	+6	+33	26.88	+5	+38	26.94	+5	+44	26.99	+5	+49
11	Brahmaputra	Chilmari	24.00	23.78	23.87	+9	-13	23.94	+7	-6	24.00	+6	0	24.06	+6	+6	24.12	+6	+12
12	Jamuna	Bahadurabad	19.50	19.50	19.62	+12	+12	19.70	+8	+20	19.76	+6	+26	19.82	+5	+32	19.88	+6	+38
13	Jamuna	Sariakandi	16.70	16.88	17.02	+14	+32	17.10	+8	+40	17.16	+6	+46	17.22	+5	+52	17.27	+6	+57
14	Jamuna	Kazipur	14.85	-	14.62	-	-23	14.71	+9	-14	14.78	+7	-7	14.83	+5	-2	14.88	+5	+3
15	Jamuna	Serajganj	13.35	13.54	13.68	+14	+33	13.79	+11	+44	13.87	+8	+52	13.93	+6	+58	13.99	+6	+64
16	Jamuna	Porabari	12.27	-	11.72	-	-55	11.82	+10	-45	11.90	+8	-37	11.95	+6	-32	12.01	+6	-26
17	Jamuna	Aricha	9.40	9.15	9.18	+3	-23	9.23	+6	-17	9.28	+5	-12	9.32	+4	-8	9.36	+4	-4
18	Old Brahmaputra	Jamalpur	17.00	15.17	15.34	+17	-166	15.47	+12	-153	15.55	+9	-145	15.62	+7	-138	15.68	+6	-132
19	Old Brahmaputra	Mymensingh	12.50	10.56	10.60	+4	-190	10.69	+9	-181	10.78	+9	-172	10.86	+8	-164	10.94	+7	-156
20	Bangshi	Nayerhat	7.32	5.58	5.63	+5	-169	5.69	+5	-163	5.73	+5	-159	5.78	+5	-154	5.83	+5	-149
21	Old Dhalesari	Jagir	8.23	-	8.57	-	+34	8.63	+6	+40	8.69	+6	+46	8.76	+7	+53	8.84	+8	+61
22	Dhaleswari	Kalagachia	4.88	-	5.47	-	+59	5.49	+2	+61	5.52	+2	+64	5.56	+4	+68	5.61	+6	+73
23	Kaliganga	Taraghat	8.38	8.14	8.20	+6	-18	8.27	+7	-11	8.34	+7	-4	8.40	+6	+2	8.47	+6	+9
24	Tongi Khal	Tongi	6.08	5.49	5.54	+5	-54	5.57	+4	-51	5.61	+3	-47	5.64	+4	-44	5.69	+4	-39
25	Turag	Mirpur	5.94	5.43	5.47	+4	-47	5.50	+3	-44	5.53	+3	-41	5.56	+3	-38	5.61	+4	-33
26	Buriganga	Dhaka (Mill Barrack)	6.00	5.00	5.04	+4	-96	5.06	+2	-94	5.08	+2	-92	5.11	+3	-89	5.16	+5	-84
27	Buriganga	Dhaka (Hariharpara)	5.79	-	5.51	-	-28	5.53	+2	-26	5.56	+2	-23	5.59	+3	-20	5.64	+5	-15
28	Balu	Demra	5.75	5.32	5.37	+5	-38	5.40	+3	-35	5.43	+3	-32	5.46	+3	-29	5.51	+5	-24
29	Lakhya	Narayanganj	5.50	5.54	5.58	+4	+8	5.61	+3	+11	5.64	+3	+14	5.67	+3	+17	5.73	+5	+23
30	Dhaleswari	Elashinghat	11.40	11.97	12.05	+8	+65	12.14	+9	+74	12.21	+7	+81	12.26	+5	+86	12.31	+5	+91
31	Lakhya	Lakhpur	5.80	6.21	6.28	+7	+48	6.34	+6	+54	6.38	+5	+58	6.43	+4	+63	6.48	+5	+68
32	Dhaleswari	Munshiganj	5.20	-	5.50	-	+30	5.53	+2	+33	5.55	+2	+35	5.58	+3	+38	5.64	+6	+44
33	Mohananda	Chapai Nawabganj	21.00	19.76	19.77	+1	-123	19.79	+2	-121	19.82	+3	-118	19.83	+1	-117	19.84	+1	-116
34	Ganges	Rajshahi	18.50	16.78	16.70	-8	-180	16.65	-5	-185	16.60	-4	-190	16.56	-5	-194	16.51	-5	-199
35	Ganges	Hardinge Br	14.25	13.36	13.25	-11	-100	13.20	-6	-105	13.16	-4	-109	13.11	-4	-114	13.07	-4	-118
36	Ganges	Talbaria	12.80	-	12.33	-	-47	12.27	-6	-53	12.22	-4	-58	12.18	-4	-62	12.14	-4	-66
37	Padma	Goalondo	8.65	8.91	8.91	0	+26	8.95	+4	+30	8.99	+4	+34	9.02	+3	+37	9.05	+3	+40

Note: 1) 24 hrs. rise/fall indicates changes in water levels from today 6 A.M. to 2-9-2015 6:00 A.M.

2) 48 hrs. rise/fall indicates changes in water levels from 2-9-2015 6:00 A.M. to 3-9-2015 6:00 A.M.

3) 72 hrs. rise/fall indicates changes in water levels from 3-9-2015 6:00 A.M. to 4-9-2015 6:00 A.M.

4) 96 hrs. rise/fall indicates changes in water levels from 4-9-2015 6:00 A.M. to 5-9-2015 6:00 A.M.

5) 120 hrs. rise/fall indicates changes in water levels from 5-9-2015 6:00 A.M. to 6-9-2015 6:00 A.M.

6) "+ above" means water level flowing above danger level, "-below" means water level flowing below danger level.

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Figure 6.4: A sample of 5 days Forecast Bulletin

Annex-2

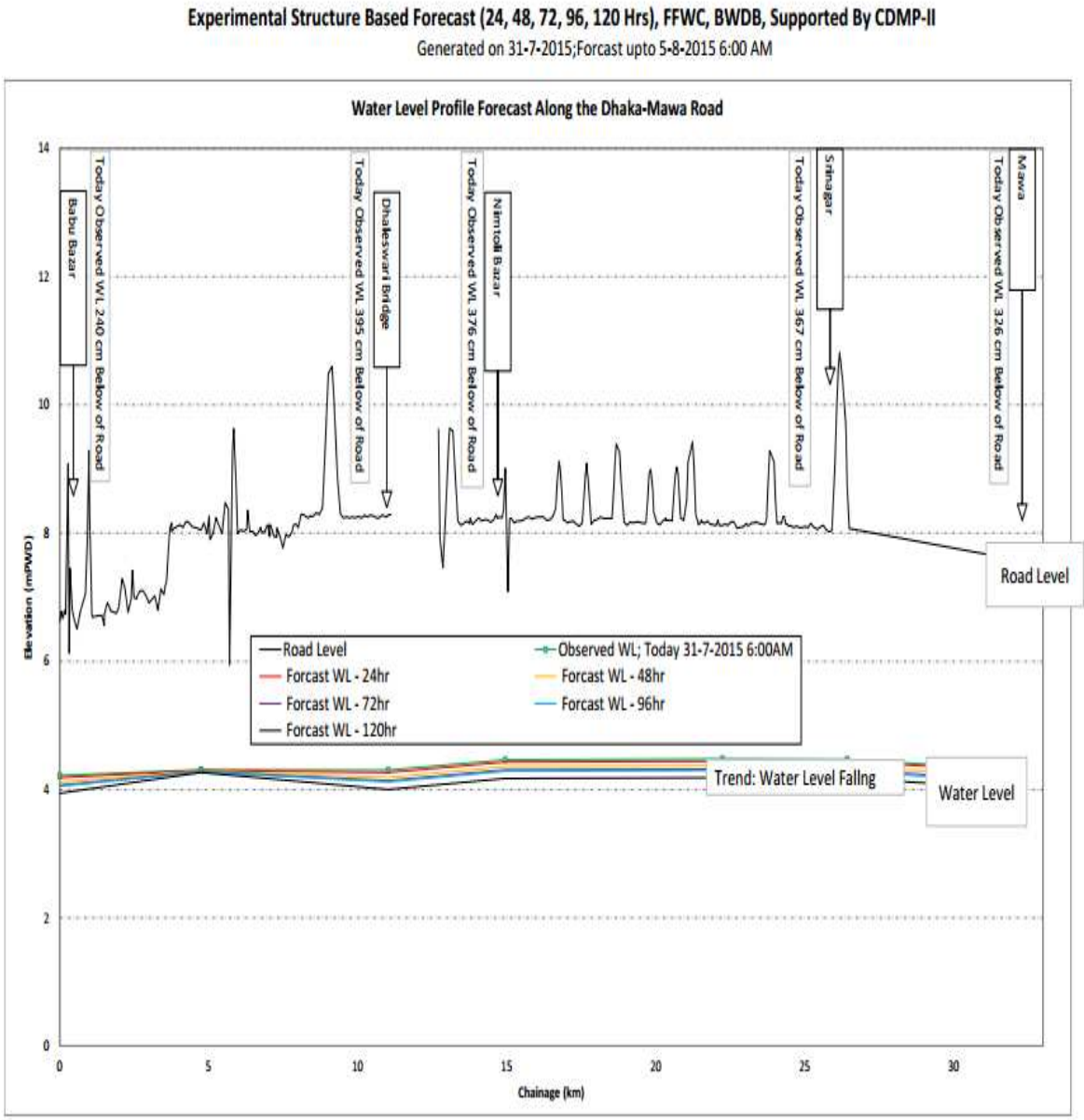

Figure 6.5: A sample of Structure Based Forecast Bulletin

Annex-3

FLOOD INFORMATION CENTRE
FLOOD FORECASTING & WARNING CENTRE
BANGLADESH WATER DEVELOPMENT BOARD
WAPDA BUILDING, 8TH FLOOR, DHAKA.
E-mail: ffwc05@yahoo.com, Site: http://www.ffwc.gov.bd Tel: 9553118, 9550755

FLASH FLOOD OUTLOOK FOR THE NORTH-EAST REGION AS ON

April 22, 2015

Experimental

RAINFALL

Significant rainfall (More than 50 mm) observed in North East,Bangladesh and its adjoining areas in India during last 24 hours.

OUTLOOK

The Surma, Kushiyara and Manu rivers are in rising condition. There is a rising trend for today and tomorrow for Surma and Kushiyara rivers and their tributaries although there is no possibility of flash flood in Sylhet and Sunamganj within next 48 hours sepceially in the low lying areas.

GENERAL RIVER CONDITION

Monitored water Level	20	Steady	0
Rise/Fall	16/1	Not Reported	3

Model Forecast: 6, 12, 24 & 48 hours

		Today	6-hr. forecast	12-hr. forecast	12-hr. +rise -fall	24-hr. forecast	24-hr. +rise -fall	48-hr. forecast	48-hr. +rise -fall
Water Level (m PWD)		22-Apr	22-Apr	22-Apr	22-Apr	23-Apr	23-Apr	24-Apr	24-Apr
River	Station	6:00	12:00	18:00	18:00	6:00	6:00	6:00	6:00
		(m)	(m)	(m)	(cm)	(m)	(cm)	(m)	(cm)
Kushiyara	AMALSHID	9.31	9.58	9.84	53	10.45	114	11.49	218
Kushiyara	SHEOLA	7.88	8.09	8.32	44	8.82	94	9.89	201
Kushiyara	SHERPUR	5.29	5.50	5.73	44	6.23	94	7.30	201
Surma	KANAIRGHAT	6.52	6.67	6.87	35	7.43	91	9.03	251
Surma	SYLHET	4.75	4.84	4.95	20	5.22	47	6.09	134
Surma	SUNAMGANJ	3.95	4.04	4.14	19	4.38	43	5.00	105
Kalni	MARKULI	4.13	4.20	4.30	17	4.48	35	4.77	64
Kangsha	JARIAJANJAIL	7.25	7.67	8.25	100	9.13	188	10.16	291
Manu	MOULVI BAZAR	8.75	9.21	9.26	51	8.47	-28	8.42	-33
Khowai	HABIGANJ	6.26	6.26	6.26	0	6.25	-1	6.37	11
Jadukata	LORERGARH	4.81	4.83	4.92	11	5.34	53	4.95	14
Manu	MANU-RLY-BR	15.58	15.25	14.05	-153	14.00	-158	13.95	-163
Surma	DEARI	-	-	-	-	-	-	-	-

Supported By CDMP-II

Figure 6.6: A sample of Flash Flood Forecast Bulletin