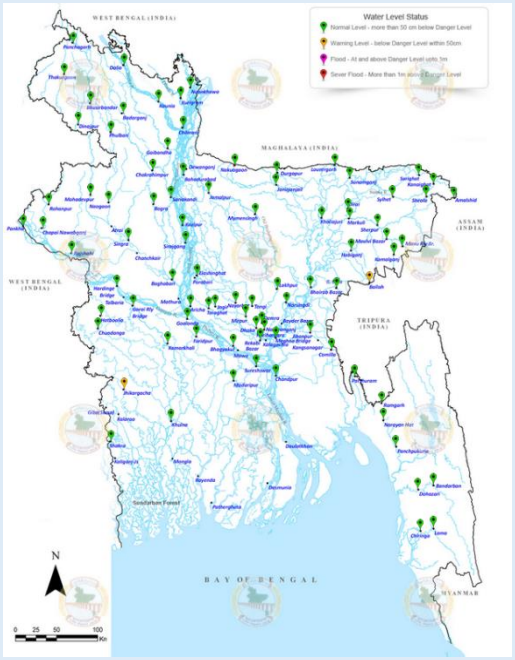
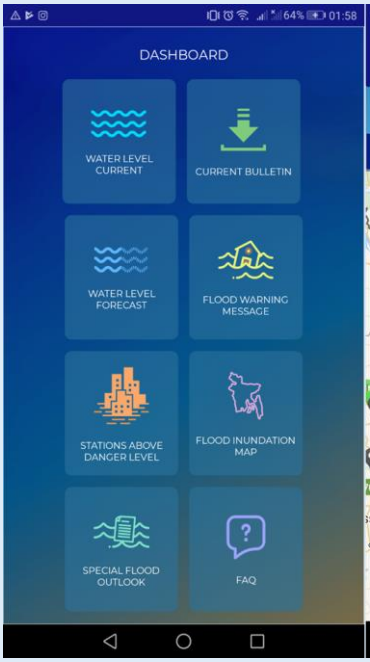
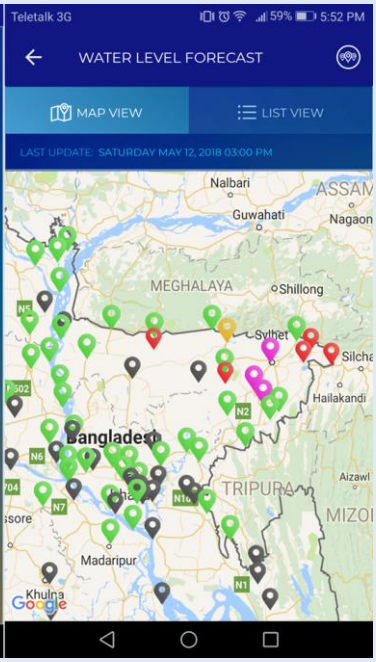
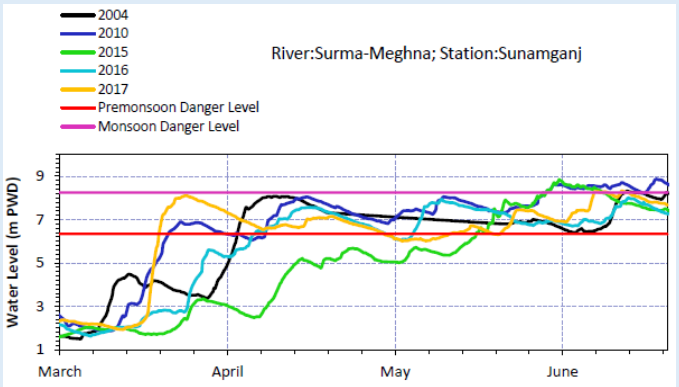
ANNUAL FLOOD REPORT 2018









FLOOD FORECASTING & WARNING CENTRE

PROCESSING & FLOOD FORECASTING CIRCLE

BANGLADESH WATER DEVELOPMENT BOARD

Annual Flood Report 2018

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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) under the Ministry of Water Resources (MoWR) and Flood Forecasting and Warning Centre (FFWC) is carrying out this duty. The FFWC was established in 1972 and is fully operative in the flood season, from April to October every year, following the Standing Orders on 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 during the pre-monsoon and 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 felt aspired by the valuable advice and guidance of the Secretary, MoWR, Govt. of Bangladesh throughout the season. FFWC gratefully acknowledge the valuable advice and leadership of the Director General, BWDB, which continuously drives FFWC forward. FFWC also gratefully acknowledge the valuable suggestions and encouragement provided by the Additional Director General (Planning), BWDB. The direct involvement and guidance of the Chief Engineer, Hydrology, BWDB and the Superintending Engineer, Processing & Flood Forecasting Circle, BWDB are respectfully acknowledged which greatly improved the quality of works of the centre.

The services of Flood Information Centres (FICs) established at the Division Offices of BWDB, Gauge Readers, 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 2018. 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.

FFWC is providing the following services on daily basis during monsoon

- Flood bulletin twice a day
- River and rainfall situation summary report
- 5-days deterministic and 10-days probabilistic flood forecast with hydrograph
- Special outlook and warning message
- Structure based forecast at 4 key locations
- Rainfall Map
- Flood Inundation Map
- Flood warning message dissemination through user-friendly website (www.ffwc.gov.bd) and toll-free Interactive Voice Response (IVR) method (number 1090) publicly and through email and fax to all relevant government organizations and selected medias, NGOs, stakeholders and others

Besides this, during the pre-monsoon season FFWC is providing flash flood forecast and outlook for the North-Eastern region of the country to minimize damage of standing Boro crops in Haor basins. From 2017, FFWC has experimentally started 3-days deterministic flash flood forecasting which has been further developed this year under the BWDB part of Haor Infrastructure and Livelihood Improvement Project (HILIP) by LGED. Also new danger levels have been adopted for the pre-monsoon season from this year on as the monsoon danger level provides much less safety factor with respect to Boro crops.

A new addition to the flood warning dissemination media is an Android mobile app launched this year named 'BWDB Flood App'. The app is a mobile friendly version of the FFWC website and can be downloaded from Google Play Store free of charge. This is expected to greatly increase the accessibility of all FFWC services to Android users.

FFWC is primarily disseminating its forecast products through website and feedback from different stakeholders is essential for overall improvement. FFWC is trying to develop further the services and system to cope-up with the technological and computational development. Two of the main struggles and demand is to increase flood forecasting and warning lead time and make location specific flood forecast.

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 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.

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Executive Summary

The characteristics of flood of 2018 as a whole, is a representative of normal one with respect to duration and magnitude. During the monsoon 2018, the flood was of short to medium duration and of normal magnitude in the Northern, North-Western and North-Central regions along the Brahmaputra-Jamuna river. Flood did not affect the main lands in the North-Western and Central regions along the Ganges-Padma river throughout the monsoon. However, moderate to severe flood situations prevailed in the North-Eastern and South-Eastern regions which were flashy and stayed for short to medium duration in the North-East while for short in the South-East. During pre-monsoon, the Haor basins were inundated slightly earlier than normal during the 2nd week of May but no significant damage to crops occurred. The monsoon was mostly active during the onset and beginning period of monsoon from the 2nd week of June to 2nd week of July. During this period all the stated regions were affected by floods. No major flood events occurred afterwards throughout the monsoon except during the 2nd-3rd week of September when the lower floodplains of the Brahmaputra-Jamuna river experienced flooding. Flash flood of Manu river at Moulvibazar during 2nd-3rd week of June was the most severe event of the season and also in last 10 years within the basin. The evaluation indicated that average accuracy of deterministic flood forecasts issued by FFWC were around 93%, 89%, 85%, 81% and 78% for 24, 48, 72, 96 and 120 hours lead time respectively in the monsoon of 2018.

The country as a whole received 30.9% less rainfall than normal during the monsoon of 2018 (May to October). The Brahmaputra, Ganges, Meghna and the South Eastern Hill basins received 48. 5%, 30.2%, 30.9% and 17.3% less rainfall than normal respectively. Basin wise monthly percentage based 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	-33.87	-1.51	+12.14	-34.50
June	-45.80%	-15.47%	-14.59%	14.60%
July	-47.91%	-10.40%	-48.76%	-3.42%
August	-44.94%	-45.34%	-51.05%	-42.21%
September	-52.40	-55.23	-23.38	-51.55
October	-70.02	-43.72	-51.05	+0.60

Notable improvements have been made during 2018 as Pre-monsoon Danger Levels for the North-East region have been introduced as well as the 3-days experimental flash flood forecasting system for the region has been expanded. An Android based mobile app named ‘BWDB Flood App’ has been launched for more user-friendly and effective dissemination.

During the monsoon of 2018, maximum flooded area was 23% of the whole country (33,941 sq-km approximately). Some of the regions experienced severe river bank erosion even under normal or below normal flooding.

List of Abbreviations

ADG	Additional Director General
BWDB	Bangladesh Water development Board
BMD	Bangladesh Meteorological Department
CDMP	Comprehensive Disaster Management Programme
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
FF	Flood Forecast
FFWC	Flood Forecasting and Warning Centre
GM	General Model
GBM	Ganges Brahmaputra Meghna
HILIP	Haor Infrastructure and Livelihood Improvement Project
IWM	Institute of Water Modelling
IVR	Interactive Voice Response
LGED	Local Government Engineering Department
MAE	Mean Absolute Error
MoWR	Ministry of Water Resources
NGO	Non-Government Organization
NWP	Numerical Weather Prediction
PMDL	Pre-monsoon Danger Level
MSL	Mean Sea Level
RHWL	Recorded Highest Water Level
RIMES	Regional Integrated Multi-hazard Early Warning System
SoB	Survey of Bangladesh
SOD	Standing Orders 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

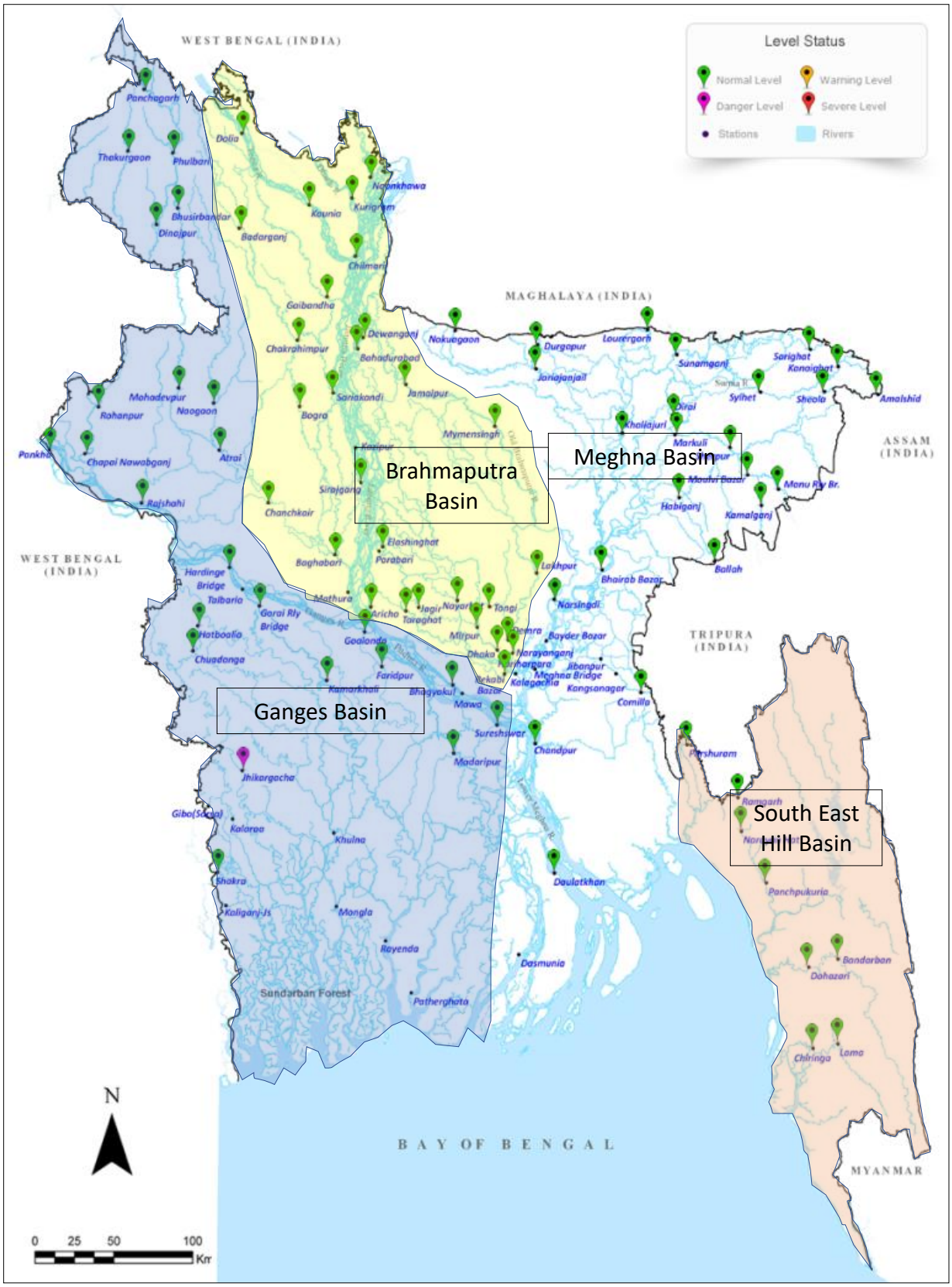


Figure 1 : Basin Map of Bangladesh with Water Level Gauge Stations

CHAPTER 1 : INTRODUCTION

1.1. THE PHYSICAL SETTING

Bangladesh lies approximately between 20º30' and 26º40' north latitude and 88º03' and 92º40' 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 are originated from Myanmar. Monsoon flood inundation of about 20% to 25% area of the country is assumed beneficial for crops, ecology and environment. But flood 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 Northwest boundary of the country 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, Sunamganj 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 Meghalay being about 11,755 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 measure 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 Processing and Flood Forecasting Circle, Hydrology, BWDB takes hydrological monitoring data of 94 representative water level stations and 70 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 54 monitoring points on the major rivers, special flood report along with different graphical and statistical presentation during the monsoon season. During the pre-monsoon season the center is involved in flash flood forecasting in the North-Eastern region with a view to saving the standing Boro crops in Haor basins. The Centre is also involved in preparation of flood status report at national level, weekly bulletin during dry season, monthly and annual flood reports. The Centre is responsible as a focal point in respect of flood from the month of April to October as per Government order for generating flood forecast & warning that are issued with the flood bulletin and also provide support services to DDM other relevant organization.

OUTPUTS of the FFWC

- **Daily Flood Bulletin & River situation summary**
- **Forecast bulletin & Hydrograph**
- **Warning message**
- **Special outlook**
- **Rainfall distribution/surface Map.**
- **River situation map**
- **Flood inundation map**
- **Structure based flood forecast**
- **Comparison Hydrographs for various years**

Step by step development has been made in the flood forecasting and warning services in Bangladesh, 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 the

coastal zone and South-Eastern hill region. Excluding these regions, the model covers about 82,000 km^2 of entire 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 database management is being done with Windows based Operating System installed with desktop 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 extended Lead Time upto 3-days
- Improved dissemination

2005-07 - Probabilistic medium range FF with lead time upto 10-days initiated at 18 points/locations of Ganges-Brahmaputra (GB) basin

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

2012-14 - Strengthening and Improvement of FFWS
- FF at 54 locations on 29 rivers with Extended Lead Time upto 5-days
- Probabilistic 10-days medium range FF expanded to 37 stations of GB basin
- Structure based FF for 4-selected projects upto 5-days lead time (Dhaka-Mawa Highway, Brahmaputra Right Embankment, Pabna Irrigation and Rural Development Project and Meghna-Dhonagoda Irrigation Project)
- Improved and more user friendly web-site with Bangla language
- IVR system for dissemination based on mobile phone introduced
- Improved LAN and display.

2017 - Experimental 3-days deterministic flash flood forecast for the North-Eastern region during pre-monsoon initiated at 17 stations

2018 - Experimental flash flood forecast expanded to 25 stations and establishment of pre-monsoon danger level in North-Eastern region
- Addition of 10 Water Level and 11 Rainfall monitoring stations in the North-Eastern region *(Total regular monitoring WL stations = 90+10-6=94, 6 only active during pre-monsoon, Total monitoring rainfall stations = 59+11=70)*
- Introduction of FFWC mobile app

1.4. OPERATIONAL STAGES BEFORE FORECAST MODEL RUN

Data Collection: The real time hydrological data (94 WL stations and 70 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 within 9.30 A.M. through mobile SMS. Limited WL, rainfall and forecasts of upper catchments from Indian stations are also collected through internet, e-mail, and from BMD. In addition, a dedicated land line radar link with BMD (Bangladesh Meteorological Department) provided frequent (five minutes interval) rainfall information.

Necessary Data & Forecast Calculation: Estimation of WL at the model boundaries and rainfall for the internal catchments are required input to the model upto the time of forecast (24, 48, 72, 96 & 120 hrs).

Collected/observed WL and rainfall data are given input to the computer database and checked. The WL and rainfall estimation up to the time of forecast 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. Some WL data are also available publicly in Indian websites. The basis for WL estimation is consideration of 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 are based on previous 3-day's rainfall and analysis of NWP model rainfall forecasts from BMD. In addition to BMD, NWP model rainfall forecasts from IMD, NOAA and ECMWF are necessary data for estimating response of rivers due to rainfall in upper catchments. 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.

Dissemination: 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. Now, all the mobile operators have started the IVR since 2015. The FFWC website is openly accessible to all and contains all flood related information. In addition, FFWC has launched a mobile app since 2018 which is publicly available.

Mode of Dissemination

- E-mail
- Website
- Media, print & electronic
- Telephone, Mobile, Fax
- Hard/print copy
- Lobby display
- IVR through mobile no 1090
- Android mobile app (since 2018)

The flood forecast is intended to alert the people of the locality about the predicted WL of floodwater 5-days ahead of its occurrence. An accurate forecast would be one where the forecast level and corresponding observed level at the stipulated time are within a small range of variation.

1.5. NATURE AND CAUSES OF FLOODING

1.5.1. Causative Factors

There are for climatic distinct seasons (i) Winter December to February (ii) Pre-monsoon March to May, (iii) Monsoon June to September (iv) Post-monsoon October to November. 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. During the pre-monsoon season, the country generally receives little rainfall, however the North-Eastern region of the country adjacent to the Meghalaya sometimes receives heavy rainfall which induces flash flood in the Haor basin.

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. Cherrapunji, 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 km^2) passes through a small area, only 8% of these catchments lie within Bangladesh. During the monsoon season the amount of water entering Bangladesh from upstream is greater than the capacity of the rivers to discharge in to the sea.
- *Bangladesh is a land of rivers:* there are 405 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.

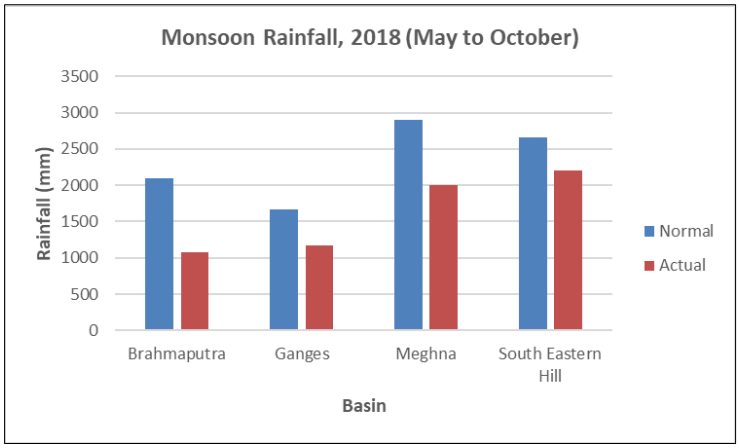
1.5.2. Statistics of Flooding

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, 2007 and 2017 all caused heavy damages to properties and considerable loss of life. During monsoon 2018, the flood was a normal one and stayed for short duration. However, the Moulvibazar district was hit by severe flash flooding due to the river Manu during the onset of monsoon in June. 23% of the country got flood affected in 2018. Percentages of total area of Bangladesh affected by flood available since 1954 are 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**	1977	12,500	8	2000	35,700	24
1955	**50,500**	**34**	1978	10,800	7	2001	4,000	2.8
1956	35,400	24	1980	33,000	22	2002	15,000	10
1960	28,400	19	1982	3,140	2	2003	21,500	14
1961	28,800	20	1983	11,100	7.5	**2004**	**55,000**	**38**
1962	37,200	25	1984	28,200	19	2005	17,850	12
1963	43,100	29	1985	11,400	8	2006	16,175	11
1964	31,000	21	1986	6,600	4	**2007**	**62,300**	**42**
1965	28,400	19	**1987**	**57,300**	**39**	2008	33,655	23
1966	33,400	23	**1988**	**89,970**	**61**	2009	28,593	19
1967	25,700	17	1989	6,100	4	2010	26,530	18
1968	37,200	25	1990	3,500	2.4	2011	29,800	20
1969	41,400	28	1991	28,600	19	2012	17,700	12
1970	42,400	29	1992	2,000	1.4	2013	15,650	10.6
1971	36,300	25	1993	28,742	20	2014	36,895	25
1972	20,800	14	1994	419	0.2	2015	47,200	32
1973	29,800	20	1995	32,000	22	2016	48,675	33
1974	**52,600**	**36**	1996	35,800	24	**2017**	**61,979**	**42**
1975	16,600	11	**1998**	**1,00,250**	**68**	2018	33,941	23
1976	28,300	19	1999	32,000	22			

CHAPTER 2 : RAINFALL SITUATION



During the Pre-monsoon months of March and April in 2018, the Meghna basin within the country in the North-Eastern and adjacent region experienced 38.6% and 7% less rainfall than normal respectively, while other parts of the country remained mostly dry. During the Monsoon-2018 (May to October), the country experienced as a whole 30.9% less rainfall than normal which can be considered as below normal monsoon. The Brahmaputra, Ganges, Meghna and South Eastern Hill basins received 48. 5%, 30.2%, 30.9% and 17.3% less rainfall than normal respectively during the season. Comparison of the country basin average of normal and actual rainfall for the Monsoon-2018 (May to October) is presented in the bar chart. Considering monthly rainfalls, all the basins have been recorded less rainfall than their respective normal during May-October period except the Meghna basin during May and South-Eastern Hill basin during June and October. 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-2018 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	Nor	Act
May	315.4	206.4	191.8	188.9	446	500.2	290.4	178.1		
Jun	433.5	230.5	327	265.4	621	500.1	599.8	655.1		
Jul	496.1	239	397.8	344	650.5	360	728.5	703.6		
Aug	339.7	187	337.8	172.1	537.9	249.1	536.9	305.5	**2331**	**1611.5**
Sep	353.4	168.2	298.7	125.9	449.2	308.3	317.9	170.7		
Oct	155.6	46.3	120.1	72.0	194.7	85.0	183.4	184.5		
Total	**2093.7**	**1077.4**	**1673.2**	**1168.3**	**2899.3**	**2002.7**	**2656.9**	**2197.5**		
%More/ Less	48.5% Less		30.2% Less		30.9% Less		17.3% Less		30.9% Less	

Month wise rainfall situations of the country during March to October for the Pre-monsoon and Monsoon seasons of 2018 are described in the following sections.

2.1 MARCH

The Meghna basin of the country experienced rainfall less than normal during the month of March 2018, while the other parts of the country remained mostly dry. The basin received 38.6% less rainfall than monthly normal.

Important Rainfall Information for March-2018
Monthly Maximum at Sheola: 193 mm
1 day maximum at Sheola: 90 mm

Table 2.2 : **Summary of the rainfall situation during the month of March-2018**

Basin:	**Meghna**
No of Stations:	17
Average Rainfall (mm) of the basin:	40.06
%More(+)/Less(-) than the Normal:	-38.62%
Number of Stations above Normal Rainfall:	05
Highest 1-day Maximum Rainfall with Stations:	Sheola 90.0 mm
Number of Rain Fed Flood* Stations:	0

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

In the Meghna basin, out of 17 rainfall monitoring stations, 5 stations received more rainfall than their monthly normal. Summary of the rainfall situation of the basin for the month is presented in Table 2.2. Considering 10-day maximum rainfall of 300 mm as a rain-fed flood index, no stations crossed the threshold in March.

2.2 APRIL

The Meghna basin of the country experienced rainfall less than normal during the month of April 2018, while the other parts of the country remained mostly dry. The basin received 7% less rainfall than monthly normal.

Important Rainfall Information for April-2018
Monthly Maximum at Kanaighat: 393 mm
1 day maximum at Narsingdi: 91.7 mm

Table 2.3 : **Summary of the rainfall situation during the month of April-2018**

Basin:	**Meghna**
No of Stations:	17
Average Rainfall (mm) of the basin:	212.21
%More(+)/Less(-) than the Normal:	-7.02%
Number of Stations above Normal Rainfall:	04
Highest 1-day Maximum Rainfall with Stations:	Narsingdi 91.7 mm
Number of Rain Fed Flood* Stations:	0

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

In the Meghna basin, out of 17 rainfall monitoring stations, 4 stations received more rainfall than their monthly normal. Summary of the rainfall situation of the basin for the month is presented in Table 2.3. Considering 10-day maximum rainfall of 300 mm as a rain-fed flood index, no stations crossed the threshold value in April.

2.3 MAY

The country as a whole, experienced rainfall less than normal during the month of May 2018. All the basins except the Meghna received less rainfall than their monthly normal.

Important Rainfall Information for May-2018

Monthly Maximum at Sherpur: 699 mm

1 day maximum at Mymensingh: 163.5 mm

Table 2.4 : **Summary of the rainfall situation during the month of May-2018**

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	19	17	12
Average Rainfall (mm) of the basin:	206.35	188.88	500.23	178.13
%More(+)/Less(-) than the Normal:	-33.87	-1.51	+12.14	-34.50
Number of Stations above Normal Rainfall:	4	8	10	4
Highest 1-day Maximum Rainfall with Stations:	Mymensingh	Barguna	B.Baria	Parshuram
	(163.5 mm)	(126 mm)	(135 mm)	(75 mm)
Number of Rain Fed Flood* Stations:	0	0	5	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, 4 stations received more rainfall than their normal. One day maximum rainfall of 163.5mm was recorded at Mymensingh. The Basin received 33.87% less rainfall than normal during the month May 2018.

In Ganges basin, out of 19 rainfall monitoring stations, 8 stations received more rainfall than their normal. One day maximum rainfall of 126mm was recorded at Barguna. The Basin received 1.51% less rainfall than normal during the month May 2018.

In the Meghna basin, out of 17 rainfall monitoring stations, 10 stations received more rainfall than their normal. One day maximum rainfall of 135mm was recorded at B.Baria, while 10-day consecutive maximum rainfall of 404 mm was observed at Sherpur-Sylhet. The Basin received 12.14% more rainfall than normal during the month May 2018.

In the South Eastern Hill basin, out of 12 rainfall monitoring stations, 4 stations received more rainfall than their normal. One day maximum rainfall of 75mm was recorded at Parshuram. The Basin received 34.50% less rainfall than normal during the month May 2018.

Summary of the rainfall situation of the country is presented in Table 2.4. Considering 10-day maximum rainfall of 300 mm as a rain-fed flood index, as many as 5 stations crossed the threshold value in this month all from the Meghna basin. The maximum 1-day rainfall of 163.5 mm was recorded at Mymensingh and 10-day consecutive maximum rainfall of 404 mm was recorded at Sherpur-Sylhet.

The Isohyet of the actual rainfall of the month of May-2018 is shown in the Figure 2.1.

2.4 JUNE

Important Rainfall Information for June, 2018

Monthly Maximum at Kanaighat: 1021 mm

1 day maximum at Narayanhat: 265 mm

The country, as a whole, experienced rainfall less than normal during the month, June 2018. Among the four basins of the country, the Brahmaputra, the Ganges and Meghna basins received less rainfall, while the South Eastern Hill basin received more rainfall than respective monthly normal rainfalls during the month of June 2018.

Table 2.5: Summary of the rainfall situation during the month of June -2018

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	19	17	12
Average Rainfall (mm) of the basin:	230.45	265.41 265.41	500.11 500.11	655.13 655.13
%More(+)/Less(-) than the Normal:	-45.80%	-15.47%	-14.59%	14.60%
Number of Stations above Normal Rainfall:	2	7	5	7
Highest 1-day Maximum Rainfall with Stations:	Kurigram 178 mm	Panchagarh 185.50 mm	Kanaighat 232 mm	Narayanhat 265 mm
Number of Rain Fed Flood* Stations:	1	2	6	9

*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, only two stations namely Dalia and Dhaka were recorded more rainfall than the monthly normal. One day maximum rainfall of 178mm was recorded at Kurigram. Ten day consecutive maximum rainfall of 458mm was recorded at Dalia. The Basin received 45.80% less rainfall than normal during the month June 2018.

7 out of 19 monitoring stations in the Ganges Basin were recorded rainfall above their monthly normal. One day maximum rainfall of 185.5mm was recorded at Panchagarh. Ten day consecutive maximum rainfall of 414mm was recorded at Panchagarh as well. The Basin received 15.47% less rainfall than monthly normal rainfall during the June 2018 .

In the Meghna basin, out of 17 rainfall monitoring stations, 5 stations were recorded more rainfall than the normal. Both one day maximum of 232 mm and the 10-day consecutive maximum rainfall of 690mm were recorded at Kanaighat in the month of June 2018. The Meghna basin as a whole received 14.59% less rainfall than the normal during the month of June-2018.

In the South Eastern Hill basin, out of 12 rainfall monitoring stations 7 stations received more rainfall than their normal rainfall during the month of June-2018. One day maximum of 265 mm was recorded at Narayanhat and the 10-day consecutive maximum rainfall of 655mm was recorded at Lama. The basin as a whole recorded 14.60% more rainfall than the normal during the month of June 2018.

Summary of the rainfall situation of the country is presented in the Table 2.5. Out of total 61 rainfall monitoring stations under FFWC system in the country, at 18 stations/points 10-day consecutive rainfall of more than 300mm were recorded. The maximum 1-day rainfall of 265mm was recorded at at Narayanhat and 10-day consecutive maximum rainfall of 690 mm was recorded at Kanaighat.

The Isohyet of the actual rainfall of the month of June-2018 is shown in the Figure 2.2.

2.5 JULY

The country, as a whole, experienced rainfall less than normal during the month, July 2018. All the basins namely the Brahmaputra, Ganges, Meghna and South Eastern Hill received less rainfall than their respective monthly normal values.

Important Rainfall Information for July 2018
Monthly Maximum at Teknaf: 1276.8 mm
1 day maximum at Cox's Bazar: 315 mm

Table 2.6: Summary of the rainfall situation during the month of July-2018

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	19	17	12
Average Rainfall (mm) of the basin:	239.0	344.6 265.41	360.0 500.11	703.6 655.13
%More(+)/Less(-) than the Normal:	-47.91%	-10.40%	-48.76%	-3.42%
Number of Stations above Normal Rainfall:	1	6	2	4
Highest 1-day Maximum Rainfall with Stations:	118mm Dalia	149.5mm Bhagykul	124mm Kanaighat	315mm Cox's Bazar
Number of Rain Fed Flood* Stations:	1	3	3	9
Name of Rain Fed Flood* Stations:	Dalia	Panchagarh, Bhygakul, Barguna	Kanaighat, Durgapur, Lorergarh	Noakhali, Narayanhat, Bandarban, Lama, Chittagong, Ramgarh, Sandwip, Cox's bazaar, Teknaf

*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 rainfall except Dhaka. The Basin received 47.91**%** less rainfall than normal during the month July 2018. Both the monthly 1-day maximum rainfall of 118mm and 10-day max of 350mm was recorded at Dalia, but the rainfall was still below normal in monthly scale. Total rainfall in Dhaka during July 2018 was recorded as 378 mm, above the monthly normal.

In Ganges basin, 13 out of 19 stations received less rainfall than their monthly normal and as a whole received 10.40**%** less rainfall than its normal during the month of July-2018. Both the one day maximum rainfall of 149.5 mm and 10-day consecutive maximum rainfall of 348.7 mm was recorded at Bhagykul.

In Meghna basin, 15 out of 17 stations were recorded less rainfall than their normal value of the month. The Basin recorded 48.76**%** less rainfall than normal during the month of July 2018. One day maximum rainfall of 124 mm as well as 10-day consecutive maximum rainfall of 400 mm were recorded at Kanaighat.

In South Eastern Hill basin, 4 out of 12 stations received more rainfall than their normal rainfall. The basin as a whole received near normal rainfall but slightly less by 3.42% than its normal during the month of July 2018. Both one day maximum rainfall of 315 mm and

10-day consecutive maximum rainfall of 806 mm was recorded at Cox's Bazar. This rainfall caused water logging and local flood at the area.

Summary of the country's rainfall situation for the month is presented in Table 2.6. Total 16 stations recorded more than 300 mm rainfall for consecutive 10-day period. Consecutive maximum 10-day and 1-day maximum rainfall of 806 mm and 315 mm respectively were recorded at Cox's Bazar. Rain fed flood situation developed at Bandarban, Barguna, Chittagong, Cox's Bazar, Dalia, Durgapur, Kanaighat, Lama, Lorergarh, Narayanhat, Noakhali, Panchagarh, Ramgarh and Sandwip.

A map with Isohyet of the actual rainfall of July-2018 is shown in the Figure 2.3.

2.6 AUGUST

Important Rainfall Information for August 2018
Monthly Maximum at Kanaighat: 609 mm
1 day maximum at Nakuagaon: 220 mm

The intensity of rainfall at most of the places over the country was significantly low during the month of August 2018. All four hydrological basins namely the Brahmaputra, Ganges, Meghna and South Eastern Hill received less rainfall than their respective monthly normal during the month of August, 2018. Table 2.7 represents the summary of rainfall situation of the month all through the country.

Table 2.7: Summary of the rainfall situation during the month of August-2018

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	19	17	12
Basin average rainfall at August, 2017(mm):	187.00	172.07	249.11	305.52
%More(+)/Less(-) than Normal:	-44.94%	-45.34%	-51.05%	-42.21%
No. of Stations above Normal Rainfall:	1	0	1	1
Highest 1-day Maximum Rainfall Stations:	Gaibandha (154 mm)	Panchagarh (123.5 mm)	Nakuaganj (220 mm)	Sandwip (173 mm)
No of Rain Fed Flood* Stations:	0	0	1	0

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

The Brahmaputra, the Ganges, the Meghna and the South Eastern Hill basins received 44.94%, 45.34%, 51.05% and 42.21% less rainfall respectively than normal for the month. 1 out of 13 in the Brahmaputra basin, none out of 19 in the Ganges basin, 1 out of 17 in the Meghna basin and 1 out of 12 rainfall stations in the South Eastern Hill the basin received more rainfall than their monthly normal. Among all monitoring stations, Nakuagaon in the

Meghna Basin has the daily highest rainfall record as well as record of being the only rain fed station of the month.

The Isohyet of the actual rainfall of the month of August-2018 is shown in the Figure 2.4.

2.7 SEPTEMBER

Important Rainfall Information for September 2018
Monthly maximum at Sunamganj : 922 mm
1-day maximum at Lorergarh : 240 mm

The country, as a whole, experienced less rainfall than normal during the month of September 2018. Among the four hydrological basins all received less rainfall than monthly normal; the Brahmaputra by 52.40 %, the Ganges by 55.23%, the Meghna by 23.38% and the South-Eastern Hill by 51.55%. Table 2.8 represents the summary of rainfall situation of the month all through the country.

Table 2.8: Summary of the rainfall situation during the month of September-2018

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	19	17	12
Basin average rainfall at September,2017(mm):	168.22	125.94	308.25	170.67
%More(+)/Less(-) than Normal:	-52.40	-55.23	-23.38	-51.55
No. of Stations above Normal Rainfall:	1	1	3	0
Highest 1-day Maximum Rainfall Stations:	Bogra (120 mm)	Dinajpur (75.5 mm)	Lorergarh (240 mm)	Rangamati (139 mm)
No of Rain Fed Flood* Stations:	1	0	4	0

*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 1 out of 13 stations in the Brahmaputra, 1 out of 19 stations in the Ganges and 3 out of 17 stations in the Meghna and none out of 12 stations in the South Eastern Hill basin received more rainfall than their monthly normal. Among all monitoring stations, Lorergarh in the Meghna basin is the daily highest (240 mm) rainfall recipient station.

The table also shows that 1 station in the Brahmaputra and 4 stations in the Meghna basin received more than 300 mm rainfall in 10-day period. As a result, some parts of Sylhet, Sunamganj, Netrokona were affected by rain feed flood during the month of September 2018.

The Isohyet of actual rainfall for September-2018 is shown in the Figure 2.5.

2.8 OCTOBER

Important Rainfall Information for October 2018

Monthly maximum at Lama: 415 mm

1 day maximum at Bandarban: 124 mm

10 day maximum at Lama: 369 mm

The country, as a whole, experienced rainfall less than normal during the month of October 2018. The Brahmaputra, the Ganges and the Meghna basins received significantly less rainfall than monthly normal, while the South Eastern Hill Basin received slightly more rainfall. Table 2.9 represents the summary of rainfall situation of the month all through the country.

Table 2.9: Summary of the rainfall situation during the month of October-2018

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	19	17	12
Average Rainfall (mm) of the basin:	46.34	71.98	85.01	184.53
%More(+)/Less(-) than the Normal:	-70.02	-43.72	-51.05	+0.60
Number of Stations above Normal Rainfall:	1	1	2	6
Highest 1-day Maximum Rainfall with Stations:	Serajganj (91.2 mm)	Patuakhali (80 mm)	Moulvi Bazar (98 mm)	Bandarban (124 mm)
Number of Rain Fed Flood* Stations:	0	0	0	2

*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, only 1 station recorded more rainfall than the normal and The Basin received 70.02% less rainfall than normal during the month October 2018. 1-day maximum rainfall of 91.2 mm was recorded at Serajganj.

In Ganges basin, out of 19 rainfall monitoring stations, only 1 station recorded more rainfall than the normal rainfall of the month. The basin as a whole received 43.72% less rainfall than the normal during the month. 1-day maximum rainfall of 80 mm was recorded at Patuakhali.

In the Meghna basin, out of 17 rainfall monitoring stations, 2 stations recorded more rainfall than the normal value of the month. The Basin received 51.05% less rainfall than monthly normal during the month. 1-day maximum rainfall of 98 mm was recorded at Moulvi Bazar.

In the South Eastern Hill basin, out of 12 rainfall monitoring stations 6 stations were recorded more rainfall than normal. The Basin as a whole recorded normal rainfall during the month. 1-day maximum rainfall of 124 mm was recorded at Bandarban, while 10-day maximum rainfall of 369 mm was recorded at Lama. 2 stations were recorded more than 300 mm rainfall in 10-day period and as a result only in this basin a short duration rain fed flood situation prevailed at a few places during October 2018

A map with the Isohyet of actual rainfall for the month of October-2018 is shown in the Figure 2.6.

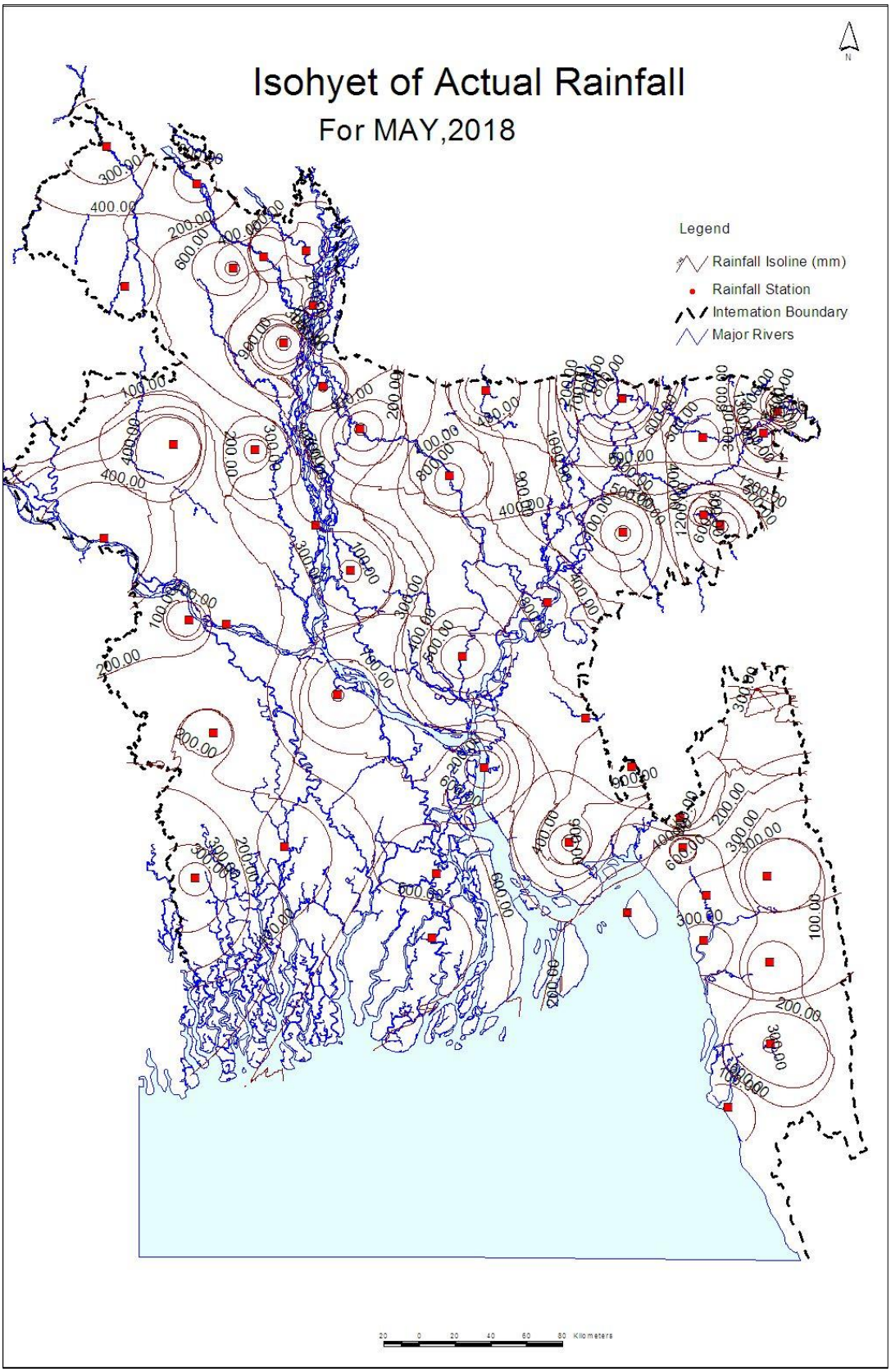


Figure 2.1 : Isohyet of Actual Rainfall (May-2018)

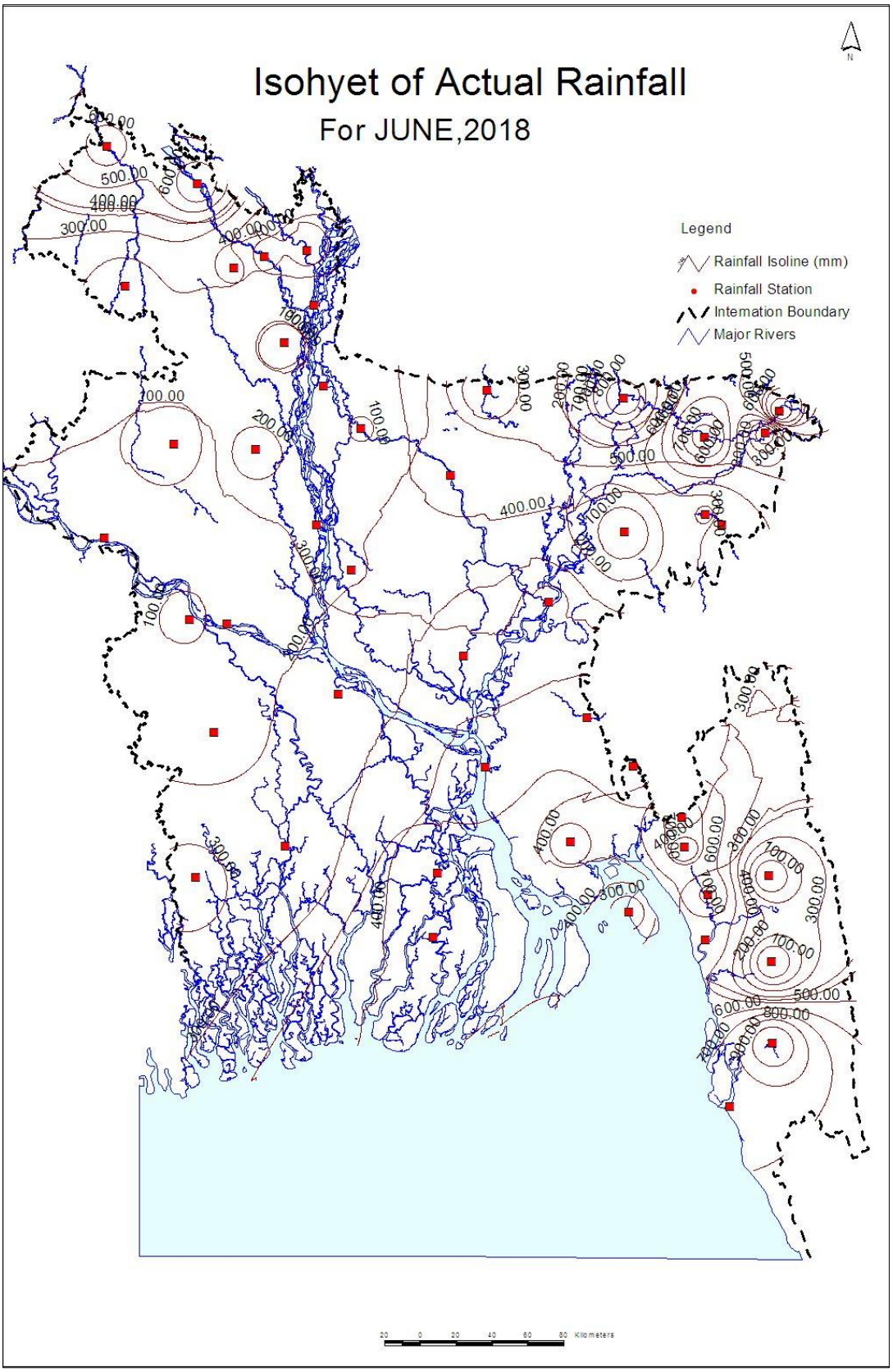


Figure 2.2 : Isohyet of Actual Rainfall (June-2018)

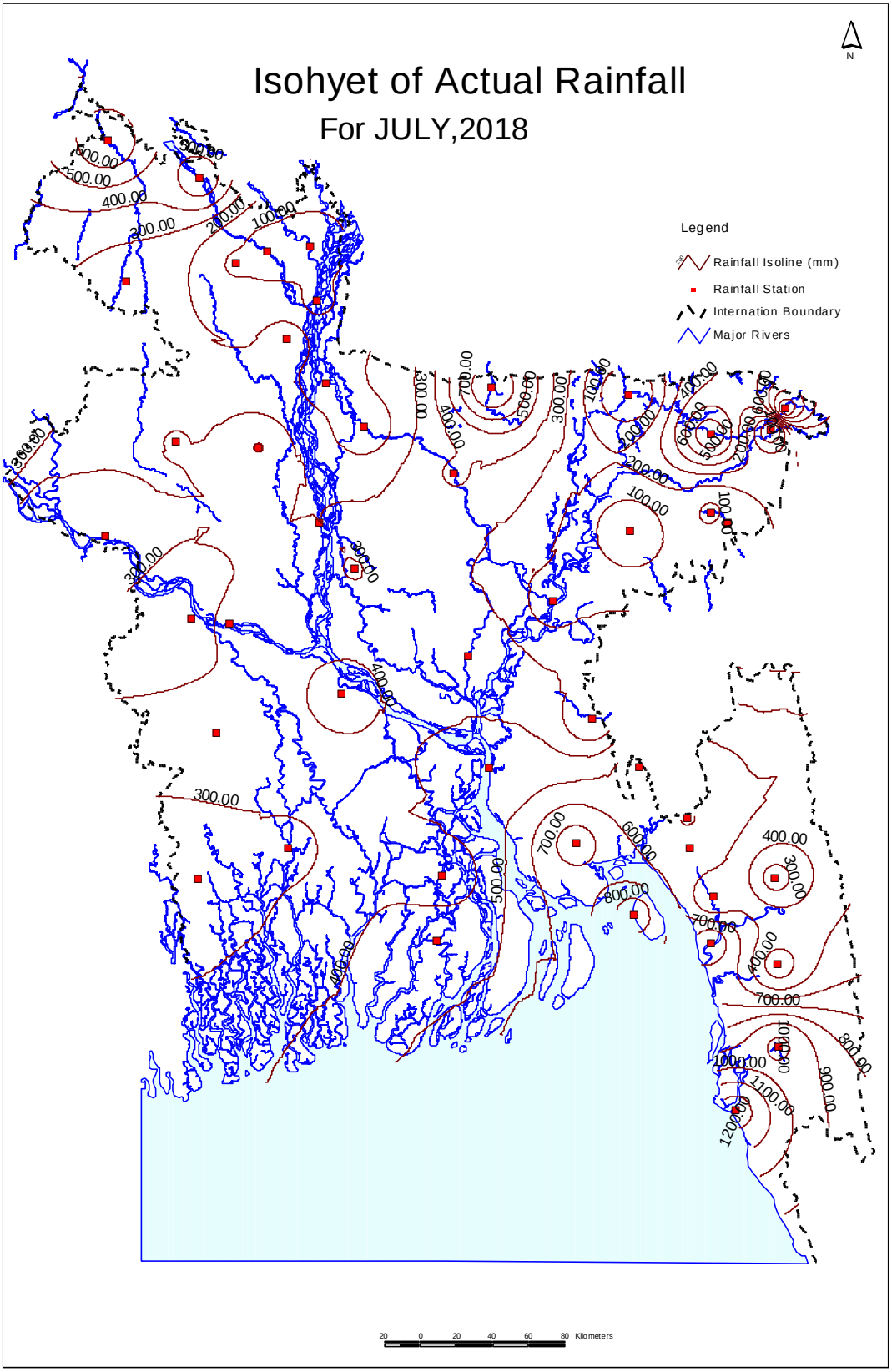


Figure 2.3 : Isohyet of Actual Rainfall (July-2018)

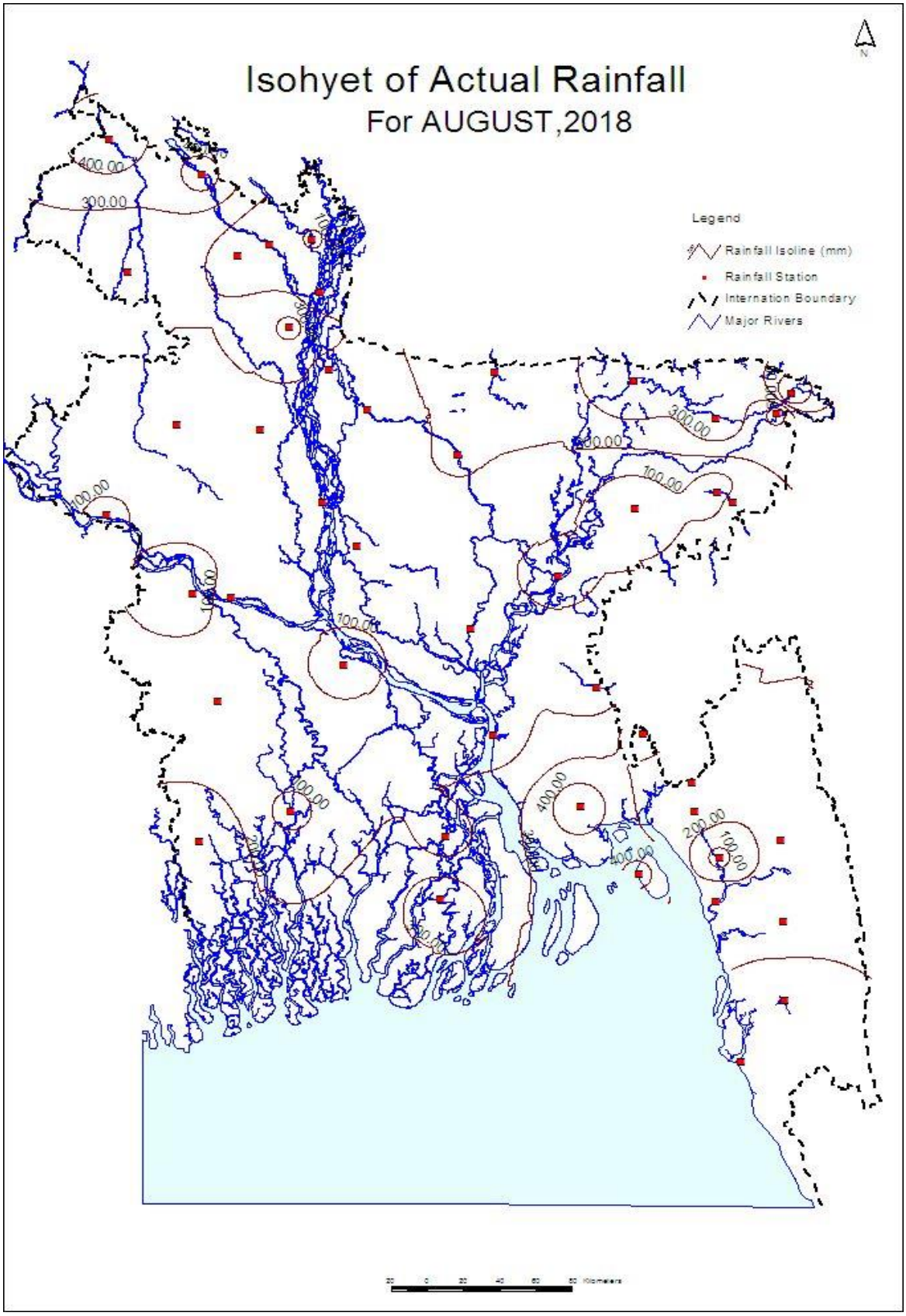


Figure 2.4 : Isohyet of Actual Rainfall (August-2018)

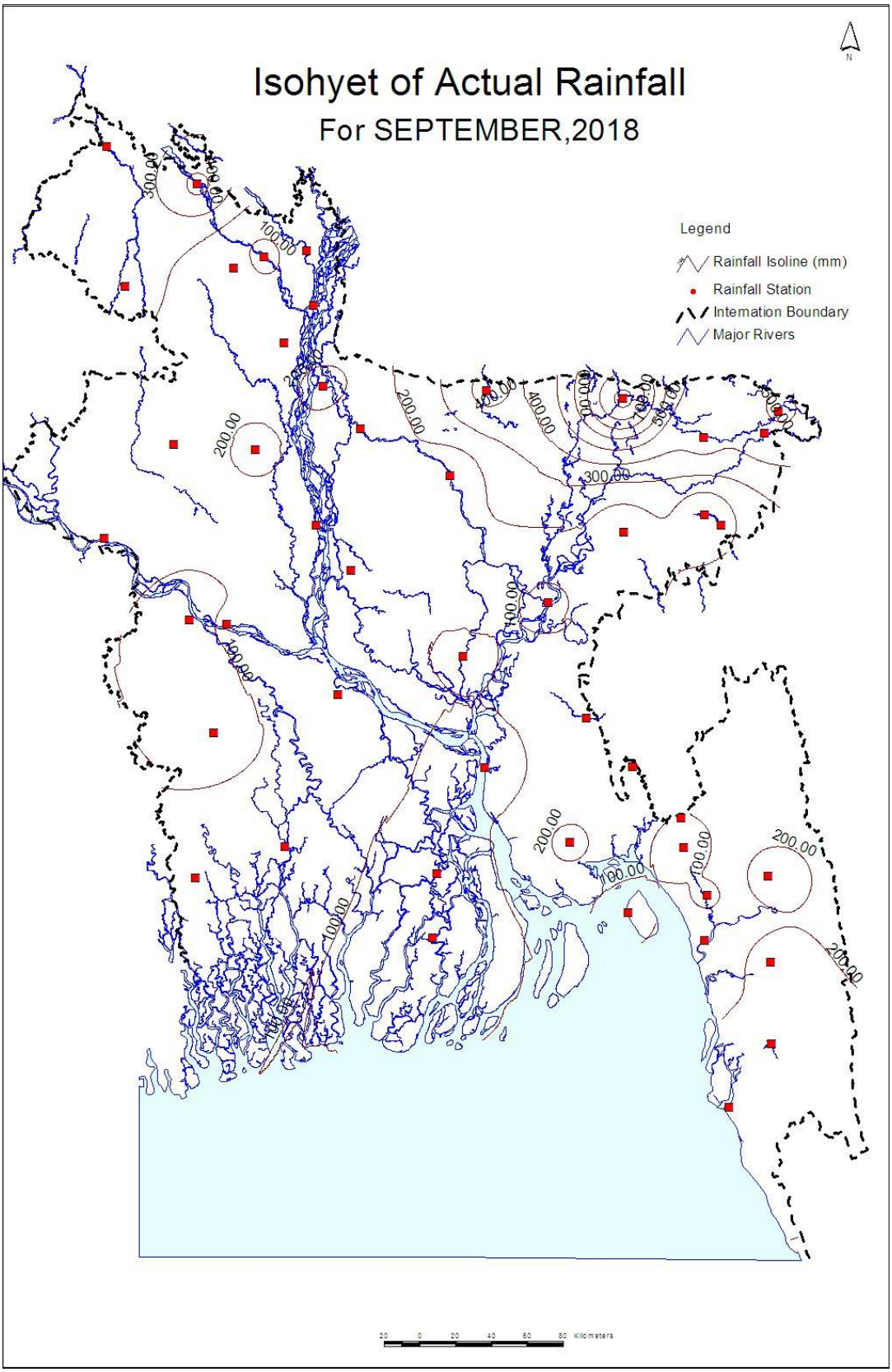


Figure 2.5 : Isohyet of Actual Rainfall (September-2018)

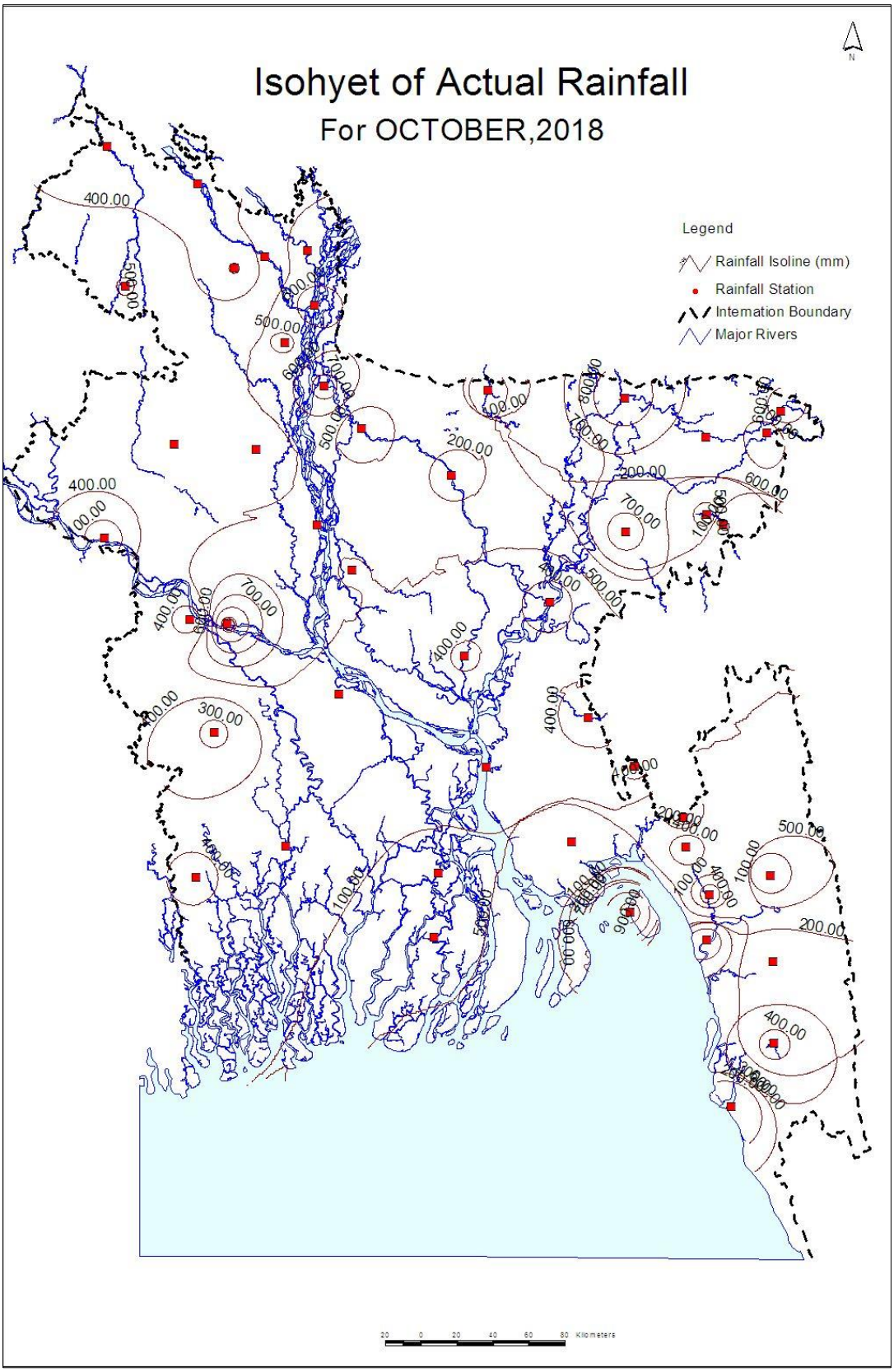


Figure 2.6 : Isohyet of Actual Rainfall (October-2018)

CHAPTER 3 : RIVER SITUATION

During the monsoon 2018, the flood was a normal one which stayed for medium duration in the Brahmaputra and the Meghna basin, while for short duration in the South Eastern Hill basin. The main lands of the Ganges basin did not experience any flood this year. The Brahmaputra basin first experienced the monsoon flood from the first week of July, while the Meghna and South-Eastern Hill basin from the second week of June, 2018. However, the Haor region of the Meghna basin was flooded during the pre-monsoon at second week of May and some higher lands of the basin were flooded for very short duration. Rise of water level was recorded in the upper portion of Ganges Basin in mid of June and peaked around mid-September. Basin wise WL situation is described in the following sections.

3.1 THE BRAHMAPUTRA BASIN

Out of 30 Water Level (WL) monitoring stations in this basin, at 07 stations, river WL crossed their respective Danger Levels (DL). Water Level of Brahamaputra Basin started rising from the fourth week of June 2018, for the first time in the monsoon, and caused a short duration of flood for this basin. In this monsoon Brahmaputra basin had experienced several peaks with two majors, one in July while another in September, which caused flood in this country in 2018. This flood situation lasted for around 10 days for the basin. As a result, low-lying areas of Kurigram, Nilphamari, Bogra, Serajgonj, Jamalpur and Tangail districts were mostly flooded for short to medium duration. A comparative statement of WL for current year 2018 and historical events of 2017 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 crossed the DL for one time during the monsoon-2018 at the 2nd week of July and flowed above DL for total 2 days. WL at Kurigram attained peak of 26.81 mPWD on 6th July which was 31 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 5 times during the monsoon, highest peak on 5th July with a WL of 52.71 mPWD, which was 31 cm above its DL (52.40m). At Dalia, it flowed above DL for 5 days throughout the monsoon period. At Kaunia, WL of the river Teesta did not cross the DL during the mosoon-2018, attained the peak of 28.50 mPWD on 18th of June which was 150 cm below the DL(30.0m) at this point.

The Jamuneswari at Badargonj

The WL of Jamuneswari river at Badargonj in monsoon-2018 attained the peak of 30.35 mPWD (DL 32.16m) on 8th July. During the whole monsoon this station flowed below DL.

The Ghagot at Gaibandha

The WL of Ghagot river at Gaibandha during the monsoon-2018 attained peak 21.51 mPWD on 17th September which was 19 cm below DL (21.70m). During the whole monsoon, this station flowed below DL.

The Karatoa at Chakrahimpur and Bogra

At Chakrahimpur, the Karatoa reached peak water level 19.46 mPWD on 18th August and flowed 69 cm below the DL (20.15m). During the whole monsoon, this station flowed below DL. At Bogra point, the Karatoa river did not cross its respective Danger Level with a peak flow of 14.78 mPWD on 1st August which was 154 cm 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, the WL of the Brahmaputra River attained the peak of 25.78mPWD on 18th September, which was 72 cm below the respective DL (26.50mPWD) at this point. Brahmaputra at Chilmari flowed below its DL(23.70 m) in 2018 monsoon. At Chilmari, the Brahmaputra reached peak water level 23.53 mPWD on 18th September and flowed 17 cm below the DL(23.70m).

The Jamuna at Fulchari, Bahadurabad, Sariakandi, Serajgonj, Kazipur and Aricha

The WL of river Jamuna at Fulchair, Bahadurabad, Sariakandi, Serajgonj & Aricha demonstrated similar trends like Brahmaputra at Noonkhawa and Chilmari. At Fulchari and Bahadurabad the Jamuna flowed above DL for 5 days with the peaks of 19.91 mPWD and 19.59 mPWD on 20th and 19th September respectively, which are both 9 cm above the DL (Fulchari 19.82m, Bahadurabad 19.50m) at these points. At these both point Jamuna crossed its DL on 16th September and continued till 20th September. At Sariakandi, the Jamuna crossed the respective DL (16.70m) in this monsoon like Bahadurabad station. It crossed the DL on 13th September and continued till 22th September for 10 days, with a peak of 16.91 mPWD on 20th September which was 21 cm above the DL (16.70 m). At Serajgonj, the Jamuna flowed below DL (13.35m) during the whole monsoon of 2018 with a peak of 13.34 mPWD on 8th July. At Kazipur, the WL of the Jamuna river crossed the Dl(15.24m) with a peak of 15.54 mPWD which is 30 cm above DL and flowed for 7 days during the 2018 monsoon.

At Aricha, the WL of the Jamuna river flowed below the DL (9.40m) during 2018 monsoon and the peak WL recorded was 9.22 mPWD on 18th September.

The Atrai at Baghabari

The WL of river Atrai at Baghabari flowed above DL (10.40m) on the month of September during 2018 monsoon for 6 days with the peak of 10.53 mPWD on 20th September which is 13 cm above the DL(10.40m) at this point.

The Dhaleswari at Elashin

The WL of river Dhaleswari at Elashin flowed above DL (11.40m) on the month of September during 2018 monsoon for 9 days with the peak of 11.73 mPWD on 20th September, which is 33 cm above the DL (11.40m) 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. At Jamalpur, the water level flowed below the DL (17.00m) with the recorded peak WL of 14.98 mPWD. At Mymensingh, the WL also remained below the DL (12.50m) during the whole monsoon. The peak WL recorded was 9.4 mPWD on 22nd September, which was 310 cm below the DL (12.5m) at this point.

The Lakhya Narayanganj

Lakhya River at Narayanganj flowed below DL (5.5 m) during monsoon 2018. It attained its monsoon peak of 4.95 mPWD on 12th September, which 55 cm above the 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 in this year. All the river around Dhaka city Flowed below their respective DLs. The Buriganga at Dhaka and the Balu at Demra recorded their highest peak of 4.64 mPWD (DL 6.0m) on 16th August, 4.92m (DL 5.75m) on 16th August respectively. The Turag at Mirpur did not cross its respective DL and flowed with a peak of 5.05 mPWD on 17th August which is 89 cm below the DL (5.94 mPWD). The water level of Tongi Khal at Tongi flowed below DL (6.08m).The peak WL recorded at this station was 5.13m on 16th August.

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 flowed below the DL with a peak of 7.44 mPWD on 22th September.

Comparative hydrographs for the year of 2018, 2017 & 1998 of few stations of the Brahmaputra basin are shown in Figures 3.1 – 3.16.

Table 3.1 : Comparison of Water Level (in mPWD) of 2018 and Historical Events of 2017 & 1998 of Some Important Stations in the Brahmaputra Basin.

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2018	2017	1998	2018	2017	98
1	Dharla	Kurigram	27.84	26.50	26.81	27.84	27.22	2	12	30
2	Teesta	Dalia	53.05	52.60	52.71	53.05	52.20	5	6	-
3	Teesta	Kaunia	30.52	29.20	28.50	29.95	29.91	0	NA	-
4	Jamuneswari	Badarganj	33.61	32.15	30.35	33.61	33.00	0	8	6
5	Ghagot	Gaibandha	22.81	21.70	21.51	22.55	22.30	0	15	51
6	Karatoa	Chakrahimpur	21.41	20.15	19.46	20.40	20.86	0	10	

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2018	2017	1998	2018	2017	98
7	Karatoa	Bogra	17.45	16.32	14.78	15.04	15.57	0	0	
8	Brahmaputra	Noonkhawa	28.10	26.50	25.78	27.39	27.35	0	3	-
9	Brahmaputra	Chilmari	25.07	23.70	23.53	24.87	24.77	0	14	22
10	Jamuna	Fulchari	21.13	19.82	19.91	21.03	-	5	NA	-
11	Jamuna	Bahadurabad	20.84	19.50	19.59	20.84	20.37	5	25	66
12	Jamuna	Sariakandi	19.07	16.70	16.91	17.96	-	9	24	
13	Jamuna	Kazipur	17.47	15.25	15.54	16.80	-	6	29	
14	Jamuna	Serajgonj	15.12	13.35	13.34	14.87	14.76	0	33	48
15	Jamuna	Aricha	10.76	9.40	9.22	10.16	10.76	0	12	68
16	Gur	Singra	13.67	12.65	12.27	13.67	-	0	24	-
17	Atrai	Baghabari	12.45	10.40	10.53	11.50	-	6	22	-
18	Dhaleswari	Elasin	12.52	11.40	11.73	12.52	-	9	31	-
19	Old Br.putra	Jamalpur	18.00	17.00	14.98	17.01	17.47	0	1	31
20	Old Br.putra	Mymensingh	13.71	12.50	9.4	12.03	13.04	0	0	33
21	Lakhya	Lakhpur	8.70	5.80	5.13	6.77	-	0	22	-
22	Buriganga	Dhaka	7.58	6.00	4.64	5.22	7.24	0	0	57
23	Balu	Demra	7.13	5.75	4.92	5.65	-	0	0	-
24	Lakhya	Narayangonj	6.93	5.50	4.95	5.74	6.93	0	10	71
25	Turag	Mirpur	8.35	5.94	5.05	5.88	7.97	0	0	70
26	Tongi Khal	Tongi	7.84	6.08	5.13	6.10	7.54	0	2	66
27	Kaliganga	Taraghat	10.39	8.38	7.44	9.34	-	0	14	-
28	Dhaleswari	Jagir	9.73	8.23	6.77	9.00	-	0	13	-
29	Dhaleswari	Rekabi Bazar	7.66	5.18	4.52	5.07	-	0	0	-
30	Banshi	Nayarhat	8.39	7.32	5.23	5.93	-	0	0	-

3.2 THE GANGES BASIN

In this basin out of 25 WL monitoring stations, all the stations flowed below their respective DLs during monsoon 2018 except Khulna. The Pashure river at Khulna station flowed above DL for 27 days. The details of the river WL situation in this basin are described below:

The Karatoa at Panchagarh

The Karatoa river at Panchgarh showed rise and fall during the monsoon 2018 and flowed below the DL (70.75m) with a peak flow of 69.95 mPWD on 5th July, which was 8 cm below the respective DL (70.75 m)

The Punarbhaba at Dinajpur

The water level of river Punarbhaba at Dinajpur showed rise and fall during the monsoon 2018 and flowed below the DL. The peak WL recorded was 32.07 mPWD on 7th July, which was 143 cm below its DL (33.50m).

The Tangon at Thakurgaon

The Tangon river is flashy in nature and showed various small peaks during the monsoon. It flowed below danger level with highest peak of 49.20 mPWD on 24th August, which was 120 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 also showed similar trend of Punarbhaba and flowed below the DL. It had a peak value of WL 38.97 mPWD on 6th July. The Atrai at Mohadevpur also flowed below the DL with peak of 17.25 mPWD on 8th July which is 134 cm below the DL (18.59m).

The Mohananda at Chapai-Nawabgonj

This river showed a gradual rise and fall in water level throughout the monsoon. It attained its peak of 20.04 m on 17st September, which was 96 cm below its DL (DL21.00m) at Chapai-Nawabgonj. The Mohananda at Chapai-Nawabgonj flowed below the DL during the whole monsoon 2018.

The Little Jamuna at Naogaon

The Little Jamuna river at Naogaon flowed below its danger level during 2018 monsoon. It attained its peak 13.64 mPWD on 17th September which was 160 cm below 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 in July as well as in mid of August but did not cross the respective DL. At Pankha the peak water level recorded was 21.65 mPWD on 17th September, which was only 85 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 17.34 mPWD on 17th September, which was 116 cm 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 13.69 mPWD on 17th September which was 56 cm below its DL (14.25m) at this point.

The Ganges/ Padma at Goalundo

At Goalondo River, WL flowed below the DL during 2018 monsoon. The WL of the river Padma at Goalondo attained its yearly peak of 8.64 mPWD on the 19th September which was only 1 cm below its DL (8.65 m) at this point.

The Padma at Bhagyakul

The river Padma has tidal influence at this point. At Bhagyakul, the WL of river Padma flowed below the DL. The WL of the river attained its highest yearly peak water level of 6.13 mPWD on 21st September which was only 17 cm below the DL (6.30m) at Bhagyakul.

The Gorai at Gorai Railway Bridge and Kamarkhali

The WL of river Gorai at Gorai Railway Bridge and Kamarkhali showed steady rise and fall during July-August period during the monsoon in 2018. 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 11.81 mPWD on 18th September, which was 94cm below the DL (12.75m) at Gorai Rail Bridge. Gorai river at Kamarkhali also flowed below the DL. The WL of the river attained its highest yearly peak of 7.75 mPWD on 18th September, which was 45cm 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 throughout the monsoon. The WL attained its highest peak of 3.36 m on 16th August, which was 81 cm below the DL (4.17m) at Madaripur.

Kobodak at Jhikorgacha

Water Level at Jikorgaha flowed below the DL during the whole monsoon with a yearly peak of 4.32 mPWD on 9th August which was 78cm below the DL (5.10m) at this point.

Comparative hydrographs for few important stations for the year of 2018, 2017 & 1998 of the Ganges basin are shown in figures 3.17 to 3.23.

Table 3.2 : Comparison of Water Level (in mPWD) of 2018 and Historical Events of 2017 & 1998 of Some Important Stations in Ganges Basin.

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger Level		
					2018	2017	1998	2018	2017	98
1	Karatoa	Panchgarh	72.65	70.75	69.95	70.81	-	0	1	-
2	Punarbhaba	Dinajpur	34.40	33.50	32.07	34.30	34.09	0	4	3
3	Ich-Jamuna	Phulbari	30.47	29.95	27.59	30.12	-	0	3	-
4	Tangon	Thakurgaon	51.30	50.40	49.20	51.30	-	0	3	-
5	Upper Atrai	Bhusirbandar	41.10	39.62	38.97	40.35	-	0	3	-
6	Mohananda	Rohanpur	23.83	22.00	20.33	22.70	-	0	14	-
7	Mohananda	Chapai-Nawabganj	23.01	21.00	20.04	21.16	-	0	6	-
8	Little Jamuna	Naogaon	16.20	15.24	13.64	16.06	-	0	13	-
9	Atrai	Mohadebpur	19.89	18.59	17.25	19.38	-	0	7	-
10	Ganges	Pankha	24.14	22.50	21.65	21.48	24.14	0	0	66
11	Ganges	Rajshahi	20.00	18.50	17.34	17.54	19.68	0	0	28
12	Ganges	Hardinge Bridge	15.19	14.25	13.69	13.85	15.19	0	0	27
13	Padma	Goalundo	10.21	8.65	8.64	9.71	10.21	0	20	68
14	Padma	Bhagyakul	7.50	6.30	6.13	6.81	7.50	0	20	72
15	Padma	Sureswar	7.50	4.45	4.41	5.04	-	0	13	-

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger Level		
					2018	2017	1998	2018	2017	98
16	Gorai	Gorai Rail Bridge	13.65	12.75	11.81	12.21	13.45	0	0	25
17	Gorai	Kamarkhali	9.48	8.20	7.75	8.24	NA	0	3	NA
18	Ichamati	Sakra	4.60	3.96	3.80	3.67	-	0	0	-
19	Mathabhanga	Chuadanga	12.67	12.05	8.27	8.67	-	0	0	-
20	Mathabhanga	Hatboalia	15.13	14.50	10.42	10.62	-	0	0	-
21	Kobodak	Jhikorgacha	5.59	5.10	4.32	4.65	NA	0	29	NA
22	Kumar	Faridpur	8.76	7.50	4.60	5.22	-	0	0	-
23	Arialkhan	Madaripur	5.80	4.17	3.36	3.89	NA	0	0	NA
24	Kirtonkhola	Barisal	3.20	2.55	-	2.69	-	-	1	-
25	Pashure	Khulna	3.48	3.04	3.45	3.48	-	24	31	-

3.3 THE MEGHNA BASIN

Most of the rivers of this basin entered from the hilly catchment of India (Barak basin, Tripua and Meghalaya) and are flashy in nature. Out of 26 WL monitoring stations in the Meghna basin, 13 stations flowed above their respective DLs, which are Surma River at Kanaighat, Sylhet and Sunamganj, Kushyara River at Amalshid, Sheola and Sherpur, Sarigowain river at Sarighat, Manu river at Manu RB, Moulvi Bazar, Khowai river at Habigonj and Ballah, Dhalai river at Kamalganj, Bhugai river at Nakuagaon, and Jadukata river at Lorergarh for 2 days to 18 days. As a result, floods of short to medium duration were experienced in the districts of Sylhet, Sunamgonj, Habiganj and Moulvi Bazar during the monsoon 2018.

Out of the stations which crossed DL this year, 4 stations crossed DL on Kushiyara, Manu and Khowai rivers during the pre-monsoon period at the second week of May. During this time 12 stations on the Surma-Kushiyara, Manu, Khowai and Kangsha rivers crossed and flowed above Pre-Monsoon Danger Levels (PMDL). No stations crossed PMDL during March-April. Table 3.3 presents comparative statistics of river situation for some selected stations on major rivers of Meghna basin during 2018 pre-monsoon with that of years 2010 and 2017 (historical pre-monsoon flash flood years).

Table 3.3 : Comparative WL of Selected Stations in the Meghna Basin for 15 Mar-15 May, 2018

Sl. No.	River	Station	Monsoon Danger Level (m PWD)	Pre-Monsoon Danger Level (m PWD)	Peak of the Duration (m PWD)			Days above Monsoon Danger Level			Days above Pre-Monsoon Danger Level
					2010	2017	2018	2010	2017	2018	2018
1	Surma	Kanaighat	13.20	11.35	14.35	14.49	12.91	13	06	-	7
2	Surma	Sylhet	11.25	8.75	10.88	11.31	9.77	-	03	-	7
3	Surma	Sunamganj	8.25	6.5	8.05	8.10	5.43	-	-	-	0

Sl. No.	River	Station	Monsoon Danger Level (m PWD)	Pre-Monsoon Danger Level (m PWD)	Peak of the Duration (m PWD)			Days above Monsoon Danger Level			Days above Pre-Monsoon Danger Level
					2010	2017	2018	2010	2017	2018	2018
4	Kushiyara	Amalshid	15.85	13.50	15.51	16.03	15.08	-	03		8
5	Kushiyara	Sheola	13.50	11.15	13.94	13.89	12.95	03	06	-	9
6	Kushiyara	Sherpur	9.0	8.25	8.80	9.03	**9.06**	0	1	**02**	7
7	Kushiyara	Markuli	8.50	6.40	7.70	8.27	**7.76**	0	0	0	9
8	Sarigowain	Sarighat	12.80	11.15	13.38	13.35	10.1	03	03	-	0
9	Manu	Manu Rly Br	18.00	16.90	16.75	17.40	18.20	-	-	01	2
10	Manu	Moulvi Bazar	11.75	10.00	10.49	11.73	11.89	-	-	01	7
11	Khowai	Habiganj	9.50	9.10	7.95	10.60	9.90	-	05	01	1
12	Khowai	Ballah	21.80	21.80	-	22.96	23.26	-	08	03	3
13	Someswari	Durgapur	13.00	11.25	11.78	12.02	11.44	-	-	-	1
14	Kangsha	Jariajanjail	11.00	6.80	6.53	9.71	9.41	-	-	-	11
15	Upper Meghna	Bhairab Bazar	6.25	6.25	3.48	3.57	3.05	-	-	-	0
16	Gumti	Comilla	11.75	11.75	7.37	9.35	9.22	-	-	-	0

The river situations with respect to Monsoon Danger Levels (DL) are described as follows:

The Surma at Kanaighat

Water Level in the Surma river started to rise from mid of April and it showed rapid rise and fall in several times. FFWC monitors 3 stations on the Surma River.

As a flashy river, WL of the river Surma at Kanaighat in Sylhet district crossed the DL several times from April to September. First it flowed above its DL at Kanaighat from 13th June to 22th June for 10 days, then 24th June to 25th June for 2 days and finally from 2nd July to 6th July for 5 days.The Surma at Kanaighat was above DL for 17 days in total during the whole monsoon. . It attained its highest peak of 14.77 mPWD on 14th June which was 157cm above the DL (13.20 m).

Surma at Sylhet

The WL of river Surma at Sylhet showed similar trend like Kanaighat. The Surma at Sylhet flowed below its DL (11.25m). It attained the monsoon peak WL of 11.07 mPWD on 18th June.

The Surma at Sunamgonj

The Surma at Sumangnaj showed rapid rise and fall in different period of the monsoon. The WL of the river Surma at Sunamgonj crossed the DL on 4th July and continued till 6th July for 3 days in total during the whole monsoon. The WL of Surma at Sunamgonj recorded its highest peak of 8.47 mPWD on 5th July which was 22 cm 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 2018. At Amalshid water level of Kushiyara crossed the DL on 13th June and continued till 21th June. The Kushiyara at Amalshid flowed above the DL for 9 days in total during the whole monsoon. At Amalshid, Kushiyara attained the peak flow of 17.4 mPWD on 16th June which was 155 cm above the DL (15.85 mPWD).

At Sheola, it also crossed the DL several times. It flowed above DL from 14th June to 20th June for 7 days in total during the whole monsoon. It attained its highest peak of 14.09 mPWD on 16th June which was 59 cm above its DL (13.50 m).

At Sherpur the river flowed similar trend like Sheola. It first crossed the DL on 11th May to 12th May for 2 days in total during the whole monsoon. It attained its highest peak of 9.06 mPWD on 11th May which was 6 cm above its DL (9.00 m)

The Sarigowain at Sarighat

As the flashy river the Sarighat on Saigowain River in Sylhet district showed several peaks during the monsoon 2018 and crossed the respective DL. This station first crossed the DL on 13th June and then again on 4th July, 2 days in total during the whole monsoon. It attained monsoon highest peak of 13.04 mPWD on 4th July which was 24 cm 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 sharp peaks during the monsoon-2018. The WL of Manu river at Manu Railway Bridge crossed the DL 2 times during monsoon 2018. It first crossed the DL on 9th May and then again on 12th June to 17th June and was above DL for 7 days throughout the whole monsoon. The WL at Manu Railway Bridge had a peak flow of 19.41 mPWD on 13th June which was 141 cm above the DL(18.0 m).

At Moulvibazar the WL of Manu crossed the DL 2 times during monsoon 2018. It first crossed the DL on 5th May, then again on 14th June which continued till 18th June and was above DL for 6 days in total during the whole monsoon. It attained its highest peak of 12.95 mPWD on 16th June which was 120 cm above its DL(11.75m) at this point.

The Khowai at Habigonj and Ballah

The Khowai at Habigonj as well as Ballah showed several peaks during the monsoon 2018. The Khowai at Habiganj first crossed the DL on 8th May then on 18th May to 19th may, on 21st of May and finally from 13th June to 16th June with total 9 days above DL throughout the monsoon. The WL recorded as its yearly highest peak was 11.5 mPWD on 19th May which was 200 cm above its DL (9.50 m).

The Khowai at Ballah crossed the DL a number of times including 7th May to 10th May, then again on 18th May to 20th May, from 10th June 17th June, 19th to 20th June, 4th July and finally on 17th August for 18 days from March to October. The highest peak was 24.31 mPWD which attained on 13th June which was 267 cm above the DL (21.64 m).

The Dhalai at Kamalgonj

The Dhalai at Kamalgonj also crossed the DL a number of times including 8th May, 13th June and finally 15th June to 16th June for 4 days in total during the 2018 monsoon. The highest peak was 20.03 mPWD which attained on 15th June which was 21 cm above the DL(19.82 m).

The Bhugai at Nakuagaon

As flashy river the Bhugai at Nakuagaon in Sherpur district recorded sharp rise & fall with several peaks in August and September. It flowed above its DL for only 1 day during monsoon 2018 on 24th August. It attained monsoon highest peak of 23.31 mPWD on 24th August which was 91 cm above its DL (22.40m) at this point.

The Jadukata at Lorergarh

Like other flashy rivers in the North-east region, the Jadukata showed several peaks during the monsoon 2018. It crossed its DL for three times in July and September. First it crossed the DL on 2nd July, then on 4th July and finally on 11th September for 3 days in total above the DL in this monsoon. It attained monsoon highest peak of 8.73 mPWD on 2nd July which was 20 cm above its DL (8.53 m).

The Someswari at Durgapur

As the flashy river the Durgapur in Netrokona district, showed rise and fall during the monsoon 2018 and flowed below its DL (13.0 m). It attained monsoon highest peak of 12.8 mPWD on 11th September.

The Kangsha at Jariajanjail

As flashy river the Kangsha at Jariajanjail in Netrokona district showed rise and fall during the monsoon-2018 and flowed below the DL (9.75m). It attained its yearly highest peak of 9.51 mPWD on 3rd August.

The Titas at Brahmanbaria

The Titas River at B. Baria point flowed below its DL (5.5m) during the monsoon 2018. It attained monsoon peak of 4.03 mPWD on 16th July.

Comparative hydrographs for few stations the year of 2018, 2017 & 1998 of rivers of the Meghna basin are shown in figures 3.24 to 3.37.

Table 3.4 : Comparison of Water Level (in mPWD) of 2018 and Historical Events of 2017 & 1998 of Some Important Stations in Meghna Basin.

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2018	2017	1998	2018	2017	1998
1	Surma	Kanaighat	15.26	13.20	14.77	14.51	15.00	17	92	73
2	Surma	Sylhet	12.44	11.25	11.07	11.70	11.72	0	11	14
3	Surma	Sunamgonj	9.75	8.25	8.47	9.19	8.90	3	15	56
4	Kushiyara	Amalshid	18.28	15.85	17.40	17.34	17.60	9	76	54
5	Kushiyara	Sheola	14.60	13.50	14.09	14.57	14.14	7	88	37
6	Kushiyara	Sherpur	9.68	9.00	9.06	9.45	NA	2	76	NA
7	Kushiyara	Markuli	8.51	8.50	7.76	8.00	-	0	0	-
8	Sarigowain	Sarighat	14.48	12.80	13.04	13.60	-	2	9	-
9	Manu	Manu RB	20.42	18.00	19.41	19.05	18.63	7	6	6
10	Manu	Moulvi Bazar	13.25	11.75	12.95	12.56	11.68	6	11	0
11	Khowai	Ballah	26.12	21.80	24.31	24.02	-	18	34	-
12	Khowai	Habiganj	12.30	9.50	11.50	12.30	11.44	9	18	8
13	Dhalai	Kamalganj	21.18	19.82	20.03	20.45	-	4	9	-
14	Old Surma	Derai	7.75	7.00	6.92	7.48	-	0	37	-
15	Baulai	Khaliajuri	9.52	8.50	5.96	7.39	-	0		-
16	Bhugai	Nakuagaon	26.01	22.40	23.31	24.86	-	1	3	-
17	Jadukata	Lorergarh	11.85	8.53	8.73	10.57	-	3	5	-
18	Someswari	Durgapur	15.20	13.00	12.80	14.45	-	0	5	-
19	Kangsha	Jariajanjail	13.37	11.00	9.51	11.59	NA	0	82	NA
20	Titas	B.Baria	6.50	5.50	4.03	6.01	-	0	30	-
21	Upper Meghna	Bhairab Bazar	7.78	6.25	4.48	6.05	7.33	0	0	68
22	Meghna	Narsingdi	7.01	5.70	4.27	5.32	-	0	0	-
23	Meghna	Meghna Bridge	6.76	5.03	3.81	4.95	-	0	0	-
24	Gumti	Comilla	13.56	11.75	10.53	11.78	12.79	0	1	17
25	Gumti	Debiddar	9.98	8.50	7.06	8.67	-	0	2	-
26	Meghna	Chandpur	5.35	4.00	4.07	4.59	-	4		-

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 and most of the rivers show similar behavior during monsoon flood. The WL of the monitoring rivers crossed their respective DLs several times throughout the monsoon-2018. Due to flashy nature, multiple short duration floods occurred at some

places of Chittagong, Feni, Bandarban, Cox's Bazar during the monsoon 2018. 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-2018 and historical events of 2017 and 1998 for this basin are shown in the Table 3.4.

The Muhuri at Parshuram

The Muhuri river in Feni, Noakhali district is a flashy which flowed above the DL several times including 12th June to 14th June, 25th June, 3rd July and finally on 2nd August for 6 days in total during the whole monsoon. It attained its highest peak 16.30 mPWD on 13th June which was 330 cm 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 first crossed DL on 11th June to 13th June and then from 24th July to 25th July for 5 days in total from June to September during the monsoon. It attained its peak of 16.92 mPWD on 12th June which was 167 cm above the DL (15.25 m) at Narayanhat.

The Halda at Panchpukuria

The Halda at Panchpukuria first crossed the DL on 12th June for only 2 days during the whole monsoon. It attained its highest peak of 10.90 mPWD on 12th June which was 140 cm above its DL (9.50 m).

The Sangu at Bandarban and Dohazari

The Sangu is also a flashy river which showed several peaks during flood period. The river crossed the DL at Bandarban three times in this monsoon-2018. It first crossed the DL on 11th june to 12th June and then was above DL from 3rd July to 4th July. In total, this station was above DL for 2 days. The peak recorded was 15.85 mPWD on 3rd July which was 60 cm above its DL (15.25m). At Dohazari also the Sangu was above DL for 3 days with 1st crossing of danger mark on 11th June and then again on 3rd July to 4th July. At Dohazari the highest peak was recorded 7.50 mPWD on 12th June which was 50 cm above its danger mark (7.00 m) at this point.

The Matamuhuri at Lama and Chiringa

The river observed several peaks in the monsoon-2018 like Sangu River. At Lama, the Matamuhuri River crossed the DL 3 times with 1st crossing on 11th June then again on 15th June and 3rd July. It was above DL for 4 days in total during the whole monsoon. At Lama the peak recorded was 13.29 mPWD on 12th June which was 104 cm above its DL (12.25m). The Matamuhuri at Chiringa crossed the DL 3 times during the monsoon. At Chiringa station the Matamuhuri River was above DL from 11th June to 12th June, 15th June and 24th July. It was above DL for 4 days in total during the whole monsoon. At Chiringa the peak recorded was 7.10 mPWD on 12th June which was 135 cm above its DL (6.25m).

The Feni at Ramgarh

The WL of river Feni at this point observed several peaks and flowed above its DL for 2 days during the monsoon-2018. The highest peak WL attained by the river was 18.36 mPWD on 13th June which was 99 cm above its DL (17.35m) at this point.

Table 3.5 : Comparison of Water Level of 2018 (in mPWD) and Historical Events of 2017 and 1998 of Some Important Station in South Eastern Hill Basin.

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2018	2017	98	2018	2017	98
1	Muhuri	Parshuram	16.33	13.00	16.30	15.20	14.60	6	5	9
2	Halda	Narayanhat	19.30	15.25	16.92	16.85	16.57	5	11	21
3	Halda	Panchpukuria	12.54	9.50	10.90	9.70	10.44	2	2	4
4	Sangu	Bandarban	20.70	15.25	15.85	16.60	15.25	2	3	1
5	Sangu	Dohazari	9.05	7.00	7.50	7.79	7.42	3	3	2
6	Matamuhuri	Lama	15.46	12.25	13.29	13.79	13.05	4	5	2
7	Matamuhuri	Chiringa	7.32	6.25	7.10	7.32	6.85	6	10	5
8	Feni	Ramgarh	21.42	17.35	18.36	16.20	17.50	2	0	1
9	Karnaphuli	Chittagong	4.98	4.60	-	-	-	-	-	-

Comparative hydrographs for the year of 2018, 2017 and 1998 of few stations of the South Eastern Hill Basin are shown in Figures 3.38 to 3.45.

3.5 PEAK AND RECORDED HIGHEST WATER LEVELS

The peak water level with dates of all the water level monitoring stations under FFWC during the monsoon 2018 as well as date of attaining recorded highest levels of some stations are shown in the following tables. No station exceeded the previously RHWL in 2018.

Table 3.6 : Recorded Peak Water Level (in mPWD) with Dates during the Monsoon-2018

SL No	River name	Station	Peak WL-2018	Date
	BRAHMAPUTRA BASIN			
1	DHARLA	KURIGRAM	26.81	06/07/18
2	TEESTA	DALIA	52.71	05/07/18
3	TEESTA	KAUNIA	28.50	18/06/18
4	JAMUNESWARI	BADARGANJ	30.35	08/07/18
5	GHAGOT	GAIBANDHA	21.51	17/09/18
6	KARATOA	CHAK RAHIMPUR	19.46	18/08/18
7	KARATOA	BOGRA	14.78	01/08/18
8	BRAHMAPUTRA	NOONKHAWA	25.78	18/09/18
9	BRAHMAPUTRA	CHILMARI	23.53	18/09/18
10	JAMUNA	FULCHARI	19.91	20/09/18
11	JAMUNA	BAHADURABAD	19.59	19/09/18
12	JAMUNA	SARIAKANDI	16.91	20/09/18
13	JAMUNA	KAZIPUR	15.54	09/07/18
14	JAMUNA	SERAJGANJ	13.34	08/07/18
15	JAMUNA	ARICHA	9.22	18/09/18

SL No	River name	Station	Peak WL-2018	Date
16	GUR	SINGRA	12.27	09/07/18
17	ATRAI	BAGHABARI	10.53	20/09/18
18	DHALESWARI	ELASIN	11.73	20/09/18
19	OLD BRAHMAPUTRA	JAMALPUR	14.98	20/09/18
20	OLD BRAHMAPUTRA	MYMENSINGH	9.40	22/09/18
21	LAKHYA	LAKHPUR	5.13	12/08/18
22	BURIGANGA	DHAKA	4.64	16/08/18
23	BALU	DEMRA	4.92	16/08/18
24	LAKHYA	NARAYANGONJ	4.95	12/09/18
25	TURAG	MIRPUR	5.05	17/08/18
26	TONGI KHAL	TONGI	5.13	16/08/18
27	KALIGANGA	TARAGHAT	7.44	22/09/18
28	DHALESWARI	JAGIR	6.77	23/09/18
29	DHALESWARI	REKABI BAZAR	4.52	14/08/18
30	BANSHI	NAYARHAT	5.23	23/09/18
GANGES BASIN				
31	KARATOA	PANCHAGARH	69.95	05/07/18
32	PUNARBHABA	DINAJPUR	32.07	07/07/18
33	ICH-JAMUNA	PHULBARI	27.59	12/09/18
34	TANGON	THAKURGAON	49.20	24/08/18
35	UPPER ATRAI	BHUSIRBANDAR	38.97	06/07/18
36	MOHANANDA	ROHANPUR	20.33	17/09/18
37	MOHANANDA	CHAPAI-NAWABGANJ	20.04	17/09/18
38	LITTLE JAMUNA	NAOGAON	13.64	17/09/18
39	ATRAI	MOHADEBPUR	17.25	08/07/18
40	GANGES	PANKHA	21.65	17/09/18
41	GANGES	RAJSHAHI	17.34	17/09/18
42	GANGES	HARDINGE BRIDGE	13.69	17/09/18
43	PADMA	GOALONDO	8.64	19/09/18
44	PADMA	BHAGYAKUL	6.13	21/09/18
45	PADMA	SURESWAR	4.41	16/08/18
46	GORAI	GORAI RAIL BRIDGE	11.81	18/09/18
47	GORAI	KAMARKHALI	7.75	18/09/18
48	ICHAMATI	SAKRA	3.80	09/05/18
49	MATHABHANGA	CHUADANGA	8.27	18/09/18
50	MATHABHANGA	HATBOALIA	10.42	18/09/18
51	KOBADAK	JHIKARGACHA	4.32	09/08/18
52	KUMAR	FARIDPUR	4.60	22/09/18
53	ARIALKHAN	MADARIPUR	3.36	16/08/18
54	KIRTONKHOLA	BARISAL	-	-
55	PASHURE	KHULNA	3.45	14/08/18
MEGHNA BASIN				
56	SURMA	KANAIGHAT	14.77	14/06/18
57	SURMA	SYLHET	11.07	18/06/18
58	SURMA	SUNAMGONJ	8.47	05/07/18
59	KUSHIYARA	AMALSHID	17.40	16/06/18
60	KUSHIYARA	SHEOLA	14.09	16/06/18
61	KUSHIYARA	SHERPUR	9.06	11/05/18
62	KUSHIYARA	MARKULI	7.76	12/05/18
63	SARIGOWAIN	SARIGHAT	13.04	04/07/18
64	MANU	MANU RAILY BRIDGE	19.41	13/06/18
65	MANU	MOULVI BAZAR	12.95	16/06/18
66	KHOWAI	BALLAH	24.31	13/06/18
67	KHOWAI	HABIGANJ	11.50	19/05/18

SL No	River name	Station	Peak WL-2018	Date
68	DHALAI	KAMALGONJ	20.03	15/06/18
69	OLD SURMA	DERAI	6.92	07/07/18
70	BAULAI	KHALIAJURI	5.96	06/07/18
71	BHUGAI	NAKUAGAON	23.31	24/08/18
72	JADUKATA	LORERGARH	8.73	02/07/18
73	SOMESWARI	DURGAPUR	12.8	11/09/18
74	KANGSHA	JARIAJANJAIL	9.51	03/08/18
75	TITAS	B. BARIA	4.03	16/07/18
76	MEGHNA	BHAIRAB BAZAR	4.48	16/07/18
77	MEGHNA	NARSINGDI	4.27	15/08/18
78	MEGHNA	MEGHNA BRIDGE	3.81	28/10/18
79	GUMTI	COMILLA	10.53	21/05/18
80	GUMTI	DEBIDDAR	7.06	21/05/18
81	MEGHNA	CHANDPUR	4.07	07/08/18
	SOUTH EASTERN HILL BASIN			
82	MUHURI	PARSHURAM	16.30	13/06/18
83	HALDA	NARAYAN HAT	16.92	12/06/18
84	HALDA	PANCHPUKURIA	10.90	12/06/18
85	SANGU	BANDARBAN	15.85	03/07/18
86	SANGU	DOHAZARI	7.50	12/06/18
87	MATAMUHURI	LAMA	13.29	12/06/18
88	MATAMUHURI	CHIRINGA	7.10	12/06/18
89	FENI	RAMGARH	18.36	13/06/18
90	KARNAPHULI	CHITTAGONG	-	-

Table 3.7 : Recorded Historical Highest Water Levels (in mPWD) with Dates

Sl. No.	River	Station	Danger Level	Recorded highest WL before 2017 flood (date)	WL (Date) Exceeding previous Highest WL
1	Dharla	Kurigram	26.50	27.84 (14.07.96)	-
2	Teesta	Dalia	52.40	53.05(13.08.17)	-
3	Teesta	Kaunia	30.00	30.52 (06.01.68)	-
4	Jamuneswari	Badarganj	32.16	33.61 (15.08.17)	-
5	Brahmaputra	Noonkhawa	27.25	28.10	-
6	Brahmaputra	Chilmari	24.00	25.07 (23.08.62)	-
7	Jamuna	Bahadurabad	19.50	20.84 (16.08.17)	-
8	Jamuna	Serajgonj	13.35	15.12 (30.08.88)	-
9	Jamuna	Aricha	9. 40	10.76 (02.09.88)	-
10	Dhaleswari	Elasin	11.40	12.80 (31.07.16)	-
11	Old Brhamaputra	Jamalpur	17.00	18.00 (31.07.54)	-
12	Old Brhamaputra	Mymensingh	12.50	13.71(01.09.88)	-
13	Buriganga	Dhaka	6.00	7.58 (04.09.68)	-
14	Lakhya	Narayangonj	5.50	6.93 (10.09.98)	-
15	Turag	Mirpur	5.94	8.35 (10.09.88)	-
16	Tongi Khal	Tongi	6.08	7.84 (01.09.62)	-
17	Kaliganga	Taraghat	8.38	10.37(02.09.88)	-
18	Punarbhaba	Dinajpur	33.50	34.40	-
19	Tangon	Thakurgaon	50.40	51.30 (12.08.17)	-
20	Gur	Singra	12.65	13.67 (22.08.17)	-
21	Padma	Pankha	21.50	24.14 (07.09.97)	-
22	Padma	Rajshahi	18.50	20.00(13.09.1910)	-
23	Padma	H. Bridge	14.25	15.19 (10.09.98)	-
24	Padma	Goalundo	8.50	10.21 (03.08.08)	-
25	Padma	Bhagyakul	6.00	7.58	-
26	Gorai	Gorai Rly Br	12.75	13.65 (02.09.98)	-
27	Surma	Kanaighat	13.20	15.58(26.06.12)	-
28	Surma	Sylhet	11.25	12.44 (19.07.04)	-
29	Surma	Sunamgonj	8.25	9.75 (20.07.04)	-
30	Kushiyara	Amalshid	15.85	18.28 (08.06.74)	-
31	Kushiyara	Sheola	13.50	14.60 (09.09.08)	-
32	Manu	Manu Rly Br	18.00	20.42 (23.05.02)	-
33	Manu	Moulvi Bazar	11.75	13.25 (08.06.93)	-
34	Khowai	Habiganj	9.50	12.00 (18.06.07)	-
35	Someswari	Durgapur	13.00	15.58 (28.07.07)	-
36	Upper Meghna	Bhairab Bazar	6.25	7.78 (24.07.04)	-
37	Gumti	Comilla	11.75	13.56 (23.07.93)	-
38	Muhuri	Parshuram	13.00	16.33 (13.09.04)	-
39	Halda	Narayanhat	15.25	19.30 (13.08.99)	-
40	Halda	Panchpukuria	7.00	12.54(27.06.03)	-
41	Sangu	Bandarban	15.25	20.7 (12.07.97)	-
42	Sangu	Dohazari	5.75	9.05	-
43	Matamuhuri	Lama	12.25	15.46 (12.08.99)	-
44	Matamuhuri	Chiringa	5.75	7.32 (04.07.17)	-
45	Feni	Ramgarh	17.37	21.42 (11.07.68)	-

WL - Water Level

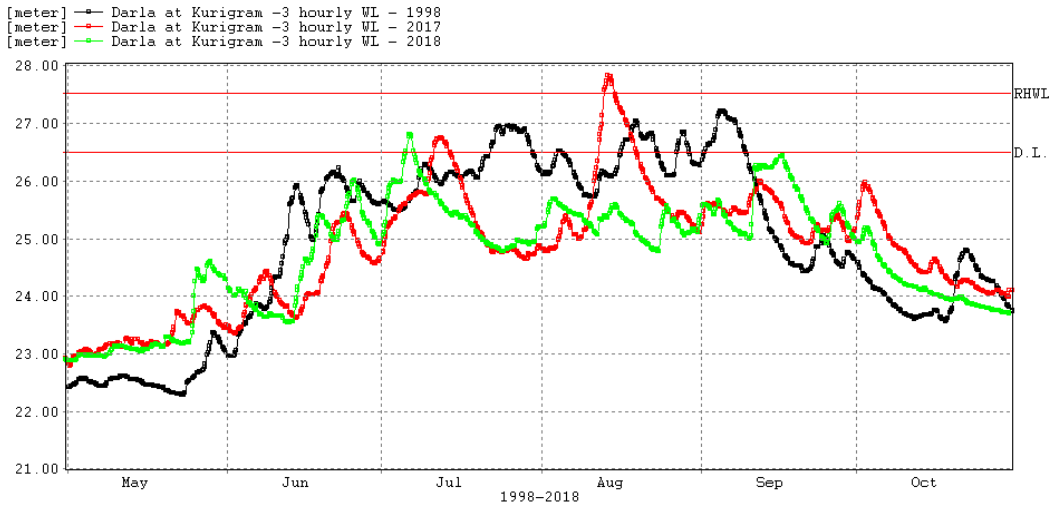


Figure 3.1: Comparison of Hydrograph on Dharla at Kurigram

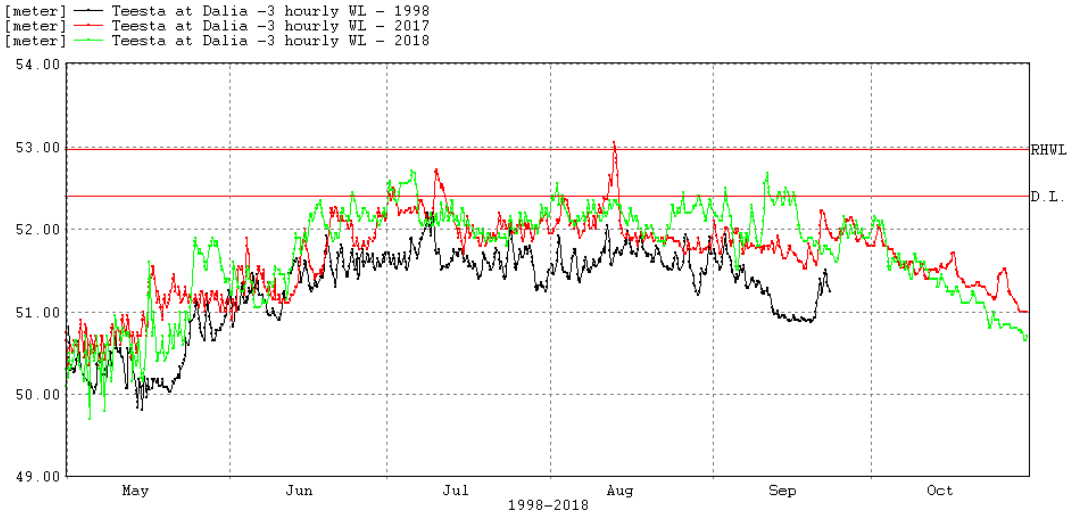


Figure 3.2: Comparison of Hydrograph on Teesta at Dalia

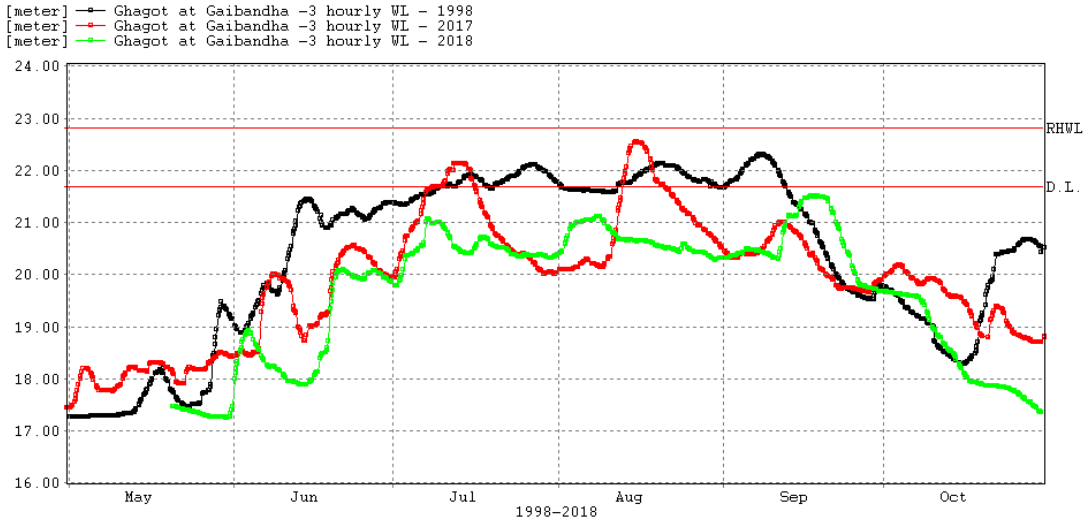


Figure 3.3: Comparison of Hydrograph on Ghagot at Gaibandha

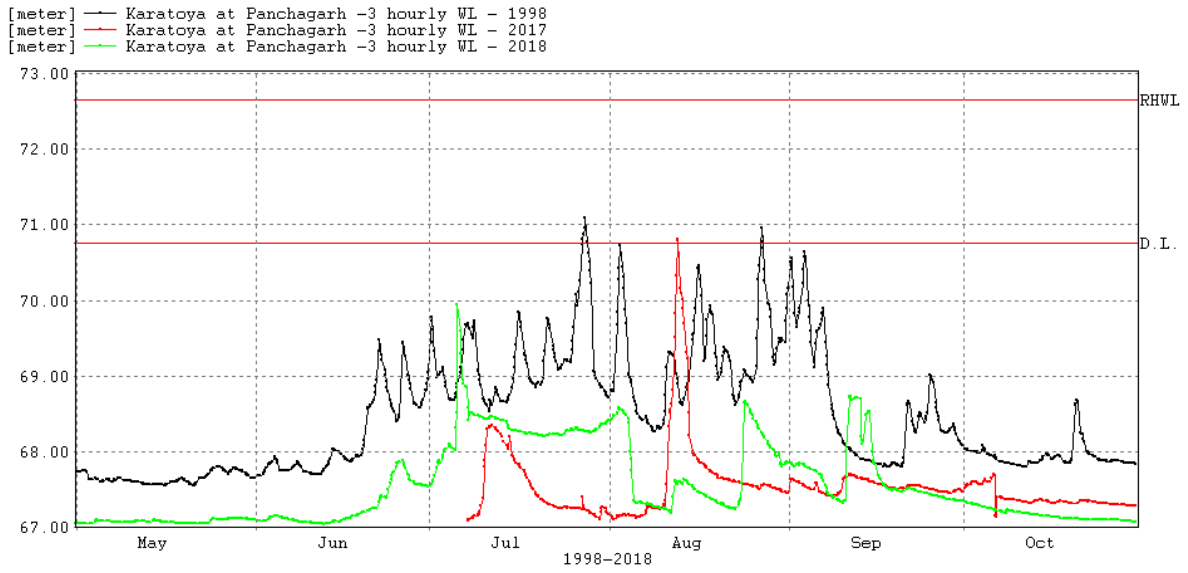


Figure 3.4: Comparison of Hydrograph on Upper Karatoa at Panchagarh

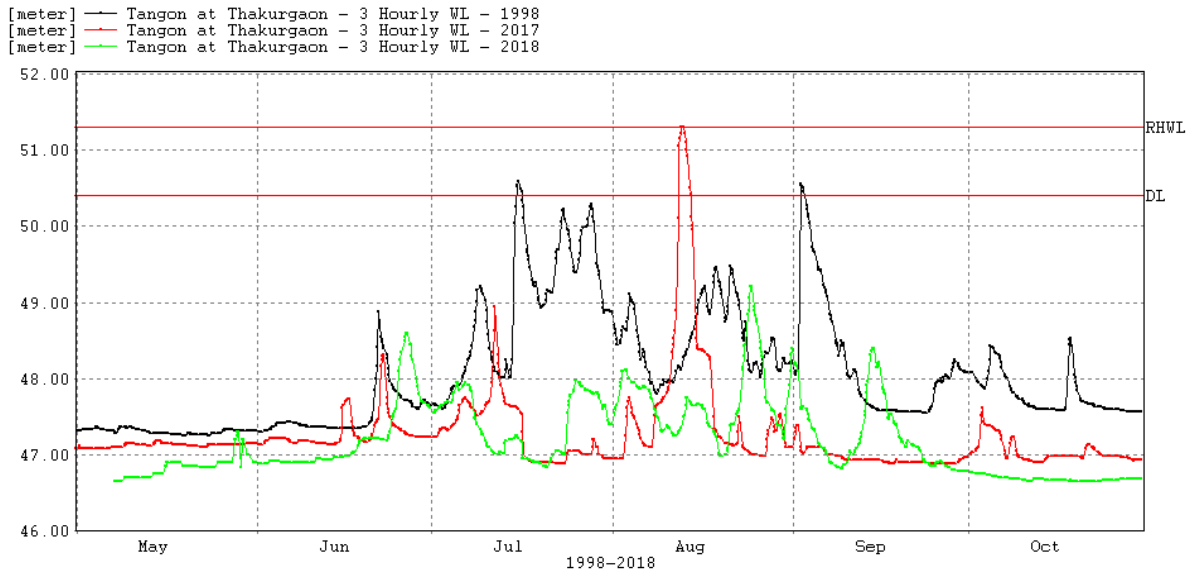


Figure 3.5: Comparison of Hydrograph on Tangon at Thakurgaon

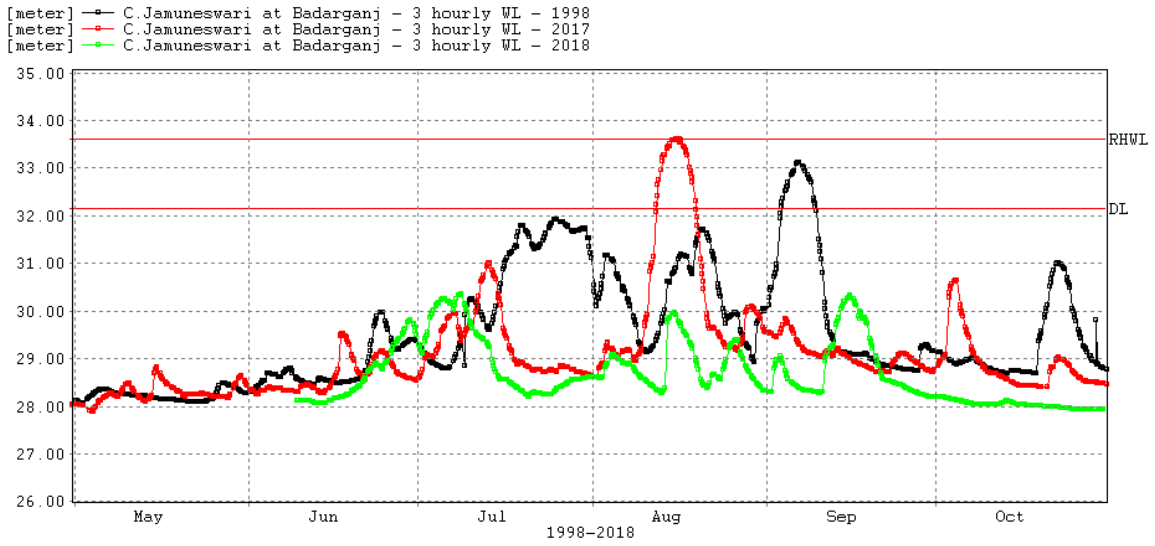


Figure 3.6: Comparison of Hydrograph on C. Jamuneswari at Badarganj

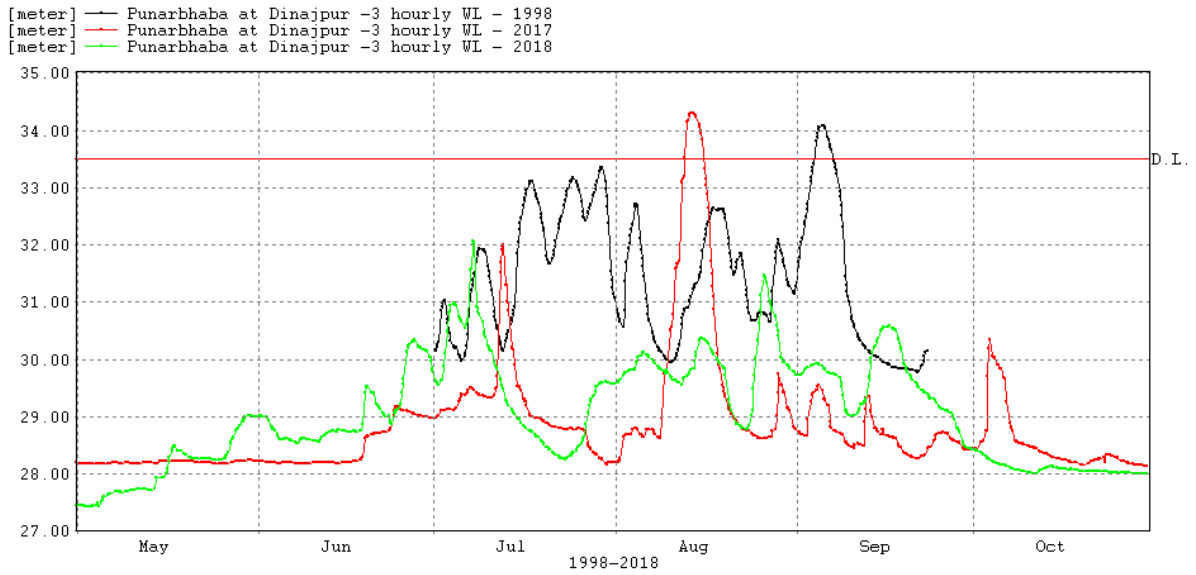


Figure 3.7: Comparison of Hydrograph on Punarbhaba at Dinajpur

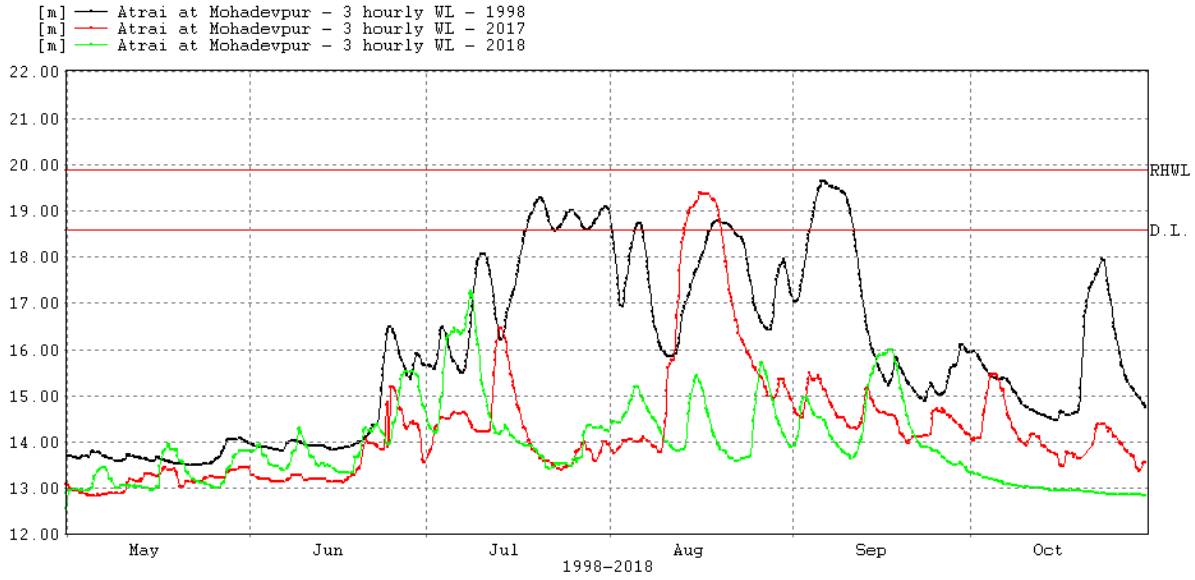


Figure 3.8: Comparison of Hydrograph on Atrai at Mohadevpur

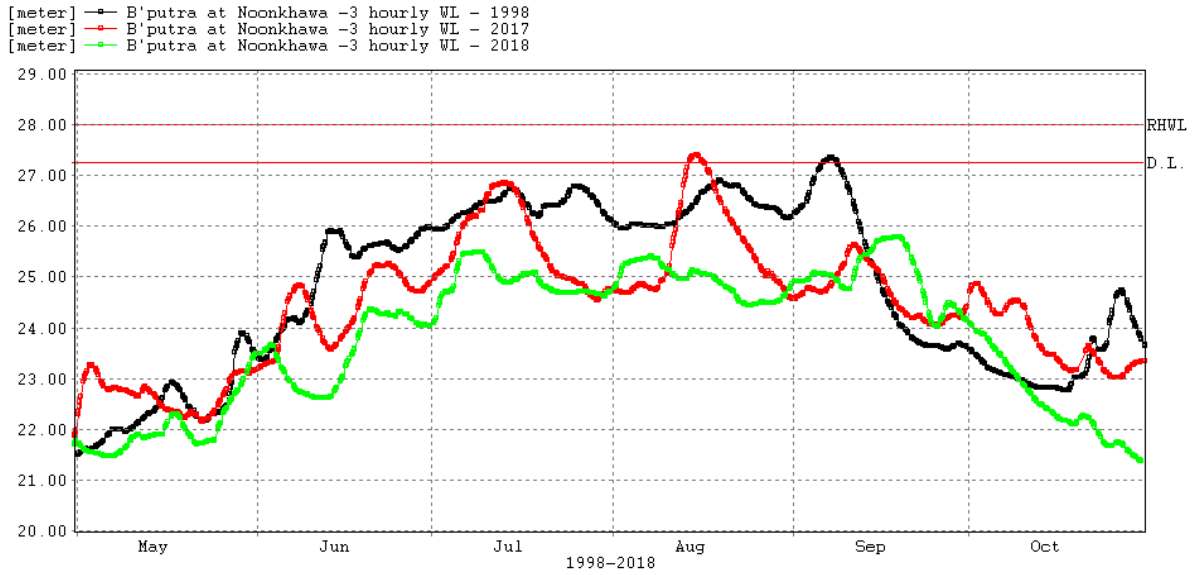


Figure 3.9: Comparison of Hydrograph on Brahmaputra at Noonkhawa

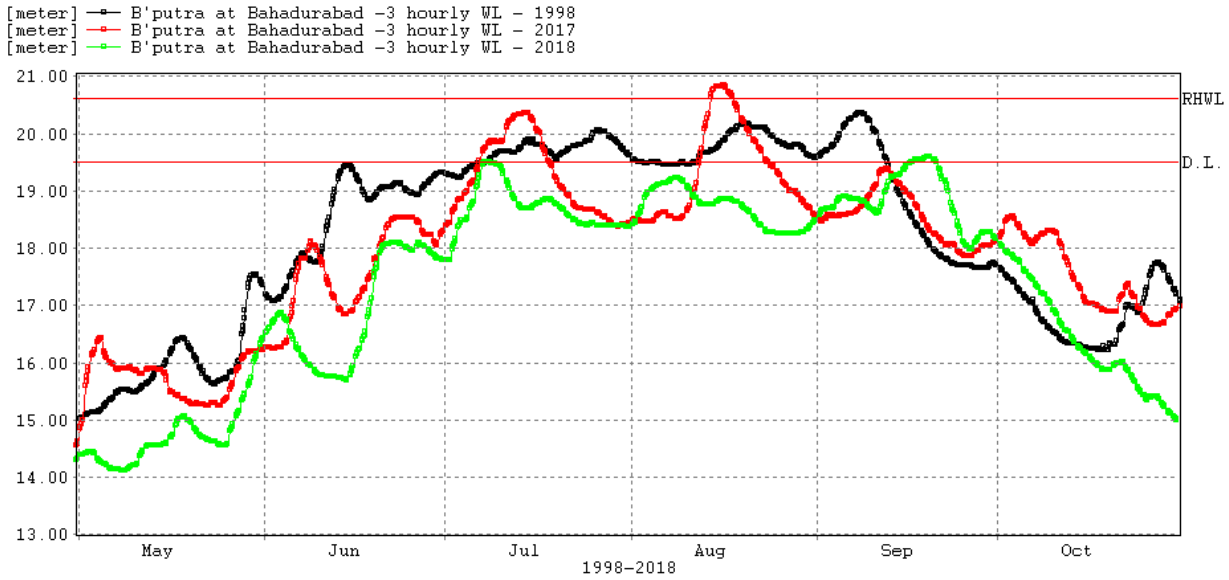


Figure 3.10: Comparison of Hydrograph on Brahmaputra at Bahadurabad

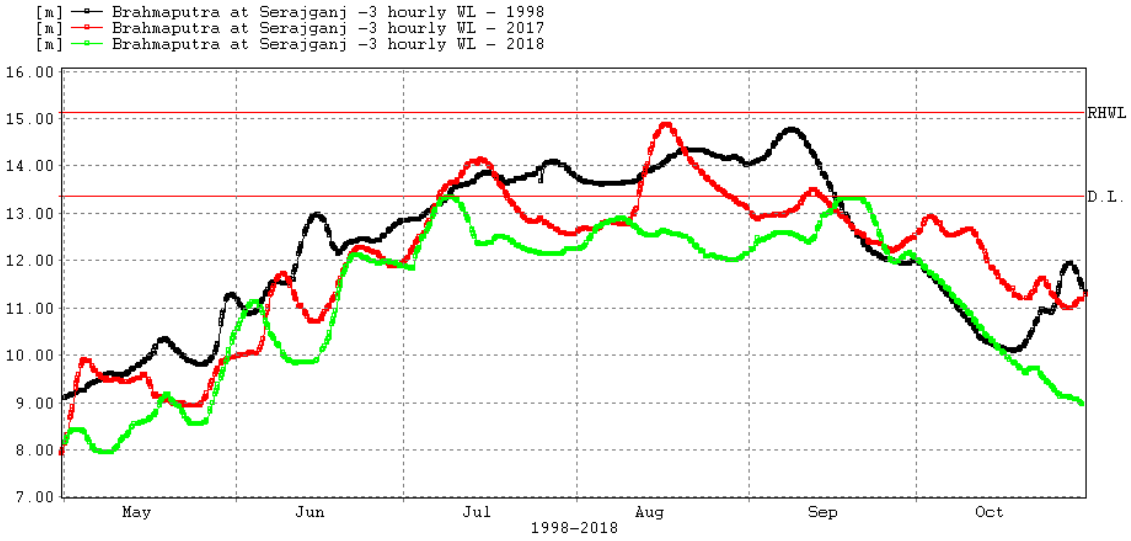


Figure 3.11: Comparison of Hydrograph on Jamuna at Serajgonj

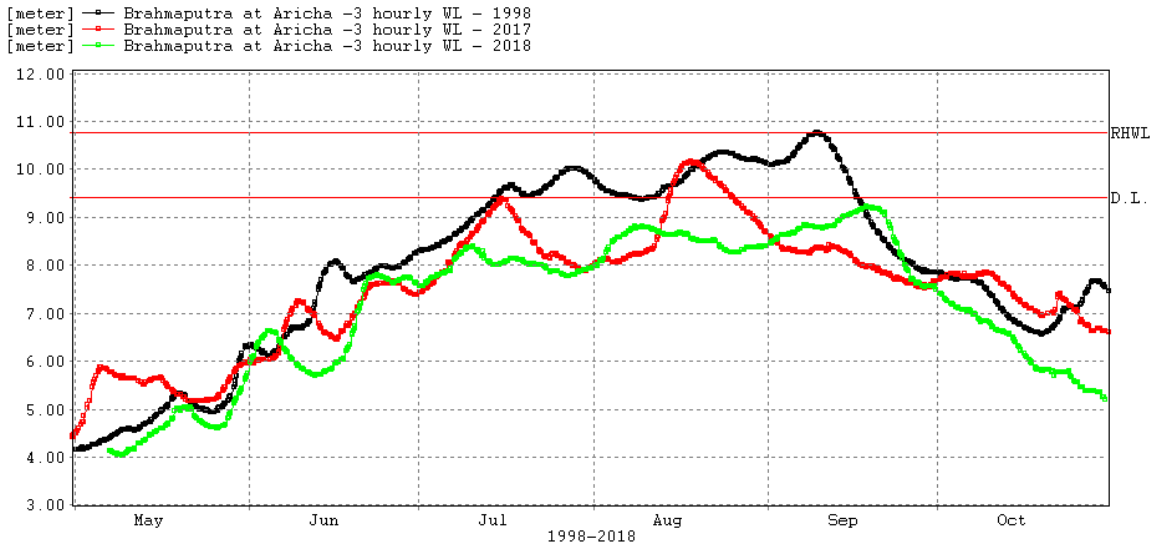


Figure 3.12: Comparison of Hydrograph on Jamuna at Aricha

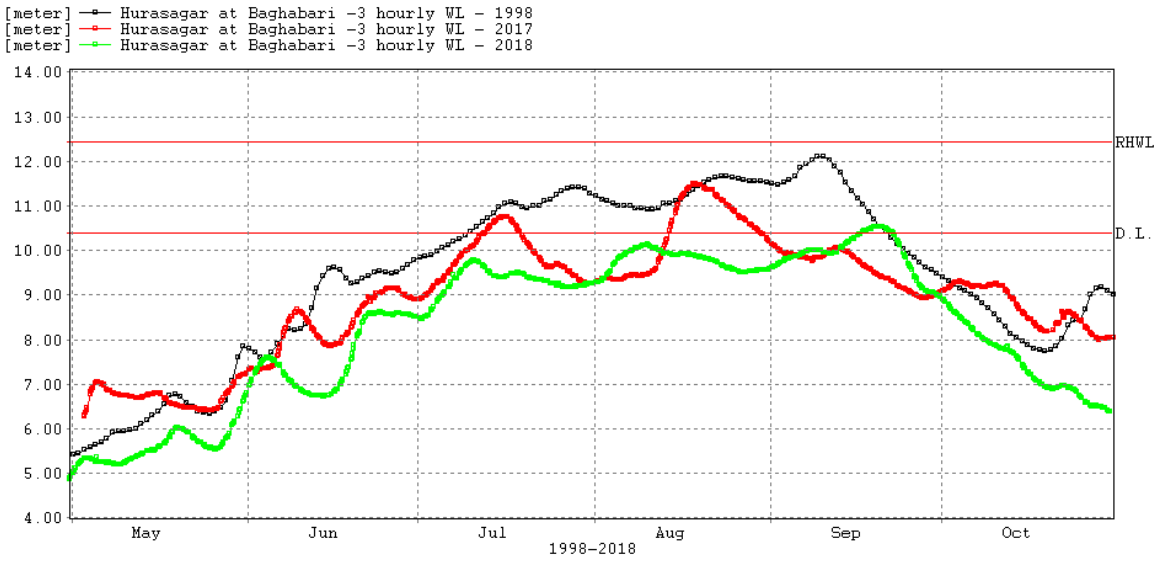


Figure 3.13: Comparison of Hydrograph on Atrai at Baghabari

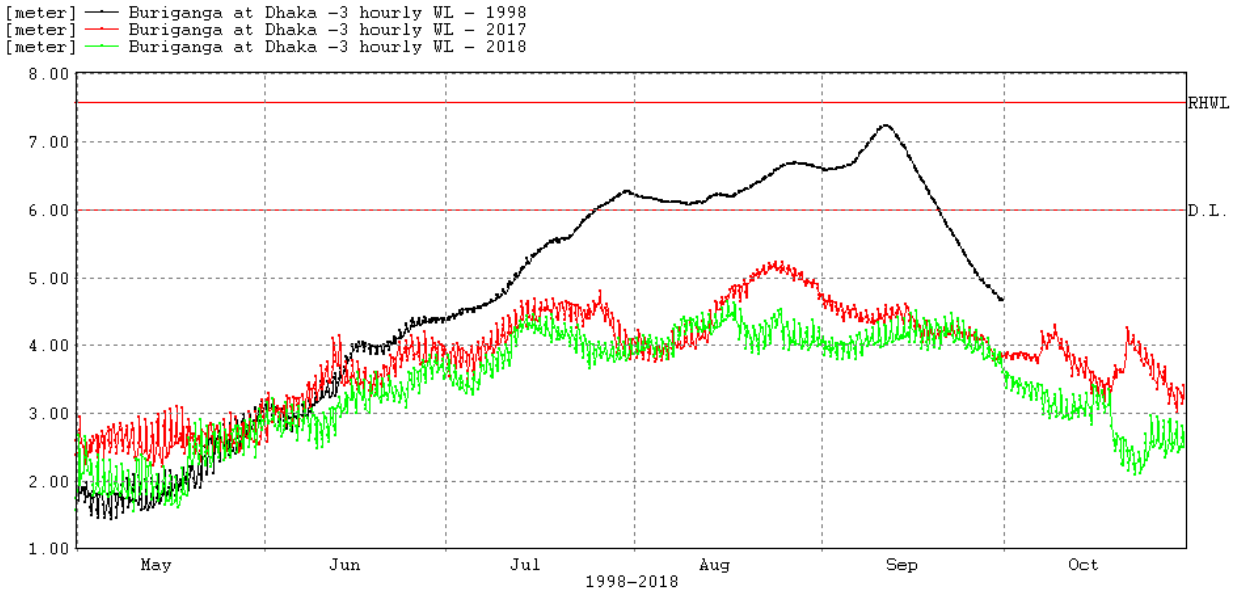


Figure 3.14: Comparison of Hydrograph on Buriganga at Dhaka (Milbarak)

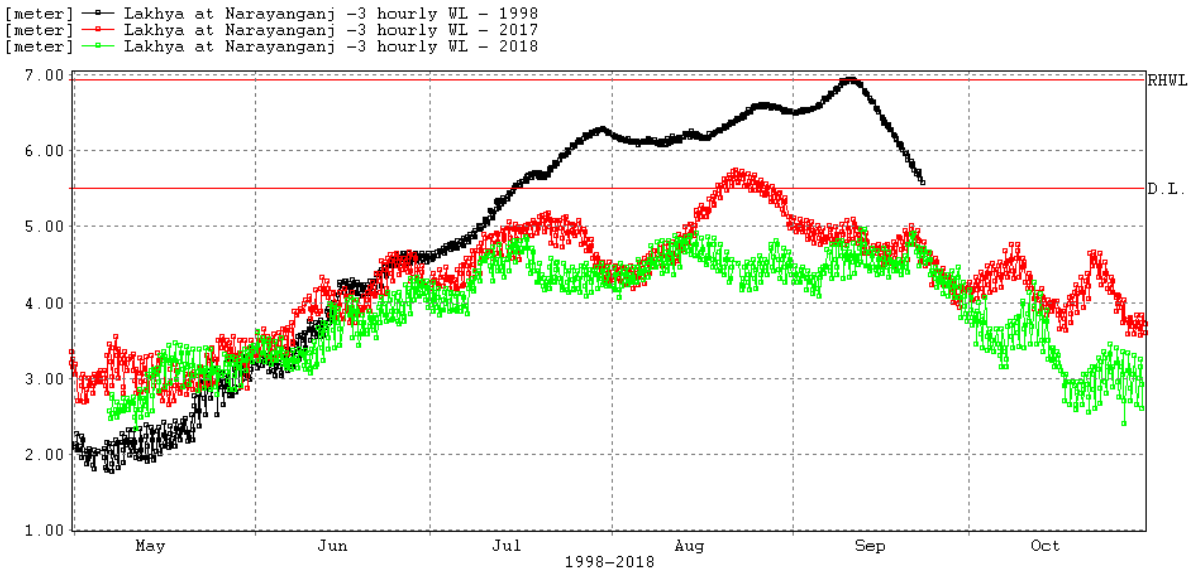


Figure 3.15: Comparison of Hydrograph on Lakhya at Narayangonj

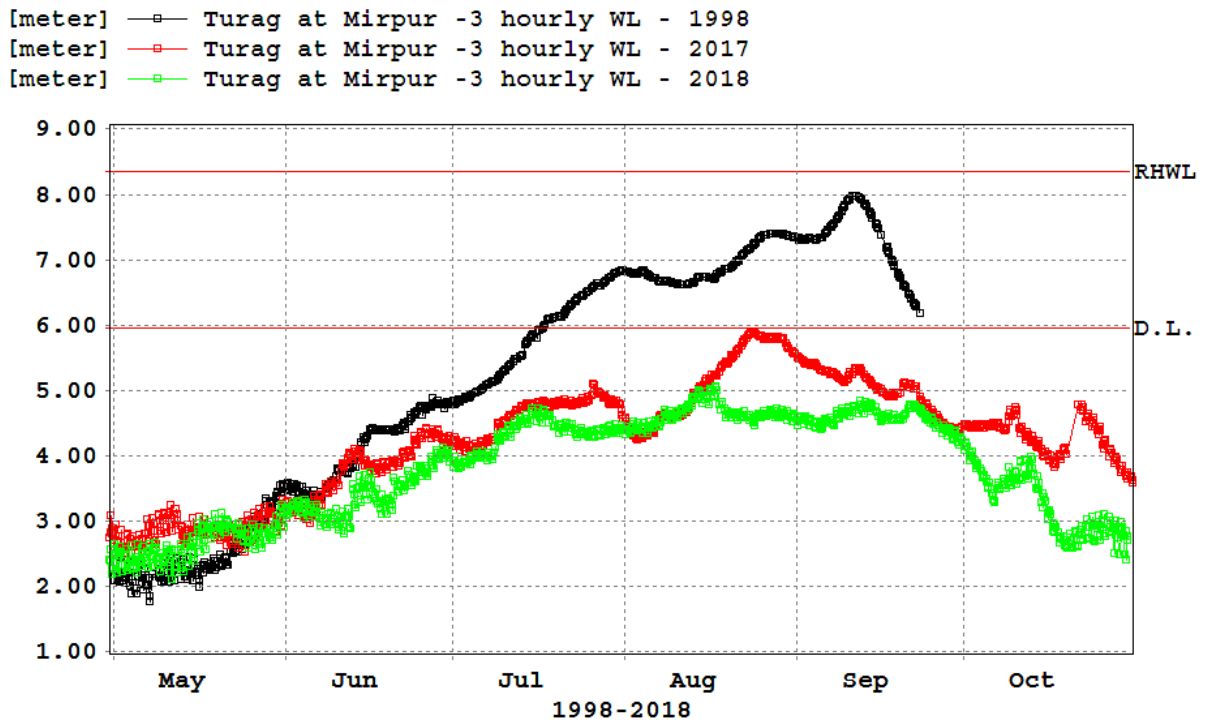


Figure 3.16 : Comparison of Hydrograph on Turag at Mirpur

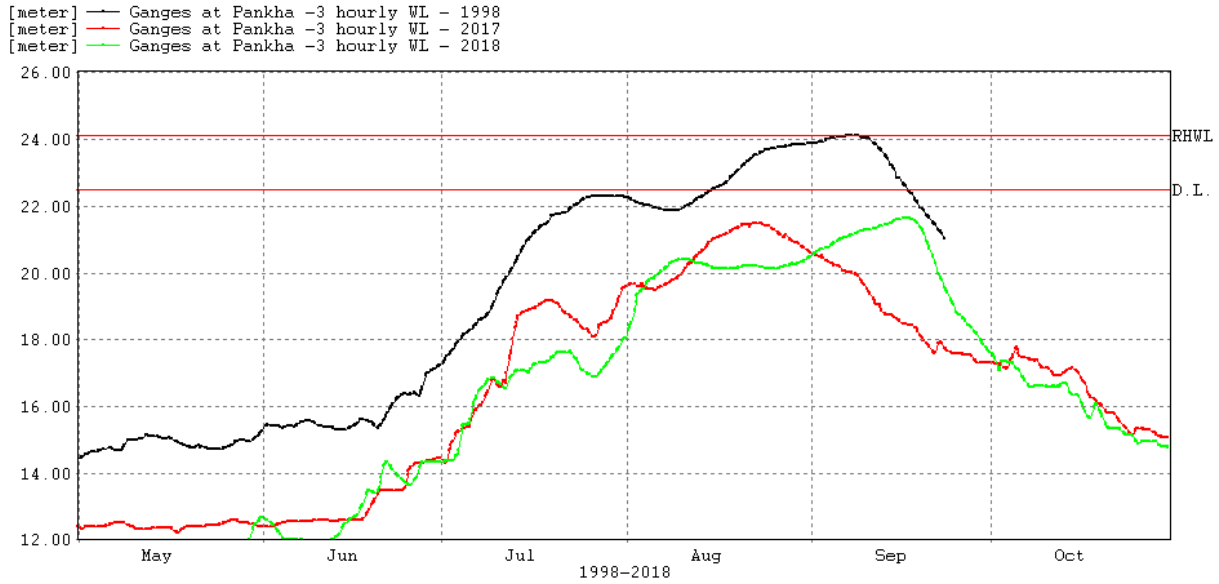


Figure 3.17: Comparison of Hydrograph on Ganges at Pankha

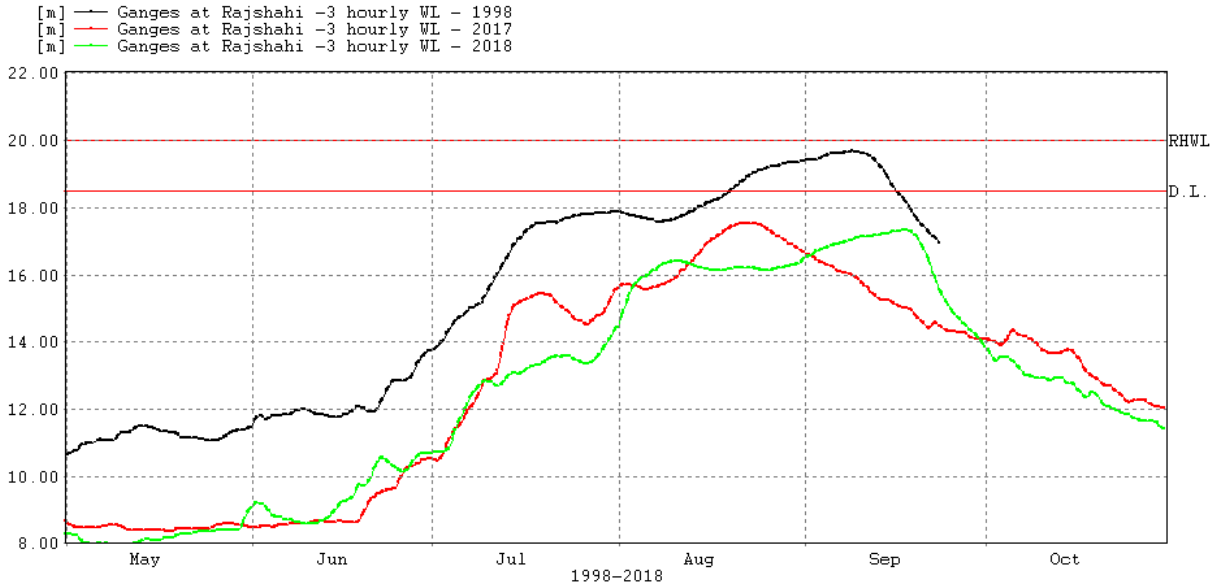


Figure 3.18: Comparison of Hydrograph on Ganges at Rajshahi

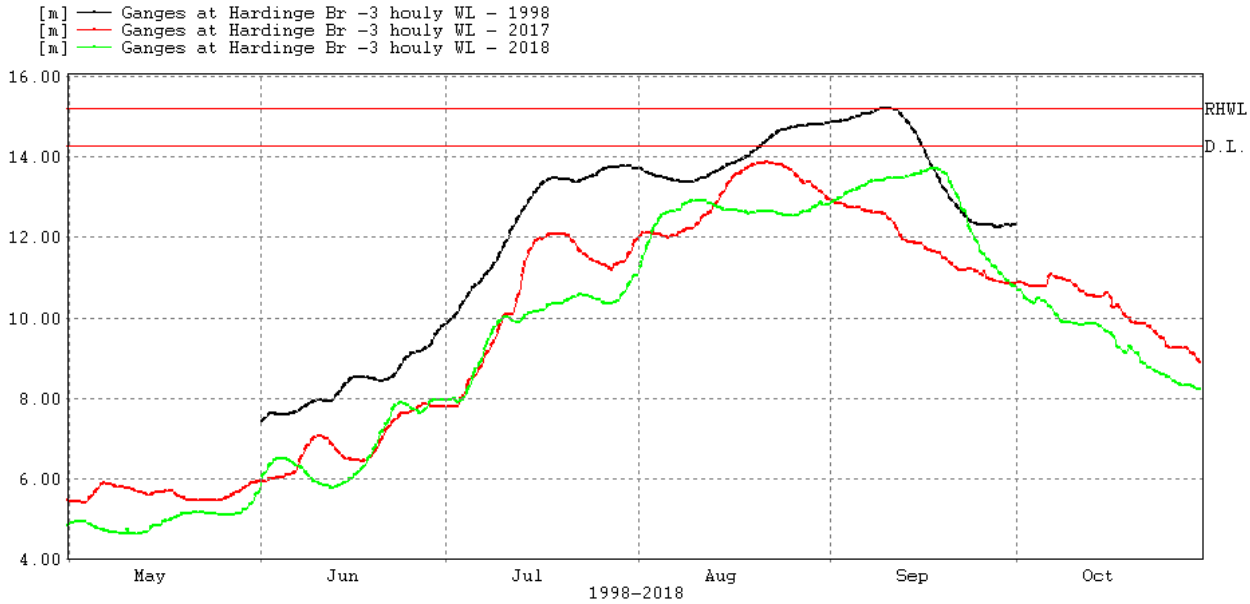


Figure 3.19: Comparison of Hydrograph on Ganges at Hardinge Bridge

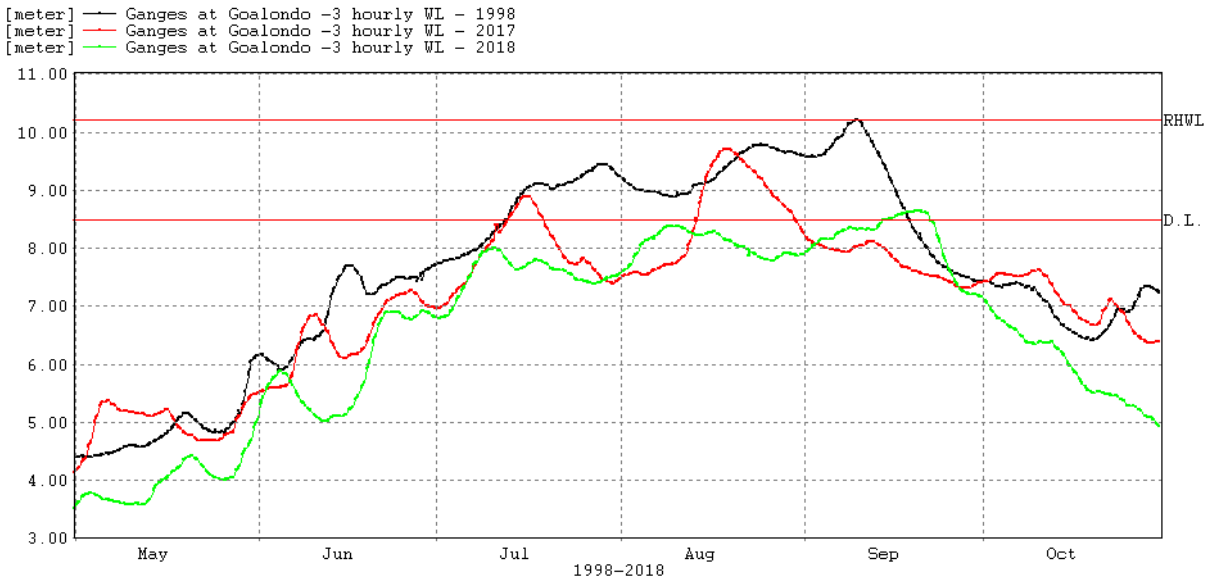


Figure 3.20: Comparison of Hydrograph on Padma at Goalondo

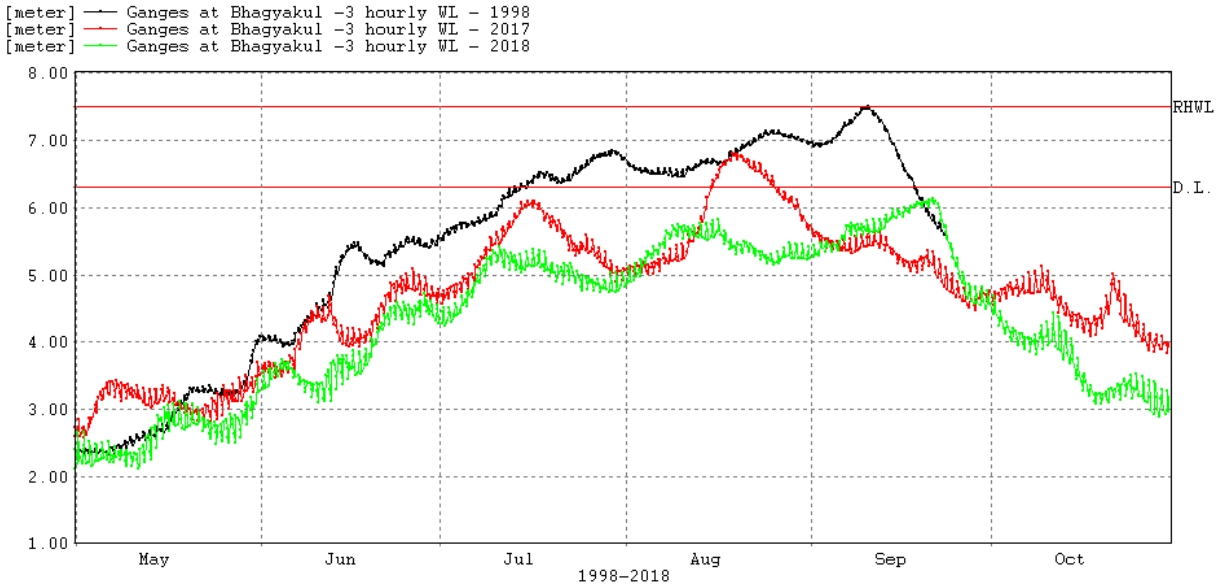


Figure 3.21: Comparison of Hydrograph on Padma at Bhagyakul

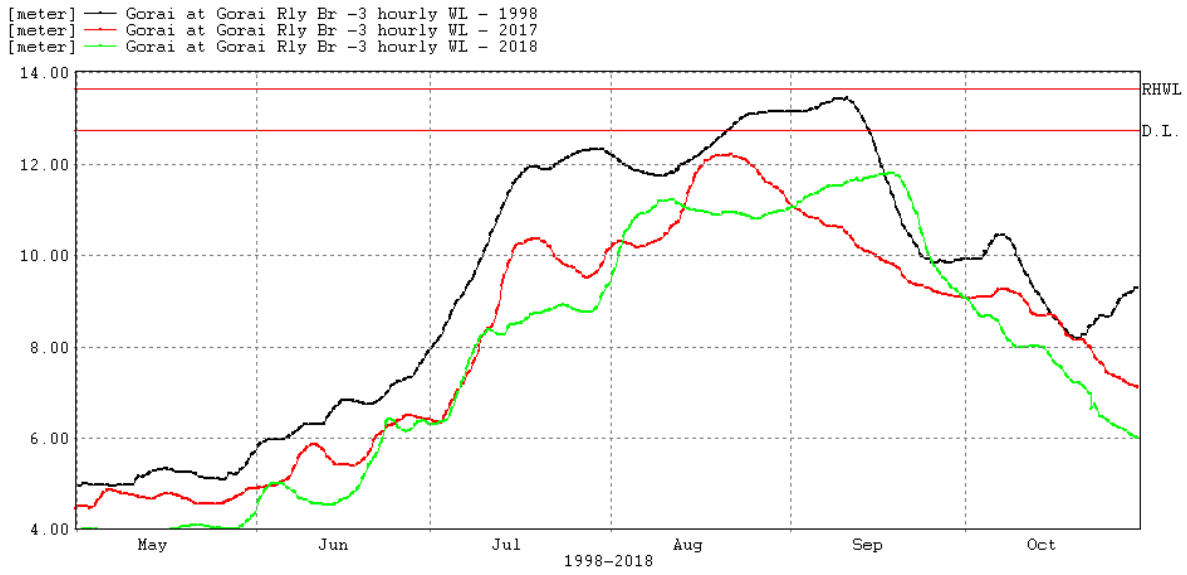


Figure 3.22: Comparison of Hydrograph on Gorai at Gorai Railway Bridge

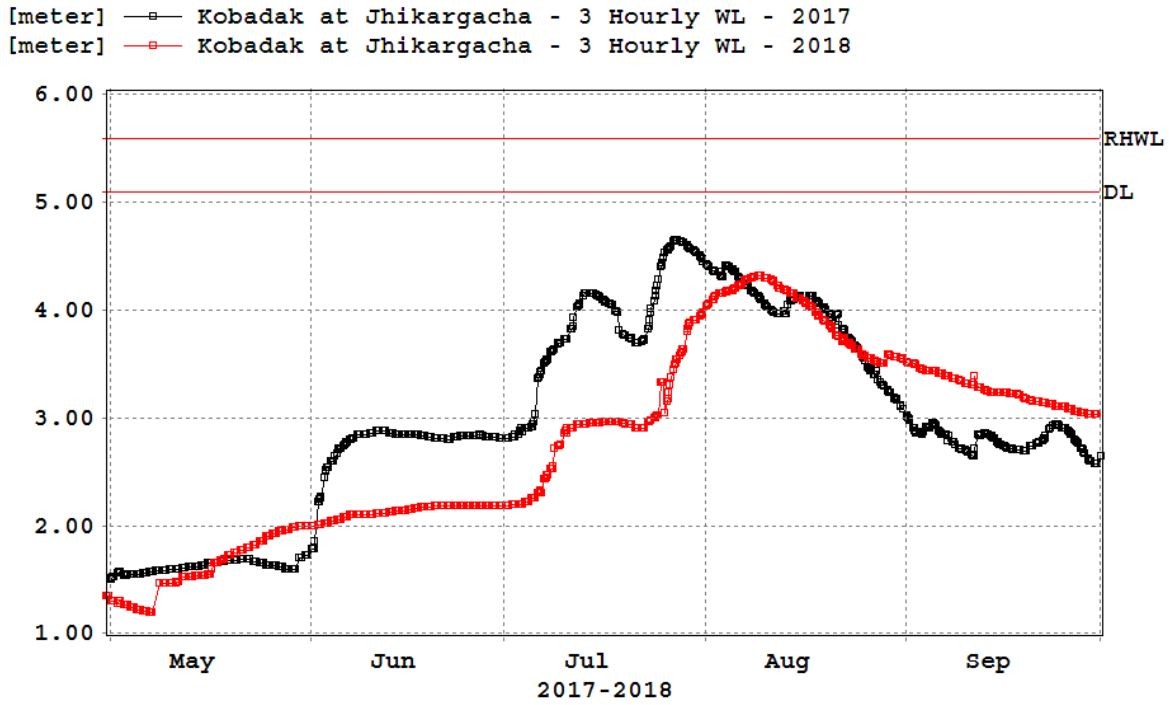


Figure 3.23: Comparison of Hydrograph on Kobodak at Jhikargacha

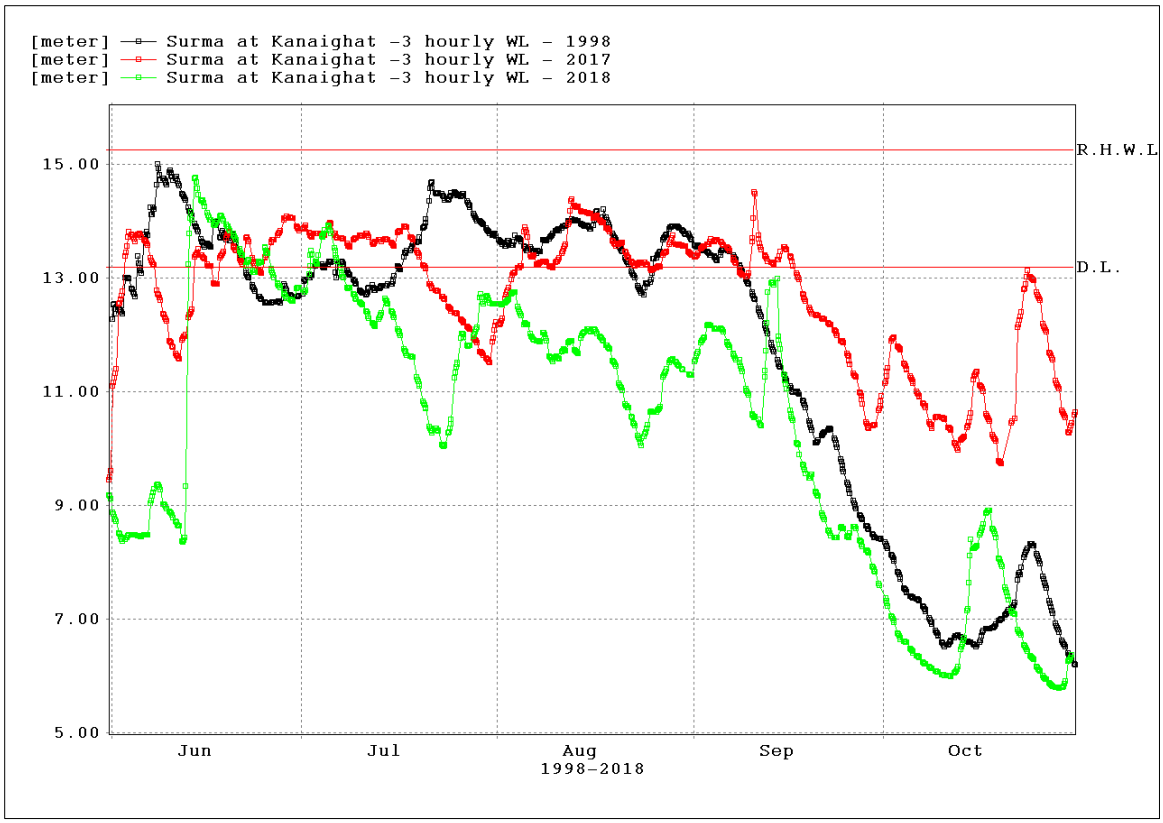


Figure 3.24: Comparison of Hydrograph on Surma at Kanaighat

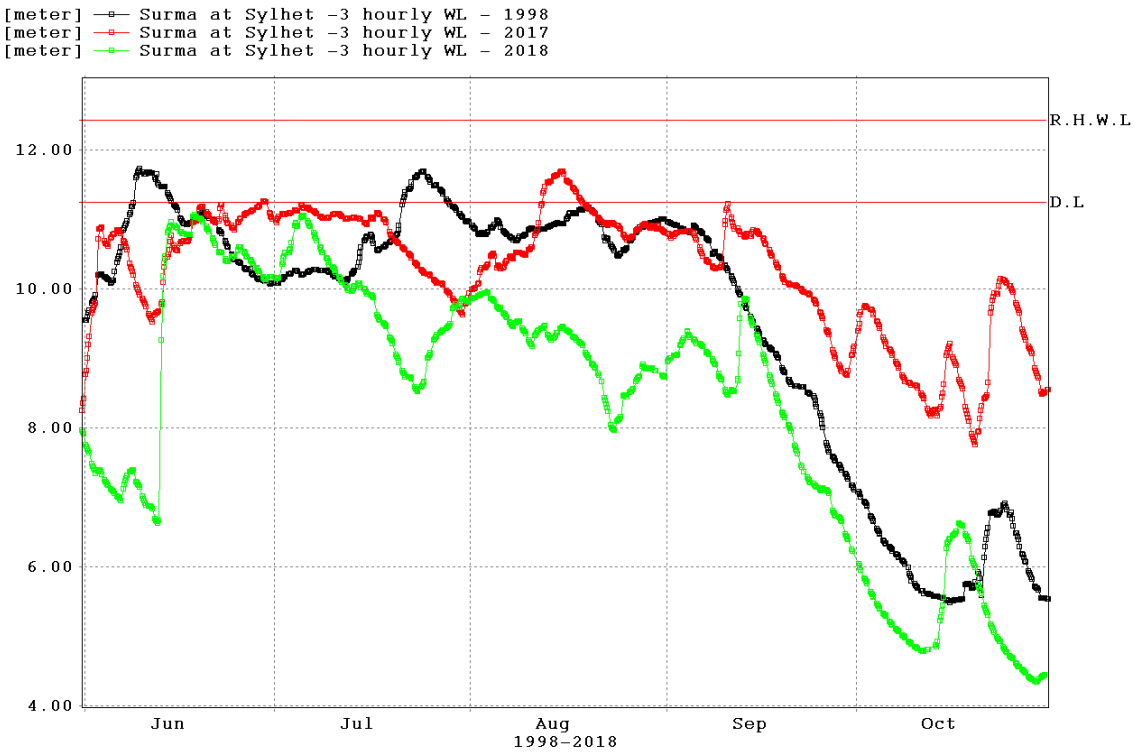


Figure 3.25: Comparison of Hydrograph on Surma at Sylhet

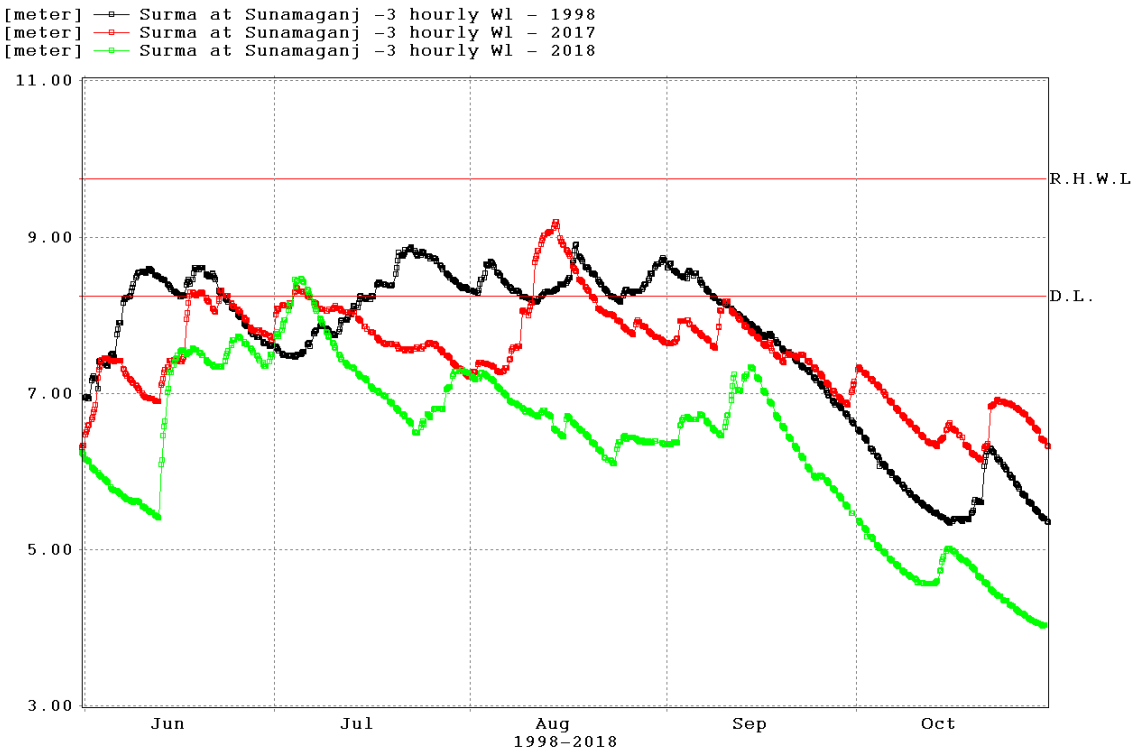


Figure 3.26: Comparison of Hydrograph on Surma at Sunamganj

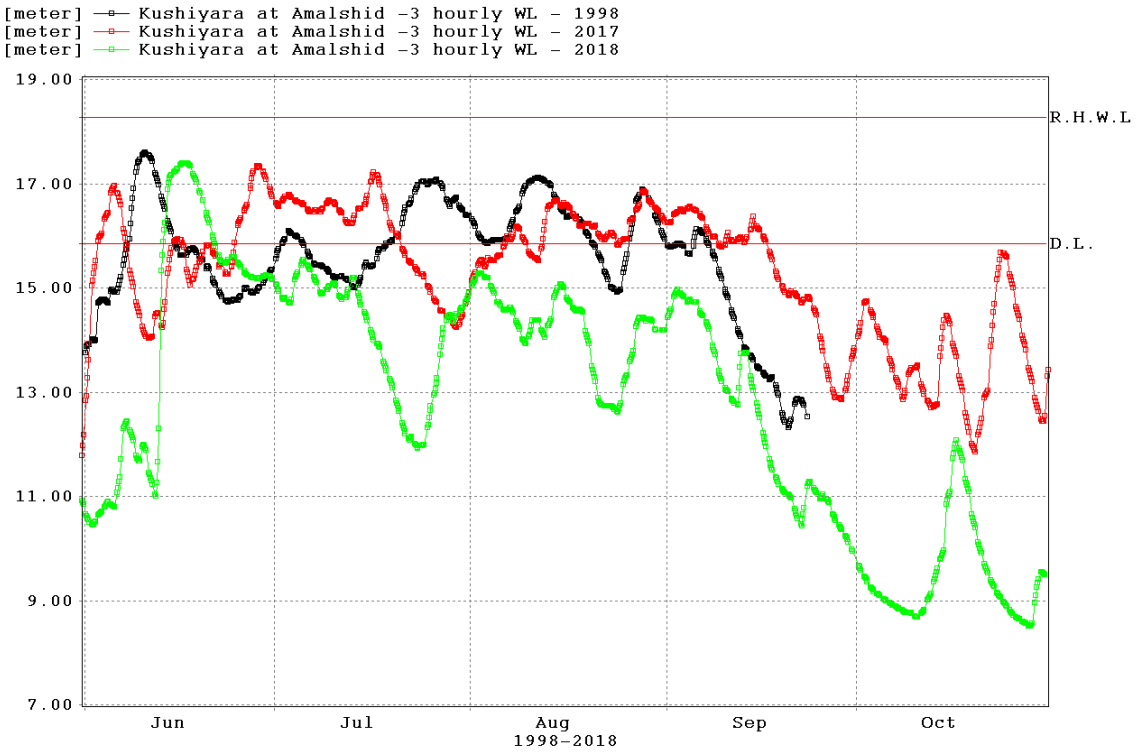


Figure 3.27: Comparison of Hydrograph on Kushiyara at Amalshid

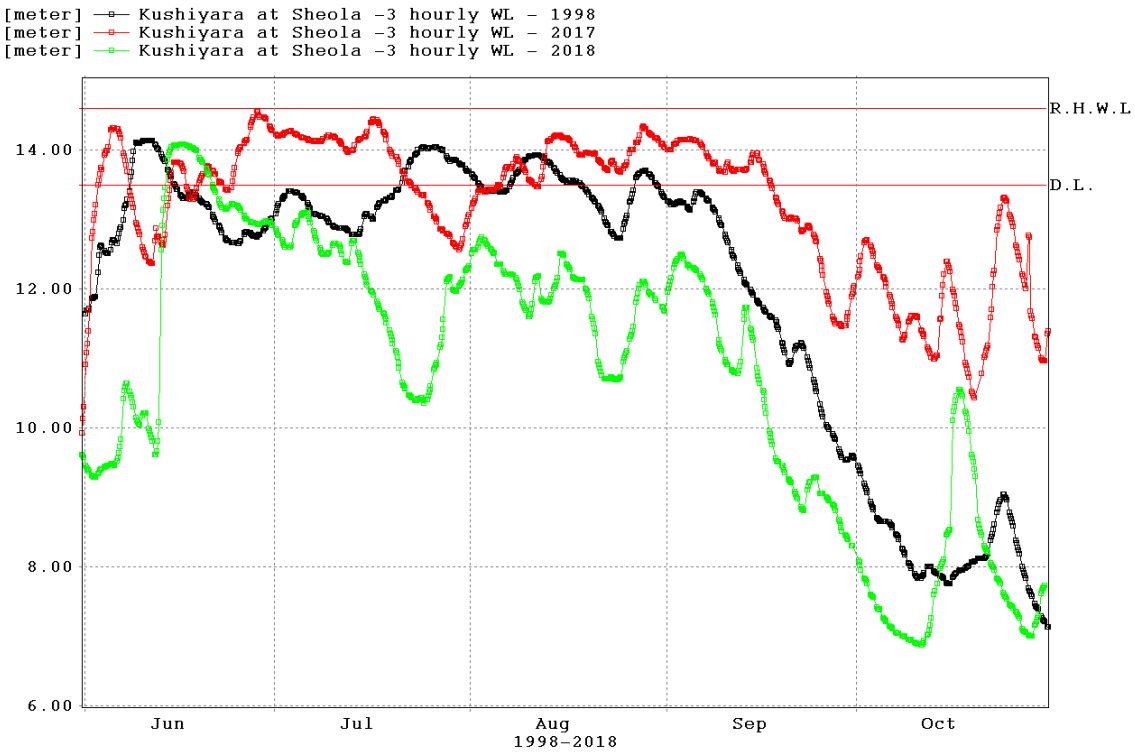


Figure 3.28: Comparison of Hydrograph on Kushiyara at Sheola

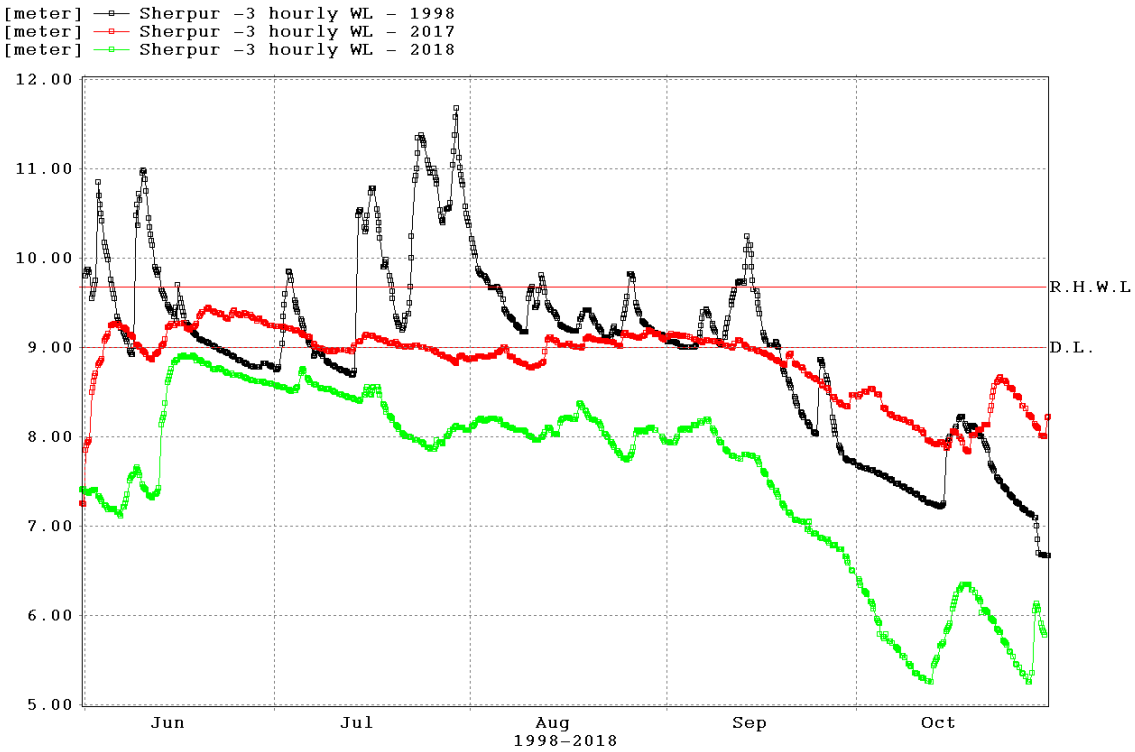


Figure 3.29: Comparison of Hydrograph on Kushiyara at Sherpur

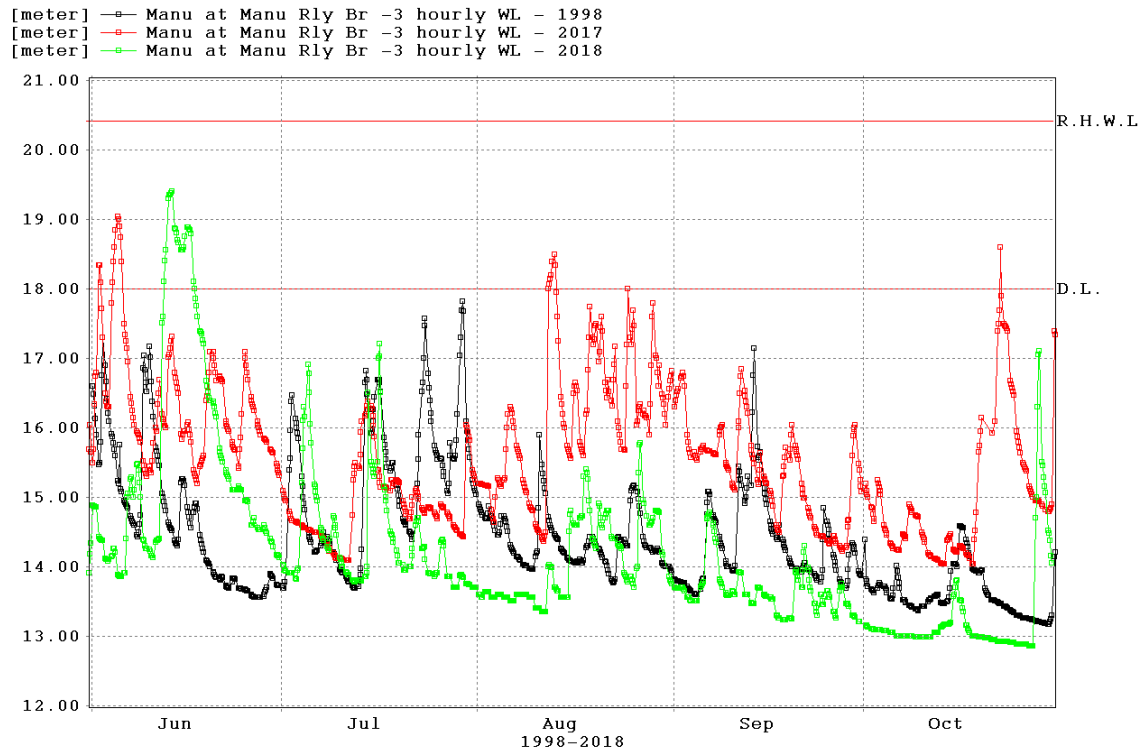


Figure 3.30: Comparison of Hydrograph on Manu at Manu Rail Bridge

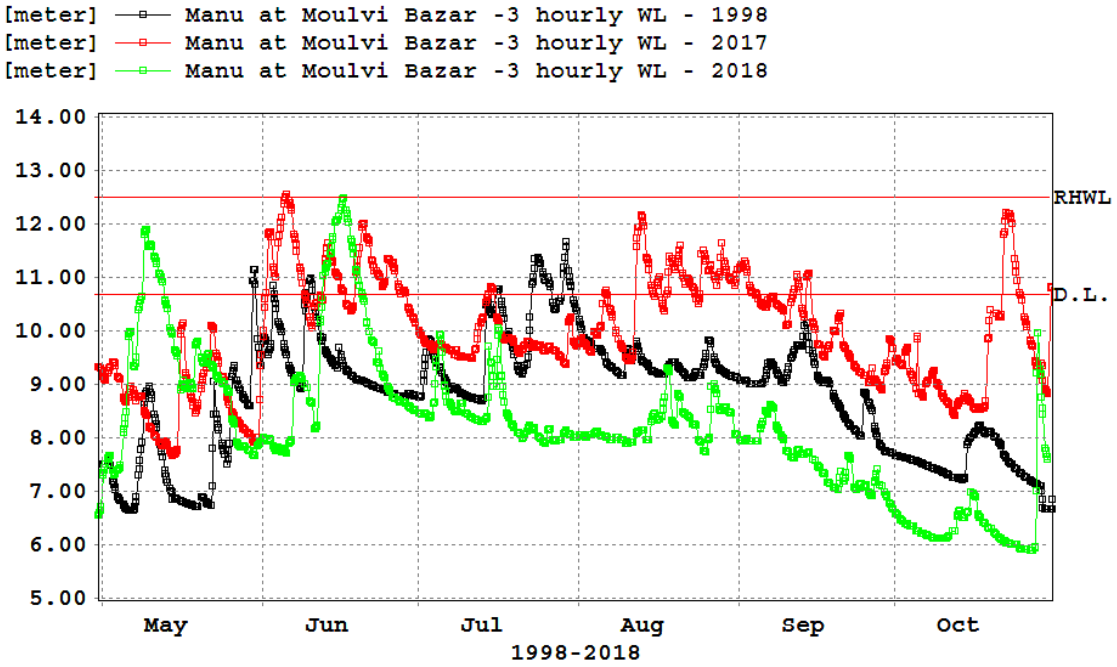


Figure 3.31: Comparison of Hydrograph on Manu at Manu Rail Bridge

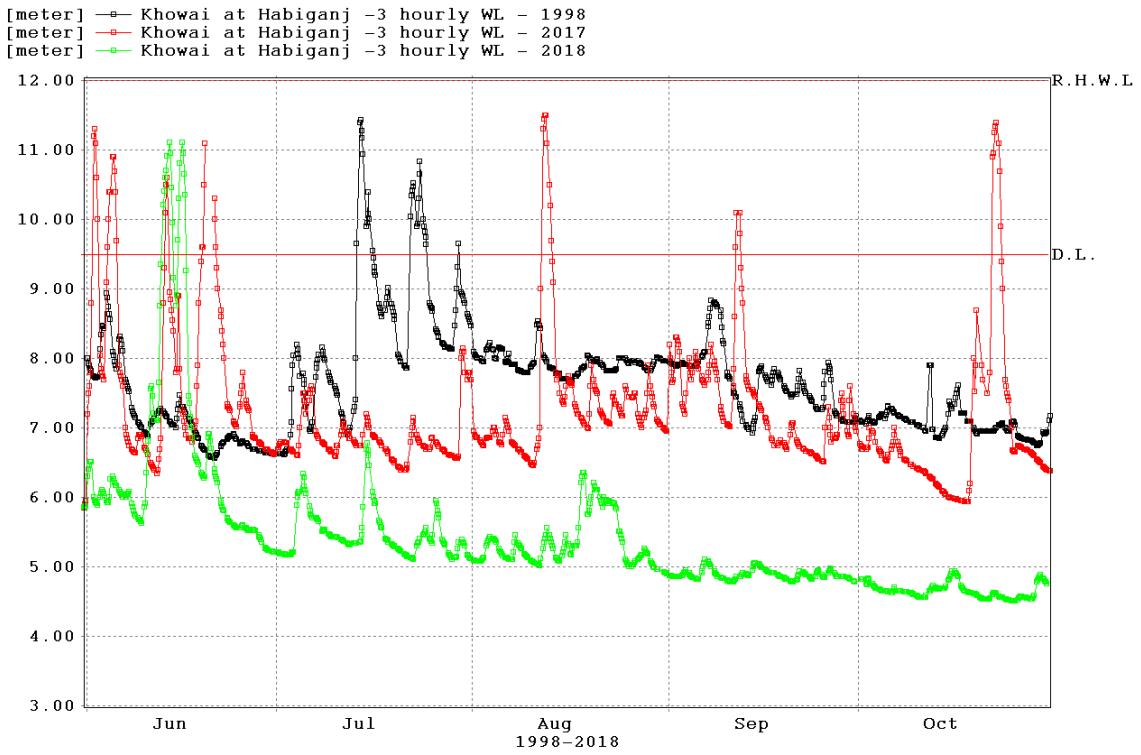


Figure 3.32: Comparison of Hydrograph on Khowai at Habiganj

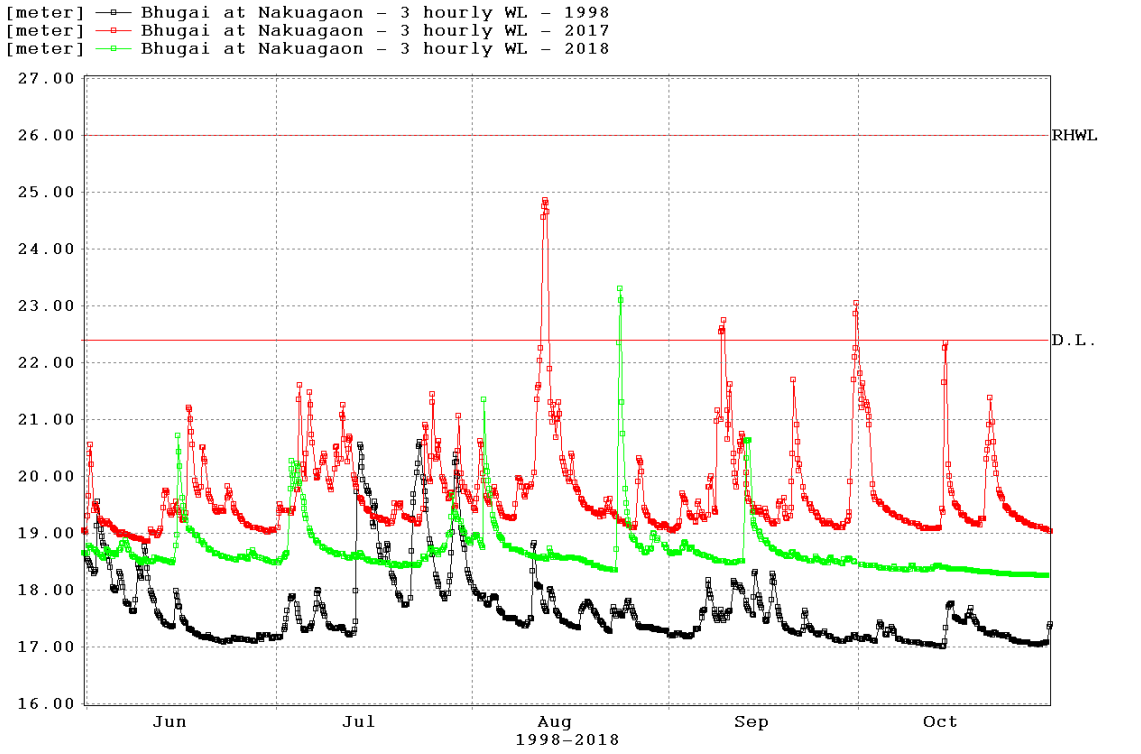


Figure 3.33: Comparison of Hydrograph on Bhugai at Nakuagaon

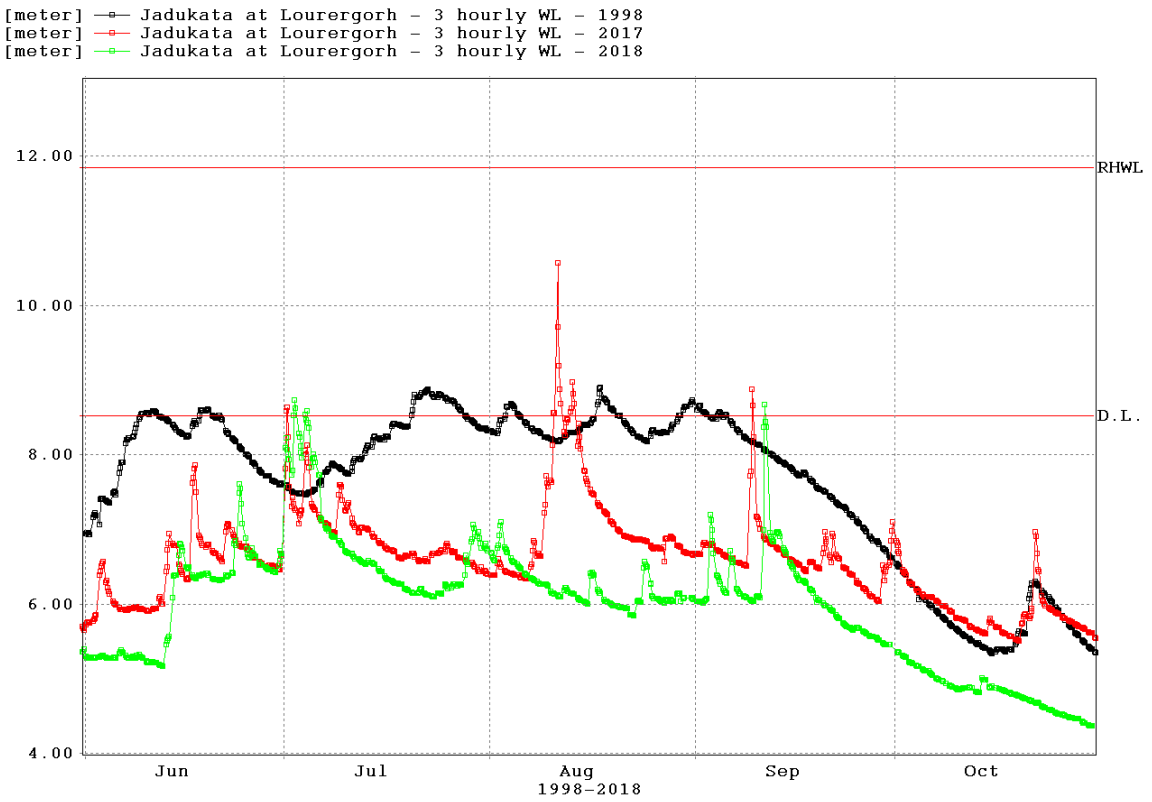


Figure 3.34: Comparison of Hydrograph on Jadukata at Lorergarh

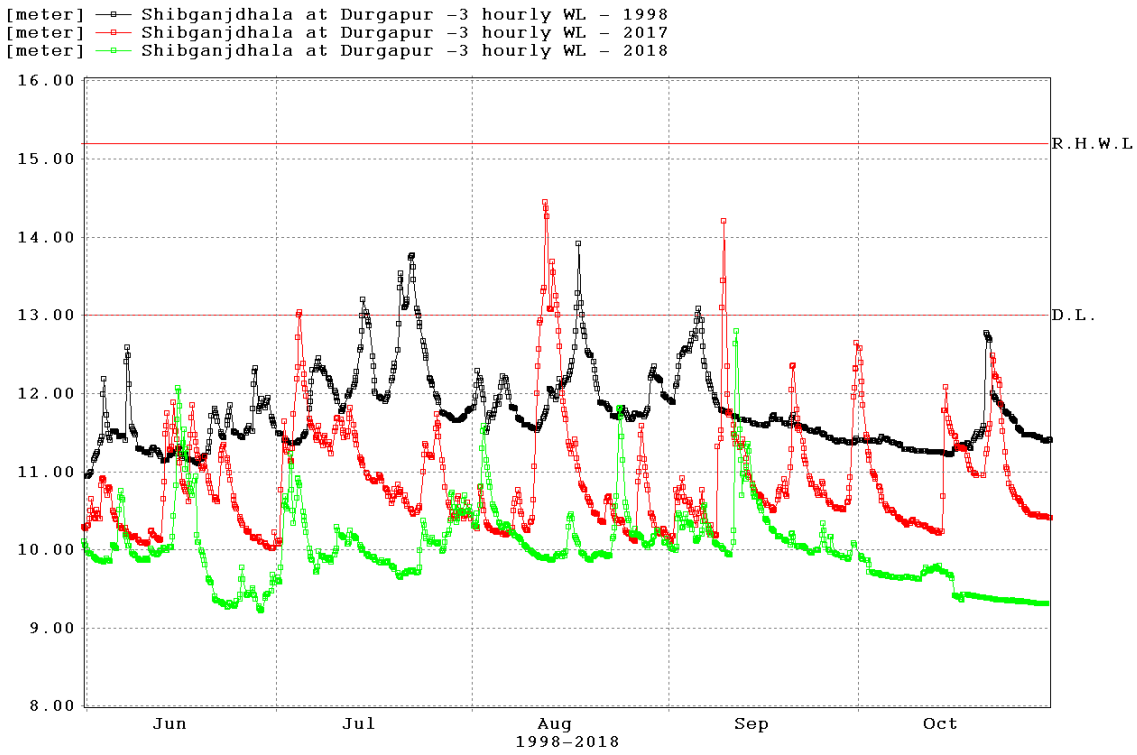


Figure 3.35: Comparison of Hydrograph on Someswari at Durgapur

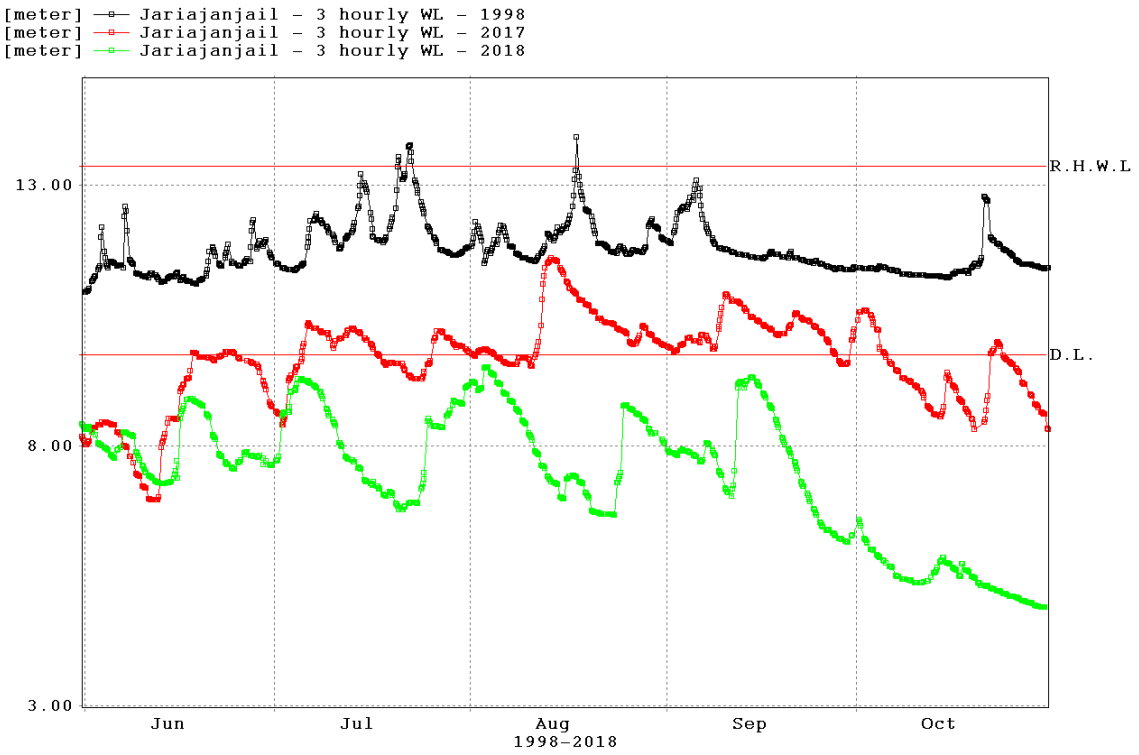


Figure 3.36: Comparison of Hydrograph on Kangsha at Jariajanjail

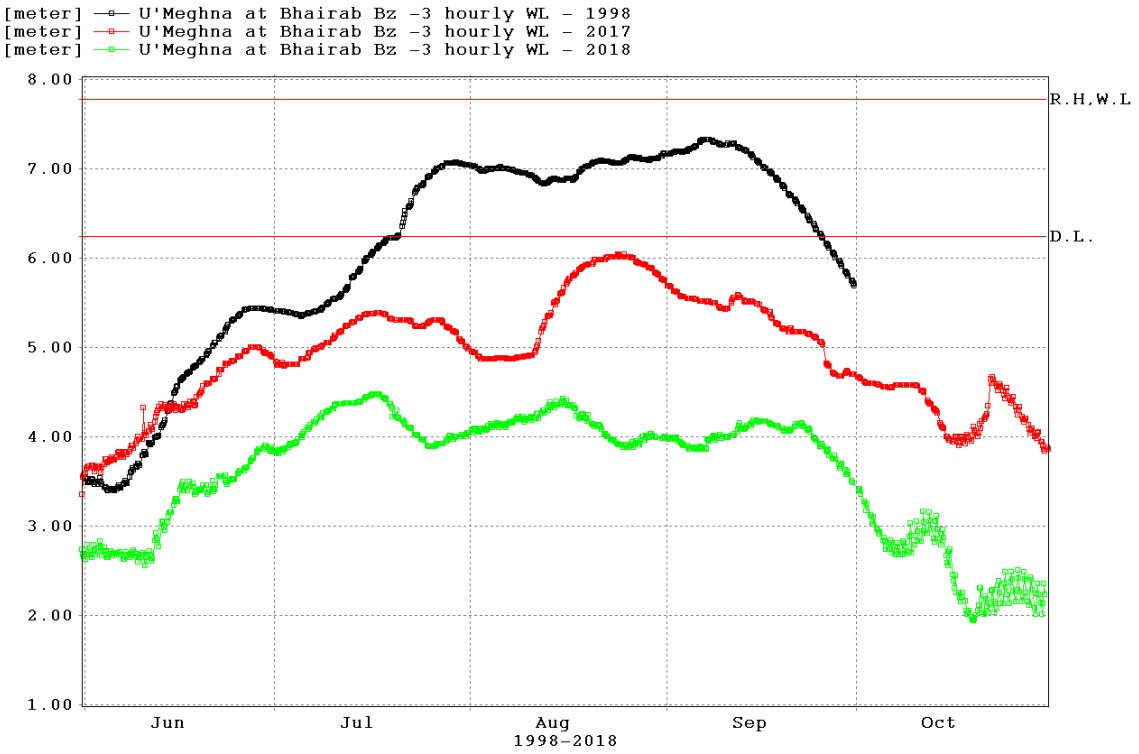


Figure 3.37: Comparison of Hydrograph on Upper Meghna at Bhairab Bazar

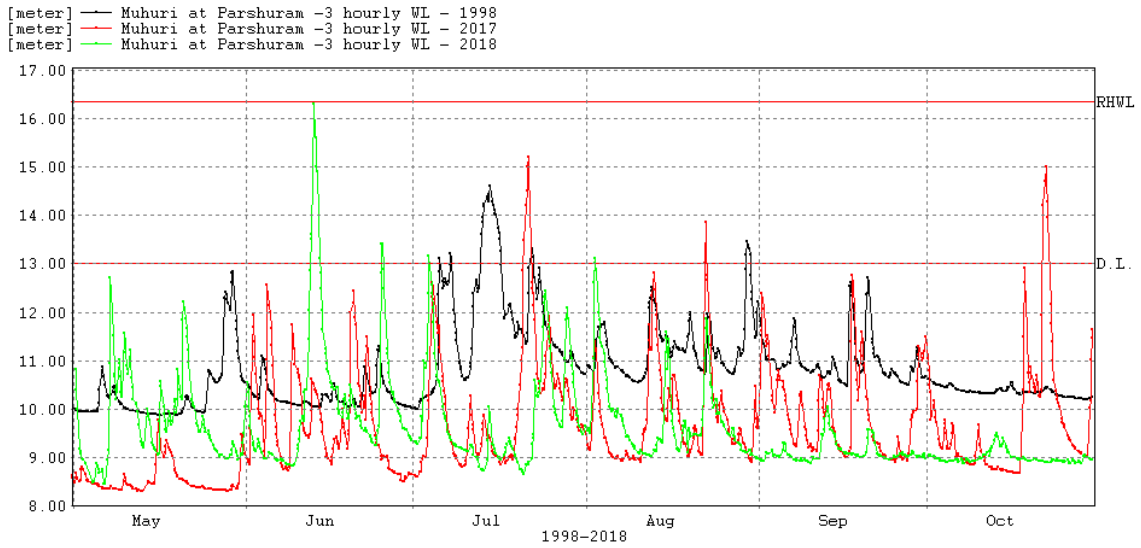


Figure 3.38: Comparison of Hydrograph on Muhuri at Parshuram

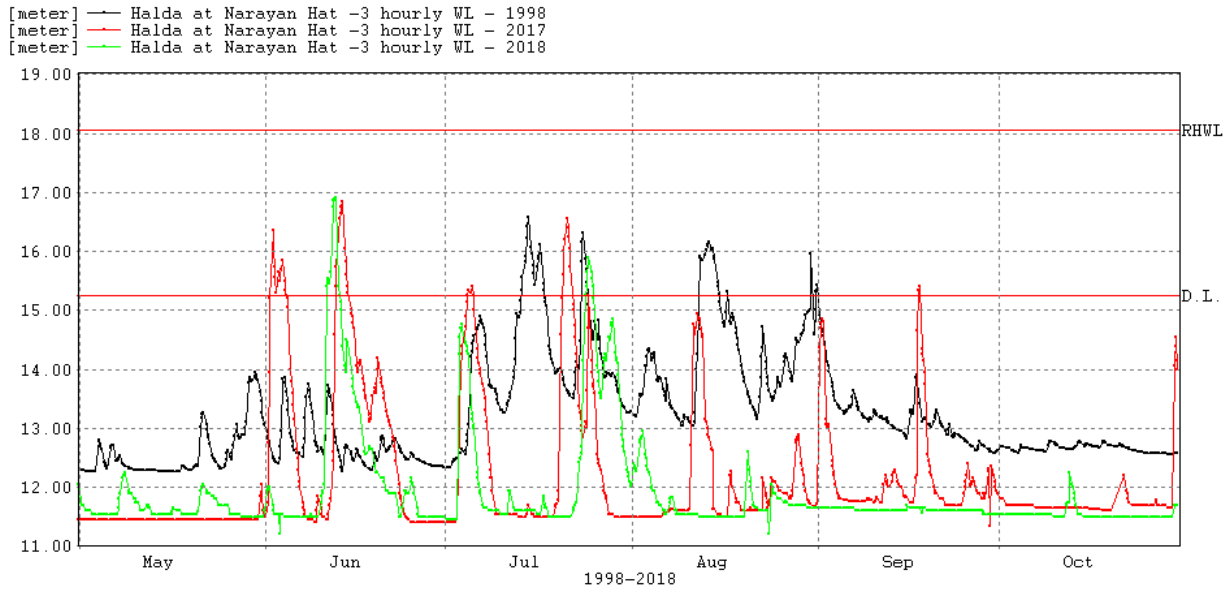


Figure 3.39: Comparison of Hydrograph on Halda at Narayanhat

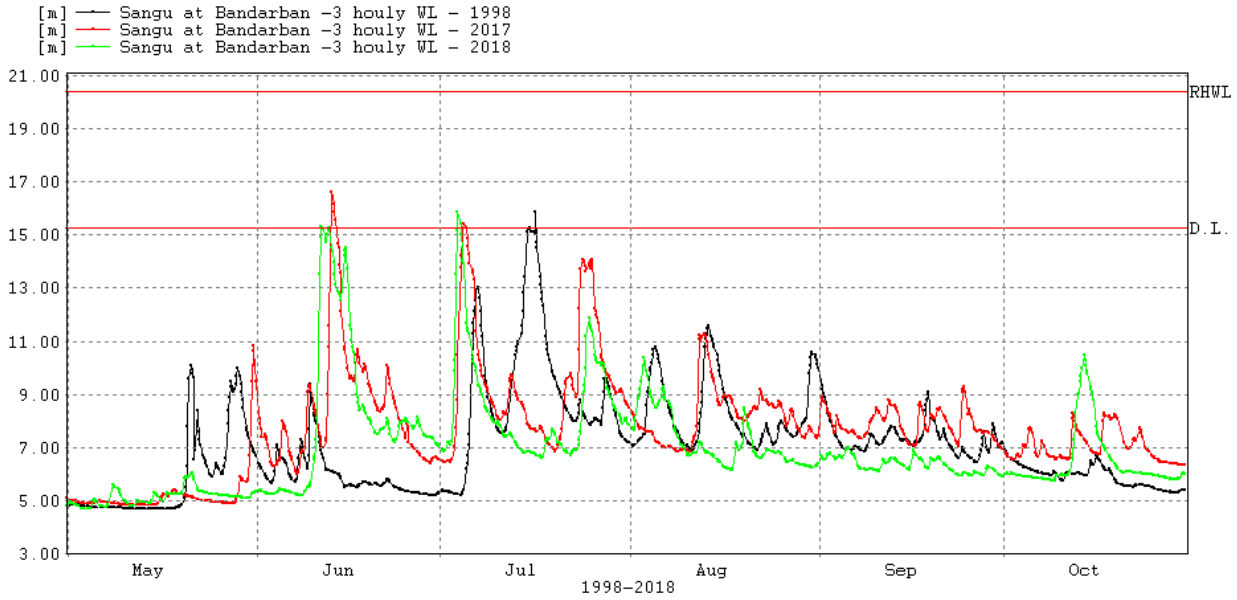


Figure 3.40: Comparison of Hydrograph on Sangu at Bandarban

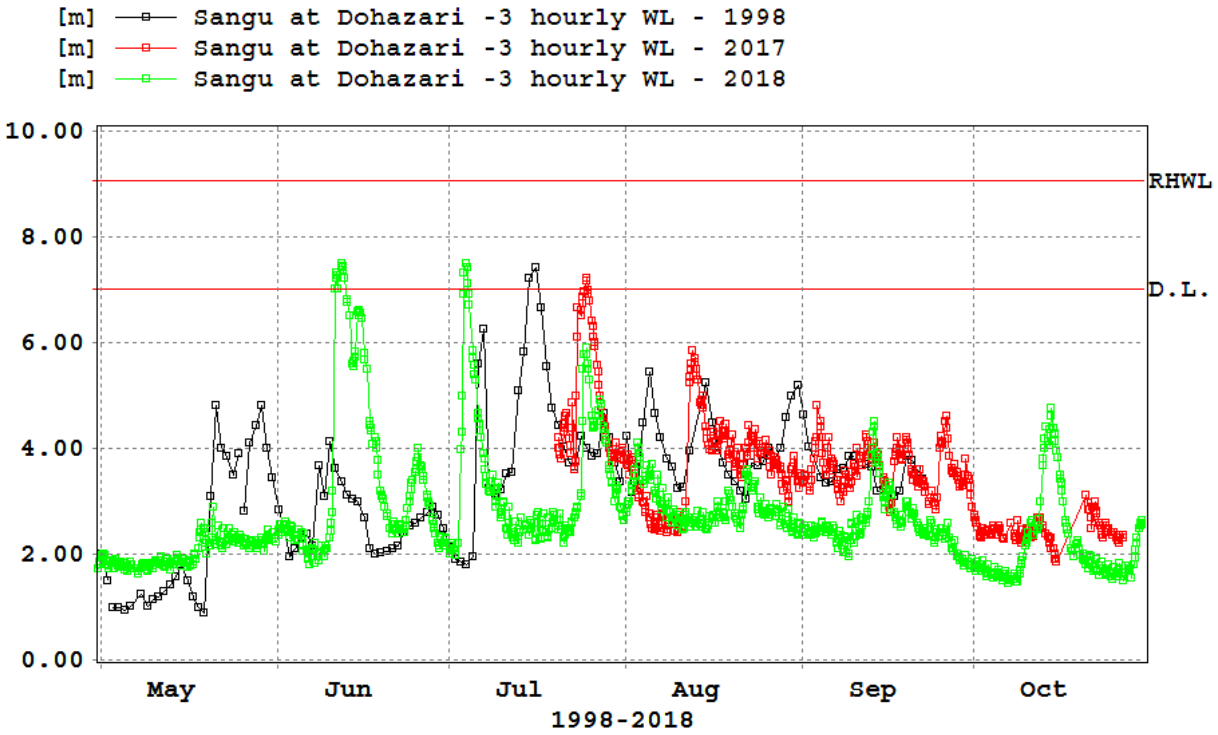


Figure 3.41: Comparison of Hydrograph on Sangu at Dohazari

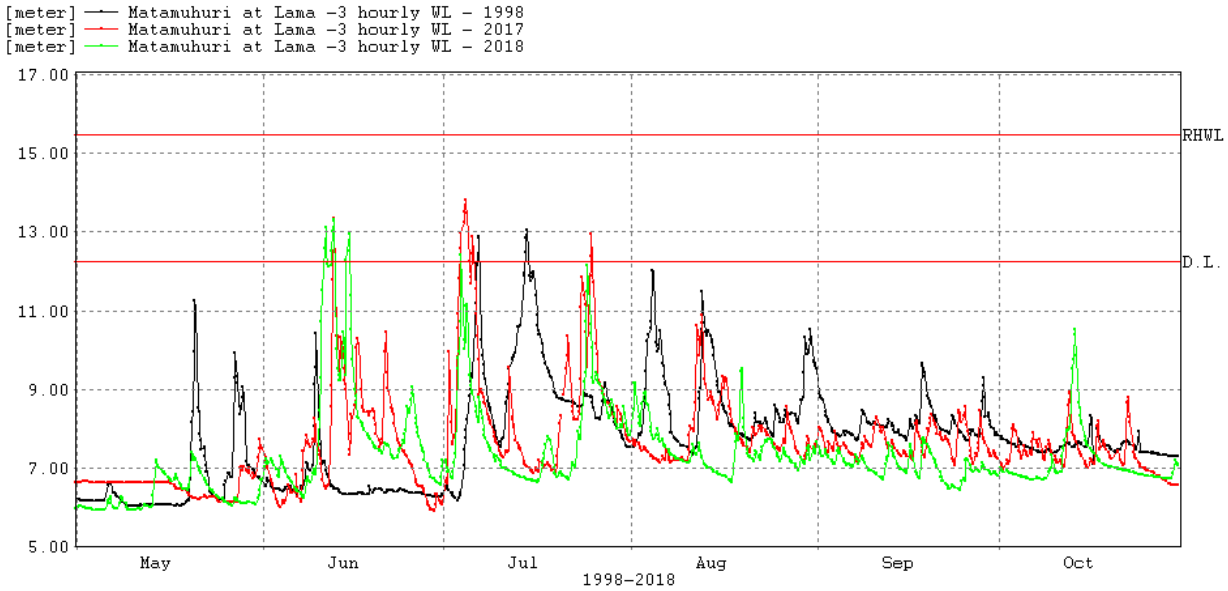


Figure 3.42: Comparison of Hydrograph on Matamuhuri at Lama

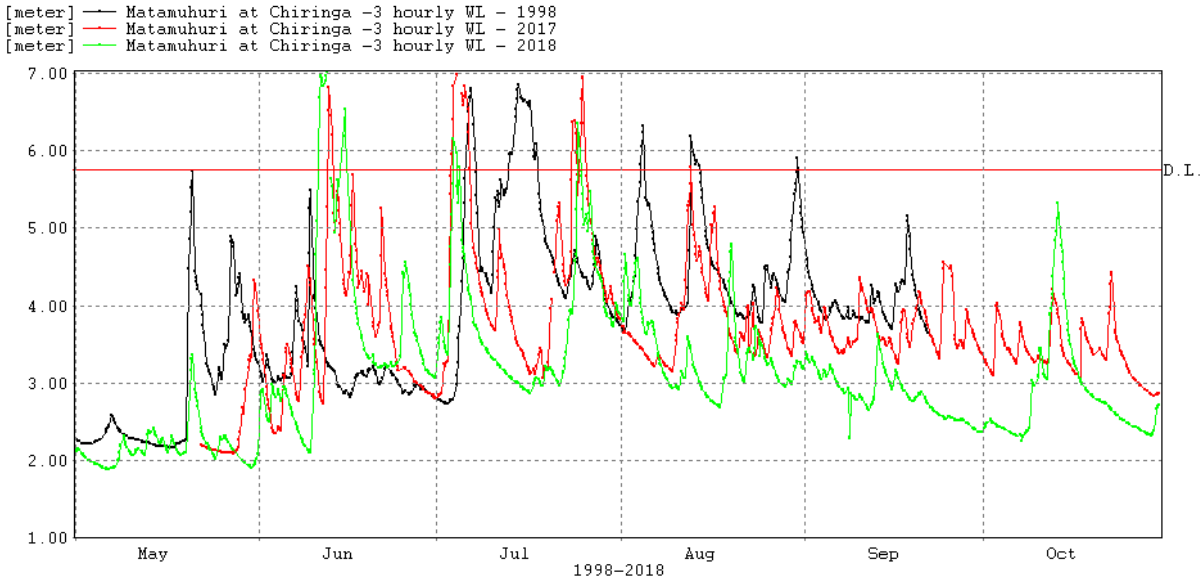


Figure 3.43: Comparison of Hydrograph on Matamuhuri at Chiringa

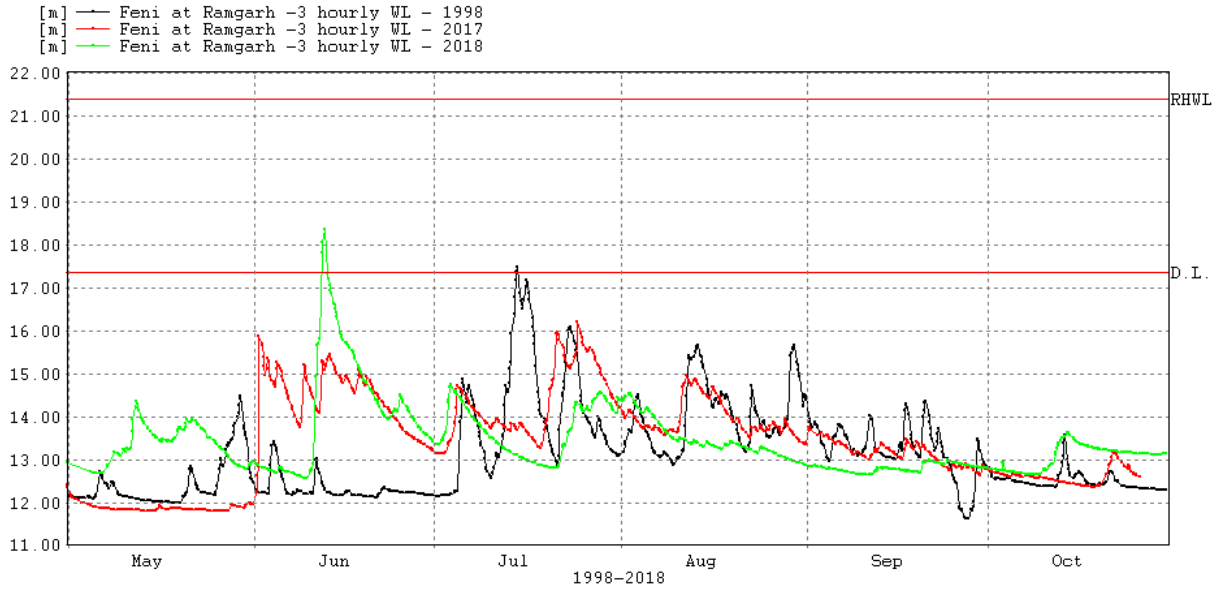


Figure 3.44: Comparison of Hydrograph on Feni at Ramgarh

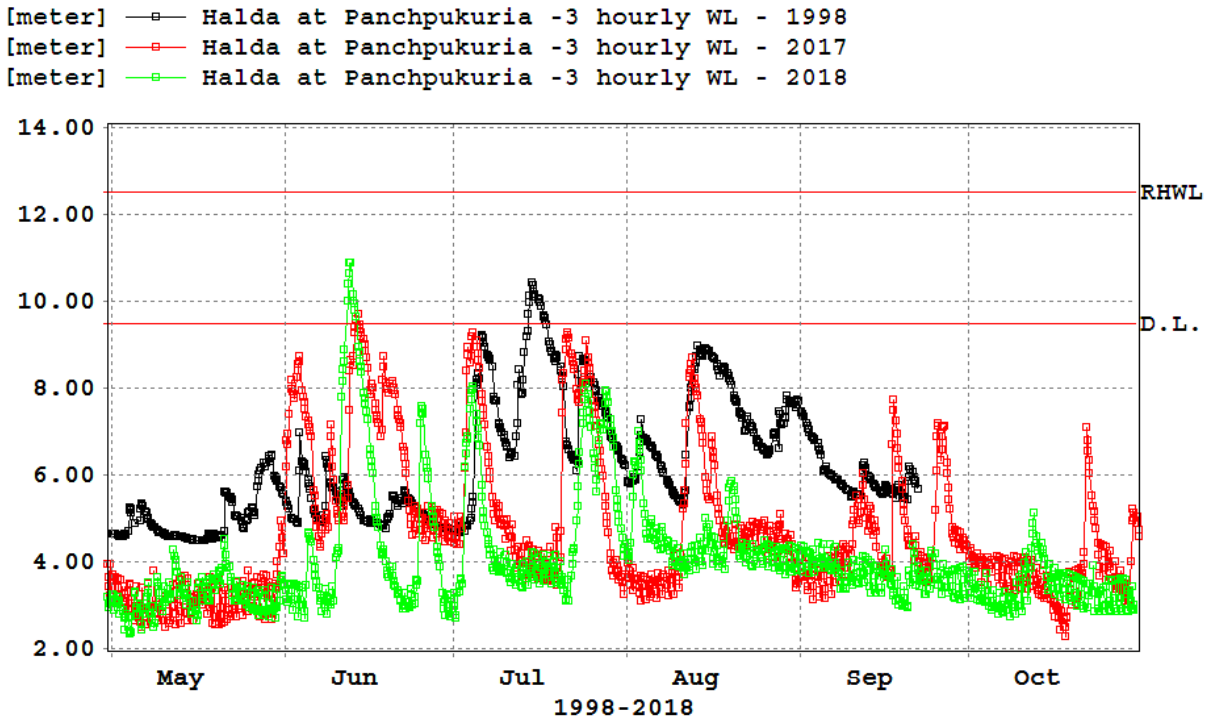


Figure 3.45: Comparison of Hydrograph on Halda at Panchpukuria

CHAPTER 4 : FORECAST EVALUATION, 2018

BWDB is the mandated organization for flood forecasting and warning services in Bangladesh as par the BWDB Act-2000. FFWC under BWDB has been carrying out this task through preparation of flood forecasting and early warning messages and its dissemination. Flood forecasting system of FFWC is developed using MIKE 11, a one-dimensional water modeling software used for the simulation of WLs and discharges in river networks and flood plains. The existing early warning system of floods provides a lead time of 120 hours, previously which was 72 hours. In order to meet the needs and expectations of flood forecast with increased lead times for cropping decisions, such as early harvesting, or to implement a contingency crop plan or protect infrastructure and preserve livelihoods, a research initiative was taken in July 2011 with support from Comprehensive Disaster Management Programme-II (CDMP-II) under Ministry of Food and Disaster Management (MoFDM) (from middle of 2012 renamed as Ministry of Disaster Management and Relief) to increase lead time for deterministic flood forecast up to 5 days (120 hours) from then existing 3-days (72 hours) forecast and also to extend the flood forecast to few selected BWDB projects. Since June 2015, FFWC is generating and disseminating 5-days deterministic flood forecast with experimental 4^{th} and 5^{th} day forecast in 54 stations during monsoon on operational basis.

The Climate Forecast Applications in Bangladesh (CFAB) project was supported by USAID/OFDA to develop and evaluate three tire overlapping forecast systems with improved lead time during monsoon seasons of 2003 and 2004. It showed a success in forecasting the discharges at Hardinge Bridge station of Ganges and Bahadurabad station of Brahmaputra river 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 of flood forecasts through pilot projects at selected sites.

Under the project, the medium range probabilistic flood forecast with 10-days lead time was initiated to a limited number of places (18 stations) on experimental basis. After the termination of the support from the USAID-CARE, this has been continued with technical support from Regional Integrated Multi-hazard Early Warning System (RIMES). Another initiative was started in July 2012 to expand the number of points for medium range 10-days probabilistic flood forecast with a view to increase the areal coverage, along with a long range seasonal flood forecast at 5 places on experimental basis with support from USAID through CARE-Bangladesh under SHOURHARDO-II programme with technical support from RIMES. Currently FFWC is experimentally generating medium range 10-days probabilistic flood forecast in 37 stations of Ganges-Brahmaputra basin during monsoon and disseminating on a limited basis.

4.1 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

4.1.1 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

4.1.2 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:

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

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

4.2 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 120 hours in the forecast period and forecasts were saved in the database at 24-hour and 48-hour, 72-hour, 96-hour and 120-hour intervals. Usually, the forecast quality gradually deteriorates with higher forecast intervals from the time of forecast. As lead time increases the forecast accuracy decreases.

4.3 DETERMINISTIC FORECAST STATISTICS AND PERFORMANCE, 2018

4.3.1 Deterministic Forecast Performance

For deterministic forecasts, simulations were made up to 120 hours (5-days) in the forecast period. Total 46 stations located within the model area (including some boundary stations) are evaluated. The deterministic forecast statistics along with performance based on the aforementioned scale are provided in Tables 4.2 to 4.6 and in Figures 4.1 to 4.5. From the following tables it can be seen that for 1-day forecast 91% stations are within the range of Good and Average, while for 2-days, 3-days, 4-days and 5-days forecast respectively 80%, 61%, 46% and 24% stations are within the range of Good and Average. A number of stations near boundary showed poor performance for increased lead time, most of which had flow of flashy characteristics or were under upstream regulation outside territory. From the Tables 4.2 to 4.6 it can also be seen that in terms of consistency based on the average statistics of co-efficient of determination, the forecasts are respectively 93% (Average MAE 0.09m), 89% (Average MAE 0.15m), 85% (Average MAE 0.20m), 81% (Average MAE 0.25m) and 78% (Average MAE 0.29m) consistent for 24, 48, 72, 96 and 120 hours of lead time in the monsoon of 2018.

Table 4.2: Statistics for 24-hours Forecast Performance (Year, 2018)

Sl. No.	Station	MAE (m)	r^2	Performance-24hrs
1	Aricha	0.05	0.99	Good
2	Baghabari	0.04	1.00	Good
3	Bahadurabad	0.05	1.00	Good
4	Bhagyakul	0.05	0.99	Good
5	Bhairab Bazar	0.06	0.93	Good
6	Bogra	0.17	0.89	Average
7	Chakrahimpur	0.10	0.98	Good
8	Chapai Nawabganj	0.08	1.00	Good
9	Chilmari	0.05	0.99	Good
10	Demra	0.06	0.98	Good
11	Derai	0.09	0.50	Not Satisfactory
12	Dhaka (Mill Barrack)	0.10	0.92	Good
13	Elashinghat	0.04	0.99	Good
14	Gaibandha	0.09	0.98	Good
15	Goalondo	0.05	0.99	Good
16	Gorai Rly Bridge	0.04	1.00	Good
17	Hardinge Br	0.05	1.00	Good
18	Jagir	0.06	0.94	Good
19	Jamalpur	0.11	0.98	Good
20	Kamarkhali	0.06	1.00	Good
21	Kaunia	0.19	0.41	Not Satisfactory
22	Kazipur	0.05	0.97	Good
23	Khaliajuri	0.04	0.98	Good
24	Kurigram	0.16	0.69	Not Satisfactory
25	Lakhpur	0.08	0.97	Good
26	Markuli	0.08	0.92	Good
27	Meghna Bridge	0.11	0.91	Good
28	Mirpur	0.07	0.96	Good
29	Mohadevpur	0.18	0.90	Average
30	Moulvi Bazar	0.24	0.84	Not Satisfactory
31	Mymensingh	0.12	0.95	Good
32	Naogaon	0.14	0.94	Good
33	Narayanganj	0.11	0.87	Average
34	Narsingdi	0.06	0.96	Good
35	Nayerhat	0.05	0.99	Good
36	Rajshahi	0.06	1.00	Good
37	Sariakandi	0.05	0.99	Good
38	Serajganj	0.05	0.99	Good
39	Sheola	0.16	0.97	Average
40	Sherpur-Sylhet	0.06	0.99	Good
41	Singra	0.07	0.93	Good
42	Sunamganj	0.08	0.98	Good
43	Sureswar	0.10	0.92	Good
44	Sylhet	0.14	0.95	Good
45	Taraghat	0.06	0.99	Good
46	Tongi	0.06	0.91	Good

Table 4.3: Statistics for 48-hours Forecast Performance (Year, 2018)

Sl. No.	Station	MAE (m)	r^2	Performance-48hrs
1	Aricha	0.09	0.98	Good
2	Baghabari	0.08	0.99	Good
3	Bahadurabad	0.10	0.98	Good
4	Bhagyakul	0.08	0.98	Good
5	Bhairab Bazar	0.09	0.93	Good
6	Bogra	0.33	0.67	Poor
7	Chakrahimpur	0.18	0.95	Average
8	Chapai Nawabganj	0.16	0.99	Average
9	Chilmari	0.10	0.98	Good
10	Demra	0.10	0.94	Good
11	Derai	0.11	0.49	Not Satisfactory
12	Dhaka (Mill Barrack)	0.15	0.84	Average
13	Elashinghat	0.07	0.99	Good
14	Gaibandha	0.15	0.94	Good
15	Goalondo	0.09	0.99	Good
16	Gorai Rly Bridge	0.08	1.00	Good
17	Hardinge Br	0.10	1.00	Good
18	Jagir	0.12	0.82	Average
19	Jamalpur	0.18	0.96	Average
20	Kamarkhali	0.09	1.00	Good
21	Kaunia	0.27	0.34	Poor
22	Kazipur	0.10	0.96	Good
23	Khaliajuri	0.07	0.94	Good
24	Kurigram	0.22	0.64	Not Satisfactory
25	Lakhpur	0.12	0.93	Good
26	Markuli	0.13	0.86	Average
27	Meghna Bridge	0.18	0.79	Average
28	Mirpur	0.11	0.93	Good
29	Mohadevpur	0.31	0.76	Poor
30	Moulvi Bazar	0.32	0.71	Poor
31	Mymensingh	0.20	0.89	Average
32	Naogaon	0.27	0.82	Not Satisfactory
33	Narayanganj	0.15	0.80	Average
34	Narsingdi	0.11	0.92	Good
35	Nayerhat	0.08	0.98	Good
36	Rajshahi	0.13	1.00	Good
37	Sariakandi	0.10	0.97	Good
38	Serajganj	0.08	0.98	Good
39	Sheola	0.35	0.90	Poor
40	Sherpur-Sylhet	0.11	0.97	Good
41	Singra	0.11	0.85	Average
42	Sunamganj	0.15	0.93	Good
43	Sureswar	0.16	0.84	Average
44	Sylhet	0.26	0.88	Not Satisfactory
45	Taraghat	0.11	0.98	Good
46	Tongi	0.09	0.90	Good

Table 4.4: Statistics for 72-hours Forecast Performance (Year, 2018)

Sl. No.	Station	MAE (m)	r^2	Performance-72hrs
1	Aricha	0.12	0.98	Good
2	Baghabari	0.11	0.98	Good
3	Bahadurabad	0.16	0.96	Average
4	Bhagyakul	0.11	0.97	Good
5	Bhairab Bazar	0.11	0.92	Good
6	Bogra	0.48	0.43	Very Poor
7	Chakrahimpur	0.26	0.90	Not Satisfactory
8	Chapai Nawabganj	0.24	0.98	Not Satisfactory
9	Chilmari	0.16	0.95	Average
10	Demra	0.13	0.90	Good
11	Derai	0.13	0.50	Not Satisfactory
12	Dhaka (Mill Barrack)	0.19	0.76	Average
13	Elashinghat	0.10	0.98	Good
14	Gaibandha	0.21	0.91	Not Satisfactory
15	Goalondo	0.12	0.98	Good
16	Gorai Rly Bridge	0.14	0.99	Good
17	Hardinge Br	0.15	0.99	Good
18	Jagir	0.17	0.68	Not Satisfactory
19	Jamalpur	0.21	0.94	Not Satisfactory
20	Kamarkhali	0.12	0.99	Good
21	Kaunia	0.32	0.25	Very Poor
22	Kazipur	0.15	0.93	Good
23	Khaliajuri	0.09	0.94	Good
24	Kurigram	0.29	0.61	Not Satisfactory
25	Lakhpur	0.16	0.90	Average
26	Markuli	0.16	0.84	Average
27	Meghna Bridge	0.23	0.70	Not Satisfactory
28	Mirpur	0.15	0.89	Average
29	Mohadevpur	0.41	0.62	Very Poor
30	Moulvi Bazar	0.41	0.63	Very Poor
31	Mymensingh	0.27	0.84	Not Satisfactory
32	Naogaon	0.37	0.72	Poor
33	Narayanganj	0.19	0.72	Average
34	Narsingdi	0.14	0.89	Average
35	Nayerhat	0.11	0.95	Good
36	Rajshahi	0.21	0.99	Not Satisfactory
37	Sariakandi	0.15	0.95	Good
38	Serajganj	0.12	0.97	Good
39	Sheola	0.48	0.84	Very Poor
40	Sherpur-Sylhet	0.15	0.93	Good
41	Singra	0.15	0.79	Average
42	Sunamganj	0.21	0.88	Not Satisfactory
43	Sureswar	0.19	0.80	Average
44	Sylhet	0.36	0.83	Poor
45	Taraghat	0.15	0.97	Good
46	Tongi	0.13	0.86	Average

Table 4.5: Statistics for 96-hours Forecast Performance (Year, 2018)

Sl. No.	Station	MAE (m)	r^2	Performance-96hrs
1	Aricha	0.16	0.97	Average
2	Baghabari	0.14	0.97	Good
3	Bahadurabad	0.22	0.94	Not Satisfactory
4	Bhagyakul	0.14	0.97	Good
5	Bhairab Bazar	0.13	0.92	Good
6	Bogra	0.59	0.26	Very Poor
7	Chakrahimpur	0.33	0.86	Poor
8	Chapai Nawabganj	0.32	0.97	Poor
9	Chilmari	0.22	0.91	Not Satisfactory
10	Demra	0.15	0.86	Average
11	Derai	0.19	0.20	Very Poor
12	Dhaka (Mill Barrack)	0.21	0.73	Not Satisfactory
13	Elashinghat	0.13	0.97	Good
14	Gaibandha	0.25	0.88	Not Satisfactory
15	Goalondo	0.16	0.97	Average
16	Gorai Rly Bridge	0.19	0.99	Average
17	Hardinge Br	0.22	0.98	Not Satisfactory
18	Jagir	0.22	0.55	Not Satisfactory
19	Jamalpur	0.25	0.92	Not Satisfactory
20	Kamarkhali	0.15	0.99	Good
21	Kaunia	0.35	0.23	Very Poor
22	Kazipur	0.20	0.90	Average
23	Khaliajuri	0.11	0.91	Good
24	Kurigram	0.36	0.55	Poor
25	Lakhpur	0.19	0.86	Average
26	Markuli	0.18	0.84	Average
27	Meghna Bridge	0.24	0.65	Not Satisfactory
28	Mirpur	0.17	0.85	Average
29	Mohadevpur	0.47	0.55	Very Poor
30	Moulvi Bazar	0.50	0.57	Very Poor
31	Mymensingh	0.33	0.81	Poor
32	Naogaon	0.45	0.64	Very Poor
33	Narayanganj	0.21	0.67	Not Satisfactory
34	Narsingdi	0.16	0.88	Average
35	Nayerhat	0.14	0.93	Good
36	Rajshahi	0.28	0.98	Not Satisfactory
37	Sariakandi	0.21	0.93	Not Satisfactory
38	Serajganj	0.17	0.94	Average
39	Sheola	0.61	0.78	Very Poor
40	Sherpur-Sylhet	0.20	0.90	Average
41	Singra	0.19	0.73	Average
42	Sunamganj	0.26	0.84	Not Satisfactory
43	Sureswar	0.22	0.75	Not Satisfactory
44	Sylhet	0.48	0.78	Very Poor
45	Taraghat	0.19	0.95	Average
46	Tongi	0.15	0.81	Average

Table 4.6: Statistics for 120-hours Forecast Performance (Year, 2018)

Sl. No.	Station	MAE (m)	r^2	Performance-120hrs
1	Aricha	0.21	0.95	Not Satisfactory
2	Baghabari	0.18	0.96	Average
3	Bahadurabad	0.28	0.90	Not Satisfactory
4	Bhagyakul	0.17	0.95	Average
5	Bhairab Bazar	0.15	0.91	Good
6	Bogra	0.68	0.17	Very Poor
7	Chakrahimpur	0.39	0.81	Poor
8	Chapai Nawabganj	0.39	0.95	Poor
9	Chilmari	0.29	0.86	Not Satisfactory
10	Demra	0.18	0.84	Average
11	Derai	0.16	0.53	Not Satisfactory
12	Dhaka (Mill Barrack)	0.22	0.71	Not Satisfactory
13	Elashinghat	0.16	0.96	Average
14	Gaibandha	0.32	0.82	Poor
15	Goalondo	0.21	0.95	Not Satisfactory
16	Gorai Rly Bridge	0.25	0.97	Not Satisfactory
17	Hardinge Br	0.29	0.97	Not Satisfactory
18	Jagir	0.27	0.46	Not Satisfactory
19	Jamalpur	0.32	0.88	Poor
20	Kamarkhali	0.21	0.98	Not Satisfactory
21	Kaunia	0.34	0.26	Very Poor
22	Kazipur	0.26	0.86	Not Satisfactory
23	Khaliajuri	0.13	0.89	Average
24	Kurigram	0.41	0.50	Very Poor
25	Lakhpur	0.23	0.83	Not Satisfactory
26	Markuli	0.19	0.83	Average
27	Meghna Bridge	0.26	0.61	Not Satisfactory
28	Mirpur	0.19	0.82	Average
29	Mohadevpur	0.53	0.46	Very Poor
30	Moulvi Bazar	0.54	0.54	Very Poor
31	Mymensingh	0.40	0.76	Poor
32	Naogaon	0.51	0.59	Very Poor
33	Narayanganj	0.24	0.62	Not Satisfactory
34	Narsingdi	0.17	0.87	Average
35	Nayerhat	0.17	0.90	Average
36	Rajshahi	0.36	0.97	Poor
37	Sariakandi	0.27	0.91	Not Satisfactory
38	Serajganj	0.23	0.91	Not Satisfactory
39	Sheola	0.74	0.71	Very Poor
40	Sherpur-Sylhet	0.23	0.88	Not Satisfactory
41	Singra	0.23	0.69	Not Satisfactory
42	Sunamganj	0.31	0.80	Poor
43	Sureswar	0.24	0.73	Not Satisfactory
44	Sylhet	0.55	0.76	Very Poor
45	Taraghat	0.24	0.93	Not Satisfactory
46	Tongi	0.18	0.77	Average

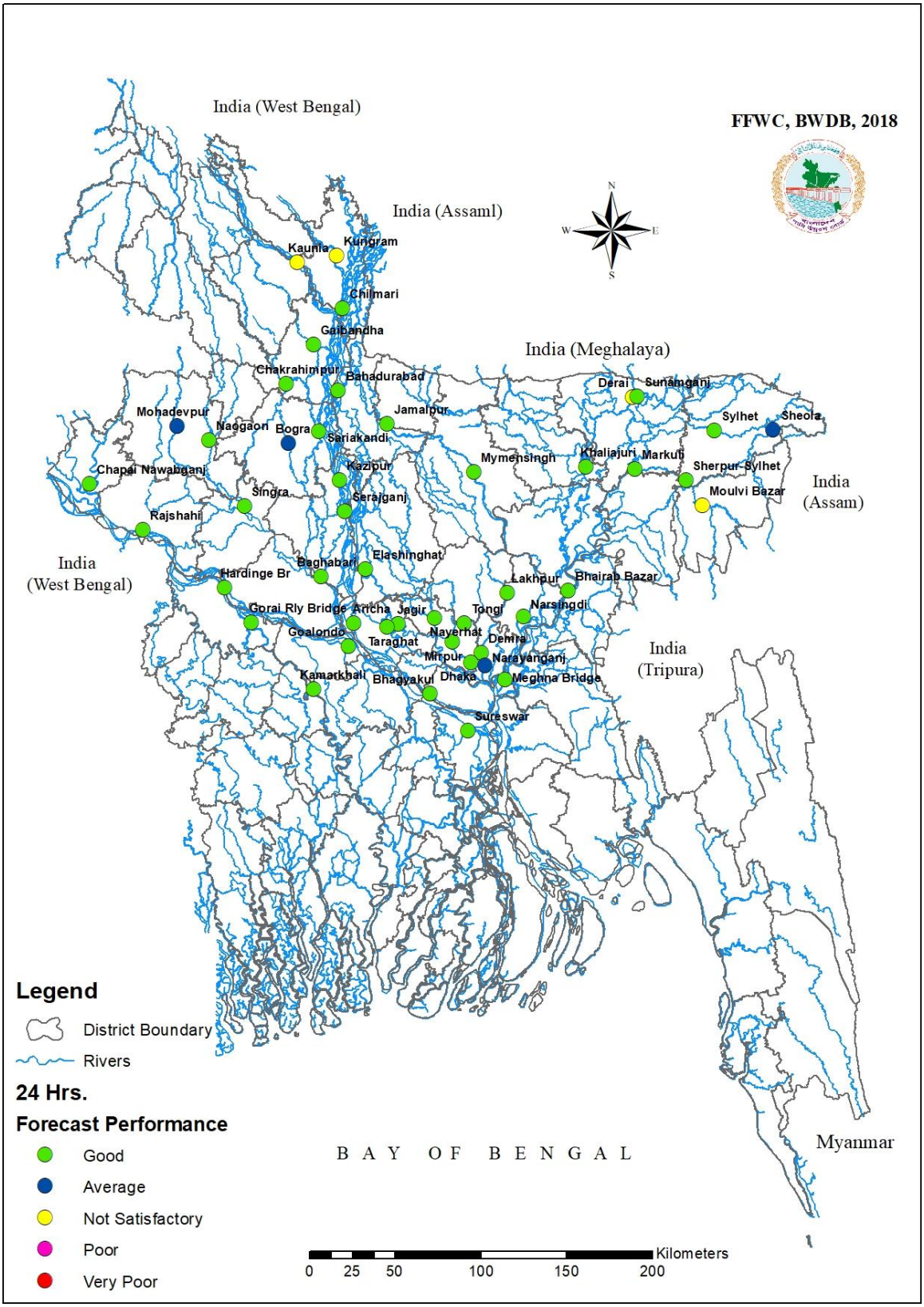


Figure 4.1 : 24-hrs Forecast Evaluation (Year, 2018)

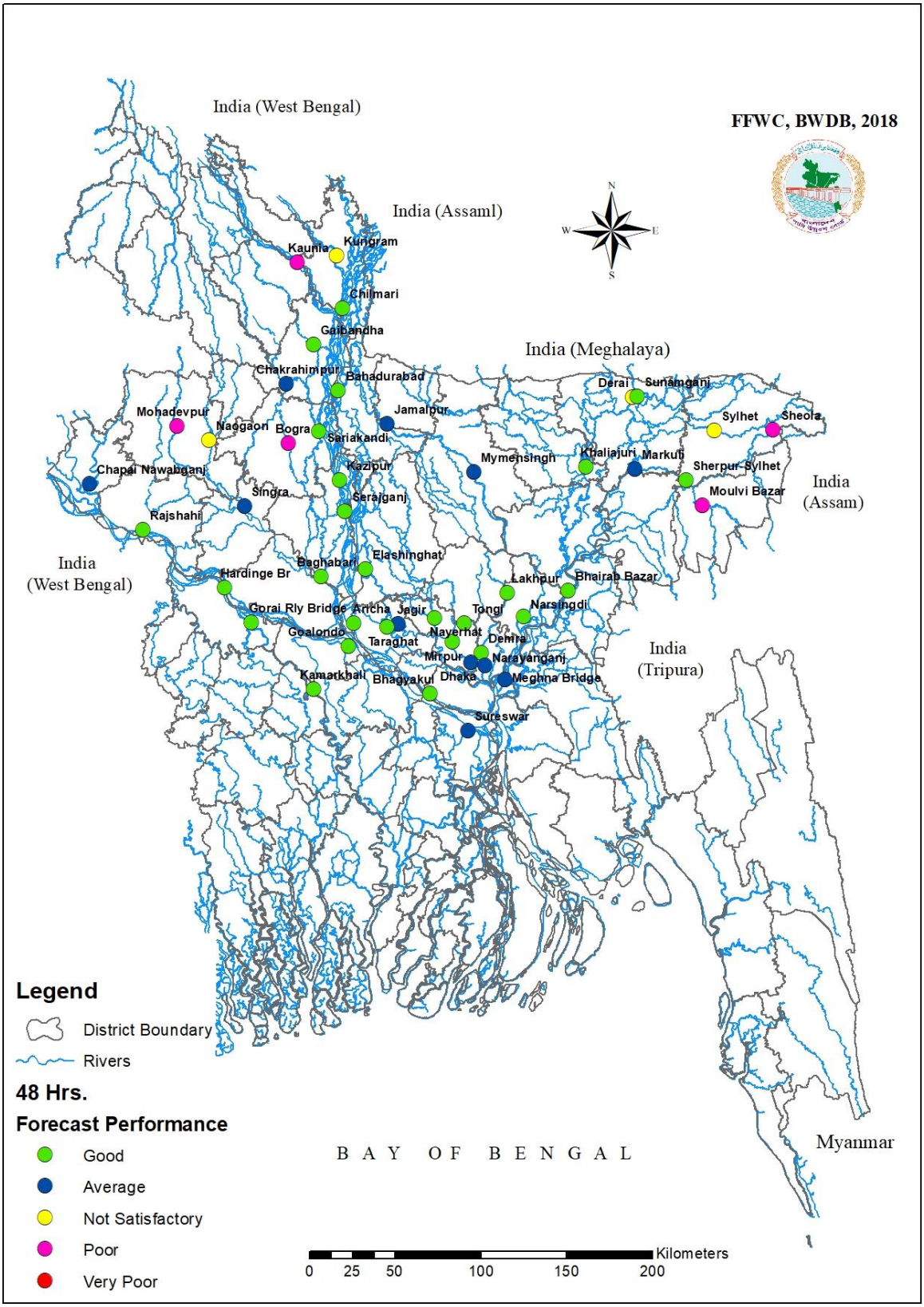


Figure 4.2 : 48-hrs Forecast Evaluation (Year, 2018)

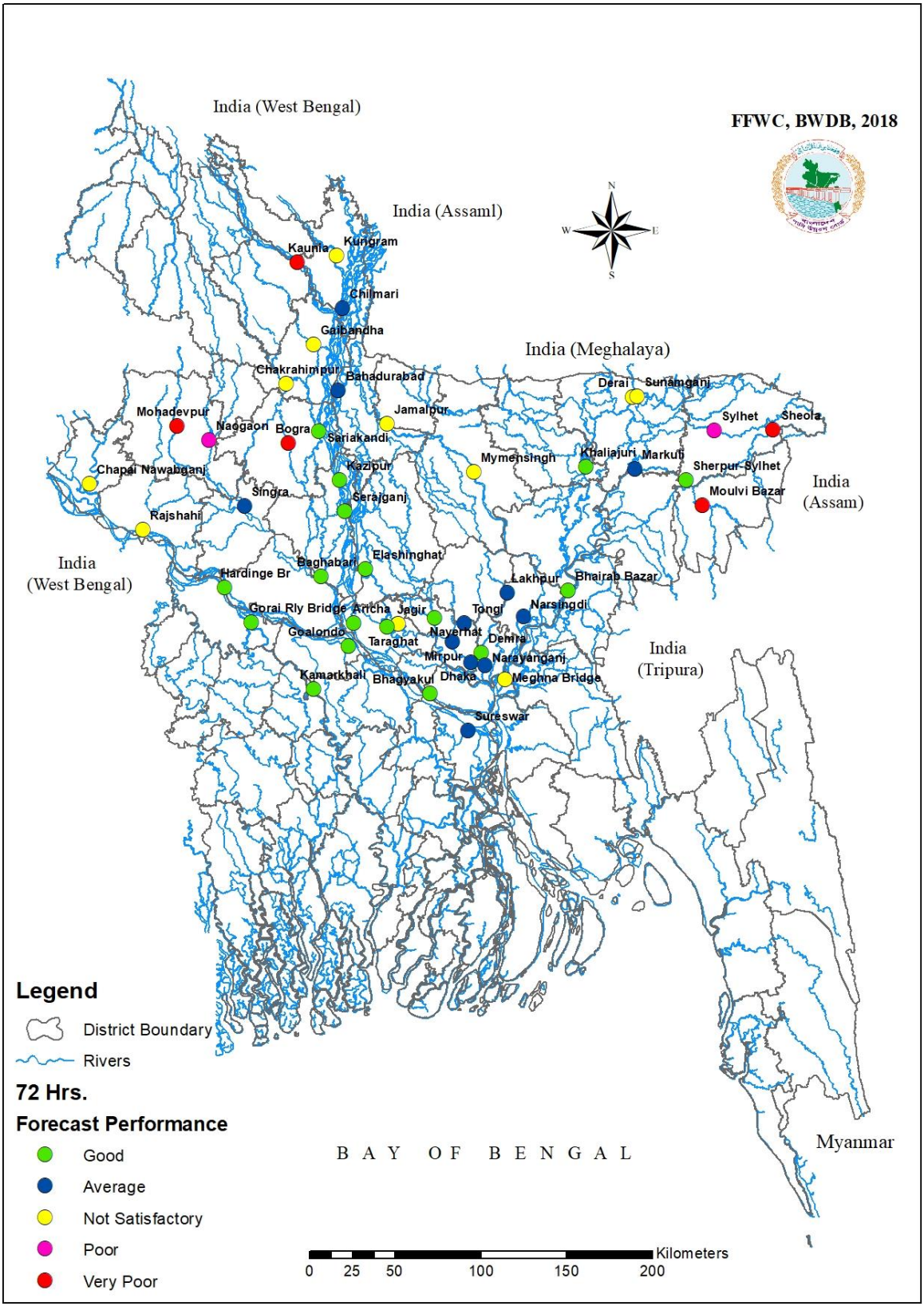


Figure 4.3 : 72-hrs Forecast Evaluation (Year, 2018)

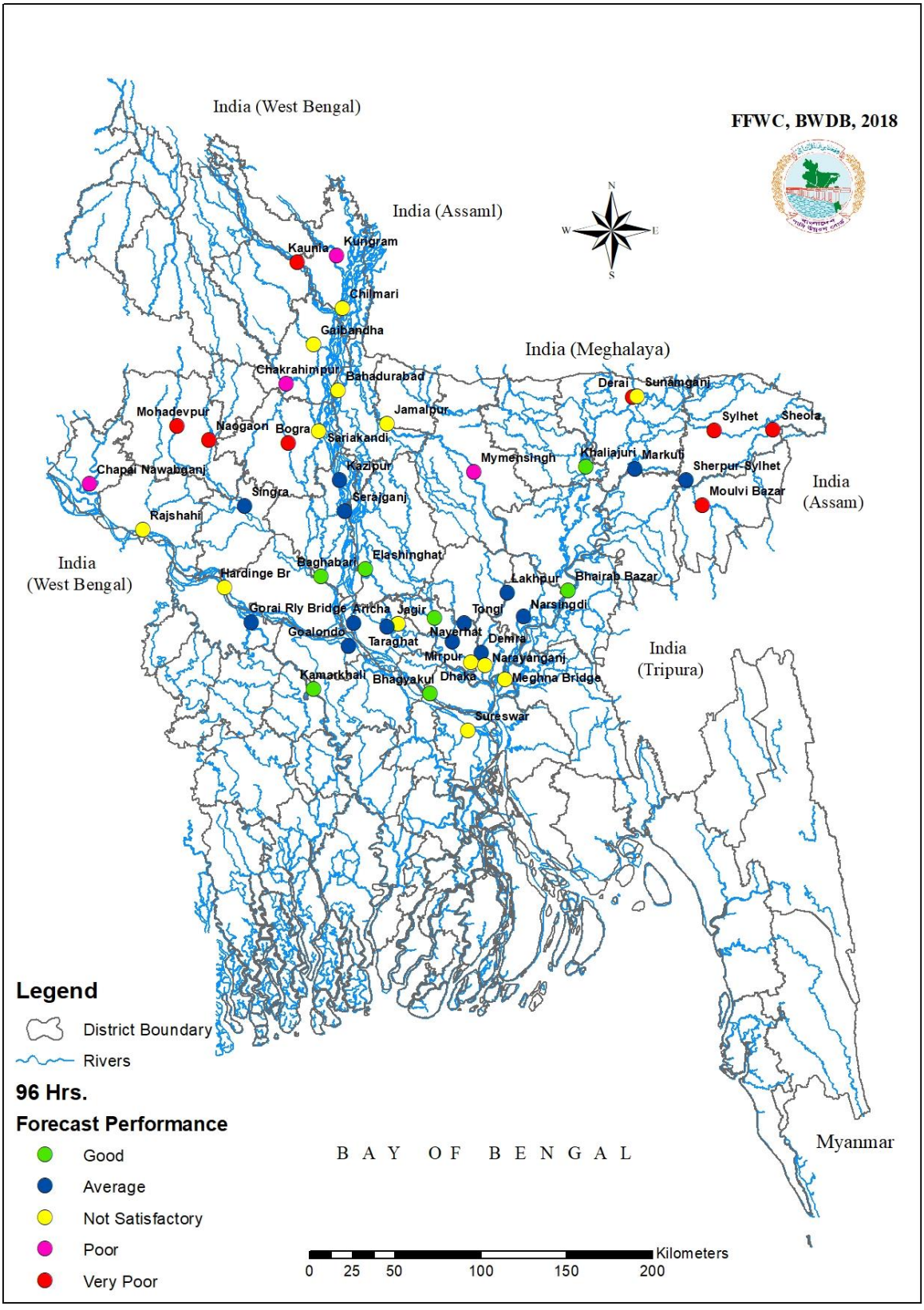


Figure 4.4 : 96-hrs Forecast Evaluation (Year, 2018)

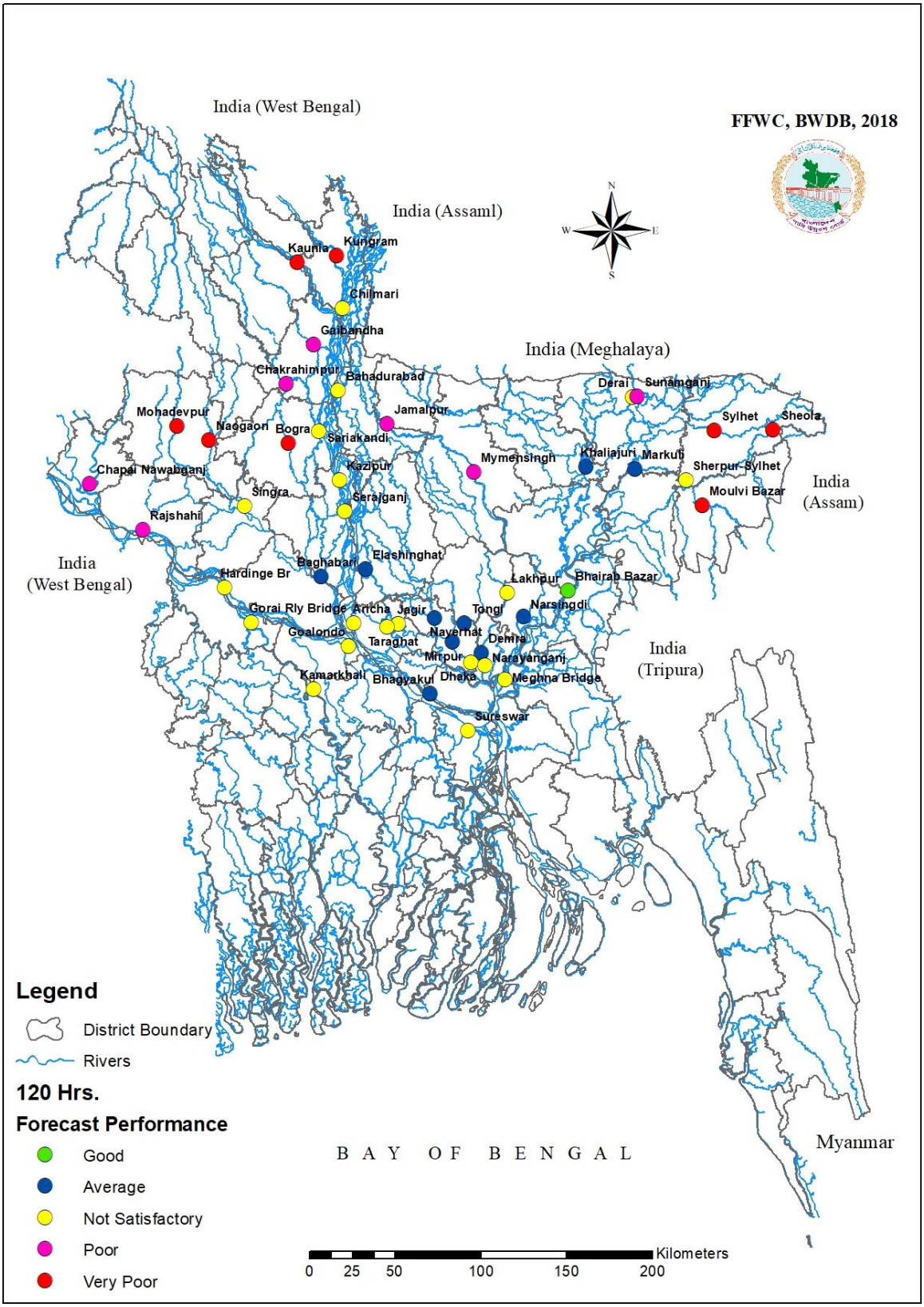


Figure 4.5 : 120-hrs Forecast Evaluation (Year, 2018)

4.3.2 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. The Mean Water Level forecasts are made from the mean discharge and the mean rainfall forecast of all 51-ensemble series. The Upper bound and Lower bound levels correspond to +1 standard deviation from the mean and -1 standard deviation from the mean respectively.

The statistics of probabilistic discharge forecast performance up to 10 days during Monsoon-2018 at Bahadurabad and Hardinge Bridge stations have been presented in Table 4.7 based on the Nash–Sutcliffe Efficiency coefficient (NSE), Co-efficient of Determination (R^2), Percent bias (Pbias) and Root Mean Square Error (RMSE).

Table 4.7 : Performance of Probabilistic Discharge Forecast up to 10 days at Bahadurabad and Hardinge Bridge Station (Year, 2018)

Station Name	Performance Indicators	Day – 1	Day – 3	Day – 5	Day – 7	Day – 10
Bahadurabad	Median					
	NSE	0.99	0.94	0.91	0.73	0.35
	R^2	0.99	0.94	0.94	0.89	0.87
	Pbias	0.0500	-2.1862	-5.9476	-13.3831	-24.0835
	RMSE (cumec)	1475.749	3108.139	3672.033	6051.205	9139.338
	16% Quantile					
	NSE	0.99	0.94	0.93	0.83	0.68
	R^2	0.99	0.94	0.94	0.89	0.87
	Pbias	0.1933	-0.7747	-2.3013	-6.5434	-12.7896
	RMSE (cumec)	1477.26	3057.195	3253.432	4724.661	6401.1
	75% Quantile					
	NSE	0.99	0.93	0.87	0.58	0.06
	R^2	0.99	0.94	0.93	0.88	0.86
	Pbias	-0.0865	-3.4499	-9.3911	-19.0277	-33.2334
	RMSE (cumec)	1475.67	3237.17	4486.524	7512.572	11686.91
Hardinge Bridge	Median					
	NSE	0.99	0.98	0.95	0.92	0.88
	R^2	0.99	0.98	0.95	0.92	0.89
	Pbias	0.0765	0.4155	1.7500	-1.5950	-4.3611
	RMSE (cumec)	631.306	2219.04	3354.00	4192.96	5469.589
	16% Quantile					
	NSE	0.99	0.98	0.95	0.93	0.88
	R^2	0.99	0.98	0.95	0.92	0.88
	Pbias	0.1657	1.25163	4.3840	2.9472	2.9701
	RMSE (cumec)	632.65	2228.79	3356.00	4019.669	5411.514
	75% Quantile					
	NSE	0.99	0.98	0.94	0.91	0.86
	R^2	0.99	0.98	0.95	0.92	0.89
	Pbias	0.0037	-0.3099	-0.4000	-5.1006	-10.0047
	RMSE (cumec)	630.80	2228.71	3447.93	4487.735	5789.510

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 along 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 Monsoon 2018 the country as a whole experienced normal flooding.

In Monsoon 2018, the Brahmaputra basin of the country experienced normal to moderate flooding of short to medium duration at low lying places, while the Ganges basin remained flood free throughout the season. The Meghna basin experienced flooding during May-June while the South Eastern Hill basin during June-July but both remained flood free afterwards. The greater Surma-Kushiyara basin of the Meghna faced moderate to severe flooding events of short to medium duration at most places, among which flash flood event of Manu river was one of the most severe ones in recent history. The South Eastern Hill basin experienced severe flash floods at some places during the onset of monsoon; however, the water stayed for short duration all throughout. Some parts of the Haor basin of the country faced slightly early pre-monsoon flooding this year during the 2nd week of May but with no notable damage to crops. In total 23% of the country got flood affected this year.

5.1 BASINWISE INUNDATION STATUS

Brahmaputra Basin:

Out of 30 Water Level (WL) monitoring stations in the Brahmaputra basin, at 8 stations WL crossed and remained over their respective DLs in 2018. Flood in the basin this year consisted of two major peaks, the first between 6th-11th July while the second between 11th-21st September. The stations that crossed and remained over DLs during these periods are: Dharala at Kurigram for 2 days peaking 31 cm above DL, Teesta at Dalia for 5 days peaking 11 cm above DL, Jamuna at both Fulchari and Bahadurabad for 5 days peaking 9 cm above DL, at Sariakandi for 9 days peaking 21 cm above DL, at Kazipur for 6 days peaking 29 cm above DL, Atrai at Baghabari for 6 days peaking 13 cm above DL and Dhaleswari at Elasinghat for 9 days peaking 33 cm above DL. Kurigram, Dalia and Kazipur exceeded DL during the first peak while Dalia, Bahadurabad, Sariakandi, Baghabari and Elashinghat during the second for which the inundation extent was greater. As a result of these events, low-lying areas of Kurigram, Lalmonirhat, Nilphamari, Gaibandha, Bogra, Sirajganj, Pabna, Jamalpur and Tangail districts experienced normal to moderate flooding of short to medium duration during 2018. The basin as a whole experienced normal flooding this year.

Ganges Basin:

In the Ganges basin out of 25 WL monitoring stations, no stations exceeded DL during 2018 except one tidal station. The basin as a whole experienced no riverine floods in main lands which was a below normal flood situation.

Meghna Basin:

Out of 26 WL monitoring stations in the Meghna basin, at 14 stations water flowed above their respective DLs during 2018. The basin faced moderate to severe flash floods during the first half of the monsoon (May-July) and water stayed for short to medium duration. During the second half of the monsoon (August-October) the basin remained mostly flood free except at one or two places for short duration. During early pre-monsoon (March-April) the Haor basins faced no flooding and remained dry. However, some parts of the Haors in Sylhet, Moulvibazar, Habiganj and Netrokona faced flash floods during 2nd week of May and got inundated slightly earlier than normal (15th May), but no notable damage to Boro crops occurred. Severe flash flooding activity took place over the greater Surma-Kushiyara basin at the time of onset of monsoon during the 2nd-3rd week of June when the Surma, Kushiyara, Manu and Khowai rivers overflowed regular banks and caused floods of moderate to severe magnitudes of short to medium duration. The Manu river at Moulvibazar during the period caused one of the severe flash floods in recent history though stayed for short duration. The Surma river again overflowed at Kanaighat and Sunamganj during 1st week of July and caused normal to severe flash floods at adjacent places. The stations that flowed above DLs during these periods are: Surma at Kanaighat and Sunamganj for 17 and 3 days peaking 157 and 22 cm above DL respectively, Kushiyara at Amalshid, Sheola and Sherpur for 9, 7 and 2 days peaking 155, 59 and 6 cm above DL respectively, Manu at Manu Railway Bridge and Moulvibazar for 7 and 6 days peaking 141 and 120 cm above DL respectively, Khowai at Ballah and Habiganj for 18 and 9 days peaking 251 and 200 cm above DL respectively, Sarigowain at Sarighat for 2 days peaking 24 cm above DL, Dhalai at Kamalganj for 4 days peaking 21 cm above DL, Bhugai at Nakuagaon for 1 day peaking 91 cm above DL, Jadukata at Lorergarh for 3 days peaking 20 cm above DL and Chandpur at Meghna for 4 days peaking 7 cm above DL. Except Nakuagaon and Chandpur all stations crossed DLs during May-July period. As a result of these events, some areas of Sylhet, Moulvibazar and Habiganj experienced moderate to severe flooding of short to medium duration, while other parts of the basin experienced normal or below normal flooding during 2018.

South Eastern Hill Basin:

In the South Eastern Hill basin, 8 out of the 9 water level monitoring stations crossed danger levels but all for short period during monsoon 2018. The first flash flood hit of the season at the time of the onset of monsoon during the 2nd week of June was the biggest of 2018 and occurred all over the basin with moderate to severe intensity. Afterwards flash flood events also occurred during 1st and 4th week of July but were more or less localized with nearly normal to moderate intensity. The stations that flowed above DLs during the season

are: Muhuri at Parshuram for 6 days peaking 330 cm above DL, Halda at Narayanhat and Panchpukuria for 5 and 2 days peaking 167 and 140 cm above DL respectively, Sangu at Bandarban and Doahazari for 2 and 3 days peaking 60 and 50 cm above DL respectively, Matamuhuri at Lama and Chiringa for 4 and 6 days peaking 104 and 85 cm above DL respectively and Feni at Ramgarh for 2 days peaking 101 cm above DL. As a result of these, low lying areas of Feni, Chittagong, Cox's Bazar and Bandarban districts experienced moderate to severe flash flooding of short duration during June-July but remained mostly flood free afterwards.

5.2 COUNTRYWIDE INUNDATION 2018

Like other previous years, this year also FFWC generated model based nationwide inundation map. Flood map has been generated from Flood Forecasting Model output result files 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 that flood peak arrived several times in 2018 which was attenuated during the fourth week of September. It was observed from monitoring that the Brahmaputra-Jamuna and Padma rivers attained peak water level on 20th September, while the Upper Meghna river on 17th July. From areal coverage perspective, 20th September, 2018 was chosen as the peak time of monsoon on which FFWC observed total number of 5 flood monitoring stations above danger levels all in Brahmaputra basin. Figure 5.2 shows the observed inundation map for 20th of September and then 24, 48, 72, 96 and 120 hours forecasted inundation maps on the day in figures 5.3 to 5.7 respectively. The map on 20th September captures the inundation scenario of the country during monsoon 2018, except relatively small inundations at the North-Eastern and South-Eastern regions due to some isolated and short-term flood events. Inundated area based on this map is around 33941 sq-km which is 23% of the country area and is the maximum inundated area found in this flood season. This inundated area excludes the permanent water bodies i.e. rivers, lakes, Haors, ponds etc. The calculation of permanent water bodies is also a crucial issue. Some literature reviews and remote sensing based analysis depict that there are approximately 6-8% of permanent water bodies existing 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 is 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 2018 was verified with Synthetic Aperture Radar (SAR) based high resolution (10 m) satellite image from Sentinel-1 by

European Space Agency (ESA). Radar based imagery are unsusceptible to cloud covers but susceptible to dense forests, so it would provide nearly accurate flooded area in the Northern and Central parts of the country but may underestimate in South-Western mangrove forest (Sundarban) parts and South-Eastern hilly forest regions. Because of non-availability of countrywide daily product, Sentinel-1 data from 15th to 22nd of September was used to cover the whole country during peak condition and compared with the FFWC flood map of 20th September, 2018 (Figure 5.1). Both of the maps are in good agreement in detecting inundated areas in North-western and North-eastern parts of the country. However, there are much spatial variability in Central regions. FFWC's present flood model domain does not cover coastal parts and the South-eastern region, so model result is not appropriate for inundation analysis or verification of that part. The variability in Central parts may be an implication of coarse resolution of the DEM along with change in land use.

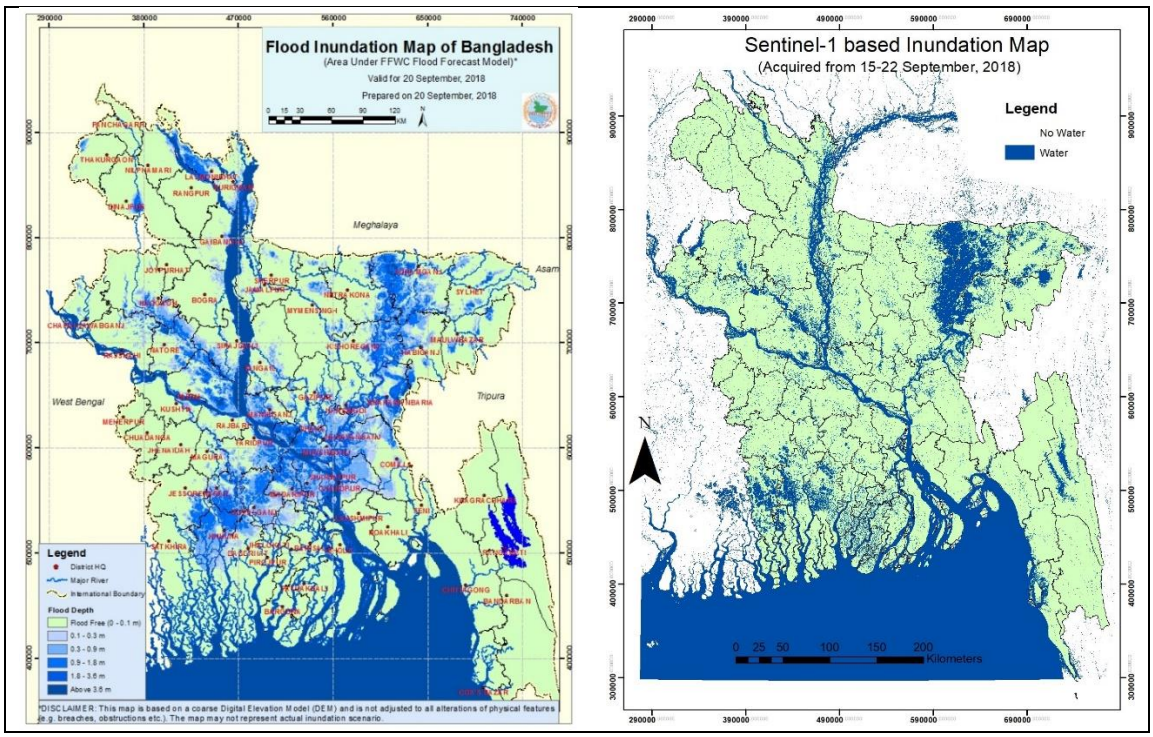


Figure 5.1 : Comparison of FFWC Flood Inundation Map (20th September 2018) with Senitnel-1 based Inundation Map (between 15th -22nd September 2018)

FFWC MIKE 11 FF Flood super model was developed decade ago. After that, catchment characteristics, river morphology and climatology had 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 along with latest version of MIKE software are needed to overcome this problem.

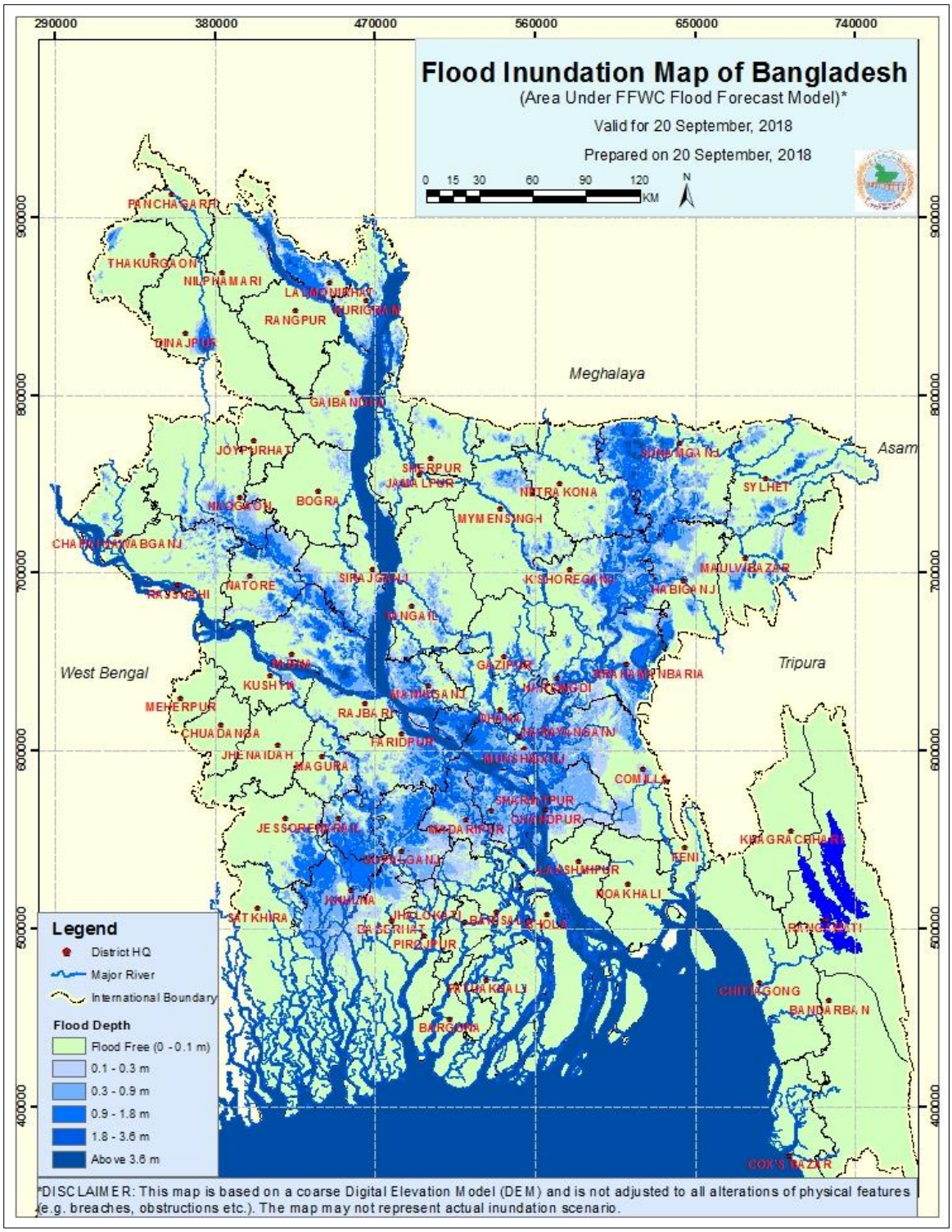


Figure 5.2 : Flood Inundation Map of Bangladesh (on 20th September 2018)

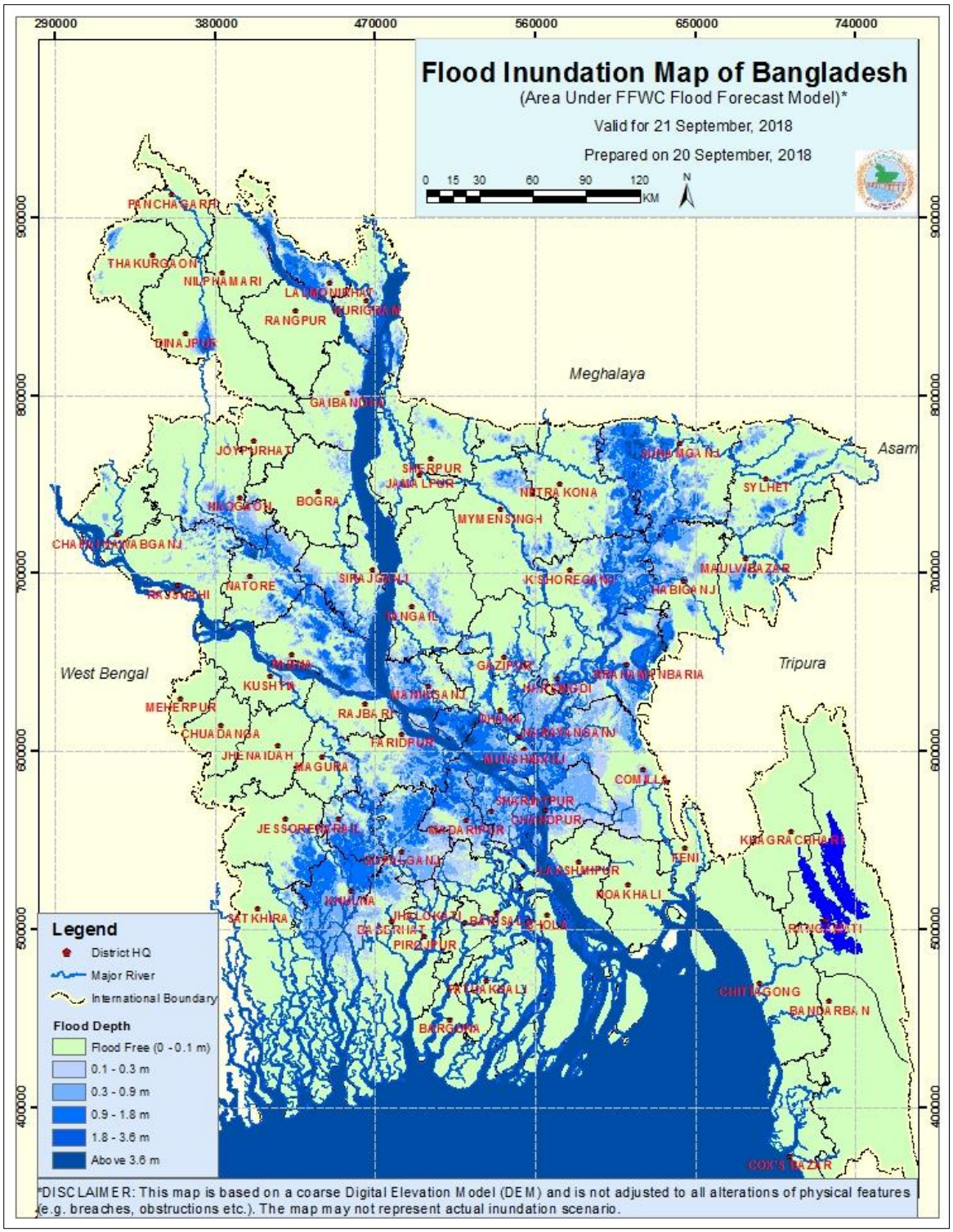


Figure 5.3 : Flood Inundation Map of Bangladesh (24hr Forecast based on 20th September 2018)

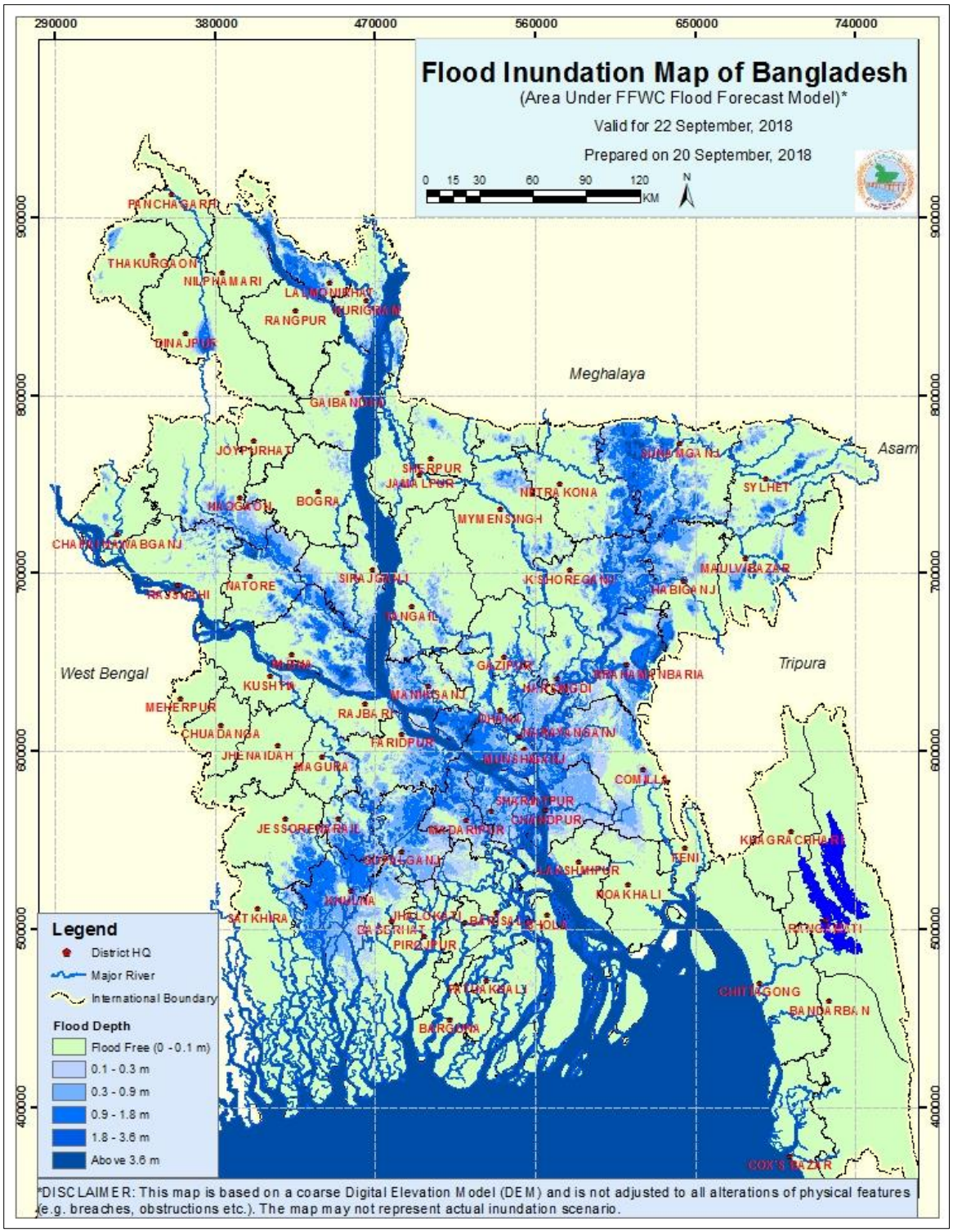


Figure 5.4 : Flood Inundation Map of Bangladesh (48hr Forecast based on 20th September 2018)

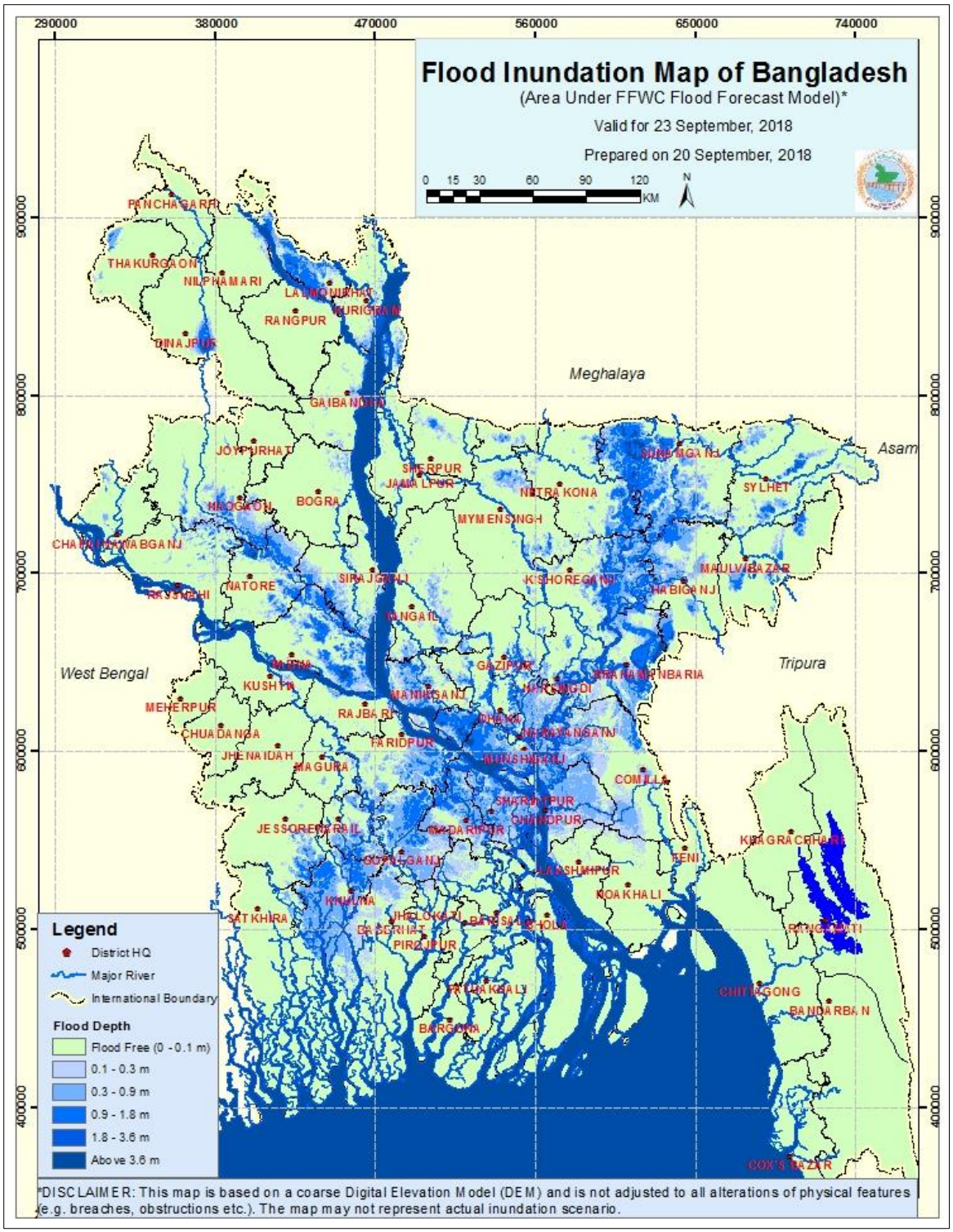


Figure 5.5 : Flood Inundation Map of Bangladesh (72hr Forecast based on 20th September 2018)

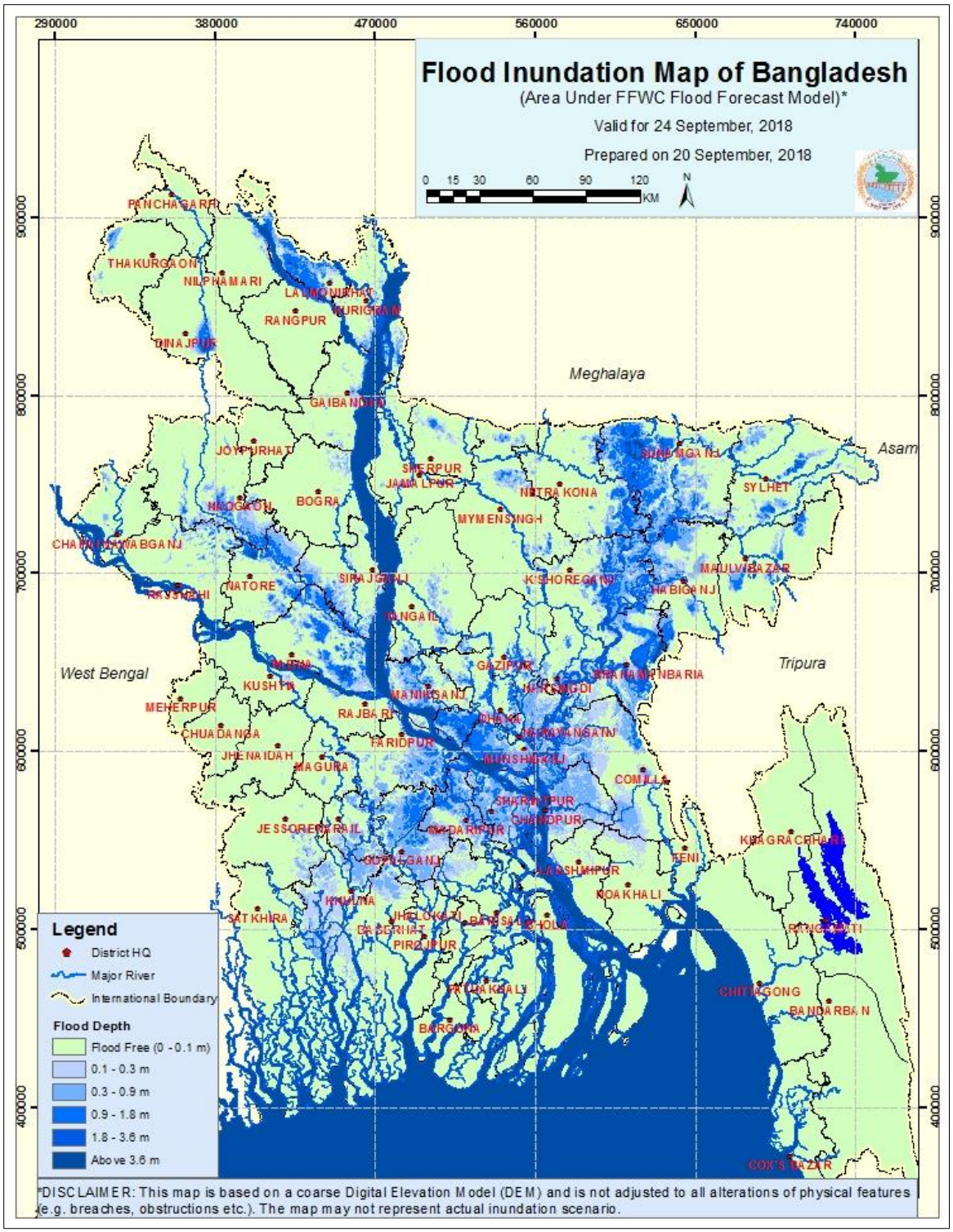


Figure 5.6 : Flood Inundation Map of Bangladesh (96hr Forecast based on 20th September 2018)

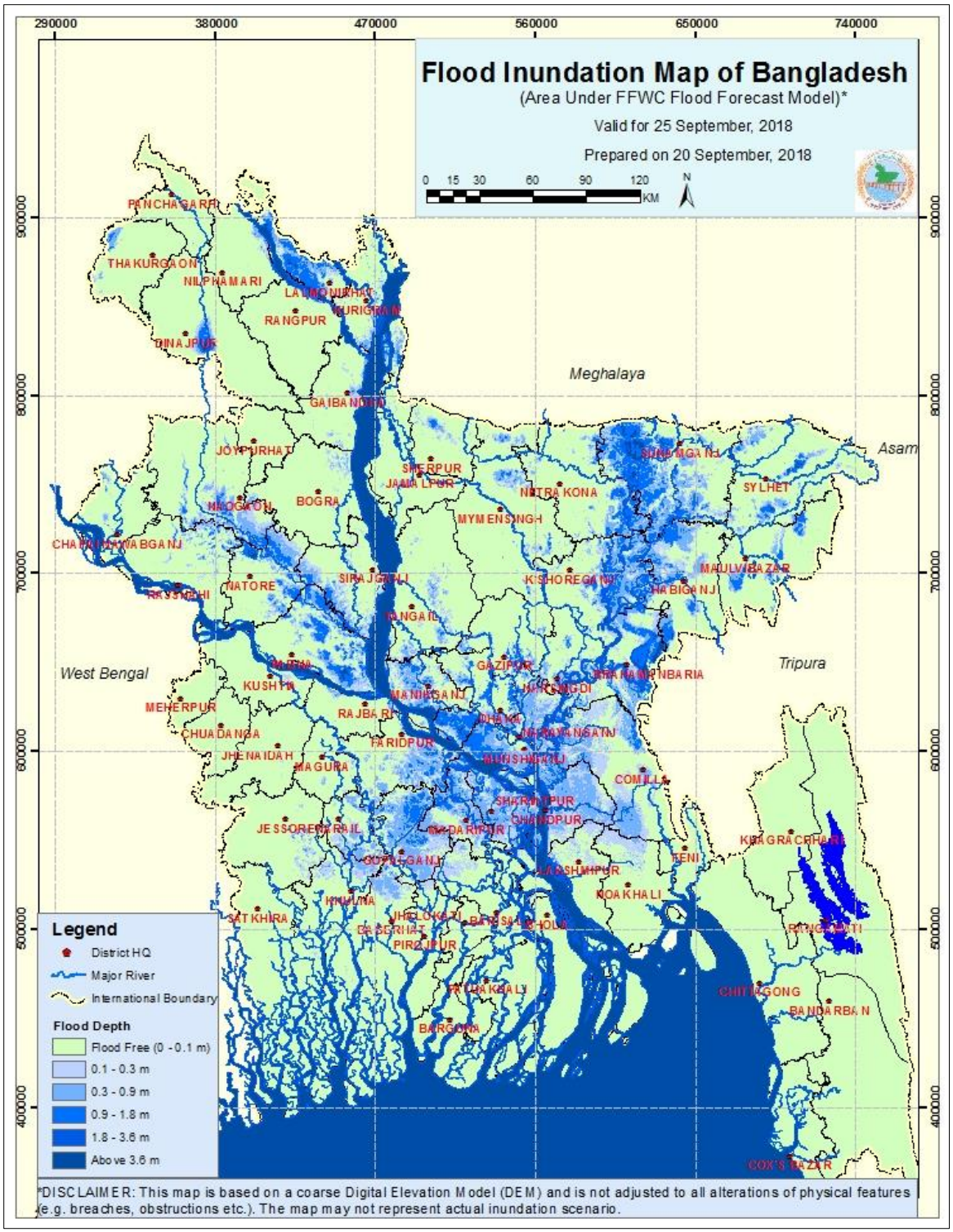


Figure 5.7 : Flood Inundation Map of Bangladesh (120hr Forecast Based on 20th September 2018)

CHAPTER 6 : CHARACTERISTICS AND SPECIAL EVENTS OF 2018 FLOOD

6.1 Characteristics of 2018 Flood

The 2018 as a whole was a normal flood season inundating 23% of the whole country (33,941 sq-km approximately). However, the flood intensity varied spatially within the country and also temporarily within the season. The spatial variation of flooding led to normal flooding in the Brahmaputra basin covering the Northern, North-Western and North-Central districts along the Brahmaputra-Jamuna; below normal flooding in the Ganges basin covering the North-Western and Central districts along the Ganges-Padma while moderate to severe flooding in the Meghna and South Eastern Hill basins covering the North-Eastern and South-Eastern districts respectively. Flood duration was short to medium at affected places facing normal or above normal flooding except at South Eastern Hill basins where the duration was short.

Considering temporal variation, the season can be divided in 4 stages: early pre-monsoon (March-April), late pre-monsoon and early monsoon (May up to 15 July), middle monsoon (15 July–10 September) and late monsoon (after 10 September). During the early pre-monsoon the Haor basins in the North-Eastern region remained dry. During the late pre-monsoon and early monsoon period, all the moderate to severe flood events took place and was the most active period of the season. Firstly, the Haor basins got inundated slightly earlier during 2nd May and in the phase some higher lands along the main rivers were flooded too. Later, Monsoon started onset over South-Eastern Bangladesh and adjoining regions during 2nd week of June and highly active phase at the time flood affected the South-Eastern Hill basin, Meghna basin and Brahmaputra basin in sequential order, which lasted until the 2nd week of July. The Meghna and South Eastern Hill basins were affected by moderate to severe flash floods in wide scale between 2nd-3rd week of June, while the Brahmaputra was affected by normal flooding at some place during 2nd week of July. During the middle monsoon period, monsoon was dormant over the GBM basin and the country mostly remained flood free. During the late monsoon period, flood affected the Brahmaputra basin and affected low lying places incurring a normal flood.

The notable damage due to flood this year was for the flash floods in North-Eastern and South-Eastern regions during the early monsoon period. Flash flood event of the Manu river at Moulvibazar was the most severe one of the series of flash floods over smaller catchments. Other notable damages due to 2018 flood include severe river erosions at some places even under normal or below normal flood situation. The right bank of Padma at Naria, Shariatpur experienced the most severe erosion during July-September though the flood was below normal.

6.2 Special Events of 2018 Flood

6.2.1 The Manu River Flood in Moulvibazar

A severe flash flood hit the North-Eastern region due to the Surma-Kushiyara rivers and tributaries at the time of onset of monsoon this year during the 2nd-3rd week of June. Among the localised events of this flooding, the flash flood of Manu river was the worst and was the most severe in last 10 years which did considerable damage to embankments, roads and households. The Moulvibazar town as well as some other parts of the district remained inundated for a few days.

The event began after 11 June evening, when WL of the Manu river jumped overnight in 12 hours by 3.10 meters at Manu Railway Bridge (14.41 to 17.51 mPWD) and 1.92 meters at Moulvibazar (8.70 to 10.62 mPWD) between 6 PM to 6 AM next morning. Almost parallely on the same day, the Dhalai which is the major tributary of the Manu, jumped by 1.61 meters in just 3 hours (18.74 to 19.06 mPWD) between 3 PM to 6 PM at Kamalganj.

The Manu at Manu Railway Bridge continued rising almost steadily crossing DL (18.00 mPWD) on 12 June noon and ultimately reaching its peak on 13 June evening to 19.41 m PWD with a total rapid rise of 5.00 meters and reaching 1.41 meters above DL. The Dhalai river at Kamalganj also attained its peak 19.88 mPWD slightly earlier on 13 June noon with a total rapid rise of 2.98 meters and reaching 6 cms above DL (19.82 mPWD). The WL at these two boundary river points started receding afterwards.

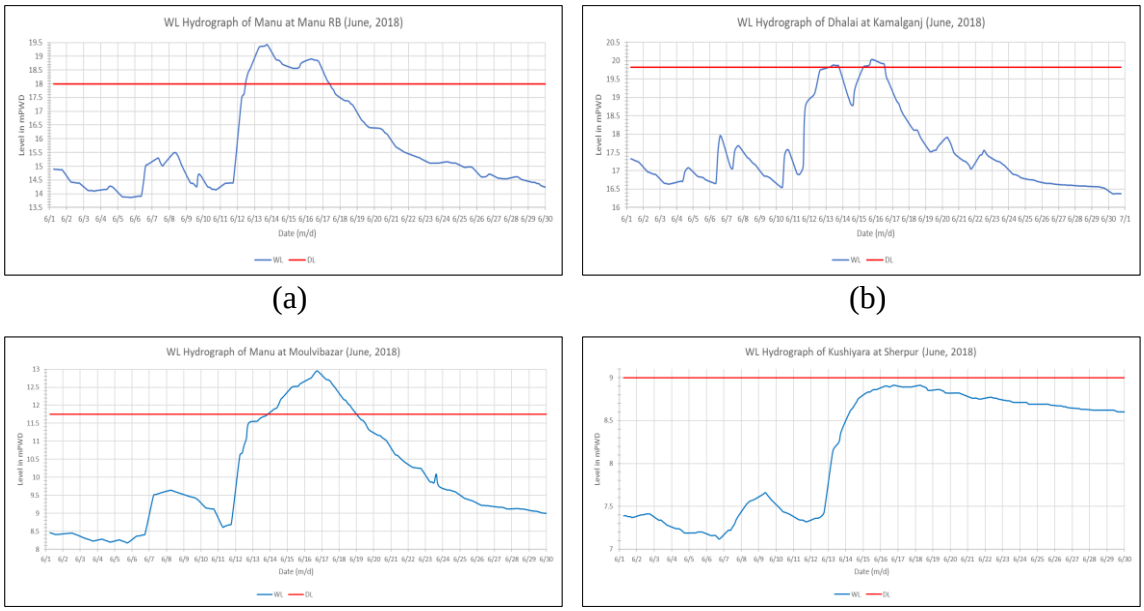
However, the WL of Manu downstream at Moulvibazar still continued rising due to the convergence of water upstream from both the Manu and Dhalai rivers. The Manu at Moulvibazar was recorded above DL (11.75 mPWD) on 14 June morning and attained peak 12.95 mPWD on 16 June evening, with a total rapid rise of 4.25 meters reaching 1.20 meters above DL. The fact that worsened this flooding is the relatively longer stay of the flood, as the Manu at Manu Railway Bridge and Dhalai at Kamalganj reached their peaks in around 2 days, it took Manu at Moulvibazar within the same confluenced downstream reach 5 days to attain peak. The WL subsequently receded below DL on 19 June morning maintaining the slower rate resulting in 5 days submersion of the Moulvibazar town. This situation was the result of follwing events:

i. Due to high velocity of onrushing water, flood protection embankment breached at a few weak spots and floodwater entered wider region transforming the channel flow to floodplain flow. As a result, WL started rising at a slower rate at Moulvibazar as evident from the hydrograph in Figure 6.1 (c), which depicts the break of rising WL rate after 12 June evening.

ii. The Dhalai at Kamalganj after reaching peak on 13 June noon started falling but rose again from 14 June evening resulting a double skewed flood hydrograph. This time the river rose rapidly by 1.24 m in 1 day and attained peak of 20.03 mPWD by 21 cm above

DL on 15 June evening. This new onrush of water expanded the base length of flood hydorgraph of Manu at Moulvibazar.

iii. The river Kushiyara also started rising rapidly from 12 June just after a day of Manu river's start of rising. The Manu is a tributary of the Kushiyara system and high stage in Kushiyara has backwater effect on Manu. The Kushiyara at Sherpur-Sylhet, which is the just downstrem gauge of Manu-Kushiyara confluence, started rising rapidly from 12 June evening and reached its peak of 8.91 m PWD (9 cms below DL) on 16 June evening simultaneously with Manu at Moulvibazar. After reaching peak, Kushiyara at Sherpur receded very slow only decreasing 32 cms throughout the rest of the month. This higher stage on Kushiyara also made receding stage of the Manu slower.



(a) (b)

(c) (d)

Figure 6.1 : The WL Hydrograph of (a) Manu at Manu Railway Bridge, (b) Dhalai at Kamalganj, (c) Manu at Moulvibazar and (d) Kushiyara at Sherpur during June-2018

Table 6.1: Rise of Water Level in Manu, Dhalai and Kushiyara (Sherpur) between 11/06/2018 to 16/06/2018 (9AM-9AM)

Water level in mPWD												
River	**Manu**			**Dhalai**			**Manu**			**Kushiyara**		
Station	**Moulvibazar**			**Kamalganj**			**Moulvibazar**			**Sherpur**		
Date	WL	Rise(+)/ Fall(-)	+/- DL	WL	Rise(+)/ Fall(-)	+/- DL	WL	Rise(+)/ Fall(-)	+/- DL	WL	Rise(+)/ Fall(-)	+/- DL
11/06/18	14.38	-	-3.62	16.90	-	-2.92	8.64	-	-3.11	7.34	-	-1.66
12/06/18	17.61	+3.23	-0.39	19.21	+2.31	-0.61	10.67	+2.03	-1.08	7.36	+0.02	-1.64
13/06/18	19.36	+1.75	**+1.36**	19.87	+0.66	**+0.05**	11.62	+0.95	-0.13	8.19	+0.83	-0.81
14/06/18	18.86	-0.50	**+0.86**	18.96	-0.91	-0.86	11.92	+0.30	**+0.17**	8.64	+0.45	-0.36
15/06/18	18.56	-0.30	**+0.56**	19.85	+0.89	**+0.03**	12.52	+0.60	**+0.77**	8.83	+0.19	-0.17
16/06/18	18.89	+0.33	**+0.89**	19.92	+0.07	**+0.10**	12.76	+0.24	**+1.01**	8.89	+0.06	-0.11
17/06/18	18.01	-0.88	**+0.01**	18.83	-1.09	-0.99	12.71	-0.05	**+0.96**	8.89	0	-0.11

It is also noteworthy that during the rising period of the Manu river, the Bangladesh part of the basin received no significantly heavy rainfall. Rainfall above 50 mm was recorded only once in Manu Railway Bridge and Moulvibazar and twice in Kamalganj during 9-16 June. The basin average rainfall within the country for the period was only 24.5 mm/day. So rainfall in the Indian catchments of the basin almost solely contributed to this huge rush of water.

Table 6.2: Recorded Rainfall in Major Stations in the Manu Basin during 09/06/2018 to 16/06/2018 (in mm)

Date	Manu RB	Moulvibazar	Kamalganj
09/06/2018	2	4	0
10/06/2018	0	0	0
11/06/2018	21	5	14
12/06/2018	35	21	**65**
13/06/2018	25	9	42
14/06/2018	0	0	0
15/06/2018	**86**	**76**	**140**
16/06/2018	23	7	11
Total	192	122	272

Figure 6.2 : Inundation in Moulvibazar Town (Courtesy: Daily New Age, 18/06/2018)

6.2.2 The Brahmaputra Flood in Tibet, China

Massive rainfall activities took place in the Brahmaputra basin part of Tibet, China between the second and last week of August in 2018. Due to this, a peak discharge of around 11,000 cumec was recorded on 1st September 2018 in the Chinese part of the Brahmaputra river near India-China border at station Nuxia, where the flow steadily increased by 4000 cumec in just 9 days. It was reported to be the highest discharge of Brahmaputra at the station in last 50 years.

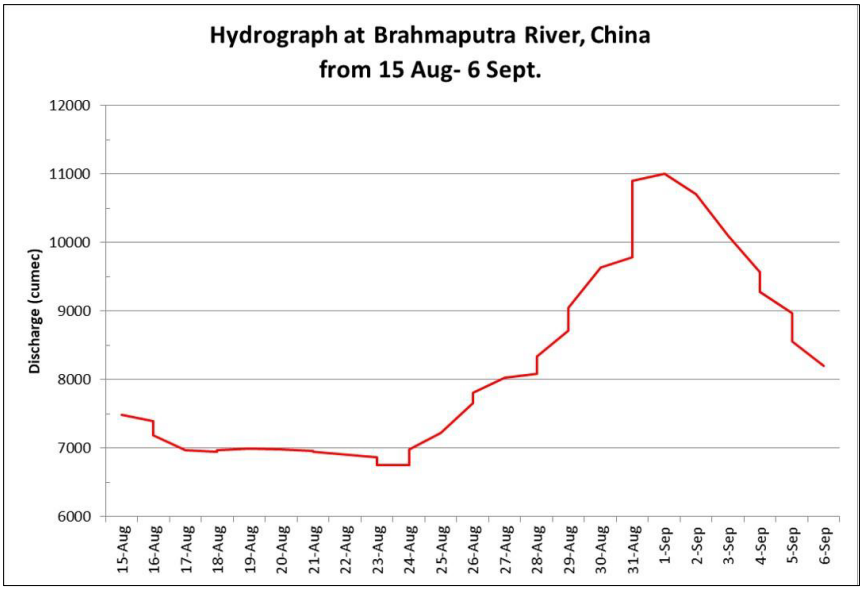


Figure 6.3 : Hydrograph at Nuxia, China on Brahmaputra between 15 Aug - 6 Sept

The Chinese authority issued a warning to the Indian counterparts as the huge outflow rushed towards India. India subsequently raised flood warnings in Arunachal and Assam states and also informed Bangladesh on the matter. There was growing a concern in both India and Bangladesh about possible chances of flooding in Brahmaputra due to the event. However, the Central Water Commission, Dibrugarh, India and FFWC, BWDB later on marked the event safe for Assam and Bangladesh respectively.

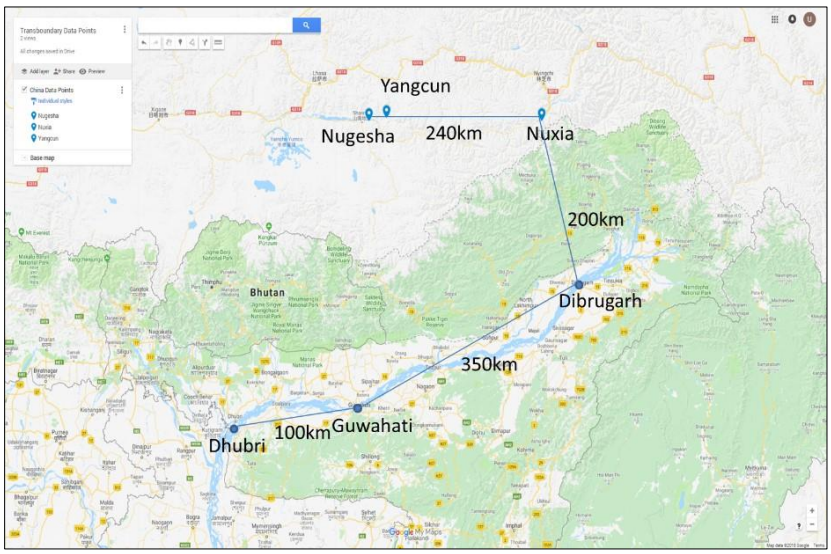


Figure 6.4 : Aerial Distance Map of Chinese and Indian Stations on Brahmaputra

When the river passes down the gorges from Tibet and Arunachal to Assam and confluences with major tributaries near Dibrugarh, the capacity of the channel increases multifold due to a great increase of channel width. As the month of July-August was relatively dry in Assam in 2018, the initial flow during the event was comparatively less. So, an addition of 4000 cumec above the normal flow was not much for the Brahmaputra river at and down of Dibrugarh. For instance, the discharge at Bahadurabad during the event was around 38000 cumec where the river can safely carry down 55000 cumec during monsoon. Moreover, the attenuation effect due to a great distance from Nuxia to Bahadurabad further nullified the threats.

However, the Brahmaputra river started rising in Bangladesh from 11 September and normal flooding occurred in the river during the third week. This event was the effect of active normal monsoon spell over the Brahmaputra valley in Assam from 10 September, in which the flow routed from Tibet only had minor contributions as that flow peak already had passed down Bahadurabad.

CHAPTER 7 : RESEARCH AND DEVELOPMENT

7.1 Experimental Pre-monsoon Danger Level for the North-Eastern Region

In Bangladesh, danger level at a river location is the level above which it is likely that the flood may cause damages to nearby crops and homesteads. In a river having no embankment, danger level is about annual average flood level. In an embanked river, danger level is fixed slightly below design flood level of the embankment. In pre-monsoon time, flash flood often hits the North-East Region and causes severe damage although in most cases, water level doesn't even touch the danger level or close to it.

In this connection, historical measured data has been statistically analyzed to calculate average year or 2.33 years return period water level of pre-monsoon season and after comparing with existing DL and embankment height of adjacent Haors, new levels have been fixed experimentally as Pre-monsoon Danger Level (PMDL) for 25 stations in the North-Eastern region. Existing monsoon danger levels have been evaluated for the North-East Region particularly for the pre-monsoon period up to 15th May and proposed water levels corresponding to 2.33-year return period with rounding to its closest value is applied as experimental PMDL for the Haor region following an office order dated on 19$_{th}$ march, 2018 issued in accordance with the Danger Level Review Committee of BWDB. Historical pre-monsoon hydrograph at Sunamganj have been shown in Figure 7.1 indicating the significance of the pre-monsoon danger level fixation. The calculation of PMDL for 25 flash flood forecast stations of North-East Region of Bangladesh and the approved experimental PMDL list have been presented in the Annexes.

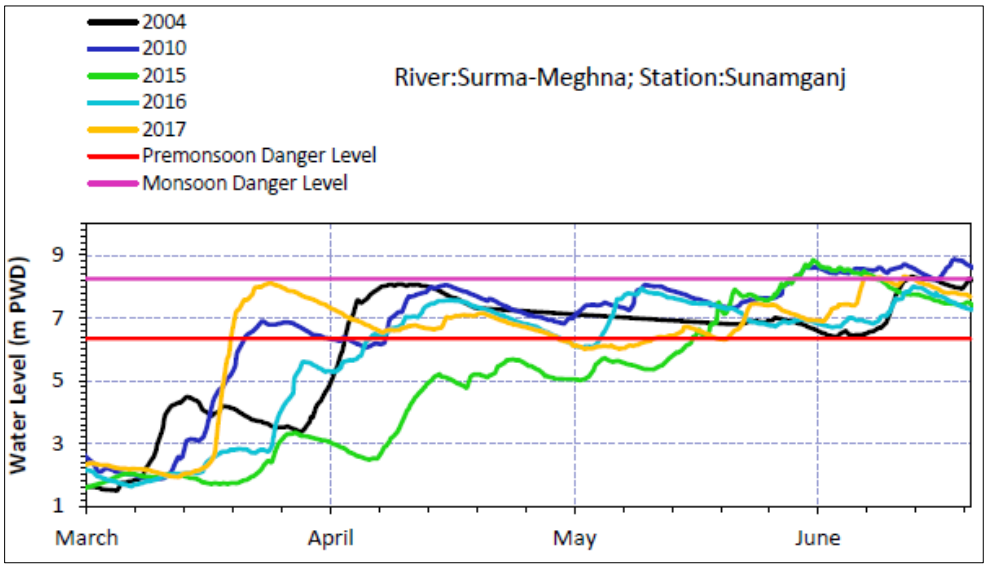


Figure 7.1 : Historical Pre-monsoon Hydrograph at Sunamganj with PMDL and DL

7.2 Expansion of Flash Flood Monitoring and Forecasting Stations

Experimental 3-days flash flood forecast is being generated and disseminated through e-mail and FFWC website during pre-monsoon period of April-May (major disaster period due to flash flood) for the North East region since 2017. This system is developed under the HILIP-BWDB programme, a component of the HILIP under LGED. Last year only regular WL and rainfall monitoring stations of FFWC were incorporated in the flash flood monitoring system. This year 10 WL and 11 rainfall stations in the North-Eastern region have been added to the flash flood monitoring system. This has raised the number of WL monitoring stations to 36 and rainfall to 28. Consequentially, the number of flash flood forecasting stations have also been increased from 17 to 25. The product is still under development but initial evaluation for the forecast during April-May period indicate fair performance. Further improvement is in progress and will be tested in the next season during April-May 2019. Sample flash flood bulletin, summary and forecasts with the list of stations have been presented in the Annexes.

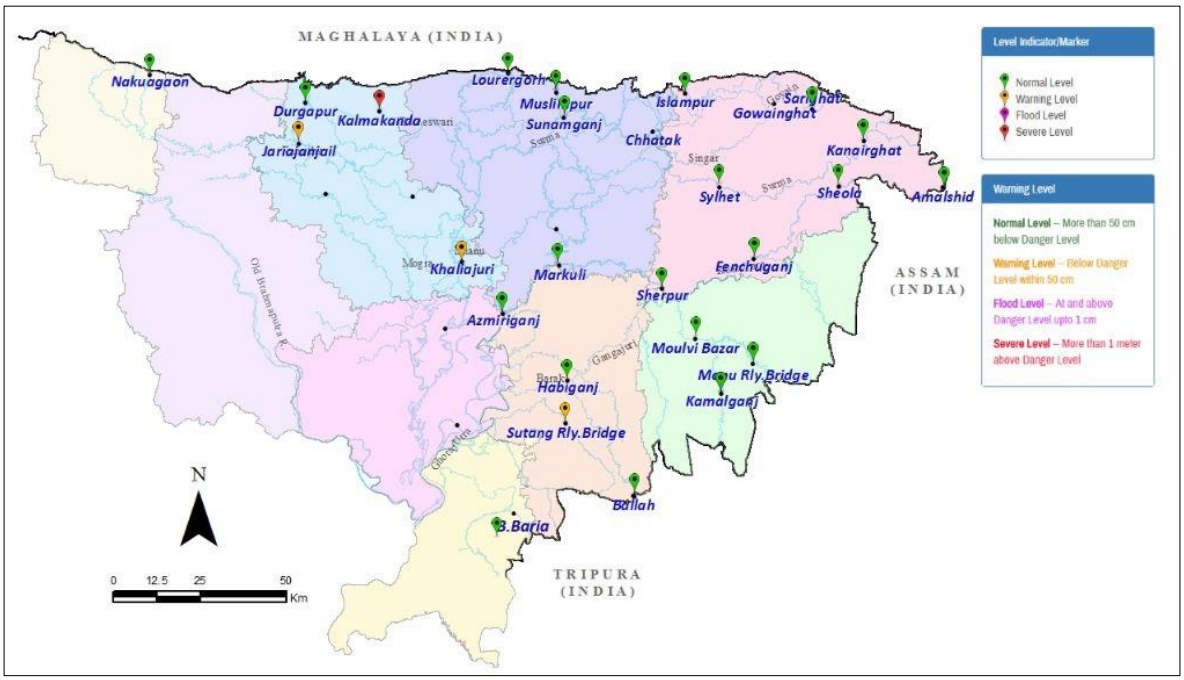


Figure 7.2 : Experimental Flash Flood Forecasting Stations during Pre-monsoon

7.3 BWDB Flood App

FFWC, BWDB works with many development partners as well as national and international agencies for continuous updating and improvement of Flood Forecasting and Warning services and capacity development of professionals for better performance. FFWC web site is located at http://www.ffwc.gov.bd, but the site is not mobile responsive and it is difficult to get required information quickly using mobile.

To cope with the recent development of ICT, BWDB planned to develop an Android based mobile application which would disseminate most requested information of FFWC in a few clicks. The mobile app will provide a subset of FFWC web site functions which are most

important or requested by field office staff of relevant for public consumption. With a view to this, FFWC of BWDB started developing a mobile flood forecasting app through technical collaboration with International Centre for Integrated Mountain Development (ICIMOD) in 2017. On 23 April 2018, the 'BWDB Flood App' was officially launched and made available to Google Play Store for Android mobile users free of charge.

An interactive dashboard is designed as the home menu of the app which provides quick links to all regular FFWC messages, services and products in an interactive and fast way. Users can readily access the following information quickly from dashboard in 1 or 2 taps:

- ❑ Water Level Information & Hydrograph
- ❑ Bulletin & Flood Summary
- ❑ 5-days Water Level Forecast & Hydrograph
- ❑ Flood Warning Message
- ❑ Stations Above Danger Level
- ❑ Flood Inundation Maps
- ❑ Special Flood Outlook

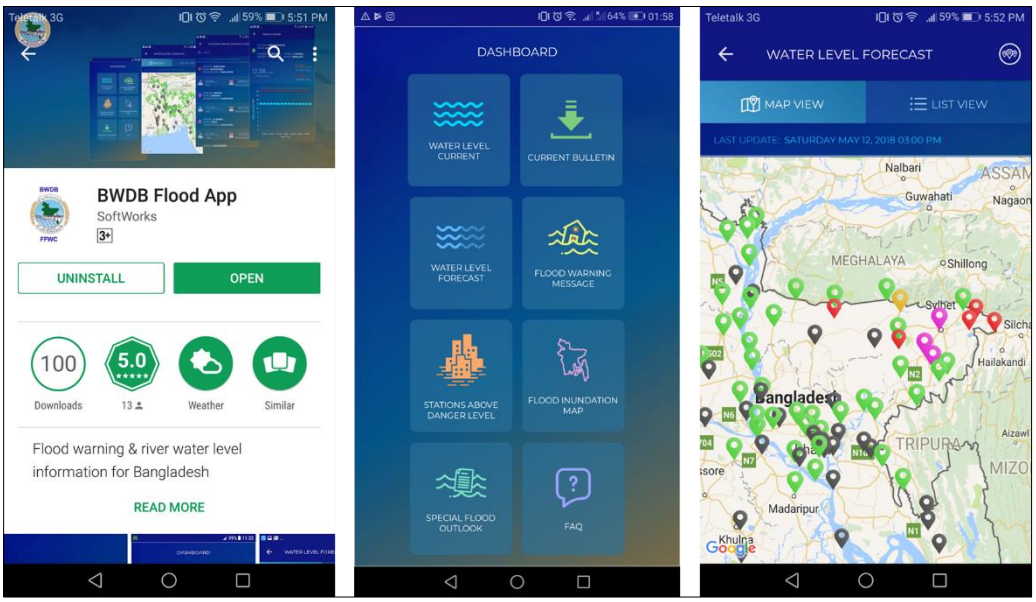


Figure 7.3 : BWDB Flood App Download Page, Dashboard and WL Forecast Map View (from Left to Right)

The app is still in the beginning phase and further improvements and modifications are planned in future updates to make the app more user friendly and accessible. However, even with the current version it is expected that an end user with an Android Smartphone and internet connection will be ready to avail flood information with just some tap of fingers from anywhere.

CHAPTER 8 : CONCLUSION

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 is about 2300 mm, the range varies from about 1500 mm in the northwest 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 are 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 MoWR monitored the flood situation during the pre-monsoon, monsoon and also beyond the period when situation demanded. The FFWC has issued daily flood bulletin from May to October with deterministic forecast lead-time of 24hrs, 48hrs, 72hrs, 96 hrs and 120 hrs (upto 5 days) along with warning messages, flood inundation maps and structure-based flood forecast at 4 selected BWDB projects. The forecast was based on 5-days WL at 54 stations on 29 major rivers and covered the major floodplains of the country only excluding the coastal and South-Eastern hill regions. There are efforts to make more localized flood forecast increasing the number of forecast stations. Also, there are plans to expand the forecasting domain to coastal and South-East regions in near future. Further improvement is needed for these initiatives.

Recurrent pre-monsoon flash floods in North-Eastern Haro regions are becoming more and more of a concern day by day. Under the CDMP-II programme during 2012-14, FFWC started limited scale 2-days deterministic flash flood forecasting for the region during the season. From 2017, under the HILIP-BWDB component project of HILIP programme by LGED, 3-days experimental flash flood forecast have been introduced for the region which has further been extended this year with addition of new monitoring and forecasting stations. Currently flash flood forecast is being generated at 25 stations during pre-monsoon with a qualitative outlook focusing on water level trend in coming days based on rainfall forecasts.

Updated/improved more user-friendly website has been in operation since June-2015 with the financial support of CDMP-II. The upgraded website having easy to operate menu and Bangla language option is added with flood warning message in Bangla. Improvement of the website is on-going to make it more user friendly and accessible to a great number of users.

In addition to deterministic flood forecasts up to 5-days lead time, FFWC issued medium range up to 10-days lead-time probabilistic forecasts at 37 locations on experimental basis with technical support from RIMES and utilizing ECMWF weather prediction data over the Ganges-Brahmaputra basin to generate 51 sets of ensemble discharge forecasts on the Brahmaputra at Bahadurabad and the Ganges at Hardinge Bridge. The updated FFWC model was taken for customization for real-time flood forecasting utilizing CFAN predictions.

Special type of flood bulletin has been issued during the critical time and disseminated through different mass media, news agencies, fax, e-mail, website and IVR through mobile phone. The IVR system using mobile started from July 2011, in cooperation of DDM, anyone can call 1090 number from any mobile operator and hear a short voice message on flood warning in Bangla free of charge. The information has been used by various communities and organizations: national and international disaster management operators, many Government agencies, NGOs and BWDB itself.

A new addition to the dissemination media this year is the Android based 'BWDB Flood App' which is a mobile friendly and simple version of the FFWC website. Development of this app has been one major step forward to mass dissemination utilizing the latest ICT technologies. Future versions of the app will be made more user friendly and accessible. It is hoped that this will significantly promote flood message dissemination in near future.

Due to different shortcomings including limited upstream hydro-meteorological information, old & relatively coarse 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 be developed for providing regional flood forecasting and warning. Moreover, flood inundation map needs to develop further. Introduction of flood forecasting in the coastal regions have been a much-talked issue which need to be addressed. Besides demand is growing day by day for urban flood forecasting.

The FFWC of BWDB took the privileges to reflect the flood situation as accurate and reliable as possible. All the combined efforts may have played an effective role in minimizing people sufferings and damages of the infrastructures during the flood of 2018.

As a whole the flood of 2018 was fairly normal compared to devastating flood of 1987, 1988, 1998, 2004, 2007 and 2017; although moderate to severe flash floods occurred in the North-Eastern and South-Eastern parts of the country, of which the flash flood in Moulvibazar was remarkable which did lot of damages.

Evaluation indicated that, the accuracy of deterministic flood forecasts issued by FFWC for monsoon-2018 on major rivers were around 93%, 89%, 85%, 81% and 78% consistent on average 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.

Professionals of the FFWC have been fully dedicated and committed to generate and disseminate flood forecasting and warning services on daily basis during the flood season.

The maximum flooded area was 23% of the whole country this year (33,941 sq-km approximately) corresponding to normal flooding. However, some of the regions experienced severe river bank erosion even under normal or below normal flooding. The right bank of Padma at Naria, Shariatpur experienced the most severe erosion during the season though the flood was below normal.

Annex-1

5 Days Deterministic Forecast (Experimental 4th & 5th Day) for 24, 48, 72, 96 & 120 Hrs

FFWC, BWDB

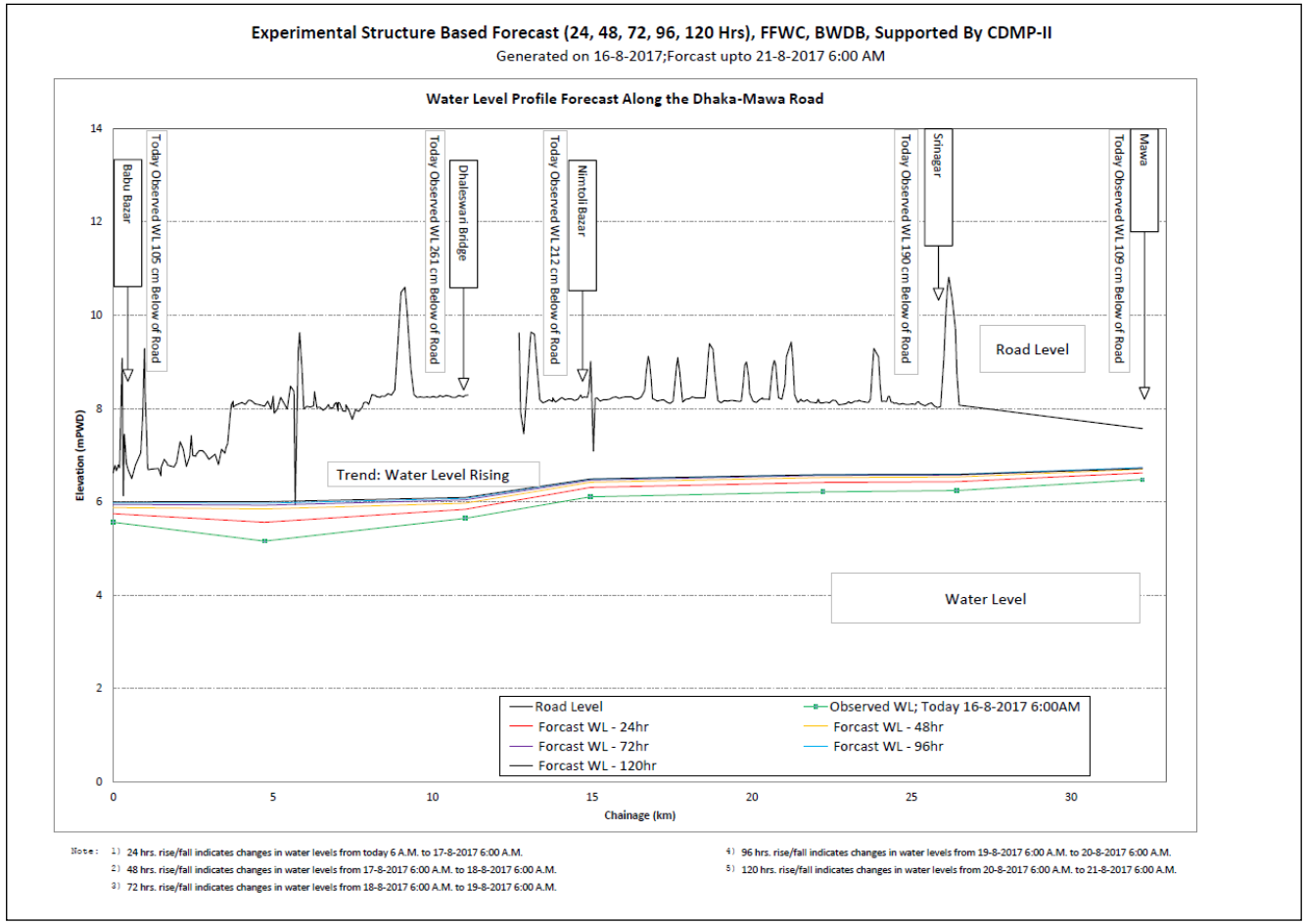
SL NO	River	Station	D.L. (meter)	Today 20-09 6:00 AM (meter)	24-hrs forecast 21-09 6:00 AM (meter)	24-hrs +Rise -fall 21-09 6:00 AM (cm)	24-hrs +above -below D.L. 21-09 6:00 AM (cm)	48-hrs forecast 22-09 6:00 AM (meter)	48-hrs +Rise -fall 22-09 6:00 AM (cm)	48-hrs +above below D.L. 22-09 6:00 AM (cm)	72-hrs forecast 23-09 6:00 AM (meter)	72-hrs +Rise -fall 23-09 6:00 AM (cm)	72-hrs +above -below D.L. 23-09 6:00 AM (cm)	96-hrs forecast 24-09 6:00 AM (meter)	96-hrs +Rise -fall 24-09 6:00 AM (cm)	96-hrs +above -below D.L. 24-09 6:00 AM (cm)	120-hrs forecast 25-09 6:00 AM (meter)	120-hrs +Rise -fall 25-09 6:00 AM (cm)	120-hrs +above -below D.L. 25-09 6:00 AM (cm)
1	Atrai	Mohadevpur	18.59	14.58	14.47	-11	-412	14.39	-8	-420	14.34	-5	-425	14.32	-2	-427	14.31	0	-428
2	Atrai	Atrai	13.72	-	12.94	-	-78	12.89	-5	-83	12.84	-5	-88	12.80	-4	-92	12.76	-4	-96
3	Atrai	Singra	12.65	11.92	11.88	-4	-77	11.83	-5	-82	11.79	-4	-86	11.75	-4	-90	11.72	-3	-93
4	Karatoa-Atrai-GGH	Baghabari	10.40	10.53	10.45	-8	+5	10.32	-13	-8	10.18	-14	-22	10.05	-13	-35	9.96	-10	-44
5	Little Jamuna	Naogaon	15.24	13.12	13.05	-7	-219	13.00	-6	-224	12.95	-4	-229	12.93	-3	-231	12.92	-1	-232
6	Karatoya	Chakrahimpur	20.15	19.08	18.95	-13	-120	18.85	-10	-130	18.76	-9	-139	18.68	-8	-147	18.61	-7	-154
7	Karatoya	Bogra	16.32	12.68	12.71	+3	-361	12.74	+3	-358	12.77	+3	-355	12.81	+4	-351	12.84	+4	-348
8	Teesta	Kaunia	30.00	27.80	27.57	-23	-243	27.47	-10	-253	27.51	+4	-249	27.58	+7	-242	27.59	0	-241
9	Ghagot	Gaibandha	21.70	21.46	21.36	-10	-34	21.26	-10	-44	21.36	+10	-34	21.26	-10	-44	21.26	0	-44
10	Dharla	Kurigram	26.50	25.73	25.60	-13	-90	25.49	-11	-101	25.45	-4	-105	25.41	-4	-109	25.37	-4	-113
11	Brahmaputra	Chilmari	24.00	23.46	23.31	-15	-69	23.19	-12	-81	23.09	-10	-91	23.08	-2	-92	23.08	0	-92
12	Jamuna	Bahadurabad	19.50	19.55	19.43	-12	-7	19.30	-13	-20	19.21	-9	-29	19.17	-5	-33	19.16	0	-34
13	Jamuna	Sariakandi	16.70	16.91	16.82	-9	+12	16.68	-13	-2	16.57	-11	-13	16.50	-7	-20	16.48	-2	-22
14	Jamuna	Kazipur	15.24	15.25	15.16	-9	-8	15.04	-12	-20	14.93	-11	-31	14.84	-8	-40	14.81	-3	-43
15	Jamuna	Serajganj	13.35	13.32	13.23	-9	-12	13.08	-14	-27	12.96	-13	-39	12.86	-10	-49	12.81	-5	-54
16	Jamuna	Porabari	12.27	-	11.21	-	-106	11.07	-14	-120	10.94	-13	-133	10.83	-11	-144	10.77	-6	-150
17	Jamuna	Aricha	9.40	9.17	9.03	-14	-37	8.84	-19	-56	8.66	-19	-74	8.50	-16	-90	8.37	-13	-103
18	Old Brahmaputra	Jamalpur	17.00	14.97	14.83	-14	-217	14.65	-19	-235	14.47	-17	-253	14.36	-12	-264	14.31	-5	-269
19	Old Brahmaputra	Mymensingh	12.50	9.28	9.25	-3	-325	9.17	-8	-333	9.02	-15	-348	8.84	-18	-366	8.68	-15	-382
20	Bangshi	Nayerhat	7.32	5.03	5.06	+3	-226	5.07	+1	-225	5.06	-1	-226	5.03	-3	-229	4.98	-5	-234
21	Old Dhalesari	Jagir	8.23	6.60	6.68	+8	-155	6.74	+6	-149	6.78	+3	-145	6.78	+1	-145	6.76	-2	-147
22	Dhaleswari	Kalagachia	4.88	-	4.82	-	-6	4.76	-5	-12	4.68	-8	-20	4.56	-13	-32	4.46	-9	-42
23	Kaliganga	Taraghat	8.38	7.28	7.33	+5	-105	7.33	+1	-105	7.31	-3	-107	7.26	-5	-112	7.19	-6	-119
24	Tongi Khal	Tongi	6.08	4.97	5.01	+4	-108	5.00	0	-108	4.99	-2	-109	4.94	-4	-114	4.89	-5	-119
25	Turag	Mirpur	5.94	4.57	4.59	+2	-135	4.56	-2	-138	4.53	-3	-141	4.47	-6	-147	4.41	-6	-153
26	Buriganga	Dhaka (Mill Barrack)	6.00	4.30	4.29	-1	-171	4.23	-6	-177	4.16	-7	-184	4.06	-10	-194	3.99	-7	-201
27	Buriganga	Dhaka (Hariharpara)	5.79	-	4.86	-	-93	4.81	-5	-98	4.73	-7	-106	4.63	-11	-116	4.55	-7	-124
28	Balu	Demra	5.75	4.51	4.52	+1	-123	4.50	-3	-125	4.46	-4	-129	4.41	-6	-134	4.35	-5	-140
29	Lakhya	Narayanganj	5.50	4.60	4.60	0	-90	4.56	-4	-94	4.49	-6	-101	4.40	-9	-110	4.33	-7	-117
30	Dhaleswari	Elashinghat	11.40	11.73	11.66	-7	+26	11.55	-11	+15	11.44	-11	+4	11.36	-8	-4	11.32	-4	-8
31	Lakhya	Lakhpur	5.80	4.59	4.63	+4	-117	4.65	+2	-115	4.65	0	-115	4.63	-2	-117	4.60	-3	-120
32	Dhaleswari	Munshiganj	5.20	-	4.84	-	-36	4.79	-6	-41	4.70	-8	-50	4.57	-13	-63	4.48	-9	-72
33	Mohananda	Chapai Nawabganj	21.00	19.63	19.45	-18	-155	19.34	-11	-166	19.26	-8	-174	19.21	-5	-179	19.15	-6	-185
34	Ganges	Rajshahi	18.50	16.92	16.64	-28	-186	16.42	-22	-208	16.26	-16	-224	16.12	-14	-238	16.03	-9	-247
35	Ganges	Hardinge Br	14.25	13.38	13.08	-30	-117	12.85	-23	-140	12.67	-18	-158	12.53	-14	-172	12.43	-10	-182
36	Ganges	Talbaria	12.80	-	12.67	-	-13	12.41	-26	-39	12.21	-20	-59	12.04	-16	-76	11.92	-13	-88
37	Padma	Goalondo	8.65	8.64	8.48	-16	-17	8.29	-20	-36	8.09	-19	-56	7.92	-17	-73	7.78	-14	-87

Note:
1) 96 hrs. (4th day) & 120 hrs. (5th day) forecasts are experimental.
2) 24 hrs. rise/fall indicates changes in water levels from today 6 A.M. to 21-9-2018 6:00 A.M.
3) 48 hrs. rise/fall indicates changes in water levels from 21-9-2018 6:00 A.M. to 22-9-2018 6:00 A.M
4) 72 hrs. rise/fall indicates changes in water levels from 22-9-2018 6:00 A.M. to 23-9-2018 6:00 A.M.
5) 96 hrs. rise/fall (experimental) indicates changes in water levels from 23-9-2018 6:00 A.M. to 24-9-2018 6:00 A.M.
6) 120 hrs. rise/fall (experimental) indicates changes in water levels from 24-9-2018 6:00 A.M. to 25-9-2018 6:00 A.M.
7) "+ above" means water level flowing above danger level, "-below" means water level flowing below danger level.

Page: 1 of 2

A Sample of 5 days Forecast Bulletin

Annex-2



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: ffwcbwdb@gmail.com, ffwc05@yahoo.com, Site: http://www.ffwc.gov.bd Tel: 9553118, 9550755 Fax: 9557386

RAINFALL AND RIVER SITUATION SUMMARY AS ON SEPTEMBER 20, 2018

- ***The Brahmaputra and the Ganges rivers are in falling trend which may continue in next 48 hours.***
- ***The Jamuna and the Padma rivers are in steady state which may fall in next 24 hours***
- ***The major rivers of the Upper Meghna basin are in falling trend which may continue in next 48 hours.***
- ***Flood Situation of Gaibandha, Bogra, Serajganj, Jamalpur & Tangail districts may improve in next 24 hours.***

Staions above Danger Levels (As on 20 September 2018, 09:00 am):

Station name	River	Today is Water Level (meter)	Rise(+)/Fall(-) (cm) during last 24 hours	Danger Level (meter)	Above Danger Level (cm)
Fulchari	Jamuna	19.91	+1	19.82	+9
Sariakandi	Jamuna	16.91	+4	16.70	+21
Bahadurabad	Jamuna	19.55	+4	19.50	+5
Baghabari	Atrai	10.53	0	10.40	+13
Elasin	Dhaleswari	11.73	+5	11.40	+33

RAINFALL

Significant rainfalls recorded within Bangladesh during last 24 hrs ending at 09:00 AM today:

Station	Rainfall(mm)	Station	Rainfall(mm)
Jamalpur	38.0	Ramgarh	31.0

Significant rainfalls (mm) recorded during last 24 hrs in Sikkim, Assam, Meghalaya & Tripura region of North-East India: Nil

General River Condition

Monitored Water Level Station	94	Inactive Gauge	01
Rise	34	Gauge Reading Missing	0
Fall	55	Total Not Reported	01
Steady	04	**Above Danger Level**	**5**

For Further Query, Feel Free to Contact:
01715040144, 01552353433

(Md. Arifuzzaman Bhuyan)
Executive Engineer
Duty Officer, FFWC, BWDB.
Cell no: 01715040144

A Sample Flood Situation Summary

Annex-4

FLOOD INFORMATION CENTRE, FLOOD FORECASTING & WARNING CENTRE
BANGLADESH WATER DEVELOPMENT BOARD, WAPDA BUILDING, 8TH FLOOR, DHAKA

E-mail: ffwcbwdb@gmail.com, ffwc05@yahoo.com, Website: http://www.ffwc.gov.bd Tel: 9553118, 9550755 Fax: 9557386

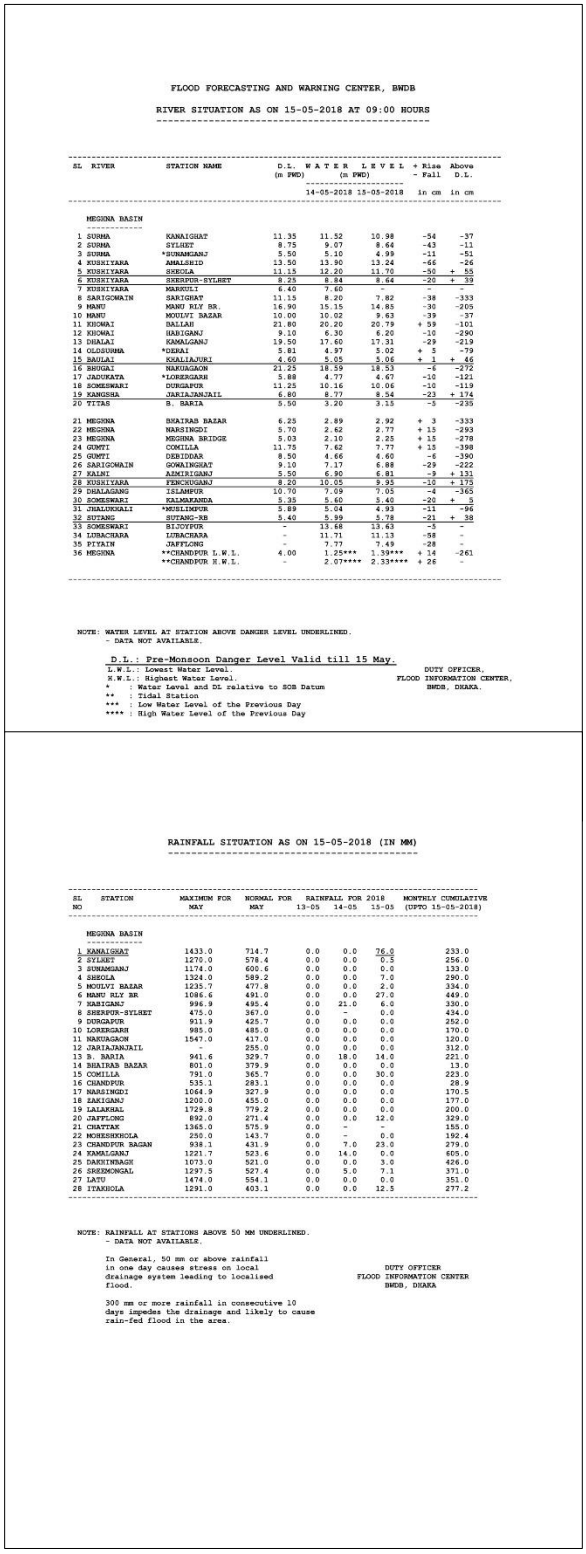
Flash Flood Forecast Bulletin for North East Region as on 15-April (Morning)

Station Name	River Name	Experimental		15-April			16-April				17-April				18-April	
		DL (PM) (mMSL)	RHWL (PM) (mMSL)	Observed 9:00 AM (mMSL)	Forecast 9:00 PM (mMSL)	12-Hr R/F (cm)	Forecast 9:00 AM (mMSL)	24-Hr R/F (cm)	Forecast 9:00 PM (mMSL)	36-Hr R/F (cm)	Forecast 9:00 AM (mMSL)	48-Hr R/F (cm)	Forecast 9:00 PM (mMSL)	60-Hr R/F (cm)	Forecast 9:00 AM (mMSL)	72-Hr R/F (cm)
Kanaighat	Surma	10.89	14.8	3.73	3.70	-3	3.68	-5	3.65	-8	3.63	-10	3.61	-12	3.59	-14
Sylhet	Surma	8.29	10.31	1.38	1.37	-1	1.37	-1	1.37	-1	1.36	-2	1.36	-2	1.35	-3
Sunamganj	Surma	6.04	7.89	1.13	1.13	0	1.13	0	1.13	0	1.13	0	1.13	0	1.12	-1
Amalshid	Kushiyara	13.04	15.82	6.38	6.32	-6	6.28	-10	6.23	-15	6.18	-20	6.12	-26	6.07	-31
Sheola	Kushiyara	10.69	13.76	4.38	4.34	-4	4.31	-7	4.27	-11	4.24	-14	4.21	-17	4.17	-21
Sherpur	Kushiyara	7.79	8.44	2.84	2.82	-2	2.80	-4	2.79	-5	2.77	-7	2.75	-9	2.73	-11
Markuli	Surma-Meghna	5.94	7.36	2.40	2.38	-2	2.37	-3	2.35	-5	2.34	-6	2.32	-8	2.31	-9
Sarighat	Sarigowain	10.69	13.61	3.51	3.51	0	3.50	-1	3.50	-1	3.49	-2	3.49	-2	3.48	-3
Manu-RB	Manu	16.44	19.96	12.35	12.31	-4	12.30	-5	12.29	-6	12.28	-7	12.28	-7	12.27	-8
Moulvi-Bazar	Manu	9.54	12.5	5.23	5.14	-10	5.17	-7	5.09	-14	5.09	-14	4.96	-27	4.99	-24
Ballah	Khowai	21.34	24.82	19.41	19.32	-9	19.24	-17	19.18	-23	19.13	-28	19.10	-31	19.07	-34
Habiganj	Khowai	8.64	11.04	4.20	4.08	-12	3.96	-24	3.86	-34	3.77	-43	3.71	-49	3.66	-54
Kamalganj	Dhalai	19.04	20.72	15.19	15.08	-11	14.99	-20	14.90	-29	14.83	-36	14.78	-41	14.73	-46
Khaliajuri	Baulai	4.14	5.31	1.12	1.17	+5	1.18	+6	1.19	+7	1.21	+9	1.22	+10	1.23	+11
Nakuagaon	Bhogai-Kangsa	20.79	22.6	17.67	17.68	+1	17.68	+1	17.69	+2	17.69	+2	17.69	+2	17.68	+1
Lourergorh	Jadukata	5.94	7.15	1.94	1.96	+2	1.96	+2	1.96	+2	1.95	+1	1.94	0	1.93	-1
Durgapur	Someswari	10.79	13.38	8.04	8.04	0	8.04	0	8.03	-1	8.03	-1	8.03	-1	8.03	-1
Jariajanjail	Bhogai-Kangsa	6.34	8.97	4.05	4.08	+3	4.10	+5	4.12	+7	4.14	+9	4.14	+9	4.13	+8
Azmiriganj	Kalni	4.54	7.17	1.95	1.94	-1	1.92	-3	1.91	-4	1.89	-6	1.88	-7	1.86	-9
Fenchuganj	Kushiyara	7.74	10.84	3.52	3.50	-2	3.48	-4	3.46	-6	3.44	-8	3.42	-10	3.40	-12
Gowainghat	Sari-Gowain	8.64	11	-	-	-	-	-	-	-	-	-	-	-	-	-
Islampur	Dhalagang	10.24	12.79	5.80	5.79	-1	5.78	-2	5.76	-4	5.75	-5	5.73	-7	5.72	-8
Kalmakanda	Someswari	4.89	5.61	1.36	1.39	+3	1.41	+5	1.43	+7	1.45	+9	1.47	+11	1.48	+12
Muslimpur	Jhalukhali	6.44	9.44	1.11	1.11	0	1.10	-1	1.10	-1	1.09	-2	1.08	-3	1.07	-4
Sutang_RB	Sutang	4.94	7.05	3.99	3.91	-8	3.82	-17	3.74	-25	3.67	-32	3.61	-38	3.55	-44

Note :- *(PM)* : *Pre-Monsoon*
R/F : *Rise/Fall*
mMSL : *metre Mean Sea Level*

Sample Experimental Flash Flood Forecast Bulletin for 25 Stations of the NE Region

Annex-5



FLOOD FORECASTING AND WARNING CENTER, BWDB

RIVER SITUATION AS ON 15-05-2018 AT 09:00 HOURS

SL	RIVER	STATION NAME	D.L. (m PWD)	WATER LEVEL (m PWD) 14-05-2018	WATER LEVEL (m PWD) 15-05-2018	+ Rise - Fall in cm	Above D.L. in cm
	MEGHNA BASIN						
1	SURMA	KANAIGHAT	11.35	11.52	10.98	-54	-37
2	SURMA	SYLHET	8.75	9.07	8.64	-43	-11
3	SURMA	*SUNAMGANJ	5.50	5.10	4.99	-11	-51
4	KUSHIYARA	AMALSHID	13.50	13.90	13.24	-66	-26
5	KUSHIYARA	SHEOLA	11.15	12.20	11.70	-50	+ 55
6	KUSHIYARA	SHERPUR-SYLHET	8.25	8.84	8.64	-20	+ 39
7	KUSHIYARA	MARKULI	6.40	7.60	-	-	-
8	SARIGOWAIN	SARIGHAT	11.15	8.20	7.82	-38	-333
9	MANU	MANU RLY BR.	16.90	15.15	14.85	-30	-205
10	MANU	MOULVI BAZAR	10.00	10.02	9.63	-39	-37
11	KHOWAI	BALLAH	21.80	20.20	20.79	+ 59	-101
12	KHOWAI	HABIGANJ	9.10	6.30	6.20	-10	-290
13	DHALAI	KAMALGANJ	19.50	17.60	17.31	-29	-219
14	OLDSURMA	*DERAI	5.81	4.97	5.02	+ 5	-79
15	BAULAI	KHALIAJURI	4.60	5.05	5.06	+ 1	+ 46
16	BHOGAI	NAVIGAION	21.25	18.59	18.53	-6	-272
17	JADUKATA	*LOREGARH	5.88	4.77	4.67	-10	-121
18	SOMESWARI	DURGAPUR	11.25	10.16	10.06	-10	-119
19	KANGSHA	JARIAJANJAIL	6.80	8.77	8.54	-23	+ 174
20	TITAS	B. BARIA	5.50	3.20	3.15	-5	-235
21	MEGHNA	BHAIRAB BAZAR	6.25	2.89	2.92	+ 3	-333
22	MEGHNA	NARSINGDI	5.70	2.62	2.77	+ 15	-293
23	MEGHNA	MEGHNA BRIDGE	5.03	2.10	2.25	+ 15	-278
24	GUMTI	COMILLA	11.75	7.62	7.77	+ 15	-398
25	GUMTI	DEBIDDAR	8.50	4.66	4.60	-6	-390
26	SARIGOWAIN	GOWAINGHAT	9.10	7.17	6.88	-29	-222
27	KALNI	AZMIRIGANJ	5.50	6.90	6.81	-9	+ 131
28	KUSHIYARA	FENCHUGANJ	8.20	10.05	9.95	-10	+ 175
29	DHALAGANG	ISLAMPUR	10.70	7.09	7.05	-4	-365
30	SOMESWARI	KALMAKANDA	5.35	5.60	5.40	-20	+ 5
31	JHALUKHALI	*MOHLIMPUR	5.89	5.04	4.93	-11	-96
32	SUTANG	SUTANG-RB	5.40	5.99	5.78	-21	+ 38
33	SOMESWARI	BIJOYPUR	-	13.68	13.63	-5	-
34	LUBACHARA	LUBACHARA	-	11.71	11.13	-58	-
35	PIYAIN	JAFFLONG	-	7.77	7.49	-28	-
36	MEGHNA	**CHANDPUR L.W.L.	4.00	1.25***	1.39***	+ 14	-261
		**CHANDPUR H.W.L.	-	2.07****	2.33****	+ 26	-

NOTE: WATER LEVEL AT STATION ABOVE DANGER LEVEL UNDERLINED.
- DATA NOT AVAILABLE.

D.L.: Pre-Monsoon Danger Level Valid till 15 May.
L.W.L.: Lowest Water Level.
H.W.L.: Highest Water Level.
* : Water Level and DL relative to SOB Datum
** : Tidal Station
*** : Low Water Level of the Previous Day
**** : High Water Level of the Previous Day

DUTY OFFICER,
FLOOD INFORMATION CENTER,
BWDB, DHAKA.

RAINFALL SITUATION AS ON 15-05-2018 (IN MM)

SL NO	STATION	MAXIMUM FOR MAY	NORMAL FOR MAY	RAINFALL FOR 2018 13-05	14-05	15-05	MONTHLY CUMULATIVE (UPTO 15-05-2018)
	MEGHNA BASIN						
1	KANAIGHAT	1433.0	714.7	0.0	0.0	76.0	233.0
2	SYLHET	1270.0	578.4	0.0	0.0	0.5	256.0
3	SUNAMGANJ	1174.0	600.6	0.0	0.0	0.0	133.0
4	SHEOLA	1324.0	589.2	0.0	0.0	7.0	290.0
5	MOULVI BAZAR	1235.7	477.8	0.0	0.0	2.0	334.0
6	MANU RLY BR	1086.6	491.0	0.0	0.0	27.0	449.0
7	HABIGANJ	996.9	495.4	0.0	21.0	6.0	330.0
8	SHERPUR-SYLHET	475.0	367.0	0.0	-	0.0	434.0
9	DURGAPUR	911.9	425.7	0.0	0.0	0.0	252.0
10	LOREGARH	985.0	485.0	0.0	0.0	0.0	170.0
11	NAVIGAGON	1547.0	417.0	0.0	0.0	0.0	120.0
12	JARIAJANJAIL	-	255.0	0.0	0.0	0.0	312.0
13	B. BARIA	941.6	329.7	0.0	18.0	14.0	221.0
14	BHAIRAB BAZAR	801.0	379.9	0.0	0.0	0.0	13.0
15	COMILLA	791.0	365.7	0.0	0.0	30.0	223.0
16	CHANDPUR	535.1	283.1	0.0	0.0	0.0	28.9
17	NARSINGDI	1064.9	327.9	0.0	0.0	0.0	170.5
18	SAKIGANJ	1200.0	455.0	0.0	0.0	0.0	177.0
19	LALAKHAL	1729.8	779.2	0.0	0.0	0.0	200.0
20	JAFFLONG	892.0	271.4	0.0	0.0	12.0	329.0
21	CHATTAK	1365.0	575.9	0.0	-	-	155.0
22	MOHESHKHOLA	250.0	143.7	0.0	-	0.0	192.4
23	CHANDPUR BAGAN	938.1	431.9	0.0	7.0	23.0	279.0
24	KAMALGANJ	1221.7	523.6	0.0	14.0	0.0	605.0
25	DAKHINBAGH	1073.0	521.0	0.0	0.0	3.0	426.0
26	SREEMONGAL	1297.5	527.4	0.0	5.0	7.1	371.0
27	LATU	1474.0	554.1	0.0	0.0	0.0	351.0
28	ITAKHOLA	1291.0	403.1	0.0	0.0	12.5	277.2

NOTE: RAINFALL AT STATIONS ABOVE 50 MM UNDERLINED.
- DATA NOT AVAILABLE.

In General, 50 mm or above rainfall in one day causes stress on local drainage system leading to localised flood.

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

DUTY OFFICER
FLOOD INFORMATION CENTER
BWDB, DHAKA

Sample Flash Flood Bulletin for 36 WL Stations and 28 Rainfall Stations of the NE Region

Annex-6

বন্যা তথ্য কেন্দ্র
বন্যা পূর্বাভাস ও সতর্কীকরণ কেন্দ্র
বাংলাদেশ পানি উন্নয়ন বোর্ড
ওয়াপদা ভবন (৯ম তলা) মতিঝিল বা/এ, ঢাকা-১০০০
ই-মেইলঃ ffwcbwdb@gmail.com, ffwc05@yahoo.com; ওয়েবসাইট : www.ffwc.gov.bd, দূরালাপনি : ৯৫৫৩১১৮, ৯৫৫০৭৫৫; ফ্যাক্স :৯৫৫৭৩৮৬

১০ বৈশাখ ১৪২৫ বং/ ২৩ এপ্রিল ২০১৮ খৃঃ

উত্তর পূর্বাঞ্চলের আকস্মিক বন্যা পরিস্থিতির সংক্ষিপ্ত প্রতিবেদন ও পূর্বাভাস

বিগত দুইদিনে বাংলাদেশের উত্তর পূর্বাঞ্চল ও তৎসংলগ্ন ভারতের উত্তর পূর্বাঞ্চলের প্রদেশ আসাম, মেঘালয় ও ত্রিপুরার অনেক স্থানে মাঝারী থেকে ভারী বৃষ্টিপাত পরিলক্ষিত হয়েছে। উল্লেখযোগ্য রেকর্ডকৃত বৃষ্টিপাত নিম্নরূপঃ

ছক: ভারতের উত্তর পূর্বাঞ্চলের প্রদেশ মেঘালয়, আসাম ও ত্রিপুরা অঞ্চলের বৃষ্টিপাতের পরিমাণ (বৃষ্টিপাত: মি.মি.)

Date	Silchar	Kailasahar/Manu	Cherrapunjee	Aizwal	Shillong
22/04/2018	36	53	59	23	3
23/04/2018	2	1	3	0	0
Total	38	54	62	23	3

ছক: বাংলাদেশের উত্তর পূর্বাঞ্চলের উল্লেখযোগ্য বৃষ্টিপাতের পরিমাণ (বৃষ্টিপাত: মি.মি.)

Date	Kanaighat	Sylhet	Sheola	Manu Rly Br	Chandpur
21/04/2018	76	70	80	29	0
22/04/2018	35	32	42	33	0
23/04/2018	63	1	2	5	38
Total	174	103	124	67	38

নদ-নদীর অবস্থাঃ

পানি সমতল স্টেশন	নদীর নাম	বিগত ২৪ ঘন্টায় বৃদ্ধি(+)/হ্রাস(-) (সে.মি.)	বিপদসীমার উপরে (+)/নিচে(-) (সে.মি.)
কানাইঘাট	সুরমা	+৫০	-৩৬৫
সিলেট	সুরমা	+৯২	-৩৩৮
সুনামগঞ্জ	সুরমা	+৪৬	-৩৭৪
অমলশীদ	কুশিয়ারা	+৬৭	-৩৭৫
শেওলা	কুশিয়ারা	+৯৫	-৩৫৪
মৌলভীবাজার	মনু	+৩৭	-২২১
কংস	জারিয়াজঙ্গাইল	+৮	-৭২
সারিগোয়াইন	সারিঘাট	+৪	-৩৮৮

বিদ্যমান আবহাওয়ার পূর্বাভাসে ভারী বৃষ্টিপাতঃ

বাংলাদেশ আবহাওয়া অধিদপ্তর ও ভারতের আবহাওয়া অধিদপ্তর হতে সরবরাহকৃত আবহাওয়ার গাণিতিক মডেলের পূর্বাভাস হতে দেখা যাচ্ছে যে, আগামী ৪৮ ঘন্টায় বাংলাদেশের উত্তর পূর্বাঞ্চলের জেলাসমূহের এবং তৎসংলগ্ন ভারতের উত্তর পূর্বাঞ্চলের প্রদেশ আসাম, মেঘালয় ও ত্রিপুরায় ভারী বৃষ্টিপাতের পূর্বাভাস নেই ।

বন্যার পূর্বাভাসঃ

এমতাবস্থায়, বর্তমানে আবহাওয়ার পূর্বাভাস ও নদ-নদীর পরিস্থিতি বিবেচনায় বাংলাদেশের উত্তর পূর্বাঞ্চলের জেলাসমূহের প্রধান নদীসমূহের পানি সমতল আগামী ২৪ ঘন্টায় স্থিতিশীল থাকতে পারে।

সংযুক্তিঃ

১. বাংলাদেশ আবহাওয়া অধিদপ্তর থেকে প্রাপ্ত গাণিতিক মডেলের পূর্বাভাস।
২. ভারতীয় আবহাওয়া অধিদপ্তরের গাণিতিক মডেলের পূর্বাভাস।

যোগাযোগঃ ১। মোঃ আরিফুজ্জামান ভূঁইয়া, নির্বাহী প্রকৌশলী (মোবাইল নম্বর ০১৭১৫-০৪০১৪৪)
২। সরদার উদয় রায়হান, উপবিভাগীয় প্রকৌশলী (মোবাইল নম্বর ০১৫৫২৩৫৩৪৩৩)
৩। জুয়েল আহমেদ, সহকারী প্রকৌশলী (মোবাইল নম্বর ০১৭৪১৪২২২৩৮)
৪। মোঃ আলরাজী লিয়ন, সহকারী প্রকৌশলী (মোবাইল নম্বর ০১৯১৫৯৭৭৭৩৮)

Sample Qualitative Flash Flood Outlook for NE region

Annex-7

FLOOD INFORMATION CENTRE,
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Website: http://www.ffwc.gov.bd
Tel: 9553118, 9550755 Fax: 9557386

Flash Flood Early Warning Bulletin for North East Region as on April 23,2018

Rainfall:

Significant rainfalls recorded during last 24 hours within Bangladesh:

Station	Rainfall (mm)
Kanaighat	63
Chandpur	38
Lalakhal	30
Chattak	30

General River Condition:

Monitored WL Stations	Rise	Fall	Steady	Not Reported	Stations above DL
33	24	05	02	02	0

Flood Condition:

- ***The Surma-Kushiyara, Sarigowain and Manu rivers of North-Eastern region are in rising trend.***
- ***All the rivers of North-Eastern zone are flowing below danger level.***

IFAD Investing in rural people LGED IWM Water Environment & Climate

1

Sample Experimental Flash Flood Summary Bulletin for NE Region

Annex-8

ক্রঃ নং	স্টেশন	নদীর নাম	বর্তমানের monsoon বিপদসীমা (mPWD)	প্রস্তাবিত pre-monsoon (mPWD)
১	Ajmiriganj	Kalni	5.49	5.00
২	Amalshid	Kushiyara	15.85	13.50
৩	Ballah	Khowai	-	21.80
৪	Kamalganj	Dhalai	19.82	19.50
৫	Durgapur	Someswari	13.00	11.25
৬	Fenchuganj	Kushiyara	9.91	8.20
৭	Gowainghat	Sarigowain	11.28	9.10
৮	Habiganj	Khowai	9.50	9.10
৯	Islampur	Dhalagang	-	10.70
১০	Jariajanjail	Kangsha	11.00	6.80
১১	Kalmakanda	Someswari	7.00	5.35
১২	Kanairghat	Surma	13.20	11.35
১৩	Khaliajuri	Baulai	8.50	4.60
১৪	Lourergorh	Jadukata	8.53	6.40
১৫	Manu RB	Manu	18.00	16.90
১৬	Markuli	Kalni	8.50	6.40
১৭	Moulvibazar	Manu	11.75	10.00
১৮	Muslimpur	Jhalukhali	-	6.90
১৯	Nakuagaon	Bhugai	22.40	21.25
২০	Sarighat	Sarigowain	12.80	11.15
২১	Sheola	Kushiyara	13.50	11.15
২২	Sherpur	Kushiyara	9.00	8.25
২৩	Sunamganj	Surma	8.25	6.50
২৪	Sutang RB	Sutang	5.79	5.40
২৫	Sylhet	Surma	11.25	8.75

Experimental PMDL Approved by BWDB

Annex-9

Sl. No.	Station	River	Pre-Monsoon RHWL (m PWD) (Up to 15 May)	Statistical Analysis		Existing Monsoon Danger Level of FFWC, BWDB (m PWD)	Adjacent Haor and Submersible Embankment Height (m PWD)			Proposed Pre-monsoon DL
				2.33-yr Return Period	10-yr Return Period		Name *(Source: Haor Rehabilitation Project, 2005)*	Embankment design crest Level (m PWD)	Approximate Distance from Station (km)	
1	Ajmiriganj	Kushiyara	7.63	4.94	6.68	-	Bhanda Beel	3.10	11.6	4.94
2	Amalshid	Kalni	16.28	12.99	15.76	15.85	Shafique Haor	13.56	18.7	12.99
3	Ballah	Khowai	25.28	21.78	23.47	21.64	-			21.78
4	Kamalganj	Dhalai	21.18	19.53	20.64	19.82	-			19.53
5	Durgapur	Someswari	13.84	11.86	12.83	13.00	Updakhali Haor	8.46	22.0	11.86
6	Fenchuganj	Kushiyara	11.3	8.18	10.23	-	Kawadighi Haor	11.87	7.5	8.18
7	Gowainghat	Sarigowain	11.46	9.11	11.27	-	-			9.11
8	Habiganj	Khowai	11.5	9.03	10.61	9.50	Hail Haor	11.37	22.0	9.03
9	Islampur	Dhalagang	13.25	11.42	12.78	-	Pathar Chauli Haor-2	9.08	6.7	11.42
10	Jariajanjail	Kangsha	9.43	6.78	8.58	9.75	Upadakhali Haor	8.94	20.4	6.78
11	Kalmakanda	Someswari	6.07	5.16	5.88	-	Updakhali Haor	7.35	2.8	5.16

Pre-monsoon Danger Level Calculation

12	Kanairghat	Surma	15.26	10.96	14.09	13.20	Shafique Haor	15.21	4.6	10.96
13	Khaliajuri	Baulai	5.77	4.32	5.25	8.50	Nawtana Haor, Katikota Haor, Balali Padmasree Haor	4.95	4.5	4.32
14	Lourergorh	Jadukata	7.61	6.46	7.50	8.53	Matian	7.75	7.7	6.46
15	Manu RB	Manu	20.42	17.68	19.18	18.00	Hail Haor	7.28	24.7	17.68
16	Markuli	Kalni	7.82	6.34	7.57	8.50	Makalkandi Haor, Tangua Haor, Bhanda Beel	5.82	2.1	6.34
17	Moulvibazar	Manu	12.96	9.91	11.87	11.75	Kawadighi Haor	12.96	0.7	9.91
18	Muslimpur	Jhalukhali	9.9	7.79	9.35	-	Kalner Haor-3, Karchar Haor	9.48	4.2	7.79
19	Nakuagaon	Bhugai	23.06	21.25	22.27	22.40	-			21.25
20	Sarighat	Sarigowain	14.07	12.24	13.65	12.80	Shafique Haor	15.21	4.6	12.24
21	Sheola	Kushiyara	14.22	10.85	13.16	13.50	Bardal Haor	14.15	5.0	10.85
22	Sherpur	Kushiyara	8.9	8.01	9.10	9.00	Kawadighi Haor	11.22	6.5	8.01
23	Sunamganj	Surma	8.35	6.34	7.75	8.25	Karcha Haor	7.46	2.1	6.34
24	Sutang RB	Sutang	7.51	5.19	6.79	-	Hail Haor	12.67	25.3	5.19
25	Sylhet	Surma	10.77	8.14	11.06	11.25	Ziker Haor-1	11.17	4.5	8.14

Pre-monsoon Danger Level Calculation (contd.)

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