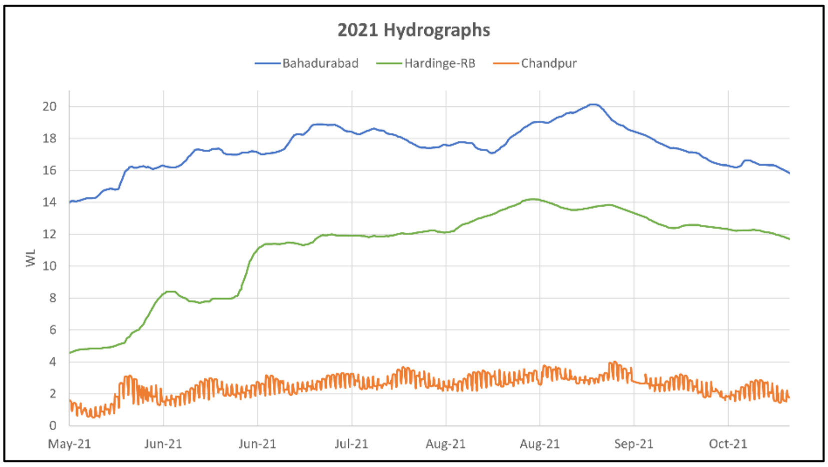
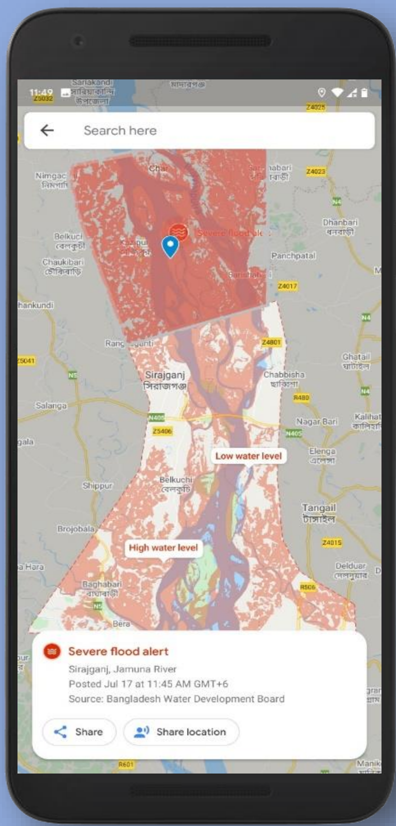
2020

Annual Flood Report





Flood Forecasting and Warning Centre
Processing and Flood Forecasting Circle
Bangladesh Water Development Board

Annual Flood Report 2020

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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 Bangladesh Meteorological Department (BMD), Department of Disaster Management (DDM) and Department of Agricultural Extension (DAE) for overall flood disaster 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 greatly inspired receiving encouraging words from Honourable State Minsiter, MoWR and Honourable Deputy Minsiter, MoWR during critical periods of the flood season. We also felt aspired by the valuable advice and guidance of the Senior Secretary, MoWR 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, Design & Research), 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 2020. A number of non-government organizations (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. All the partner supports are more specially acknowledged this year as they relentlessly aided in flood management throughout the difficult situation due to the ongoing Covid-19 pandemic.

FFWC is providing the following services on daily basis during monsoon

- Flood bulletin twice a day
- River and rainfall situation summary report
- 3-days deterministic flash flood forecast
- 5-days deterministic and 10-days probabilistic monsoon flood forecast
- Special outlook and warning message
- Rainfall Map
- Flood Inundation Map
- Flood warning message dissemination publicly through website (www.ffwc.gov.bd), toll-free Interactive Voice Response (IVR) method (1090) and Android mobile based 'BWDB Flood App'
- Flood warning message dissemination through email and fax to all relevant government organizations and selected medias, NGOs, stakeholders and others

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 demands are to increase flood forecasting and warning lead time and make location specific flood forecast. One step towards increasing lead time has been initiated this year by launching experimental 15-days probabilistic flow forecast with collaboration from Regional Integrated Multi-Hazard Early Warning System (RIMES) at 3 stations on the major rivers– Brahmaputra, Ganges and Meghna. Another step towards improving the local flood warning had been initiated last year by entering into parthership with tech giant 'Google'. By utilizing the 5-day flood forecasts and observed water level data of FFWC of BWDB, Google has been able to experimentally produce high-resolution inundation map this year for the Jamuna-Padma river belt which users can access by Android push notification or by searching thorugh Google or Google map.

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 2020 flood as a whole is representative of a severe one with respect to both magnitude and duration. During the monsoon 2020, major flood events occurred throughout the monsoon from second half of June till first half of October in six spells, mostly in countrywide scale. The flood stayed up to long duration in all regions of Bangladesh except the South-Eastern. More active than normal monsoon triggered simultaneous and rapid rise of the major rivers of country through successive heavy rainfall events. The first 3 spells of flooding resulted in severe countrywide long duration flooding between 27 June – 6 July, 11 July – 20 July and 20 July – 8 August. The Teesta river at Dalia and Gur river at Singra exceeded the previously recorded highest water levels (RHWLs) during this time. Dhaka and the surroundings also got flooded during this time for long duration which occurred first since 2007. Though the flood water receded from Northern parts of the country during the second half of August, it persisted in the Central parts of the country. Also upstream rush of water combined with excessive rainfall in the coastal regions and above normal spring tide during the new moon created tidal flooding in the coastal rivers of the South-Western and South-Central regions during 16 August – 25 August. Following that, two final monsoon spells of heavy rainfall incurred flooding between 16 September – 21 September in the Northern region, and between 24 September – 9 October in a smaller countrywide scale. The Atrai river at Atrai exceeded RHWL during this time. Notable flood durations of the season included: Dharala at Kurigram for 47 days, Jamuna at Sariakandi for 55 days, Gur at Singra for 63 days, Padma at Goalundo for 60 days, Kirtonkhola at Barisal for 21 days, Surma at Sunamganj for 20 days and Meghna at Chandpur for 42 days. The 2020 flood surpassed the duration of 1988 and 2007 floods at many places in the Northern, North-Western, North-Central and Central regions of Bangladesh, but stayed for shorter duration than 1998. In terms of magnitude the flood was less severe than historical major ones except in the Northern region. No pre-monsoon flooding occurred this year. Average accuracy of 5-days deterministic forecasts were around 95%, 91%, 87%, 83% and 78% for 24, 48, 72, 96 and 120 hours respectively.

The monsoon was more or less active over the GBM basin throughout 2020 except during August. The country as a whole received 0.3% more rainfall than normal during May to October. The Brahmaputra, Ganges and the Meghna basins received respectively 5.8%, 7.8% and 3.4% more rainfall than normal, while the South Eastern Hill basin received 12.1% less rainfall than normal. Monthly percentage based basin wise less (-) or more (+) rainfall than the normal is presented in following table.

Month	Brahmaputra basin	Ganges basin	Meghna basin	South East Hill basin
May	19.28%	36.24%	-11.34%	-23.67%
June	-21.90%	6.50%	7.39%	-20.96%
July	24.12%	-5.04%	10.49%	-19.57%
August	-56.29%	-15.03%	-35.07%	-12.48%
September	65.72%	26.57%	32.89%	-6.45%
October	-3.46%	24.23%	45.65%	56.40%

Notable improvements have been made during 2020 as a 15-days experimental probabilistic streamflow forecasting system has been made operational. Also by collaboration with Google and a2i, high-resolution inundation maps for the Jamuna-Padma river belt have been produced. During the monsoon of 2020, maximum flooded area was 40% of the whole country (59,028 sq-km approximately). Some of the regions experienced severe river bank erosion which continued both during and after the flooding.

List of Abbreviations

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
DMC	Disaster Management Committee
DHI	Danish Hydraulic Institute
ECMWF	European Centre for Medium-Range Weather Forecasts
DEM	Digital Elevation Model
FbA	Forecast based Action
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
SUFAL	Supporting Flood Forecast Based Early Action and Learning
UNDP	United Nations Development Porgramme
USAID	United States Agency for International Development
WL	Water Level

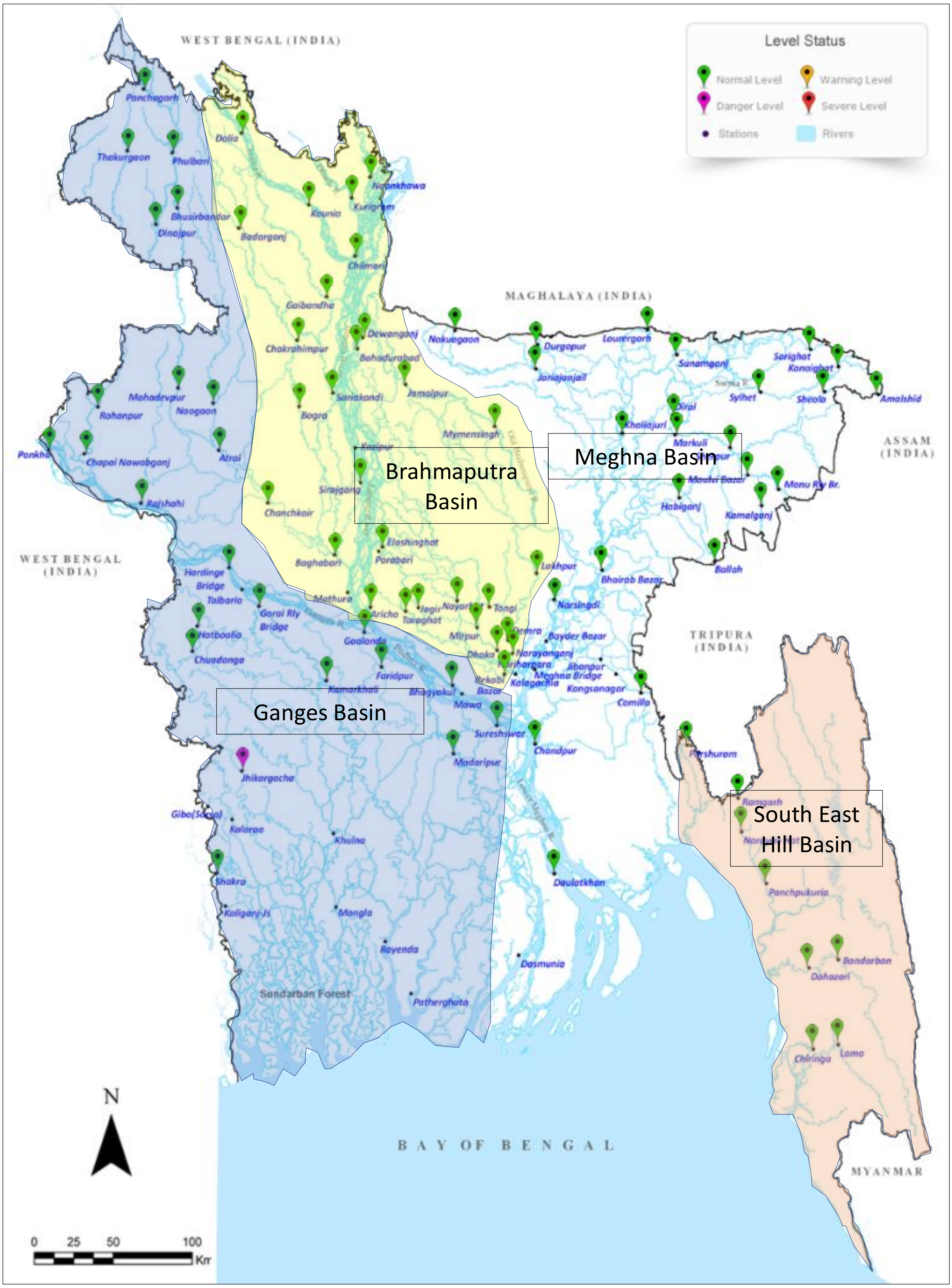


Figure 1 : Basin Map of Bangladesh with Water Level Gauge Stations

CHAPTER 1 : INTRODUCTION

1.1. THE PHYSICAL SETTING

Bangladesh lies approximately between 20°30' and 26°40' north latitude and 88°03' and 92°40' east longitude. It is one of the biggest active deltas in the world with an area of about 1,47,570 sq-km. The country is under sub-tropical monsoon climate, annual average precipitation is 2,300 mm, varying from 1,200 mm in the north-west to over 5,000 mm in the north-east. India borders the country in west, north and most part of east. The Bay of Bengal is in the south, Myanmar borders part of the south-eastern area. It has 405 rivers including 57 transboundary rivers, among them 54 originated from India including three major rivers the Ganges, the Brahmaputra and the Meghna (*Ref. Bangladesher Nod Nodi, BWDB, August 2011*). Three rivers 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 101 representative water level stations and 72 rainfall stations throughout the country. The principal outputs are the daily statistical bulletin of floods, river situation, a descriptive flood bulletin, deterministic forecast for 24, 48, 72, 96 and 120 hours at 54 monitoring points on the major rivers, 10-days probabilistic flood forecast at 37 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 3-days deterministic flash flood forecasting at 25 monitoring points on the major rivers 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**
- **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 28 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.

2017-19 - Operational 3-days deterministic flash flood forecast at 25 stations for the North-Eastern region
- Establishment of pre-monsoon danger level in North-Eastern region
- Introduction of FFWC mobile app

2020 - 15-days probabilistic flow forecast (experimental) at 3 stations on the major rivers– Brahmaputra, Ganges and Meghna
- High-resolution inundation map for the Jamuna-Padma river belt with support form Google

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 websites, e-mail and from Bangladesh Meteorological Department (BMD).

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 Central Water Commission (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 Numerical Weather Prediction (NWP) model rainfall forecasts from BMD. In addition to BMD, NWP model rainfall forecasts from India Meteorological Department (IMD), National Oceanic and Atmospheric Administration (NOAA) and European Centre for Medium Range Weather Forecast (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, non-government organizations (NGOs) 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

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 ('BWDB Flood App')

accessible to all and contains all flood related information. In addition, FFWC has launched a mobile app since 2018 which is publicly available. High-resolution inundation map has been also made experimentally available this year for the Jamuna-Padma river belt which users can see by opening Google map or searching in the Google web.

The flood forecast is intended to alert the people of the locality about the predicted WL of floodwater 5-days ahead of its occurrence during monsoon. 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.

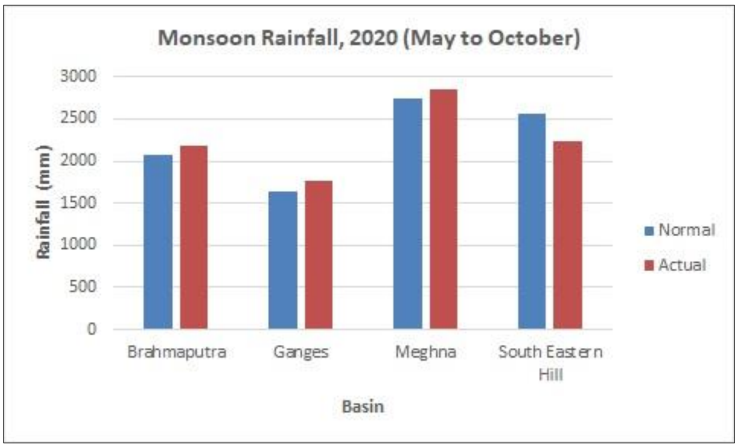
1.5.2. Statistics of Flooding

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, 2017 and 2019 all caused heavy damages to properties and considerable loss of life. During monsoon 2020, the flood was also a severe one which stayed for long duration as well. The Brahmaputra-Jamuna, Padma and Upper Meghna river systems caused the severe flood this year affecting low lying lands of Northern, North-Western, North-Central, North-Eastern, Eastern, Central, South-Western and South-Central regions Bangladesh for relatively much longer than normal duration in multiple peaks. 40% of the country got flood affected in 2020. 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**	
	Sq-Km	**%**		**Sq-Km**	**%**
1954	**36,800**	**25**	1990	3,500	2.4
1955	**50,500**	**34**	1991	28,600	19
1956	35,400	24	1992	2,000	1.4
1960	28,400	19	1993	28,742	20
1961	28,800	20	1994	419	0.2
1962	37,200	25	1995	32,000	22
1963	43,100	29	1996	35,800	24
1964	31,000	21	**1998**	**1,00,250**	**68**
1965	28,400	19	1999	32,000	22
1966	33,400	23	2000	35,700	24
1967	25,700	17	2001	4,000	2.8
1968	37,200	25	2002	15,000	10
1969	41,400	28	2003	21,500	14
1970	42,400	29	**2004**	**55,000**	**38**
1971	36,300	25	2005	17,850	12
1972	20,800	14	2006	16,175	11
1973	29,800	20	**2007**	**62,300**	**42**
1974	**52,600**	**36**	2008	33,655	23
1975	16,600	11	2009	28,593	19
1976	28,300	19	2010	26,530	18
1977	12,500	8	2011	29,800	20
1978	10,800	7	2012	17,700	12
1980	33,000	22	2013	15,650	10.6
1982	3,140	2	2014	36,895	25
1983	11,100	7.5	2015	47,200	32
1984	28,200	19	2016	48,675	33
1985	11,400	8	**2017**	**61,979**	**42**
1986	6,600	4	2018	33,941	23
1987	**57,300**	**39**	**2019**	**45,747**	**31**
1988	**89,970**	**61**	**2020**	**59,028**	**40**
1989	6,100	4			

CHAPTER 2 : RAINFALL SITUATION



During the pre-monsoon months of March and April in 2020, the Meghna basin within the country in the North-Eastern and adjacent region experienced 94.4% and 26.5% less rainfall than normal respectively, while other parts of the country remained mostly dry. During the monsoon-2020 (May to October), the country experienced as a whole 0.3% more rainfall than normal which can be considered as slightly above normal monsoon. The Brahmaputra, Ganges and Meghna basins received 5.8%, 7.8% and 3.4% more rainfall than normal respectively, while the South Eastern Hill basin received 12.1% less rainfall than normal during the season. Comparison of the country basin average of normal and actual rainfall for the monsoon-2020 (May to October) is presented in the bar chart. Considering monthly rainfalls, the country as a whole received more rainfall than normal during the May-October period except in June and August. Two out of four hydrological basins received more rainfall than normal duing May-July, while three out of four hydrological basins received more rainfall than normal duing September-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-2020 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	312.1	372.3	189.4	258.0	446.1	395.5	275.2	210.1	**2253**	**2260.2**
Jun	425.2	332.1	317.9	338.6	585.5	628.8	570.5	450.9		
Jul	484.9	601.9	401.4	381.2	632.3	698.6	677.2	544.7		
Aug	339.6	148.5	318.8	270.9	508.9	330.5	515.6	451.3		
Sep	353.4	585.7	281.9	356.8	402.3	534.6	348.9	326.4		
Oct	154.6	149.3	129.6	161.0	173.7	253.0	166.6	260.6		
Total	**2069.8**	**2189.6**	**1639.0**	**1766.4**	**2748.8**	**2841.0**	**2554.1**	**2243.9**		
%More/ Less	5.8% More		7.8% More		3.4% More		12.1% Less		0.3% More	

Month wise rainfall situations of the country during March to October for the pre-monsoon and monsoon seasons of 2020 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 2020, while the other parts of the country remained mostly dry. The basin received 94.42% less rainfall than monthly normal.

Important Rainfall Information for March-2020
Monthly Maximum at Nakuagaon : 28.5 mm
1 day maximum at Nakuagaon : 18.5 mm

Table 2.2: **Summary of the rainfall situation during the month of March-2020**

Basin:	**Meghna**
No of Stations:	19
Average Rainfall (mm) of the basin:	3.68
%More(+)/Less(-) than the Normal:	-94.42%
Number of Stations above Normal Rainfall:	01
Highest 1-day Maximum Rainfall with Stations:	Nakuagaon 18.50 mm
Number of Rainfed Flood* Stations:	0

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

In the Meghna basin, out of 19 rainfall monitoring stations, only 1 station received more rainfall than monthly normal. During March, monthly 1-day maximum rainfall of 18.5 mm and 10-day consecutive maximum rainfall of 28.5 mm were observed at Nakuagaon. 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 2020, while the other parts of the country remained mostly dry. The basin received 26.45% less rainfall than monthly normal.

Important Rainfall Information for April-2020
Monthly Maximum at Chandpur : 307.2 mm
1 day maximum at Moulvi Bazar : 92 mm

Table 2.3: **Summary of the rainfall situation during the month of April-2020**

Basin:	**Meghna**
No of Stations:	19
Average Rainfall (mm) of the basin:	168.16
%More(+)/Less(-) than the Normal:	-26.45%
Number of Stations above Normal Rainfall:	06
Highest 1-day Maximum Rainfall with Stations:	Moulvi Bazar 92 mm
Number of Rainfed Flood* Stations:	0

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

In the Meghna basin, out of 19 rainfall monitoring stations, 6 stations received more rainfall than respective monthly normal. During April, monthly 1-day maximum rainfall of 92 mm was observed at Moulvi Bazar, while 10-day consecutive maximum rainfall of 255 mm was observed at Manu Rly. Br. 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 slightly more than normal during the month of May 2020.

Important Rainfall Information for May-2020

Monthly Maximum at B. Baria : 808 mm

10 day maximum at Lorergarh : 609 mm

1 day maximum at B. Baria : 190 mm

Table 2.4: **Summary of the rainfall situation during the month of May-2020**

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	19	19	11
Average Rainfall (mm) of the basin:	372.26	258.04	395.51	210.07
%More(+)/Less(-) than the Normal:	19.28	36.24	-12.23	-23.67
Number of Stations above Normal Rainfall:	10	16	6	3
Highest 1-day Maximum Rainfall with Stations:	Mymensingh	Dinajpur	B. Baria	Lama
	(186 mm)	(185 mm)	(190 mm)	(117 mm)
Number of Rainfed Flood* Stations:	2	1	5	0

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

In Brahmaputra basin, out of 13 rainfall monitoring stations, 10 stations received more rainfall than their normal. One day maximum rainfall of 186 mm was recorded at Mymensingh. The Basin received 19.28% more rainfall than normal during the month May 2020.

In Ganges basin, out of 19 rainfall monitoring stations, 16 stations received more rainfall than their normal. One day maximum rainfall of 185 mm was recorded at Dinajpur. The Basin received 36.24% more rainfall than normal during the month May 2020.

In the Meghna basin, out of 19 rainfall monitoring stations, 6 stations received more rainfall than their normal. One day maximum rainfall of 190 mm and 10-day consecutive maximum rainfall of 808 mm was recorded at B. Baria. The Basin received 12.23% less rainfall than normal during the month May 2020.

In the South Eastern Hill basin, out of 11 rainfall monitoring stations, 3 stations received more rainfall than their normal. One day maximum rainfall of 117 mm was recorded at Lama. The Basin received 23.67% less rainfall than normal during the month May 2020.

Summary of the rainfall situation of the country is presented in Table 2.4. Considering 10-day maximum rainfall of 300 mm as a rainfed flood index, as many as 8 stations crossed the threshold value in this month. The maximum 1-day rainfall of 197 mm was recorded at Panchagarh and 10-day consecutive maximum rainfall of 609 mm was recorded at Lorergarh.

The Isohyet of the actual rainfall of the month of May-2020 is shown in the Figure 2.1.

2.4 JUNE

Important Rainfall Information for June-2020

Monthly Maximum at Lorergarh : 1314 mm

1 day maximum at Lorergarh : 360 mm

The country, as a whole, experienced less rainfall than normal during the month of June 2020. Out of the four hydrological basins, the Brahmaputra and the South-Eastern Hill basins received 28.04% and 26.78% less rainfall, while the Ganges and the Meghna basins received 7.26% and 7.23% more rainfall respectively in June 2020. Table 2.5 represents the summary of rainfall situation all through the country.

Table 2.5: Summary of the rainfall situation during the month of June -2020

Basin:	**Brahmaputra**	**Ganges**	**Meghna**	**South Eastern Hill**
No of Stations:	13	18	19	12
Basin average rainfall at June, 2020 (mm):	332.08	338.56	628.77	450.91
%More(+)/Less(-) than Normal:	-28.04%	+7.26%	+7.23%	-26.78%
No. of Stations above Normal Rainfall:	3	11	9	4
Highest 1-day Maximum Rainfall Stations:	Dalia (142 mm)	Kushtia (143 mm)	Lorergarh (360 mm)	Cox's Bazar (253 mm)
No of Rainfed Flood* Stations:	1	2	9	4

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

The above table shows that 3 out of 13 stations in the Brahmaputra, 11 out of 18 stations in the Ganges, 9 out of 19 stations in the Meghna and 4 out of 12 stations in the South Eastern Hill basin received more rainfall than their monthly normal rainfall. Among all monitoring stations, Lorergarh in the Meghna basin is the daily highest (360 mm) rainfall recipient station.

The table also shows that 1 station in the Brahmaputra, 2 stations in the Ganges, 9 stations in the Meghna and 4 stations in the South Eastern Hill basins received more than 300 mm rainfall in 10-day period. As a result, some parts of Nilphamari, Panchagarh, Barguna, Sylhet, Sunamganj, Netrokona, B. Baria, Kishoreganj, Noakhali, Bandarban and Cox's Bazar districts were affected by rain feed flood during the month of June 2020. It is to be mentioned here that 300 mm or more rainfall in 10-Day period may cause rainfed flood.

The Isohyet of the actual rainfall of the month of June-2020 is shown in the Figure 2.2.

2.5 JULY

The country, as a whole, experienced slightly more rainfall than normal during the month of July 2020. The Brahmaputra and the Meghna basins received 19.43% and 10.21% more rainfall, while the Ganges and South Eastern Hill basins received 5.30% and 27.47% less rainfall than respective normal values during the month.

Important Rainfall Information for July-2020

Monthly Maximum at Sunmganj : 2128 mm

10 day maximum at Sunamganj : 870 mm

1 day maximum at Lorergarh : 282 mm

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Table 2.6: Summary of the rainfall situation during the month of July-2020

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	18	19	12
Basin average rainfall in July, 2020 (mm):	601.85	381.16	698.65	544.68
%More(+)/Less(-) than the Normal:	+19.43%	-5.30%	+10.21%	-27.47%
Number of Stations above Normal Rainfall:	9	7	12	3
Highest 1-day Maximum Rainfall with Stations:	Gaibandha (250 mm)	Barguna (185 mm)	Lorergarh (282 mm)	Cox's Bazar (161 mm)
Number of Rainfed Flood* Stations:	6	3	7	4
Name of Rainfed Flood* Stations:	Kurigram, Dalia, Chilmari, Dewanganj, Gaibandha, Jamalpur	Panchagarh, Bhagyakul, Barguna	Kanaighat, Sylhet, Sunamganj, Sheola, Durgapur, Lorergarh, Nakuagao	Cox's Bazar, Teknaf, Noakhali, Lama

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

In Brahmaputra basin, among the 13 stations, 9 stations received more rainfall than their normal. The Basin received 19.43% more rainfall than normal during the month July 2020. Monthly 1-day maximum rainfall of 250 mm and 10-day consecutive maximum rainfall of 549.5 mm was recorded at Gaibandha. Rainfall of Dhaka in July 2020 was recorded as 442.5 mm, which was above the normal rainfall.

In Ganges basin, 7 of 18 stations received more rainfall than their normal. The basin as a whole received 5.30% less rainfall than normal during the month of July 2020. One day maximum rainfall of 185 mm was recorded at Barguna, while 10-day consecutive maximum rainfall of 523.8 mm was recorded at Panchagarh.

In Meghna basin, 12 out of 19 stations were recorded more rainfall than normal value of the month. The basin as a whole recorded 10.21% more rainfall than normal during the month of July 2020. One day maximum rainfall of 282 mm was recorded at Lorergarh and 10-day consecutive maximum rainfall of 870 mm was recorded at Suanmganj.

In South Eastern Hill basin, 3 out of 12 stations received more rainfall than normal. The basin as a whole received 27.47% less rainfall than normal during the month of July 2020. One day maximum rainfall of 161 mm was recorded at at Cox's Bazar and 10-day consecutive maximum rainfall of 539.5 mm was recorded at Noakhali. This rainfall caused water logging and local flood at that area.

Summary of the country's rainfall situation is presented in Table 2.6. Out of 62 stations, total 31 stations received more rainfall than normal and 20 stations recorded more than 300 mm rainfall for consecutive 10-day period. Monthly maximum raifall of 2128 mm was recorded at Sunamganj which was also the recorded highest at that station. Country maximum 10-day consecutive rainfall was 870 mm at Sunamganj, while maximum 1-day rainfall was 282 mm at Lorergarh. Rainfed flood situation developed at Cox's Bazar, Teknaf, Lama, Noakhali, Barguna, Kanaighat, Sylhet, Sunamganj, Sheola, Lorergarh, Durgapur, Nakuagaon, Panchagarh, Kurigram, Dalia, Chilmari, Dewanganj, Gaibandha, Jamalpur and Dhaka with some additional surrounding places.

A map with Isohyet of the actual rainfall of July-2020 is shown in the Figure 2.3.

2.6 AUGUST

Important Rainfall Information for August-2020
Monthly Maximum at Cox's Bazar : 1058 mm
1 day maximum at Moheshkhola : 175.4 mm

The intensity of rainfall over Bangladesh was low at most of the places during the month of August 2020. All the four hydrological basins received less rainfall than respective monthly normal during the month of August, 2020. The Brahmaputra, Ganges, Meghna and South Eastern Hill basins received 56.54%, 15.03%, 35.07% and 12.48% less rainfall than respective normals. Table 2.7 represents the summary of rainfall situation all through the country.

Table 2.7: Summary of the rainfall situation during the month of August-2020

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	20	28	11
Basin average rainfall at August, 2017(mm):	148.45	270.89	330.45	451.25
%More(+)/Less(-) than Normal:	-56.54	-15.03	-35.07	-12.48
No. of Stations above Normal Rainfall:	0	6	1	2
Highest 1-day Maximum Rainfall Stations:	Gaibandha	Barguna	Moheshkhola	Cox's Bazar
	(110 mm)	(108 mm)	(175.4 mm)	(155 mm)
No of Rainfed Flood* Stations:	0	4	4	4

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

The above table shows that 6 out of 20 stations in the Ganges basin, 1 out of 28 stations in the Meghna basin and 2 out of 11 stations in the South Eastern Hill basins received more rainfall than monthly normal. No stations in the Brahmaputra basin received higher than monthly normal rainfall. Among all monitoring stations, Moheshkhola in the Meghna basin was the highest daily rainfall station.

The Table 2.7 shows that 4 stations each in the Ganges, Meghna and South Eastern Hill basins received more than 300 mm rainfall in consecutive 10-day period. 300 mm or more rainfall in consecutive 10-day period may have caused rainfed flood in that locality.

The Isohyet of the actual rainfall of the month of August-2020 is shown in the Figure 2.4.

2.7 SEPTEMBER

Important Rainfall Information for September-2020
Monthly maximum at Jaflong : 1479 mm
10 day maximum at Panchagarh : 929.4 mm
1 day maximum at Panchagarh : 315 mm

The country, as a whole, experienced more rainfall than normal during the month of September 2020. The Brahmaputra, Ganges and Meghna basins received 65.72%, 26.57% and 29.08% more rainfall than respective normal of the month. The South Eastern Hill basin received 6.46% less rainfall than normal of the month. 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-2020

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	20	28	11
Basin average rainfall at September, 2020 (mm):	585.66	356.79	534.61	326.40
%More(+)/Less(-) than Normal:	65.72	26.57	29.08	-6.46
No. of Stations above Normal Rainfall:	11	8	18	5
Highest 1-day Maximum Rainfall Stations:	Rangpur (265 mm)	Panchagarh (315 mm)	Lourergorh (215 mm)	Cox's Bazar (81 mm)
No of Rainfed Flood* Stations:	5	7	8	1

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

In Brahmaputra basin, among the 13 stations, 11 stations received more rainfall than their normal. The Basin received 65.72% more rainfall than normal during the month September 2020. Monthly 1-day maximum rainfall of 265 mm was recorded at Rangpur, while 10-day consecutive maximum rainfall of 683 mm was recorded at Dalia.

In Ganges basin, 8 of 20 stations received more rainfall than their normal. The basin as a whole received 26.57% more rainfall than normal during the month of September 2020. Monthly 1-day maximum rainfall of 315 mm and 10-day consecutive maximum rainfall of 929.4 mm was recorded at Panchagarh.

In Meghna basin, 18 out of 28 stations were recorded more rainfall than normal value of the month. The basin as a whole recorded 29.08% more rainfall than normal during the month of September 2020. Monthly 1-day maximum rainfall of 215 mm and 10-day consecutive maximum rainfall of 820 mm were recorded at Lorergarh.

In South Eastern Hill basin, 5 out of 11 stations received more rainfall than normal. The basin as a whole received 6.46% less rainfall than normal during the month of September 2020. One day maximum rainfall of 81 mm was recorded at at Cox's Bazar and 10-day consecutive maximum rainfall of 344.5 mm was recorded at Noakhali.

Summary of the country's rainfall situation is presented in Table 2.8. Out of 72 stations, total 42 stations received more rainfall than normal and 21 stations recorded more than 300 mm rainfall for consecutive 10-day period. Monthly maximum raifall of 1479 mm was recorded at Jaflong which was also the recorded highest at that station. Both country maximum 10-day consecutive rainfall of 929.4 mm and 1-day rainfall of 315 mm were recorded at Panchagarh. Rainfed flood situation developed at Noakhali, Barishal, Patuakhali, Kanaighat, Sylhet, Chhatak, Sunamganj, Lalkhal, Jaflong, Lorergarh, Moheshkhola, Durgapur, Panchagarh, Thakurgaon, Dinajpur, Kurigram, Dalia, Rangpur, Chilmari, Gaibandha and Atrai with some additional surrounding places. Monthly raifall of September 2020 exceeded the recorded highest rainfall of the month at Dalia, Chilmari, Gaibandha, Panchagarh and Lorergarh.

A map with Isohyet of the actual rainfall of September-2020 is shown in the Figure 2.5.

2.8 OCTOBER

The country, as a whole, experienced rainfall more than normal during the month of October 2020. The Ganges, Meghna and South Eastern Hill basins received 24.23%, 34.39% and 56.43% more rainfall than respective normal of the month. The Brahmaputra basin received 3.43% less rainfall than normal of the month. Table 2.9 represents the summary of rainfall situation of the month all through the country.

Important Rainfall Information for October-2020

Monthly maximum at Barguna : 674.1 mm

10 day maximum at Barguna : 609 mm

1 day maximum at Barguna : 350 mm

Table 2.9: Summary of the rainfall situation during the month of October-2020

Basin:	Brahmaputra	Ganges	Meghna	South Eastern Hill
No of Stations:	13	20	28	11
Average Rainfall (mm) of the basin:	149.25	161.00	253.00	260.56
%More(+)/Less(-) than the Normal:	-3.43	24.23	34.39	56.43
Number of Stations above Normal Rainfall:	6	9	21	7
Highest 1-day Maximum Rainfall with Stations:	Dewanganj (80 mm)	Barguna (350 mm)	Moheshkhola (283.5 mm)	Lama (175 mm)
Number of Rainfed Flood* Stations:	0	3	2	2

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

In Brahmaputra basin, out of 13 rainfall monitoring stations, 6 stations recorded more rainfall than the normal but the basin received 3.43% less rainfall than normal during the month October 2020. 1-day maximum rainfall of 80 mm was recorded at Dewanganj. 10-day consecutive maximum rainfall of 190.7 mm was recorded at Dhaka.

In Ganges basin, out of 20 rainfall monitoring stations, 9 stations recorded more rainfall than the normal rainfall of the month. The basin as a whole received 24.23% more rainfall than the normal during the month. 1-day maximum rainfall of 350 mm and 10-day consecutive maximum rainfall of 609 mm were recorded at Barguna.

In the Meghna basin, out of 28 rainfall monitoring stations, 21 stations recorded more rainfall than the normal of the month. The Basin received 34.39% more rainfall than monthly normal during the month. 1-day maximum rainfall of 283.5 mm was recorded at Moheshkhola. 10-day consecutive maximum rainfall of 397 mm was recorded at Chhatak.

In the South Eastern Hill basin, out of 11 rainfall monitoring stations, 7 stations recorded more rainfall than normal. The Basin received 56.43% more rainfall than monthly normal during the month. 1-day maximum rainfall of 175 mm and 10-day consecutive maximum rainfall of 345.2 mm were recorded at Lama.

Summary of the country's rainfall situation is presented in Table 2.9. Out of 72 stations, total 43 stations received more rainfall than normal and 7 stations recorded more than 300 mm rainfall for consecutive 10-day period. Monthly maximum raifall of 674.1 mm was recorded at Barguna which was also the recorded highest at that station. Both country maximum 10-day consecutive rainfall of 609 mm and 1-day rainfall of 350 mm were recorded at Barguna. Rainfed flood situation developed at Lama, Noakhali, Barishal, Patuakhali, Barguna, Chhatak and Moheshkhola with some additional surrounding places.

A map with the Isohyet of actual rainfall for the month of October-2020 is shown in the Figure 2.6.

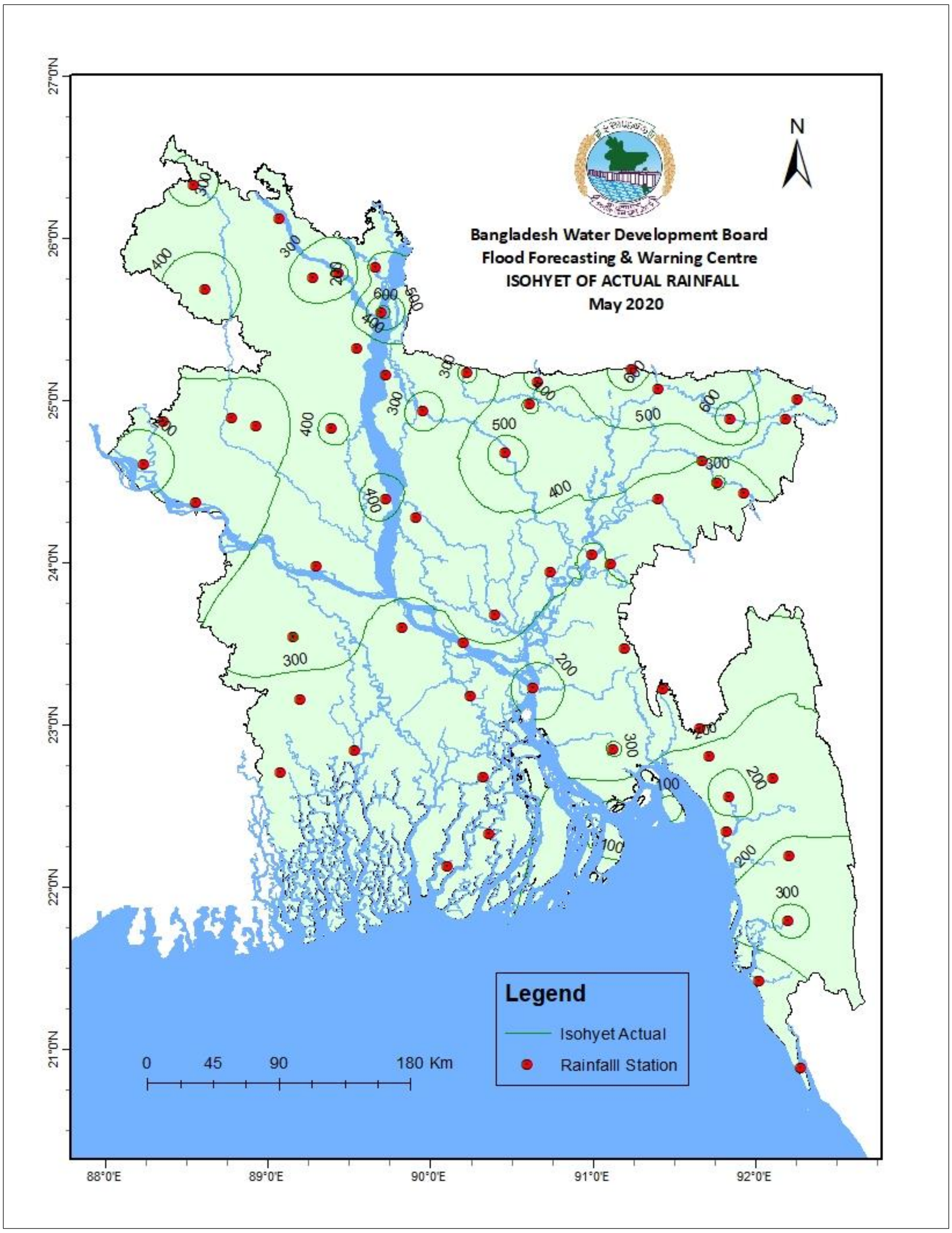


Figure 2.1: Isohyet of Actual Rainfall (May-2020)

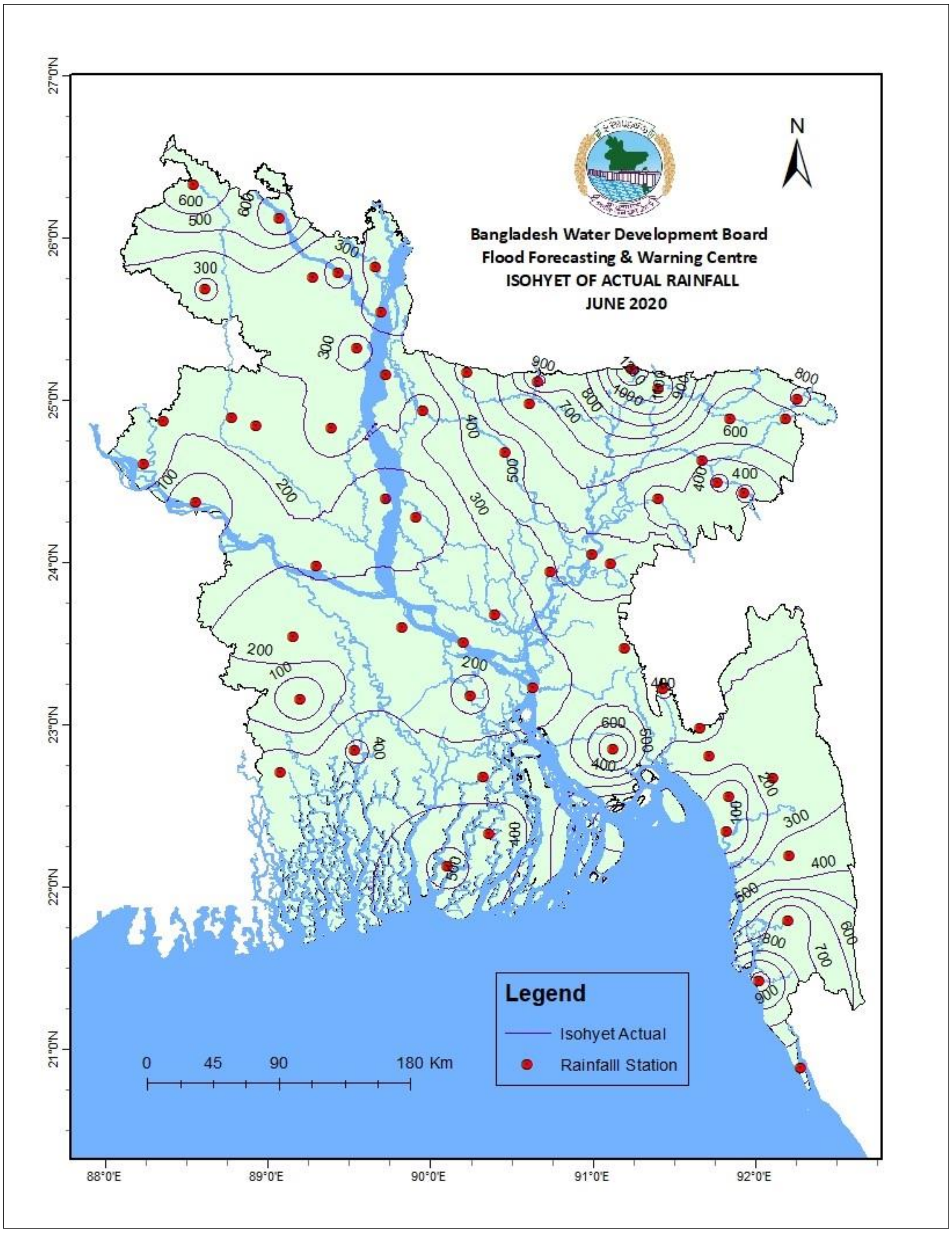


Figure 2.2: Isohyet of Actual Rainfall (June-2020)

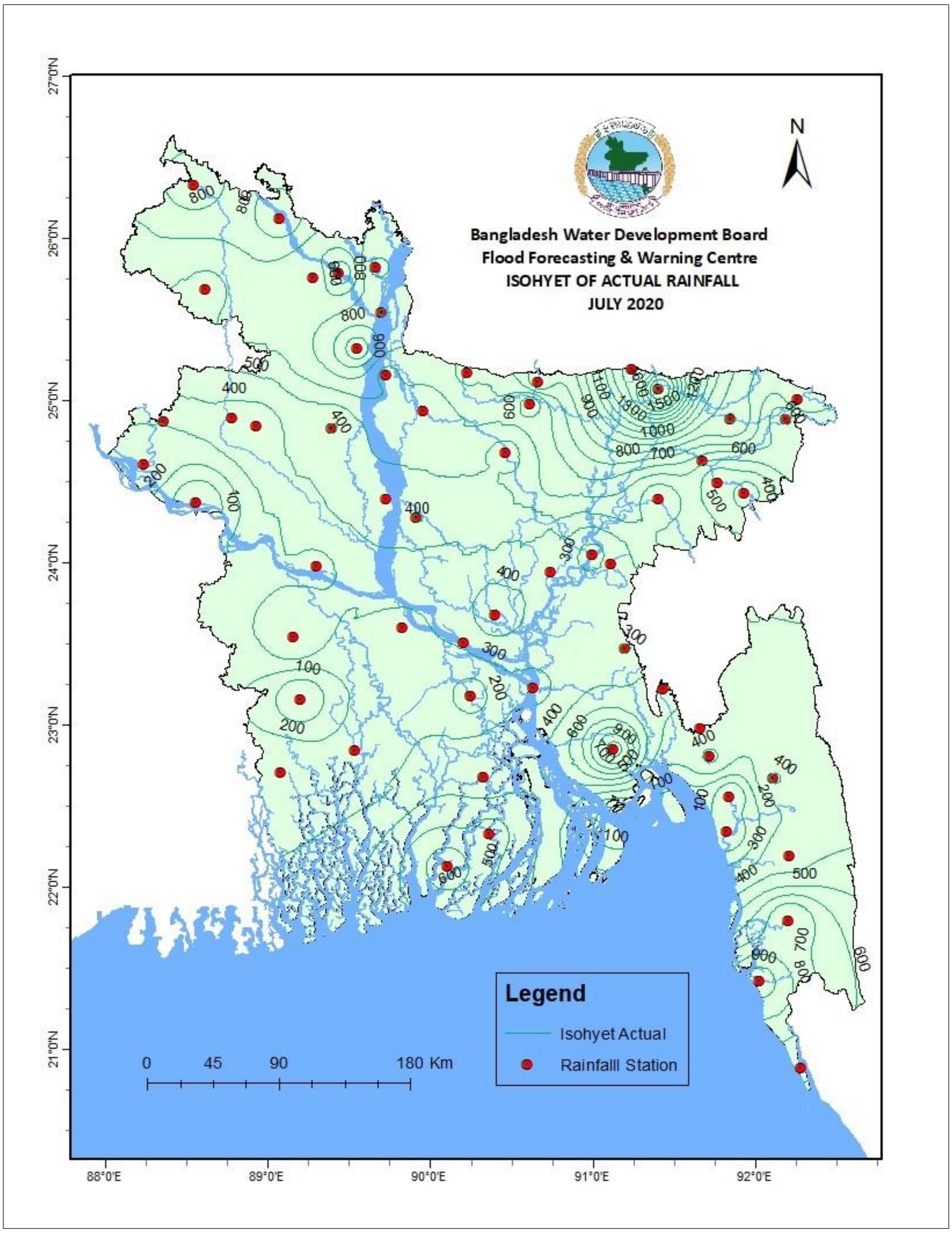


Figure 2.3: Isohyet of Actual Rainfall (July-2020)

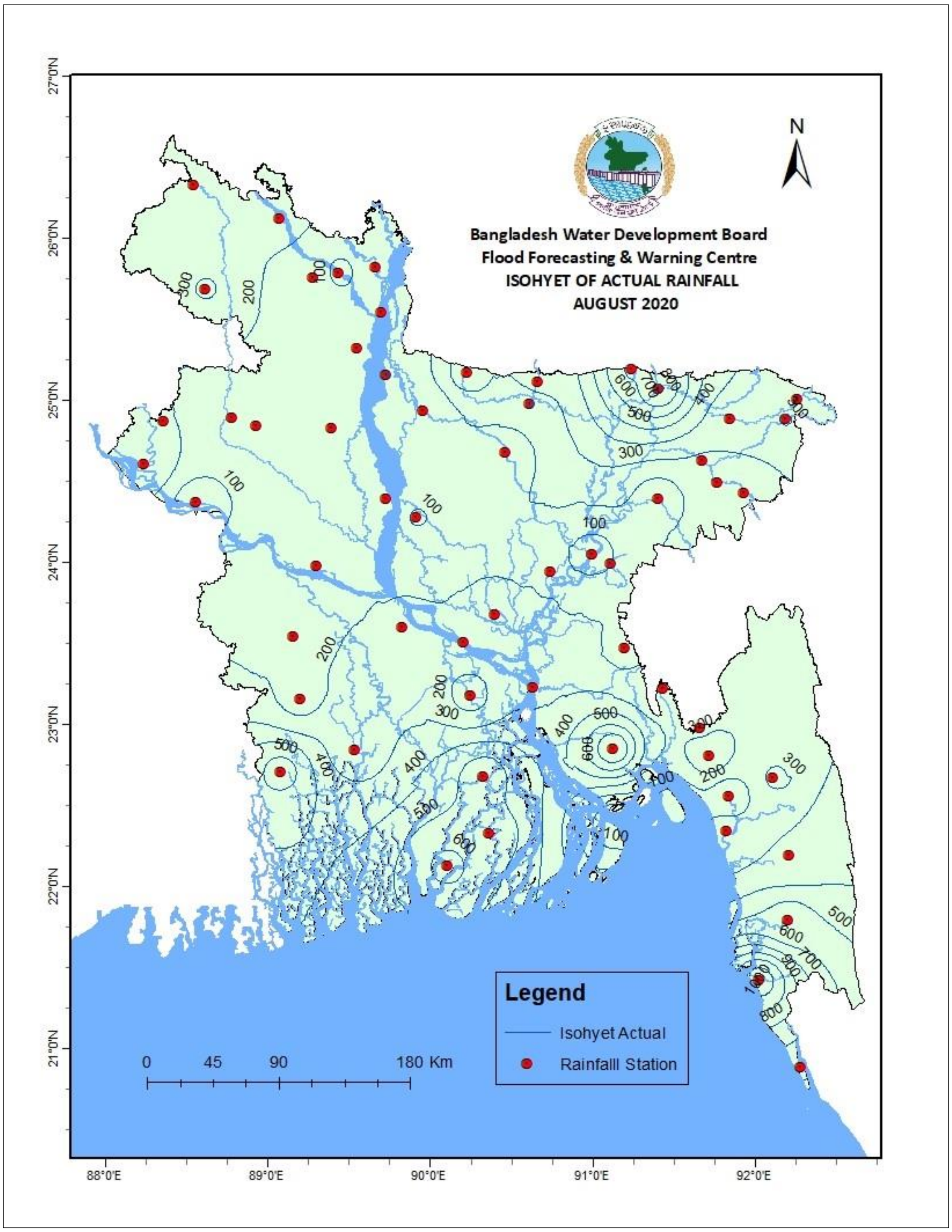


Figure 2.4: Isohyet of Actual Rainfall (August-2020)

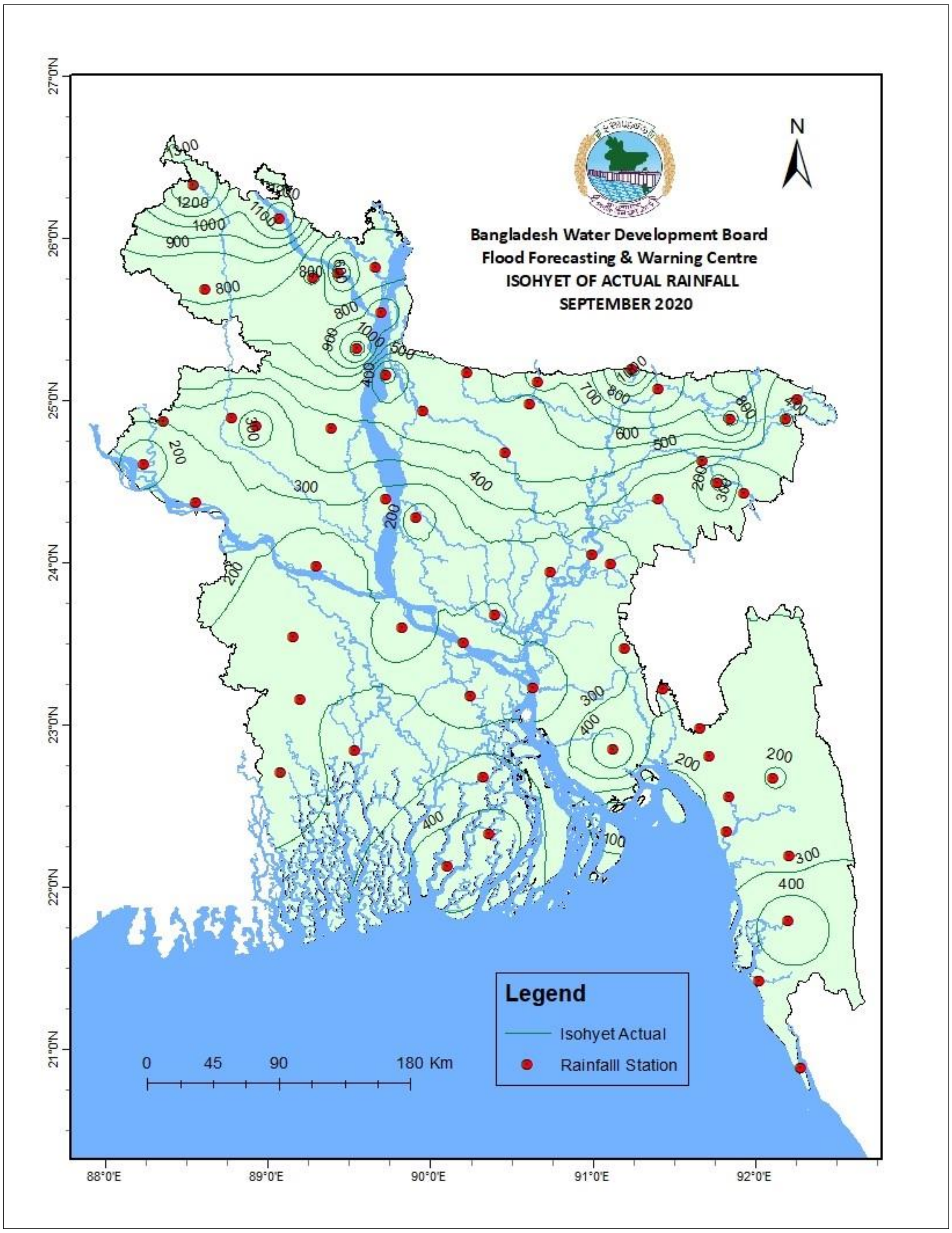


Figure 2.5: Isohyet of Actual Rainfall (September-2020)

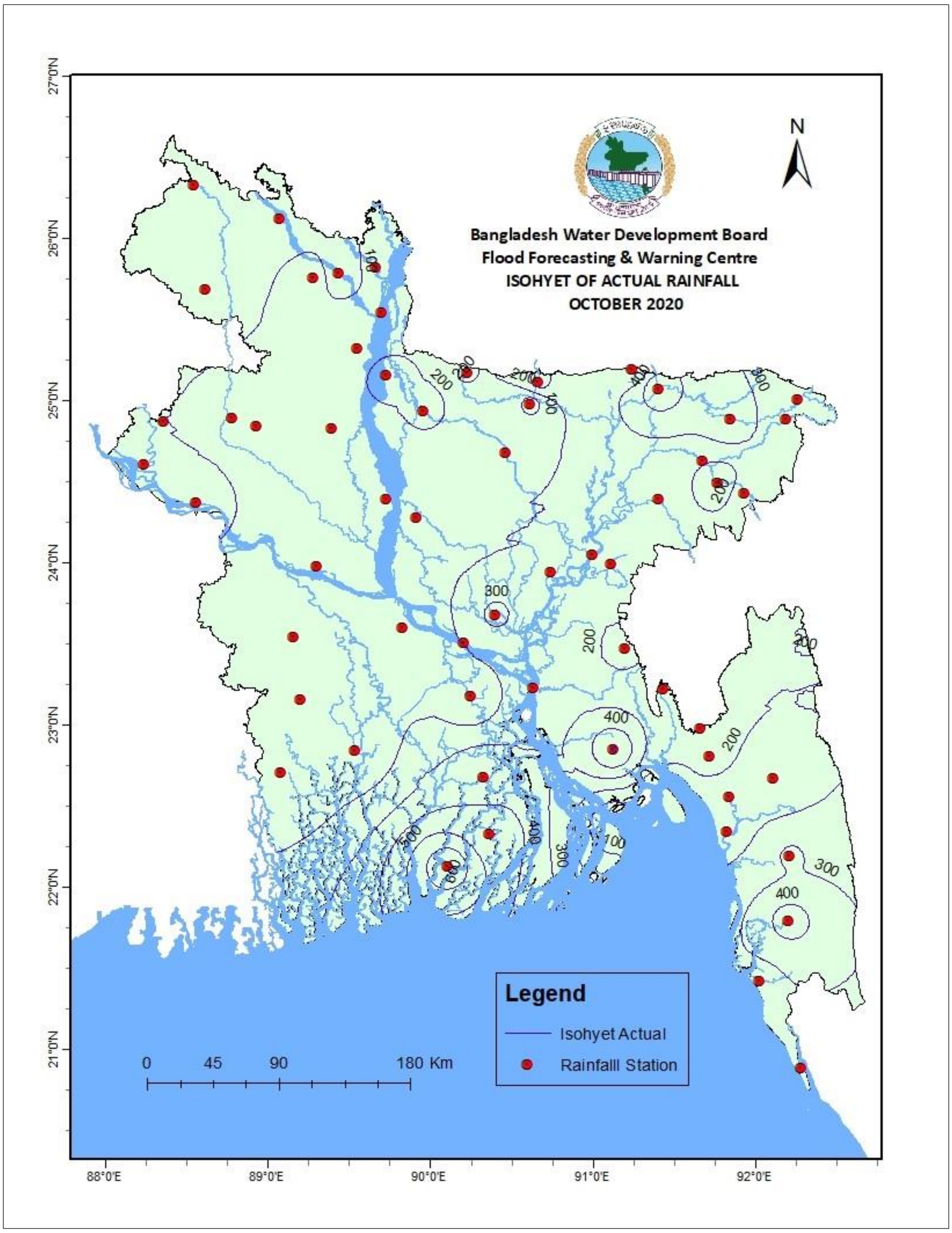


Figure 2.6: Isohyet of Actual Rainfall (October-2020)

CHAPTER 3 : RIVER SITUATION

During the monsoon 2020, the flood was a severe one which stayed for long duration across the Brahmaputra, Ganges and Meghna basins with comparatively greater duration in the lower parts of basins. The South Eastern Hill basin however faced short duration flooding. The Brahmaputra, Ganges and Meghna basins experienced flooding throughout second half of June to first half of August. Flooding persisted in the middle parts of the Ganges and Meghna basins in the late half of August and later created in the lower coastal parts of the Ganges basin. The three basins got flood affected altogether again during second half of September to first half of October for a relatively short period. The South Eastern Hill basin was only affected by short duration flooding during second half of June to first half of July. No flooding occurred in the Upper Meghna basin during pre-monsoon period. Basin wise water level situation is described in the following sections.

3.1 THE BRAHMAPUTRA BASIN

Out of 31 Water Level (WL) monitoring stations in the Brahmaputra basin, river WL crossed their respective Danger Levels (DLs) at 25 stations. Water level of Brahamaputra Basin started rising from the second half of May 2020, for the first time in the monsoon, and later caused a severe flood situation in July which lasted up to 63 days at low lying places. As a result, low-lying areas of Kurigram, Lalmonirhat, Nilphamari, Rangpur, Gaibandha, Bogra, Sirajganj, Natore, Pabna, Jamalpur, Tangail, Manikganj, Dhaka and Narayanganj districts were mostly flooded for short to long duration during this monsoon. The Teesta River at Dalia on 13th July 2020 and the Gur River at Singra on 1st October 2020 reached peaks and crossed the previously recorded highest water levels (RHWLs). A comparative statement of WL for current year 2020 and historical events of 2007 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 4 times during the monsoon-2020 and flowed above DL for a total of 47 days. WL at Kurigram attained peak of 27.53 m PWD on 14th July which was 103 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 7 times during the monsoon with highest peak on 13th July with a WL of 53.15 m PWD, which was 55 cm above its DL (52.60 m) and exceeded previous RHWL of 53.12 m. At Dalia, it flowed above DL for 14 days throughout the monsoon period. At Kaunia, WL of the river Teesta crossed its DL mark 3 times during the mosoon-2020, and attained the peak of 29.35 m PWD on 13th of July which was 15 cm above the DL (29.20 m) at that point.

The Jamuneswari at Badarganj

The WL of Jamuneswari river at Badarganj in monsoon-2020 attained the peak of 32.92 m PWD (DL 32.15 m) on 29th September, which was 77 cm above DL. The station flowed above DL for 5 days in the adjacent time but stayed below DL during the rest of monsoon.

The Ghagot at Gaibandha

The WL of Ghagot river at Gaibandha during the monsoon-2020 attained peak of 22.64 m PWD on 15th July which was 94 cm above DL (21.70 m). This station crossed its DL mark 3 times during the monsoon and flowed above for 38 days.

The Karatoa at Chakrahimpur and Bogra

At Chakrahimpur, the Karatoa reached peak water level of 21.31 m PWD on 2nd October and flowed 116 cm above the DL (20.15 m). In the whole monsoon, the station crossed its DL mark 5 times and flowed above for 25 days. At Bogra point, the Karatoa river did not cross its respective DL with a peak flow of 15.54 m PWD on 8th October, which was 78 cm below the respective DL (16.32 m PWD).

The Brahmaputra at Noonkhawa and Chilmari

The Brahmaputra at Noonkhawa and Chilmari crossed respective DLs 3 and 4 times separately during 2020 monsoon. At Noonkhawa, the WL of the Brahmaputra River attained the peak of 27.46 m PWD on 15th July, which was 96 cm above the DL (26.50 m PWD). During the whole monsoon, this station flowed above its DL mark for 28 days.

Brahmaputra at Chilmari flowed above its DL (23.70 m) for 36 days in 2020 monsoon. At Chilmari, the Brahmaputra reached peak water level 24.73 m PWD on 15th July and flowed 103 cm above the DL (23.70 m).

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

The WL of river Jamuna at Fulchari, Bahadurabad, Sariakandi, Serajganj, Kazipur & Aricha demonstrated similar trends like Brahmaputra at Noonkhawa and Chilmari and crossed the DL 3 or more times during the monsoon. At Fulchari, the Jamuna flowed above DL (19.82 m) during the monsoon of 2020 for 40 days with a peak of 21.06 m PWD on 16th July which was 124 cm above DL. On the same date of peak as Fulchari, WL of the Jamuna river reached the peak of 20.79 m PWD at Bahadurabad which was 129 cm above DL (19.50 m), and flowed above for 40 days during the 2020 monsoon. At Sariakandi, the Jamuna crossed respective DL (16.70 m) in this monsoon like Bahadurabad station. With a peak of 17.98 m PWD on 17th July which was 128 cm above the DL, it flowed above for 55 days in the season. At Kazipur, the WL of the Jamuna attained a peak of 16.47 m PWD on 17th July which was 123 cm above DL (15.24 m) and flowed above for 41 days during the 2020 monsoon. At Serajganj, the Jamuna flowed above DL (13.35 m) for 37 days during the monsoon with a peak of 14.36 m PWD on 17th July, which was 101 cm above DL.

At Aricha, the WL of the Jamuna river flowed above the DL (9.40 m) during 2020 monsoon for 31 days and the peak WL recorded was 10.20 mPWD on 27th July, which was 80 cm above DL.

The Gur at Singra

The WL of river Gur at Singra flowed above DL (12.65 m) during 2020 monsoon for 63 days with the peak of 13.76 m PWD on 1st October, which was 111 cm above the DL at that point and exceeded previous RHWL of 13.67 m. The river crossed its DL mark for 3 times at Singra during the season.

The Atrai at Baghabari

The WL of river Atrai at Baghabari flowed above DL (10.40 m) during 2020 monsoon for 55 days with the peak of 11.54 m PWD on 27th July, which was 114 cm above the DL.

The Dhaleswari at Elasin

The WL of river Dhaleswari at Elasin flowed above DL (11.40 m) in the during 2020 monsoon for 62 days with the peak of 12.62 mPWD on 27th July, which was 122 cm above the DL at that 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 above the DL (17.00 m) for 8 days with the recorded peak WL of 17.18 m PWD on 28th July. At Mymensingh, the WL remained below the DL (12.50 m) during the whole monsoon. The peak WL recorded was 12.43 m PWD on 30th July, which was 7 cm below the DL at that point.

The Lakhya at Narayanganj

Lakhya River at Narayanganj flowed above DL (5.50 m) for 25 days during monsoon 2020. It attained its monsoon peak of 5.87 m PWD on 6th August, which was 37 cm above DL.

The Rivers around Dhaka

Stations near or around Dhaka city attained the peak of the monsoon during first half of August this year. Except the Buriganga, all the rivers around Dhaka city flowed above their respective DLs. The Buriganga at Dhaka and Hariharpara recorded their peaks of 5.53 m PWD (DL 6.0 m) and 5.48 m (DL 5.79 m) respectively on 7th August. The Balu at Demra recorded the peak of 6.00 m PWD (DL 5.75 m) on 6th August which was 25 cm above DL. The Turag at Mirpur flowed with a peak of 6.50 m PWD on 7th August which was 56 cm above the DL (5.94 m PWD). The water level of Tongi Khal at Tongi flowed above DL (6.08 m) as well and the peak WL recorded at that station was 6.50 m on 8th August. All these rivers flowed above DL for 18-20 days around the time of the peak.

The Kaliganga at Taraghat

The WL of Kaliganga River at Taraghat showed a trend similar to that of the Buriganga at Dhaka but flowed above the DL for continuous 26 days. The river at that station flowed above the DL (8.40 m) with a peak of 9.58 m PWD on 28th July, which was 118 cm above DL.

Comparative hydrographs for the years of 2020, 2007 & 1998 at few stations of the Brahmaputra basin are shown in Figures 3.1 to 3.16.

Table 3.1 : Comparison of Water Level (in m PWD) of 2020 and Historical Events of 2007 & 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		
					2020	2007	1998	2020	2007	1998
1	Dharla	Kurigram	27.84	26.50	27.53	27.56	27.22	47	15	30
2	Teesta	*Dalia	53.12	52.60	53.15	52.95	52.20	14	2	-
3	Teesta	Kaunia	30.52	29.20	29.35	29.66	29.91	4	4	-
4	Jamuneswari	Badarganj	33.61	32.15	32.92	31.50	33.00	5	0	6
5	Ghagot	Gaibandha	22.81	21.70	22.64	22.56	22.30	38	16	51
6	Karatoa	Chakrahimpur	21.41	20.15	21.31	20.73	20.86	25	11	-
7	Karatoa	Bogra	17.45	16.32	15.54	15.7	15.57	0	0	-
8	Brahmaputra	Noonkhawa	28.10	26.50	27.46	27.91	27.35	28	24	29
9	Brahmaputra	Chilmari	25.07	23.70	24.73	24.81	24.77	36	23	22
10	Jamuna	Fulchari	21.35	19.82	21.06	-	-	40	-	-
11	Jamuna	Bahadurabad	21.16	19.50	20.79	20.40	20.37	40	21	66
12	Jamuna	Sariakandi	19.07	16.70	17.98	18.10	-	55	31	-
13	Jamuna	Kazipur	17.47	15.25	16.47	-	-	41	-	-
14	Jamuna	Serajganj	15.12	13.35	14.36	14.95	14.76	37	55	48
15	Jamuna	Aricha	10.76	9.40	10.20	10.67	10.76	31	38	68
16	Gur	*Singra	13.67	12.65	13.76	-	-	63	-	-
17	Atrai	Baghabari	12.45	10.40	11.54	11.58	-	55	38	-
18	Dhaleswari	Elasin	12.52	11.40	12.62	10.31	-	62	0	-
19	Old Br.putra	Jamalpur	18.00	17.00	17.18	17.24	17.47	8	6	31
20	Old Br.putra	Mymensingh	13.71	12.50	12.43	12.55	13.04	0	3	33
21	Lakhya	Lakhpur	8.70	5.80	5.79	-	-	0	-	-
22	Buriganga	Dhaka	7.58	6.00	5.53	6.02	7.24	0	2	57
23	Buriganga	Hariharpara	7.13	5.79	5.48	-		0	-	
24	Balu	Demra	7.13	5.75	6.00	6.27	-	18	22	-
25	Lakhya	Narayanganj	6.93	5.50	5.87	6.05	6.93	25	22	71
26	Turag	Mirpur	8.35	5.94	6.50	6.62	7.97	18	26	70
27	Tongi Khal	Tongi	7.84	6.08	6.50	6.87	7.54	20	29	66
28	Kaliganga	Taraghat	10.39	8.38	9.58	9.79	-	26	34	-
29	Dhaleswari	Jagir	9.73	8.23	9.29	9.43	-	24	26	-
30	Dhaleswari	Rekabi Bazar	7.66	5.18	5.20	6.13	-	1	47	-
31	Banshi	Nayarhat	8.39	7.32	7.58	6.84	-	11	0	-

*stations exceeding RHWL in 2020

3.2 THE GANGES BASIN

In the Ganges basin, out of 30 WL monitoring stations, 16 stations flowed above their respective DLs during monsoon 2020. The Padma at Goalundo, Bhagyakul & Mawa stations flowed above DL for 40 to 60 days. As a result, low-lying areas of Rajbari, Faridpur, Manikganj, Dhaka, Munshiganj, Madaripur and Shariatpur districts were mostly flooded this year in July which lasted for long duration. The Ganges river flowed below DL throughout the monsoon 2020. Due to tidal influences and upstream water rush, the

Pashure at Khulna and Mongla flowed above DL for 48 and 166 days respectively during the season, while the Kirtonkhola at Barisal flowed above DL for 21 days during second half of August. The upper parts of the basin also experienced short to long duration flooding where notably the Atrai river at Atrai crossed the previously RHWL on 16th July 2020. The Pashure river at Mongla flowed above DL for some extended periods mostly due to tidal fluctuations. A comparative statement of WL for current year 2020 and historical events of 2007 and 1998 for the Ganges Basin is shown in the Table 3.2. The details of the river WL situation in this basin are described below.

The Karatoa at Panchagarh

The Karatoa river at Panchgarh showed rise and fall during the monsoon 2020 and flowed below the DL (70.75 m) with a peak level of 70.25 m PWD on 13th July, which was 50 cm below the respective DL.

The Punarbhaba at Dinajpur

The water level of river Punarbhaba at Dinajpur showed rise and fall during the monsoon 2020 and flowed above the DL for only 1 day. The peak WL recorded was 33.60 m PWD on 28th September, which was 10 cm above its DL (33.50 m).

The Tangon at Thakurgaon

The Tangon river is flashy in nature and showed various small peaks during the monsoon. It flowed above danger level for only 1 day with its highest peak of 50.56 m PWD on 27th September, which was 16 cm above the DL (50.40 m).

The Upper Atrai at Bhusirbandar and Atrai at Mohadebpur and Atrai

The WL of river Upper Atrai at Bhusirbandar also showed similar trend of Punarbhaba and flowed above the DL for 4 days. It had a peak value of WL 39.98 m PWD on 14th July flowing 36 cm above DL (39.62 m). The Atrai at Mohadebpur also flowed above the DL for 3 days with peak of 18.94 m PWD on 30th September, which was 35 cm above the DL (18.59 m). The Atrai at Atrai flowed above the DL for a longer duration of 28 days with peak of 14.40 m PWD on 16th July, which was 68 cm above the DL (13.72 m) and exceeded previous RHWL of 14.31 m.

The Mohananda at Chapai-Nawabganj

The Mohananda river showed a gradual rise and fall in water level throughout the monsoon. It attained its peak of 20.15 m on 27th July, which was 85 cm below its DL (21.00 m) at Chapai-Nawabganj. The Mohananda at Chapai-Nawabganj flowed below the DL during the whole monsoon 2020.

The Little Jamuna at Naogaon

The Little Jamuna river at Naogaon flowed above its danger level for 7 days during 2020 monsoon and crossed the DL mark 2 times. It attained its peak 15.43 mPWD on 1st October which was 19 cm above the DL (15.24 m).

The Ganges at Pankha, Rajshahi, Hardinge Bridge and Talbaria

The Ganges River at Pankha showed a gradual rise in June as well as in the end of September but did not cross the respective DL. At Pankha the peak water level recorded was 20.87 m PWD on 23rd August, which was 163 cm below the DL (22.50m). At Rajshahi, the Ganges followed nearly similar trend as Pankha and also flowed below its respective DL. The Ganges attained its peak of 16.94 m PWD on 29th July, which was 156 cm below its DL (18.50 m) at Rajshahi. Similarly at Hardinge Bridge, water level flowed below the respective DL and attained its peak of 13.50 m PWD on 28th July which was 75 cm below its DL (14.25 m). Also at Talbaria, the peak water level recorded was 13.07 m PWD on 27th July, which was 43 cm below the DL (13.50 m).

The Padma at Goalundo

At Goalundo, the WL of Padma crossed the DL 4 times during 2020 monsoon and flowed above the DL for 60 days in total. The WL of the river Padma at Goalundo attained its yearly peak of 9.84 m PWD on the 27th July, which was 119 cm above its DL (8.65 m) at that point.

The Padma at Bhagyakul, Mawa and Sureswar

At Bhagyakul, Mawa and Sureswar, the WL of river Padma crossed the DL 3 times and flowed above DL for around 40 days. The river Padma has tidal influence at these points. The WL of the river attained its highest yearly peak water level of 7.14 m PWD on 27th July at Bhagyakul, which was 84 cm above the DL (6.30 m). At Mawa, The WL of the river attained its yearly peak water level of 6.85 m PWD on 26th July, which was 75 cm above the DL (6.10 m). At Sureswar, The WL of the river attained its yearly peak water level of 4.99 m PWD on 5th August, which was 54 cm above the DL (4.45 m).

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 2020 but did not cross the DL. The WL of the river attained its highest yearly peak of 12.13 m PWD on 28th July, which was 62 cm below the DL (12.75m) at Gorai Railway Bridge. Gorai river at Kamarkhali attained its highest yearly peak of 8.11 m PWD on 29th July, which was 9 cm below the DL (8.20m).

The Arialkhan at Madaripur

At Madaripur, the WL of the river Arialkhan showed similar trend of rise and fall as with the river Padma. The WL of Arialkhan at Madaripur flowed above the DL for 18 days in the monsoon. The WL attained its highest peak of 4.37 m on 29th July, which was 20 cm above the DL (4.17 m).

Kobodak at Jhikargacha

Water Level at Jhikargaha flowed below the DL during the whole monsoon with a yearly peak of 4.41 m PWD on 24th August, which was 69 cm below the DL (5.10 m) at that point.

Comparative hydrographs for few important stations of the basin for the years of 2020, 2007 & 1998 are shown in Figures 3.17 to 3.25.

Table 3.2 : Comparison of Water Level (in m PWD) of 2020 and Historical Events of 2007 & 1998 of Some Important Stations in the Ganges Basin

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger Level		
					2020	2007	1998	2020	2007	1998
1	Karatoa	Panchagarh	72.65	70.75	70.25	70.27	-	0	0	-
2	Punarbhaba	Dinajpur	34.40	33.50	33.60	32.56	34.09	1	0	3
3	Ich-Jamuna	Phulbari	30.47	29.95	29.36	28.87	-	0	0	-
4	Tangon	Thakurgaon	51.30	50.40	50.56	49.93	-	1	0	-
5	Upper Atrai	Bhusirbandar	41.10	39.62	39.98	39.45	-	4	0	-
6	Mohananda	Rohanpur	23.83	22.00	21.45	21.89	-	0	0	-
7	Mohananda	Chapai-Nawabganj	23.01	21.00	20.15	20.42	-	0	0	-
8	Little Jamuna	Naogaon	16.20	15.24	15.43	15.38	-	7	8	-
9	Atrai	Mohadebpur	19.89	18.59	18.94	17.70	-	3	0	-
10	Atrai	*Atrai	14.31	13.72	14.40	-		28	-	
11	Ganges	Pankha	24.14	22.50	20.87	21.71	24.14	0	0	66
12	Ganges	Rajshahi	20.00	18.50	16.94	17.80	19.68	0	0	28
13	Ganges	Hardinge Bridge	15.19	14.25	13.50	14.00	15.19	0	0	27
14	Ganges	Talbaria	14.53	13.50	13.07	-		0	-	
15	Padma	Goalundo	10.21	8.65	9.84	10.01	10.21	60	46	68
16	Padma	Bhagyakul	7.50	6.30	7.14	7.15	7.50	41	33	72
17	Padma	Mawa	7.14	6.10	6.85	-		40	-	
18	Padma	Sureswar	7.50	4.99	4.89	5.25	-	43	31	73
19	Gorai	Gorai Rail Bridge	13.65	12.75	12.13	12.45	13.45	0	0	25
20	Gorai	Kamarkhali	9.48	8.20	8.11	8.38	NA	0	5	NA
21	Ichamati	Sakra	4.60	3.96	4.42	4.98	-	1	83	-
22	Mathabhanga	Chuadanga	12.67	12.05	9.48	10.31	-	0	0	-
23	Mathabhanga	Hatboalia	15.13	14.50	10.96	12.19	-	0	0	-
24	Kobadak	Jhikargacha	5.59	5.10	4.41	4.70	NA	0	0	NA
25	Betna	Kalaroa	4.89	3.81	4.75	-		101	-	
26	Kumar	Faridpur	8.76	7.50	5.55	7.25	-	0	0	-
27	Arialkhan	Madaripur	5.80	4.17	4.37	4.77	NA	18	35	NA
28	Kirtonkhola	Barisal	3.20	2.55	3.07	-	-	21	-	-
29	Pashure	Khulna	3.48	3.04	3.43	-	-	48	-	-
30	Pashure	Mongla	3.28	2.07	3.16	-		166	-	

*stations exceeding RHWL in 2020

3.3 THE MEGHNA BASIN

Most of the rivers of the Meghna basin have entered Bangladesh from the hilly catchments of India (Assam, Tripura and Meghalaya) and are flashy in nature. During the pre-monsoon (15 March - 15 May) of 2020, out of 36 WL monitoring stations in the basin, all stations flowed below their respective pre-monsoon danger levels (PMDLs). Table 3.3 presents comparative statistics of WL during 2020 pre-monsoon for some selected stations on major rivers of Meghna basin with historical pre-monsoon flash flood years 2010 and 2017. All WL stations of the basin flowed below their respective respective monsoon DL during the period.

Table 3.3 : Comparison of Water Level (in m PWD) of 2020 and Historical Events of 2017 & 2010 of Some Important Stations in the Meghna Basin during the Pre-Monsoon (15 Mar-15 May)

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	2020	2010	2017	2020	2020
1	Surma	Kanaighat	13.20	11.35	14.35	14.49	5.31	13	06	0	0
2	Surma	Sylhet	11.25	8.75	10.88	11.31	3.56	0	03	0	0
3	Surma	Sunamganj	8.25	6.50	8.05	8.10	3.04	0	0	0	0
4	Kushiyara	Amalshid	15.85	13.50	15.51	16.03	8.00	0	03	0	0
5	Kushiyara	Sheola	13.50	11.15	13.94	13.89	5.86	03	06	0	0
6	Kushiyara	Sherpur	9.00	8.25	8.80	9.03	3.22	0	01	0	0
7	Kushiyara	Markuli	8.50	6.40	7.70	8.27	3.53	0	0	0	0
8	Sarigowain	Sarighat	12.80	11.15	13.38	13.35	-	03	03	0	0
9	Manu	Manu Rly Br	18.00	16.90	16.75	17.40	14.26	0	0	0	0
10	Manu	Moulvi Bazar	11.75	10.00	10.49	11.73	9.00	0	0	0	0
11	Khowai	Habiganj	9.50	9.10	7.95	10.60	5.53	0	05	0	0
12	Khowai	Ballah	21.80	21.80	-	22.96	20.64	0	08	0	0
13	Someswari	Durgapur	13.00	11.25	11.78	12.02	9.64	0	0	0	0
14	Kangsha	Jariajanjail	11.00	6.80	6.53	9.71	6.13	0	0	0	0
15	Upper Meghna	Bhairab Bazar	6.25	6.25	3.48	3.57	2.14	0	0	0	0
16	Gumti	Comilla	11.75	11.75	7.37	9.35	-	0	0	0	0

In the monsoon 2020, out of 29 WL monitoring stations in the Meghna basin, 17 stations flowed above their respective DL. The Surma, Kushiyara, Sarigowain, Khowai, Jadukata, Someswari, Bhugai, Old Surma and Titas rivers of the Upper Meghna basin crossed and stayed above their respective DLs in multiple spells generally. The total duration of flooding of the rivers varied from 1 to 26 days, which occurred during June-July and late half of September. Due to tidal influences and upstream water rush, the Meghna river at Chandpur and the Lower Meghna river at Daulatkhan flowed above DL for around 40 days during the season. As a result, floods of short to long duration were experienced at low lying places of Sylhet, Sunamganj, Moulvibazar, Habiganj, Netrokona, Brahmanbaria, Narayanganj, Narsingdi, Chandpur and Bhola districts during the monsoon 2020. The Lower Meghna river flowed above DL for some extended periods mostly due to tidal fluctuations.

A comparative statement of WL for current year 2020 and historical events of 2007 and 1998 for the Meghna Basin is shown in the Table 3.4. The details of the river WL situation in this basin are described below.

The Surma at Kanaighat, Sylhet and Sunamganj

Water level in the Surma river started rising from the last half of May and it showed rapid rise and fall several times. FFWC monitors 3 stations on the Surma River.

At Kanaighat, the Surma river crossed the DL mark 7 times during the monsoon 2020. The Surma at Kanaighat was above DL for 26 days in total during the whole monsoon. It attained its highest peak of 14.04 m PWD on 21st July, which was 84 cm above the DL (13.20 m).

The WL of river Surma at Sylhet showed similar trend like Kanaighat. The Surma at Sylhet flowed above its DL (11.25 m) only for 5 days and attained the monsoon peak WL of 11.36 m PWD on 12th July.

The Surma at Sumanganj showed rapid rise and fall in different periods of the monsoon and crossed the DL mark 5 times. The WL of the river Surma at Sunamganj flowed above its DL (8.25 m) for 20 days during the monsoon. The WL of Surma at Sunamganj recorded its highest yearly peak of 8.96 m PWD on 28th June, which was 71 cm above its DL.

The Kushiyara at Amalshid, Sheola and Sherpur

The Kushiyara river at Amalshid, Sheola and Sherpur (Sylhet district) exhibited similar rising and falling trend throughout the monsoon 2020. At Amalshid, water level of Kushiyara crossed the DL only once. The Kushiyara at Amalshid flowed above the DL for 6 days in total during the whole monsoon. At Amalshid, Kushiyara attained the peak level of 16.65 m PWD on 14th July, which was 80 cm above the DL (15.85 m PWD).

At Sheola, the river crossed the DL one time only also. It flowed above DL for 3 days during the whole monsoon and attained its highest peak of 13.66 m PWD on 17th July which was 16 cm above the respective DL (13.50 m).

At Sherpur, the river flowed in a similar trend like Sheola but stayed below DL. It attained its highest peak of 8.89 mPWD on 13th July, which was 11 cm below its DL (9.00 m)

The Sarigowain at Sarighat

As a flashy river the Sarighat on Saigowain River in Sylhet district showed several peaks during the monsoon 2020 and crossed the respective DL 9 times. It attained monsoon highest peak of 13.26 m PWD on 21st July, which was 46 cm above its DL (12.80 m) and flowed above for a total of 12 days during the monsoon.

The Manu at Manu Railway Bridge and Moulvibazar

As a flashy river, the WL of the river Manu at Manu Railway Bridge and at Moulvibazar exhibited several sharp peaks during the monsoon-2020. The WL of Manu river at Manu Railway Bridge and at Moulvibazar flowed beow the DL during monsoon 2020. The WL at Manu Railway Bridge had a peak level of 17.61 m PWD on 24th October, which was 39 cm below the DL (18.0 m). At Moulvibazar, the WL of Manu attained its highest peak of 11.21 m PWD on 24th October also, which was 54 cm below DL (11.75 m) at that point.

The Khowai at Habiganj and Ballah

The Khowai at Habiganj as well as at Ballah showed several peaks during the monsoon 2020. The Khowai at Ballah crossed DL 2 times during the season for very short period and flowed above DL for 2 days. The highest peak of the season was 22.04 m PWD attained on 24th October, which was 24 cm above the DL (21.80 m). The Khowai at Habiganj however flowed below DL throughout the monsoon. The WL recorded as its yearly highest peak was 8.91 m PWD on 24th October, which was 59 cm below its DL (9.50 m).

The Dhalai at Kamalganj

The Dhalai at Kamalganj flowed below DL during the 2020 monsoon. The highest peak was 19.45 m PWD on 4th June, which was 37 cm below the DL (19.82 m).

The Jadukata at Lorergarh

Like other flashy rivers in the North-Eastern region, the Jadukata showed several peaks during the monsoon 2020, crossing its DL 10 times during the monson. The river attained monsoon highest peak of 10.50 m PWD on 27th June, which was 197 cm above its DL (8.53 m) and flowed above for a total of 15 days during the monsoon.

The Someswari at Durgapur and Kalmakanda

As a flashy river, the Someswari at Durgapur in Netrokona district showed rise and fall during the monsoon 2020 and flowed above its DL (13.0 m) for only 2 days. It attained monsoon highest peak of 13.34 m PWD on 12th July, which was 34 cm above its DL. The Someswari at Kalmakanda in Netrokona on the other hand crossed DL 4 times during the monsoon. It attained monsoon highest peak of 7.38 m PWD on 12th July also, which was 38 cm above its DL (7.00 m) and flowed above for a total of 14 days during the monsoon.

The Bhugai at Nakuagaon

As a flashy river, the Bhugai at Nakuagaon in Sherpur district recorded sharp rise & fall with several peaks duing the monsoon. It flowed above its DL during monsoon 2020 for 4 days. It attained the monsoon highest peak of 22.85 m PWD on 17th September, which was 45 cm above DL (22.40 m) at that point.

The Kangsha at Jariajanjail

As a flashy river, the Kangsha at Jariajanjail in Netrokona district also showed rise and fall during the monsoon-2020 but flowed below the DL (11.0 m). It attained its yearly highest peak of 10.61 m PWD on 25th September, which was 39 cm below DL.

The Titas at Brahmanbaria

The Titas River at B. Baria point flowed below its DL (5.50 m) for continuous 16 days during the monsoon 2020. It attained monsoon peak of 5.85 mPWD on 26th July, which was 35 cm above DL.

The Meghna at Bhairab Bazar, Narsingdi, Meghna Bridge, Baidyar Bazar and Chandpur

The Meghna at Bhairab Bazar point flowed below its DL (6.25 m) during the monsoon 2020. It attained monsoon peak of 5.73 m PWD on 25th July, which was 52 cm below DL. The Meghna at Narsingdi followed similar trend as Bhairab Bazar and flowed below DL in 2020 as well. It attained monsoon peak of 5.15 m PWD on 25th July also, which was 55 cm below its DL (5.70 m).

The Meghna at Baidyar Bazar and Meghna Bridge has significant tidal influence. The Meghna at these points flowed below DL during the monsoon 2020. It attained monsoon peak of 5.13 m PWD on 25th July at Baidyar Bazar, which was 5 cm below DL (5.18 m). At Meghna Bridge it attained monsoon peak of 4.48 m PWD on 25th July also, which was 55 cm below DL (5.03 m) at that point.

Being further downstream, the Meghna at Chandpur has more prominent tidal influence than at Meghna Bridge. The Meghna at that point flowed above its DL (4.00 m) for 42 days during the monsoon 2020. It attained monsoon peak of 4.66 m PWD on 5th August, which was 66 cm above DL at that point.

Comparative hydrographs for the years of 2020, 2007 & 1998 at few stations of the Meghna basin are shown in Figures 3.26 to 3.39.

Table 3.4 : Comparison of Water Level (in m PWD) of 2020 and Historical Events of 2007& 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		
					2020	2007	1998	2020	2007	1998
1	Surma	Kanaighat	15.26	13.20	14.04	15.22	15.00	26	64	73
2	Surma	Sylhet	12.44	11.25	11.36	11.83	11.72	5	29	14
3	Surma	Sunamganj	9.75	8.25	8.96	9.10	8.90	20	38	56
4	Kushiyara	Amalshid	18.28	15.85	16.65	17.95	17.60	6	48	54
5	Kushiyara	Sheola	14.60	13.50	13.66	14.60	14.14	3	50	37
6	Kushiyara	Sherpur	9.68	9.00	8.89	9.31	NA	0	23	NA
7	Kushiyara	Markuli	8.51	8.50	7.58	8.14	-	0	0	-
8	Sarigowain	Sarighat	14.48	12.80	13.26	13.57	-	12	14	-
9	Manu	Manu RB	20.42	18.00	17.61	19.58	18.63	0	8	6
10	Manu	Moulvi Bazar	13.25	11.75	11.21	12.68	11.68	0	11	0
11	Khowai	Ballah	26.12	21.80	22.04	24.13	-	2	16	-
12	Khowai	Habiganj	12.30	9.50	8.91	12.00	11.44	0	10	8
13	Dhalai	Kamalganj	21.18	19.82	19.45	20.71	-	0	7	-
14	Old Surma	Derai	7.75	7.00	7.41	-	-	26	-	-
15	Baulai	Khaliajuri	9.52	8.50	7.28	7.93	-	0	0	-
16	Jadukata	Lorergarh	11.85	8.53	10.50	11.39	-	15	18	-
17	Someswari	Durgapur	15.20	13.00	13.34	15.58	-	2	27	-

Sl.No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2020	2007	1998	2020	2007	1998
18	Someswari	Kalmakanda	13.27	7.00	7.38	-	-	14	-	-
19	Bhugai	Nakuagaon	26.01	22.40	22.85	25.40	-	4	25	-
20	Kangsha	Jariajanjail	13.37	11.00	10.61	11.63	NA	0	11	NA
21	Titas	B. Baria	6.50	5.50	5.85	-	-	16	-	-
22	Upper Meghna	Bhairab Bazar	7.78	6.25	5.73	6.94	7.33	0	38	68
23	Meghna	Narsingdi	7.01	5.70	5.15	6.19	-	0	21	-
24	Meghna	Baidyar Bazar	6.98	5.18	5.13	-		0	-	
25	Meghna	Meghna Bridge	6.76	5.03	4.48	-	-	0	-	-
26	Gumti	Comilla	13.56	11.75	9.98	13.12	12.79	0	14	17
27	Gumti	Debiddar	9.98	8.50	6.29	9.98	-	0	15	-
28	Meghna	Chandpur	5.35	4.00	4.66	4.95	-	42	43	44
29	Lower Meghna	Daulatkhan	5.11	3.41	4.50	-		41	-	

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, Halda, Sangu, Matamuhuri and Feni in the South-Eastern Part of the country. Most of these rivers show similar behavior during monsoon flood. The WL at some of the monitoring stations crossed their respective DLs in the monsoon-2020 but the duration was small. Some parts of the low-lying places of Feni, Bandarban and Cox’s Bazar faced short duration flood during this time. A comparative statement of water level and days flowed above the DLs for the monsoon-2020 and historical events of 2007 and 1998 for this basin are shown in the Table 3.5. The details of WL of different rivers of the basin are described in following sections.

The Muhuri at Parshuram

The Muhuri river flowing through Feni and Noakhali districts is a flashy one which flowed above the DL on 12-13 July and 31 October-1 November for 4 days in total during the whole monsoon. It attained its highest peak 14.32 m PWD on 12th July which was 132 cm above its DL (13.00 m).

The Halda at Narayanhat and Panchpukuria

As a flashy river, the WL of the river Halda at Narayanhat in Hathazari upzilla of Chittagong also showed several peaks during this monsoon but flowed below DL. It attained its peak of 14.47 m PWD on 12th July which was 78 cm above the DL (15.25 m). The Halda at Panchpukuria also flowed below DL during the whole monsoon. It attained its highest peak of 7.65 m PWD on 24th October which was 185 cm below 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 but flowed below DL during the monsoon 2020. The yearly peak recorded at Bandarban was 12.40 m PWD on 18th June which was 285 cm below its DL (15.25 m). The peak recorded at Dohazari was as 5.25 m PWD on 18th June also, which was 175 cm below danger mark (7.00 m) at that point.

The Matamuhuri at Lama and Chiringa

The Matamuhuri river showed several peaks in the monsoon-2020 like the Sangu River. At Lama, the Matamuhuri River crossed the DL only once and stayed above for 1 day. The peak recorded it Lama was 12.44 m PWD on 17th June which was 19 cm above its DL (12.25m). The Matamuhuri at Chiringa crossed the DL also for once during the monsoon and stayed above for 2 days. The peak recorded at Chiringa was 7.18 m PWD on 17th June which was 93 cm above its DL (6.25 m).

The Feni at Ramgarh

The WL of river Feni at Ramgarh showed several peaks as well but flowed below its DL during the monsoon-2020. The highest peak WL attained by the river was 15.08 m PWD on 21st July which was 227 cm below its DL (17.35 m) at that point.

Comparative hydrographs for the years of 2020, 2007 & 1998 at few stations of the South Eastern Hill basin are shown in Figures 3.40 to 3.47.

Table 3.5 : Comparison of Water Level of 2020 (in m PWD) and Historical Events of 2007 and 1998 of Some Important Stations in South Eastern Hill Basin

Sl. No	River	Station	Previously Recorded Maximum	Danger Level	Peak of the year			Days above Danger level		
					2020	2007	98	2020	2007	98
1	Muhuri	Parshuram	16.33	13.00	14.32	15.00	14.60	4	14	9
2	Halda	Narayanhat	19.30	15.25	14.47	17.00	16.57	0	13	21
3	Halda	Panchpukuria	12.54	9.50	7.65	6.38	10.44	0	0	4
4	Sangu	Bandarban	20.70	15.25	12.40	16.50	15.25	0	1	1
5	Sangu	Dohazari	9.05	7.00	5.25	7.10	7.42	0	1	2
6	Matamuhuri	Lama	15.46	12.25	12.44	14.45	13.05	1	1	2
7	Matamuhuri	Chiringa	7.32	6.25	7.18	6.41	6.85	2	2	5
8	Feni	Ramgarh	21.42	17.35	15.08	18.43	17.50	0	3	1
9	Karnaphuli	Chittagong	4.98	4.60	4.45	-	-	0	-	-

3.5 PEAK AND RECORDED HIGHEST WATER LEVELS

The peak water level with dates during the monsoon 2020 for all the water level monitoring stations under FFWC is presented in Table 3.6. The recorded highest level information along with dates of attainment for some monitoring stations of FFWC, as well as their new recorded highest levels if exceeded in 2020 with dates are provided in Table 3.7. Two stations in the Brahmaputra basin namely- Dalia on the Teesta river along with Singra on the Gur river, and one station in the Ganges basin namely Atrai on the Atrai river exceeded their previously RHWL in 2020.

Table 3.6 : Peak Water Level (in m PWD) with Dates during the Monsoon-2020

SL No	River name	Station	Peak WL-2020	Date
	BRAHMAPUTRA BASIN			
1	DHARLA	KURIGRAM	27.53	14/07/20
2	TEESTA	DALIA	53.12	13/07/20
3	TEESTA	KAUNIA	29.35	13/07/20
4	JAMUNESWARI	BADARGANJ	32.92	29/09/20
5	GHAGOT	GAIBANDHA	22.64	15/07/20
6	KARATOA	CHAK RAHIMPUR	21.31	02/10/20
7	KARATOA	BOGRA	15.54	08/10/20
8	BRAHMAPUTRA	NOONKHAWA	27.46	15/07/20
9	BRAHMAPUTRA	CHILMARI	24.73	15/07/20
10	JAMUNA	FULCHARI	21.06	16/07/20
11	JAMUNA	BAHADURABAD	20.79	16/07/20
12	JAMUNA	SARIAKANDI	17.98	17/07/20
13	JAMUNA	KAZIPUR	16.47	17/07/20
14	JAMUNA	SERAJGANJ	14.36	17/07/20
15	JAMUNA	ARICHA	10.20	27/07/20
16	GUR	SINGRA	13.76	01/10/20
17	ATRAI	BAGHABARI	11.54	27/07/20
18	DHALESWARI	ELASIN	12.62	27/07/20
19	OLD BRAHMAPUTRA	JAMALPUR	17.18	28/07/20
20	OLD BRAHMAPUTRA	MYMENSINGH	12.43	30/07/20
21	LAKHYA	LAKHPUR	5.79	01/08/20
22	BURIGANGA	DHAKA	5.53	07/08/20
23	BURIGANGA	HARIHARPARA	5.48	07/08/20
24	BALU	DEMRA	6.00	06/08/20
25	LAKHYA	NARAYANGANJ	5.87	06/08/20
26	TURAG	MIRPUR	6.50	07/08/20
27	TONGI KHAL	TONGI	6.50	08/08/20
28	KALIGANGA	TARAGHAT	9.58	28/07/20
29	DHALESWARI	JAGIR	9.29	29/07/20
30	DHALESWARI	REKABI BAZAR	5.20	06/08/20
31	BANSHI	NAYARHAT	7.58	02/08/20
GANGES BASIN				
32	KARATOA	PANCHAGARH	70.25	13/07/20
33	PUNARBHABA	DINAJPUR	33.60	28/09/20
34	ICH-JAMUNA	PHULBARI	29.36	28/09/20
35	TANGON	THAKURGAON	50.56	27/09/20
36	UPPER ATRAI	BHUSIRBANDAR	39.98	14/07/20
37	MOHANANDA	ROHANPUR	21.45	05/10/20
38	MOHANANDA	CHAPAI-NAWABGANJ	20.15	27/07/20
39	LITTLE JAMUNA	NAOGAON	15.43	01/10/20
40	ATRAI	MOHADEBPUR	18.94	30/09/20
41	ATRAI	ATRAI	14.40	16/07/20
42	GANGES	PANKHA	20.87	23/08/20
43	GANGES	RAJSHAHI	16.94	29/07/20
44	GANGES	HARDINGE BRIDGE	13.50	28/07/20
45	GANGES	TALBARIA	13.07	27/07/20
46	PADMA	GOALONDO	9.84	27/07/20
47	PADMA	BHAGYAKUL	7.14	27/07/20
48	PADMA	MAWA	6.85	26/07/20
49	PADMA	SURESWAR	4.99	05/08/20
50	GORAI	GORAI RAIL BRIDGE	12.13	28/07/20

SL No	River name	Station	Peak WL-2020	Date
51	GORAI	KAMARKHALI	8.11	29/07/20
52	ICHAMATI	SAKRA	4.42	10/07/20
53	MATHABHANGA	CHUADANGA	9.48	30/07/20
54	MATHABHANGA	HATBOALIA	10.96	22/07/20
55	KOBADAK	JHIKARGACHA	4.41	24/08/20
56	BETNA	KALAROA	4.75	27/08/20
57	KUMAR	FARIDPUR	5.55	29/07/20
58	ARIALKHAN	MADARIPUR	4.37	29/07/20
59	KIRTONKHOLA	BARISAL	3.07	20/08/20
60	PASHURE	KHULNA	3.43	24/07/20
61	PASHURE	MONGLA	3.16	19/08/20
MEGHNA BASIN				
62	SURMA	KANAIGHAT	14.04	21/07/20
63	SURMA	SYLHET	11.36	12/07/20
64	SURMA	SUNAMGONJ	8.96	28/06/20
65	KUSHIYARA	AMALSHID	16.65	16/07/20
66	KUSHIYARA	SHEOLA	13.66	17/07/20
67	KUSHIYARA	SHERPUR	8.89	13/07/20
68	KUSHIYARA	MARKULI	7.58	24/07/20
69	SARIGOWAIN	SARIGHAT	13.26	21/07/20
70	MANU	MANU RAILY BRIDGE	17.61	24/10/20
71	MANU	MOULVI BAZAR	11.21	24/10/20
72	KHOWAI	BALLAH	22.04	24/10/20
73	KHOWAI	HABIGANJ	8.91	24/10/20
74	DHALAI	KAMALGONJ	19.45	04/06/20
75	OLD SURMA	DERAI	7.41	23/07/20
76	BAULAI	KHALIAJURI	7.28	23/07/20
77	JADUKATA	LORERGARH	10.50	27/06/20
78	SOMESWARI	DURGAPUR	13.34	12/07/20
79	SOMESWARI	KALMAKANDA	7.38	12/07/20
80	BHUGAI	NAKUAGAON	22.85	17/09/20
81	KANGSHA	JARIAJANJAIL	10.61	25/09/20
82	TITAS	B. BARIA	5.85	26/07/20
83	MEGHNA	BHAIRAB BAZAR	5.73	25/07/20
84	MEGHNA	NARSINGDI	5.15	25/07/20
85	MEGHNA	BAIDYAR BAZAR	5.13	25/07/20
86	MEGHNA	MEGHNA BRIDGE	4.48	25/07/20
87	GUMTI	COMILLA	9.98	13/07/20
88	GUMTI	DEBIDDAR	6.29	14/07/20
89	MEGHNA	CHANDPUR	4.66	05/08/20
90	LOWER MEGHNA	DAULATKHAN	4.50	10/06/20
	SOUTH EASTERN HILL BASIN			
91	MUHURI	PARSHURAM	14.32	12/07/20
92	HALDA	NARAYAN HAT	14.47	12/07/20
93	HALDA	PANCHPUKURIA	7.65	24/10/20
94	SANGU	BANDARBAN	12.40	18/06/20
95	SANGU	DOHAZARI	5.25	18/06/20
96	MATAMUHURI	LAMA	12.44	17/06/20
97	MATAMUHURI	CHIRINGA	7.18	17/06/20
98	FENI	RAMGARH	15.08	21/07/20
99	KARNAPHULI	CHITTAGONG	4.45	06/08/20

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

Sl. No.	River	Station	Danger Level	Recorded Highest WL before 2020 with Date	WL in 2020 Exceeding Previous Level with Date
1	Dharla	Kurigram	26.50	27.84 (14.07.96)	-
2	Teesta	Dalia	52.40	53.12 (12.07.19)	**53.15 (13.07.2020)**
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	21.16 (18.07.19)	-
8	Jamuna	Fulchari	19.82	21.35 (18.07.19)	-
9	Jamuna	Serajganj	13.35	15.12 (30.08.88)	-
10	Jamuna	Aricha	9. 40	10.76 (02.09.88)	-
11	Dhaleswari	Elasin	11.40	12.80 (31.07.16)	-
12	Old Brahmaputra	Jamalpur	17.00	18.00 (31.07.54)	-
13	Old Brahmaputra	Mymensingh	12.50	13.71 (01.09.88)	-
14	Buriganga	Dhaka	6.00	7.58 (04.09.68)	-
15	Lakhya	Narayangonj	5.50	6.93 (10.09.98)	-
16	Turag	Mirpur	5.94	8.35 (10.09.88)	-
17	Tongi Khal	Tongi	6.08	7.84 (01.09.62)	-
18	Kaliganga	Taraghat	8.38	10.37 (02.09.88)	-
19	Punarbhaba	Dinajpur	33.50	34.40	-
20	Tangon	Thakurgaon	50.40	51.30 (12.08.17)	-
21	Gur	Singra	12.65	13.67 (22.08.17)	**13.76 (01.10.2020)**
22	Atrai	Atrai	13.72	14.31	**14.40 (16.07.2020)**
23	Padma	Pankha	21.50	24.14 (07.09.97)	-
24	Padma	Rajshahi	18.50	20.00 (13.09.1910)	-
25	Padma	H. Bridge	14.25	15.19 (10.09.98)	-
26	Padma	Goalundo	8.50	10.21 (09.09.98)	-
27	Padma	Bhagyakul	6.00	7.58	-
28	Gorai	Gorai Rly Br	12.75	13.65 (02.09.98)	-
29	Surma	Kanaighat	13.20	15.58 (26.06.12)	-
30	Surma	Sylhet	11.25	12.44 (19.07.04)	-
31	Surma	Sunamgonj	8.25	9.75 (20.07.04)	-
32	Kushiyara	Amalshid	15.85	18.28 (08.06.74)	-
33	Kushiyara	Sheola	13.50	14.60 (09.09.08)	-
34	Manu	Manu Rly Br	18.00	20.42 (23.05.02)	-
35	Manu	Moulvi Bazar	11.75	13.25 (08.06.93)	-
36	Khowai	Habiganj	9.50	12.00 (18.06.07)	-
37	Someswari	Durgapur	13.00	15.58 (28.07.07)	-
38	Upper Meghna	Bhairab Bazar	6.25	7.78 (24.07.04)	-
39	Gumti	Comilla	11.75	13.56 (23.07.93)	-
40	Muhuri	Parshuram	13.00	16.33 (13.09.04)	-
41	Halda	Narayanhat	15.25	19.30 (13.08.99)	-
42	Halda	Panchpukuria	7.00	12.54 (27.06.03)	-
43	Sangu	Bandarban	15.25	20.70 (12.07.97)	-
44	Sangu	Dohazari	5.75	9.05	-
45	Matamuhuri	Lama	12.25	15.46 (12.08.99)	-
46	Matamuhuri	Chiringa	5.75	7.32 (04.07.17)	-
47	Feni	Ramgarh	17.37	21.42 (11.07.68)	-

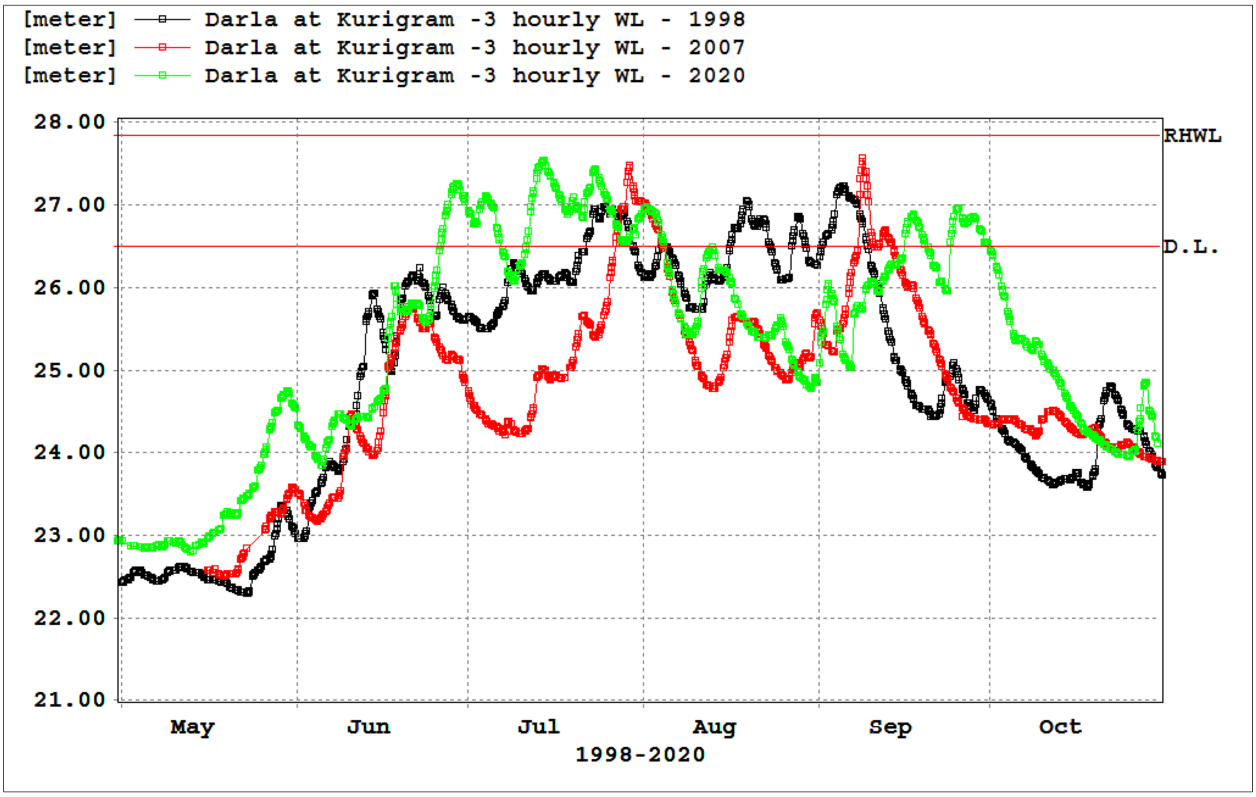


Figure 3.1: Comparison of Hydrograph on Dharla at Kurigram

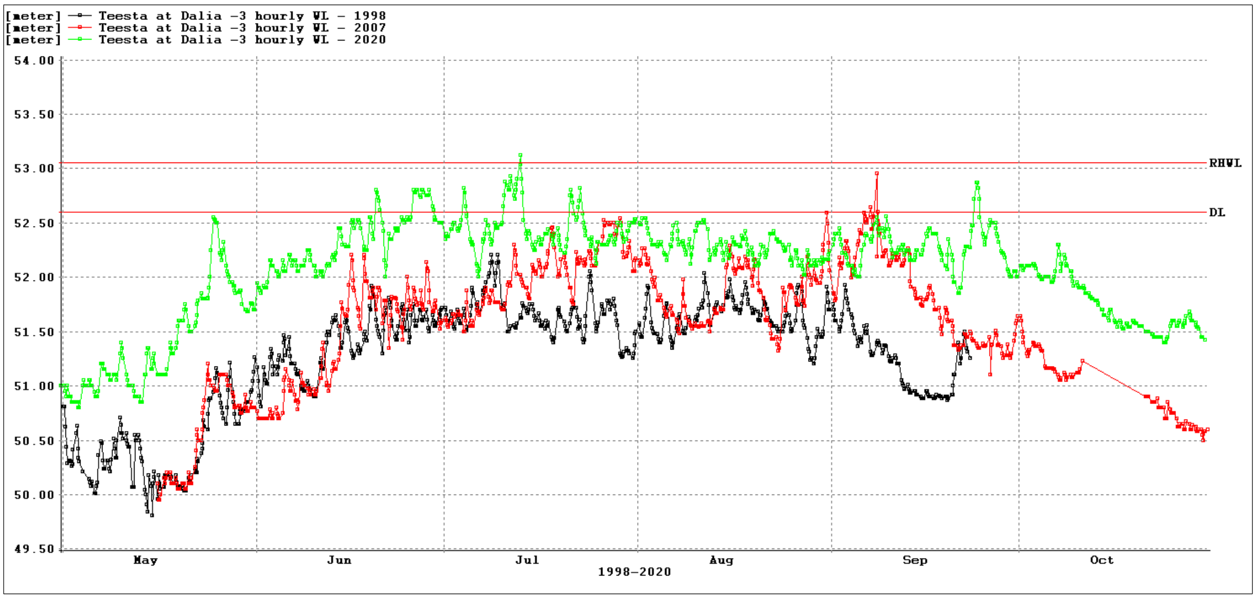


Figure 3.2: Comparison of Hydrograph on Teesta at Dalia

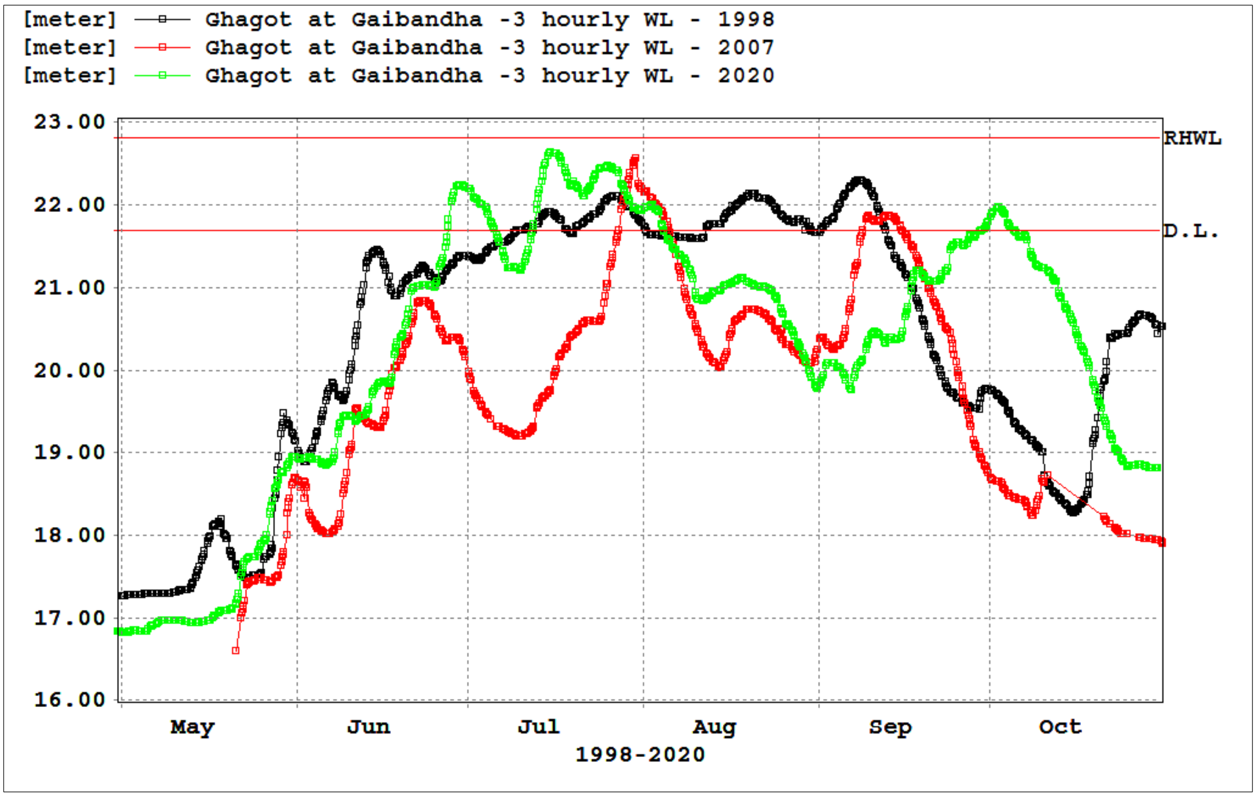


Figure 3.3: Comparison of Hydrograph on Ghagot at Gaibandha

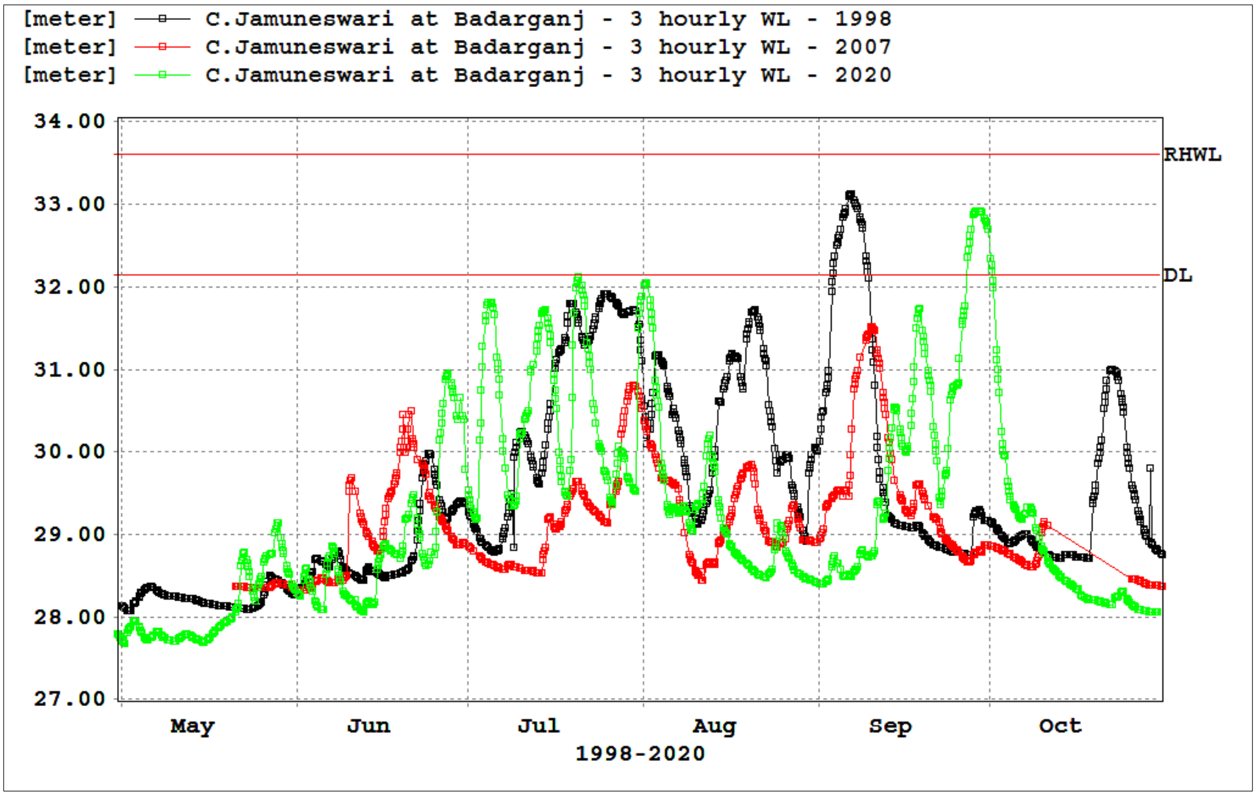


Figure 3.4: Comparison of Hydrograph on C. Jamuneswari at Badarganj

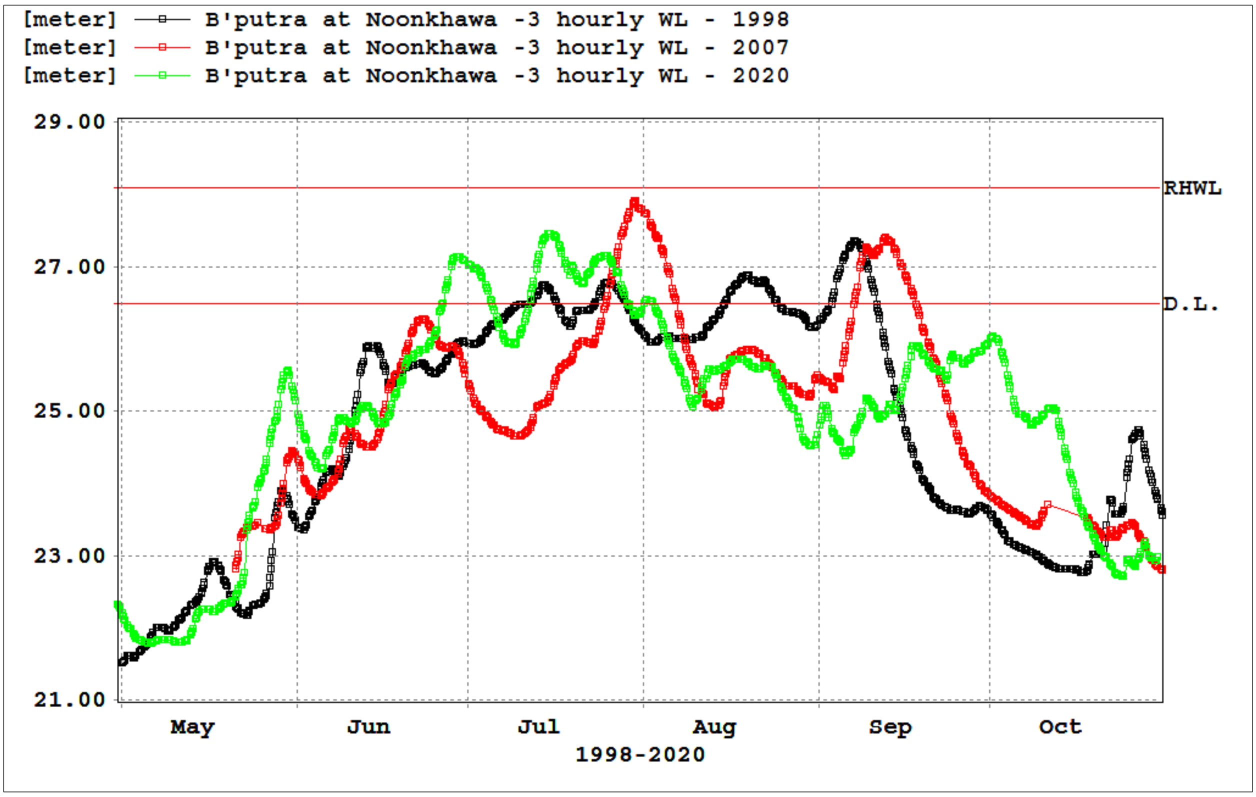


Figure 3.5: Comparison of Hydrograph on Brahmaputra at Noonkhawa

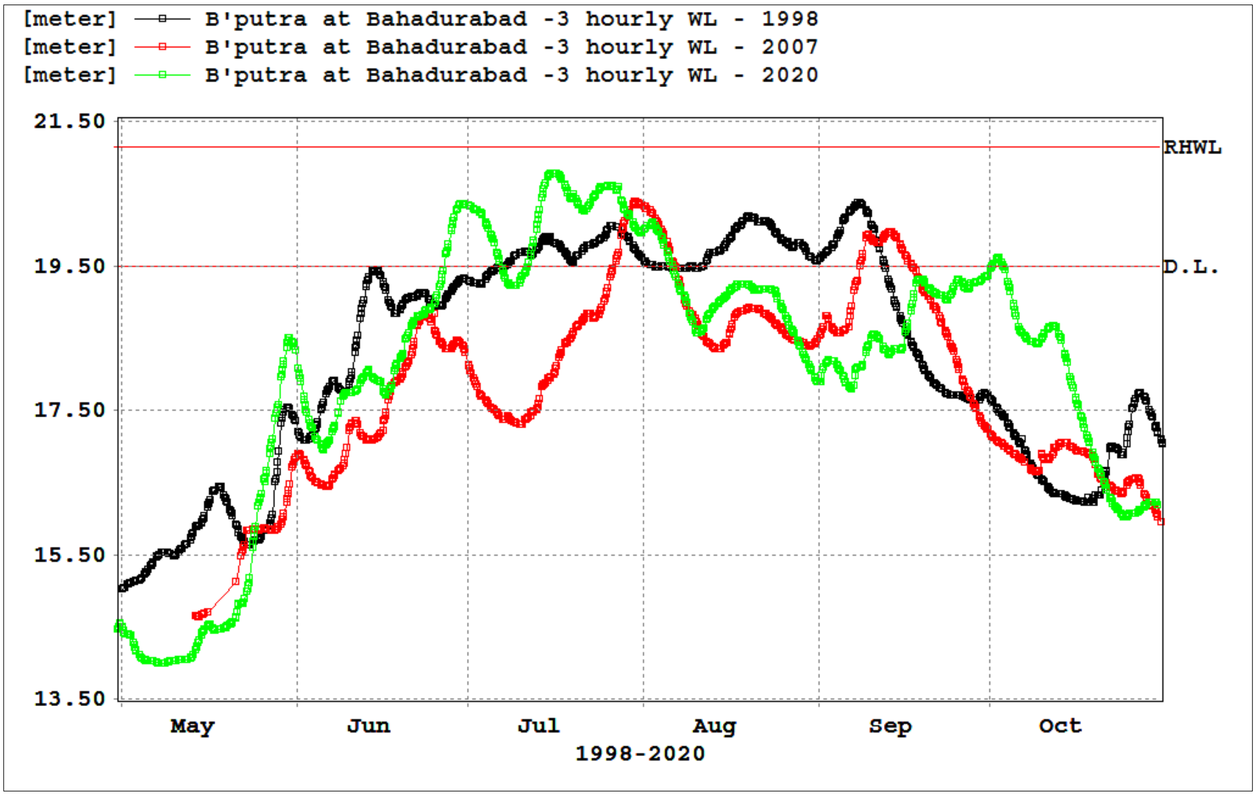


Figure 3.6: Comparison of Hydrograph on Jamuna at Bahadurabad

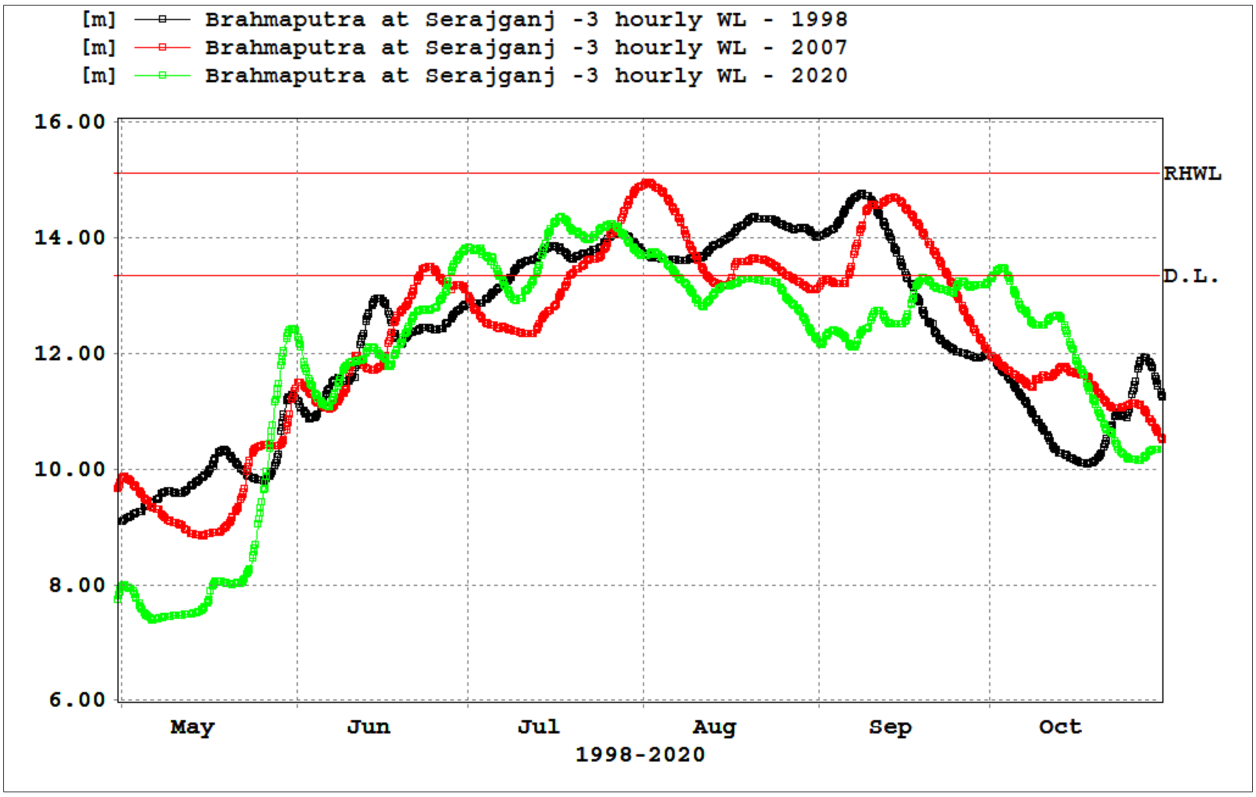


Figure 3.7: Comparison of Hydrograph on Jamuna at Serajganj

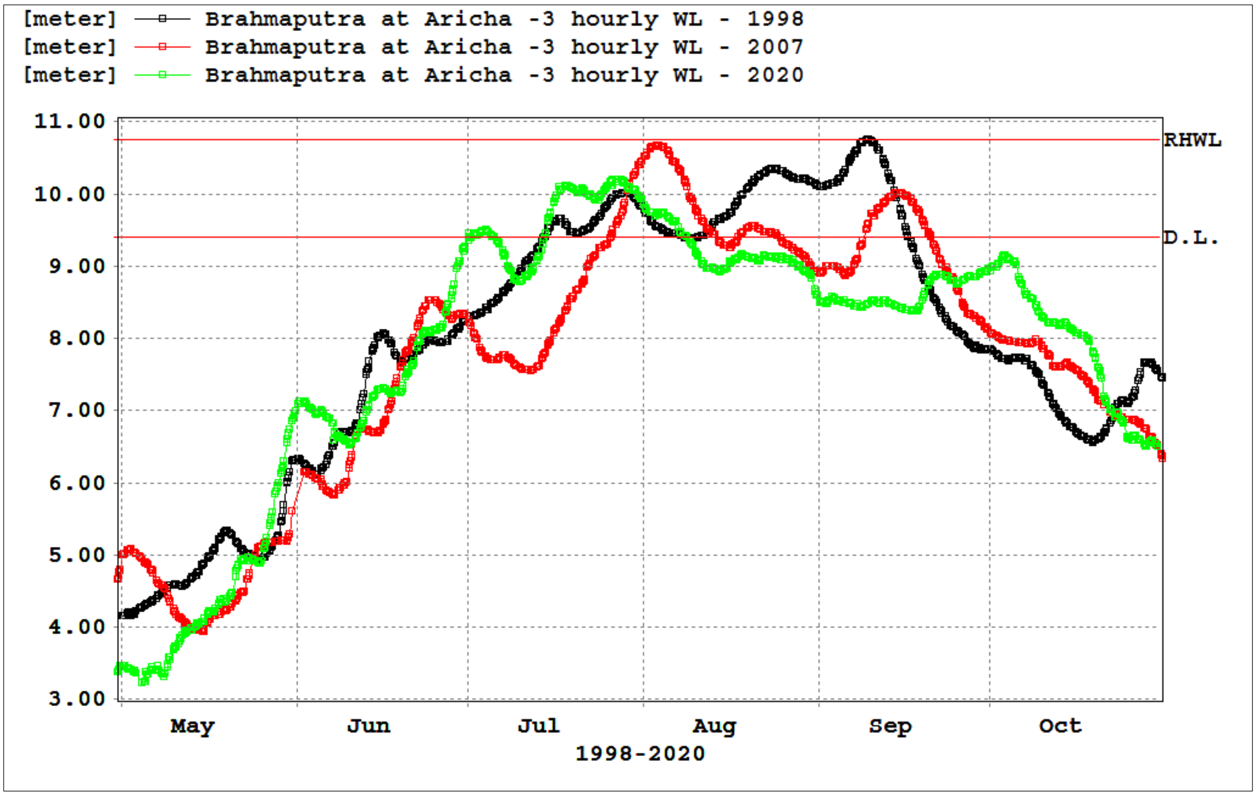


Figure 3.8: Comparison of Hydrograph on Jamuna at Aricha

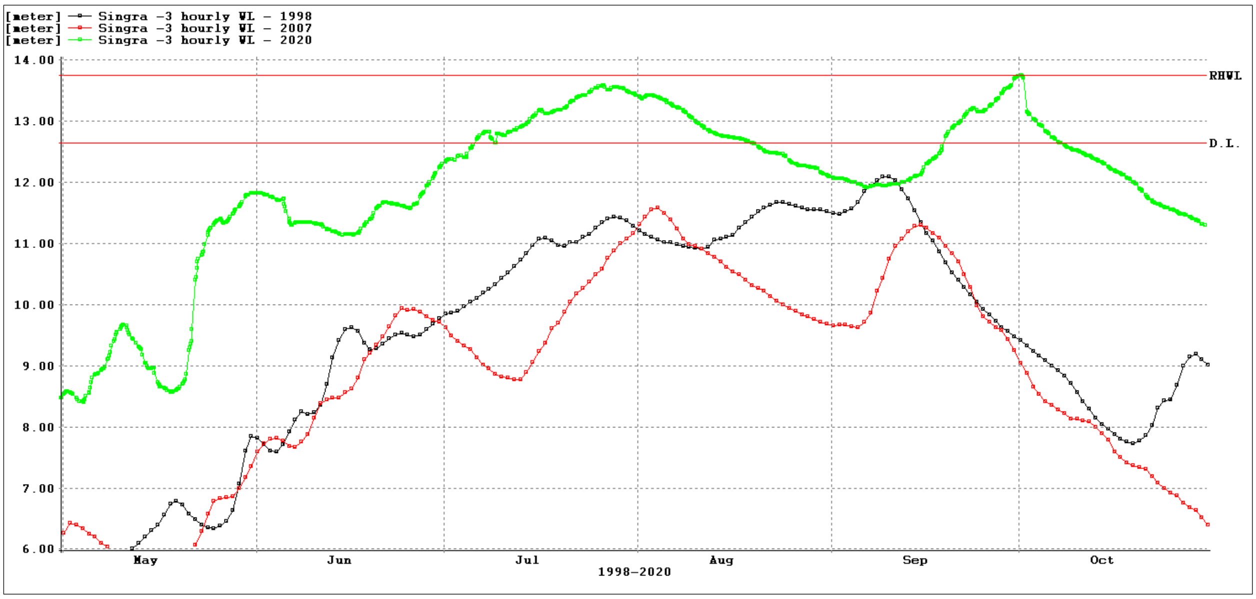


Figure 3.9: Comparison of Hydrograph on Gur at Singra

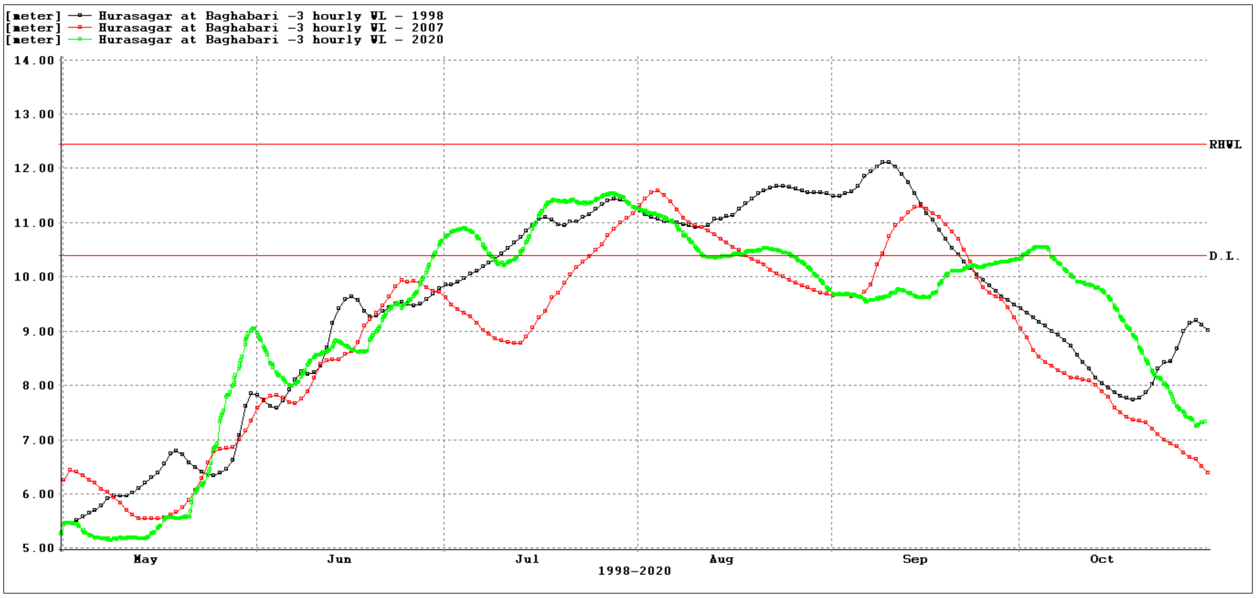


Figure 3.10: Comparison of Hydrograph on Atrai at Baghabari

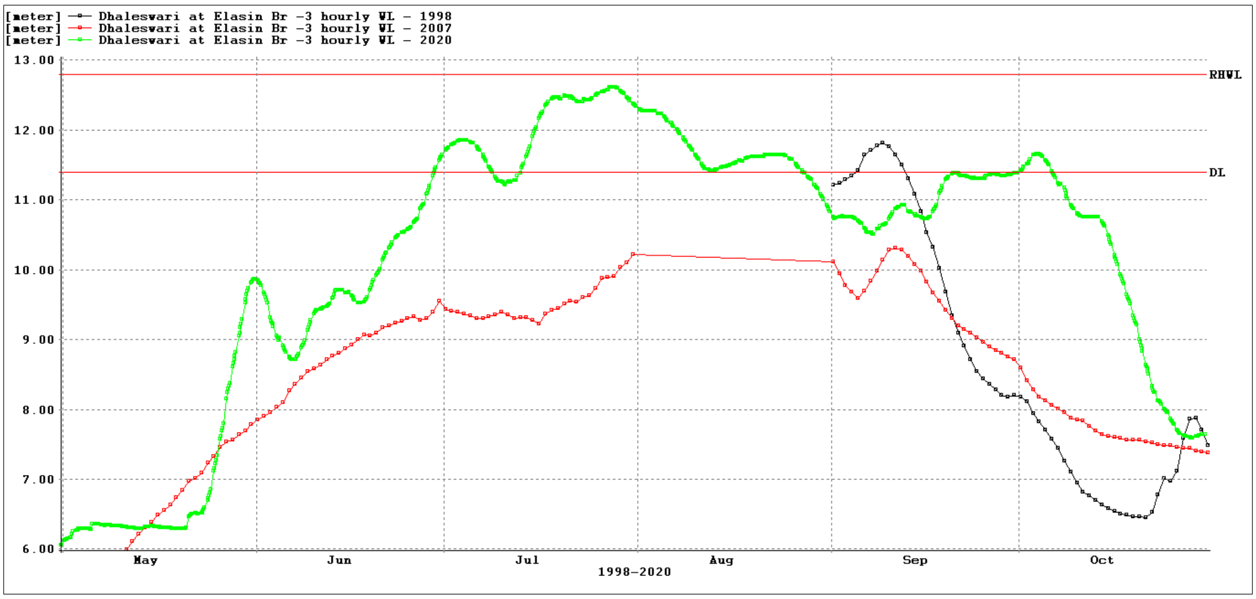


Figure 3.11: Comparison of Hydrograph on Dhaleswari at Elasin

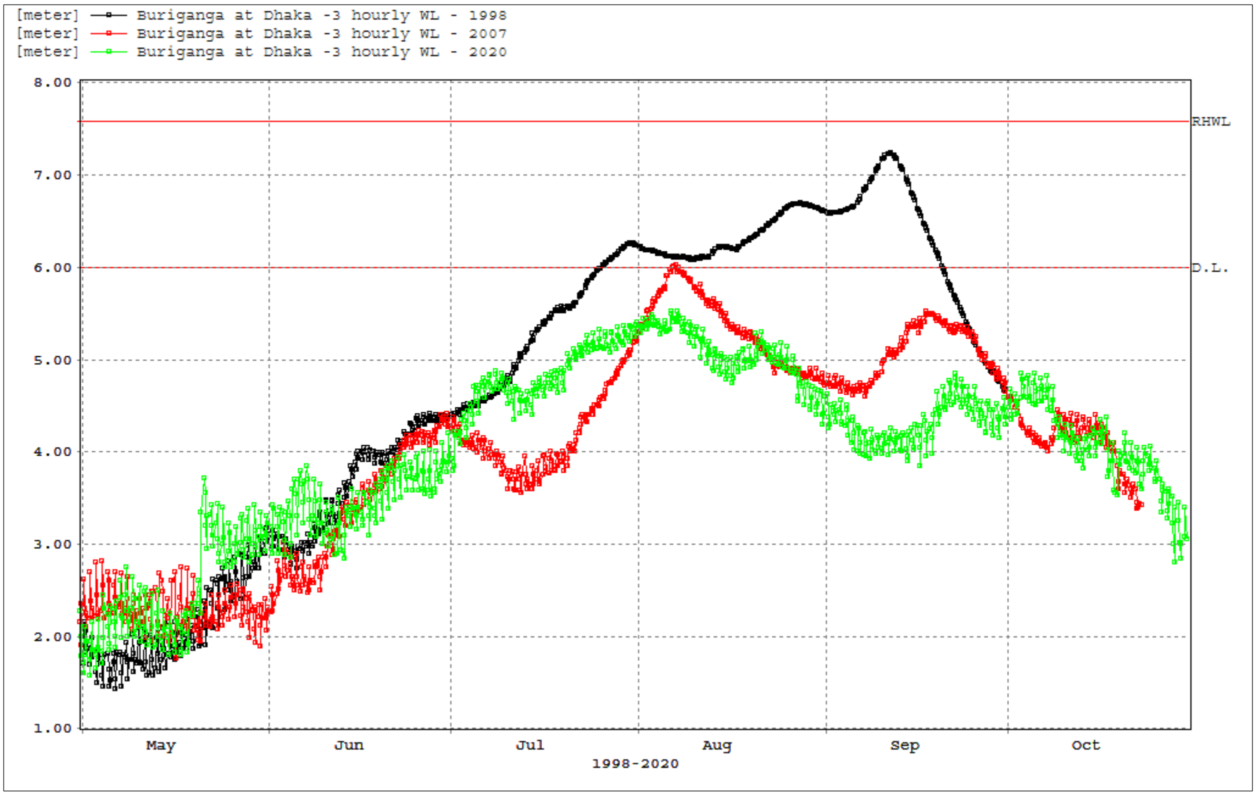


Figure 3.12: Comparison of Hydrograph on Buriganga at Dhaka (Milbarak)

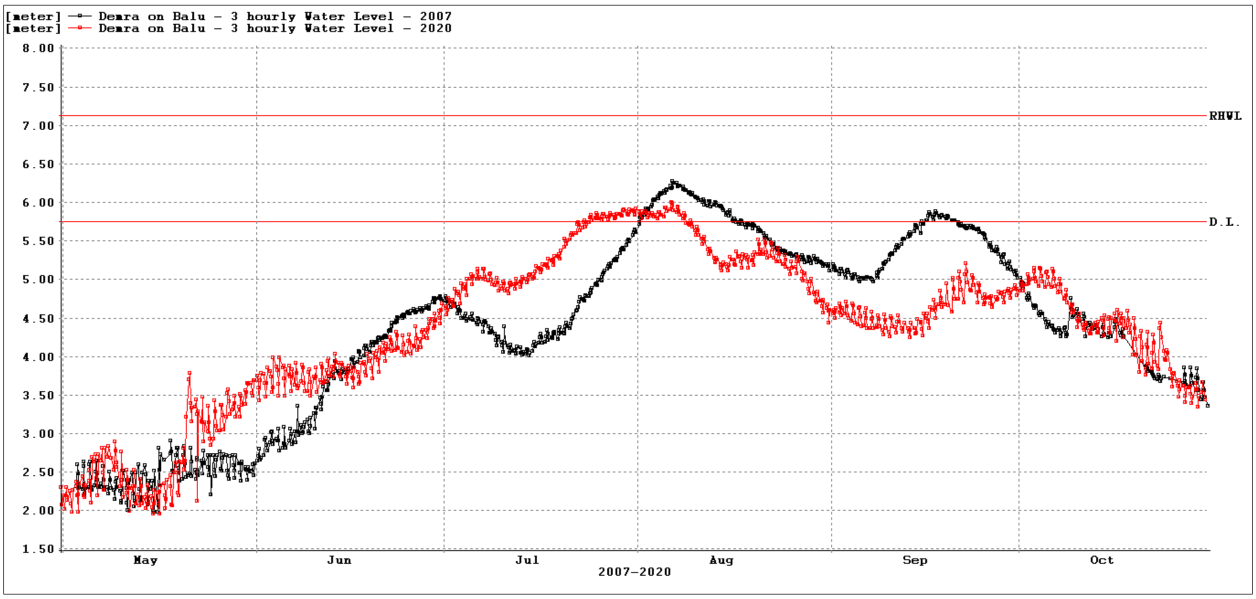


Figure 3.13: Comparison of Hydrograph on Balu at Demra

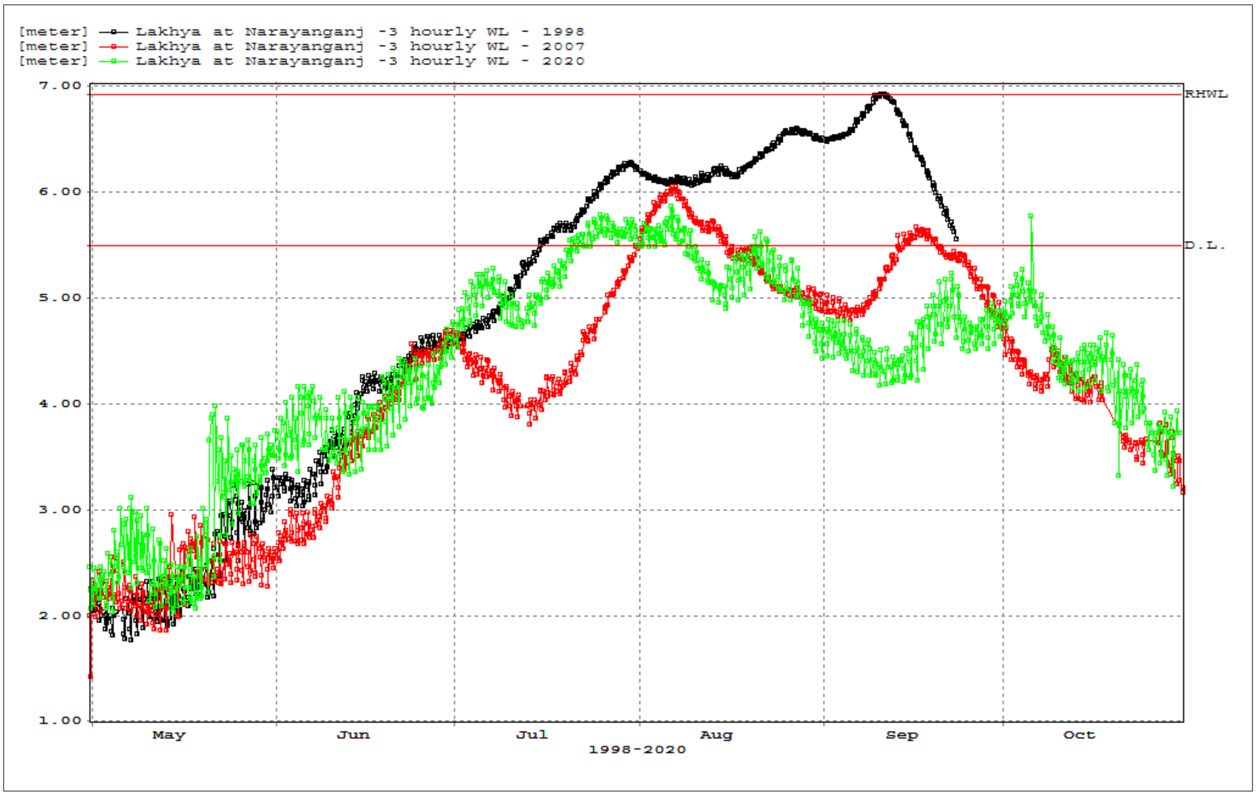


Figure 3.14: Comparison of Hydrograph on Lakhya at Narayanganj

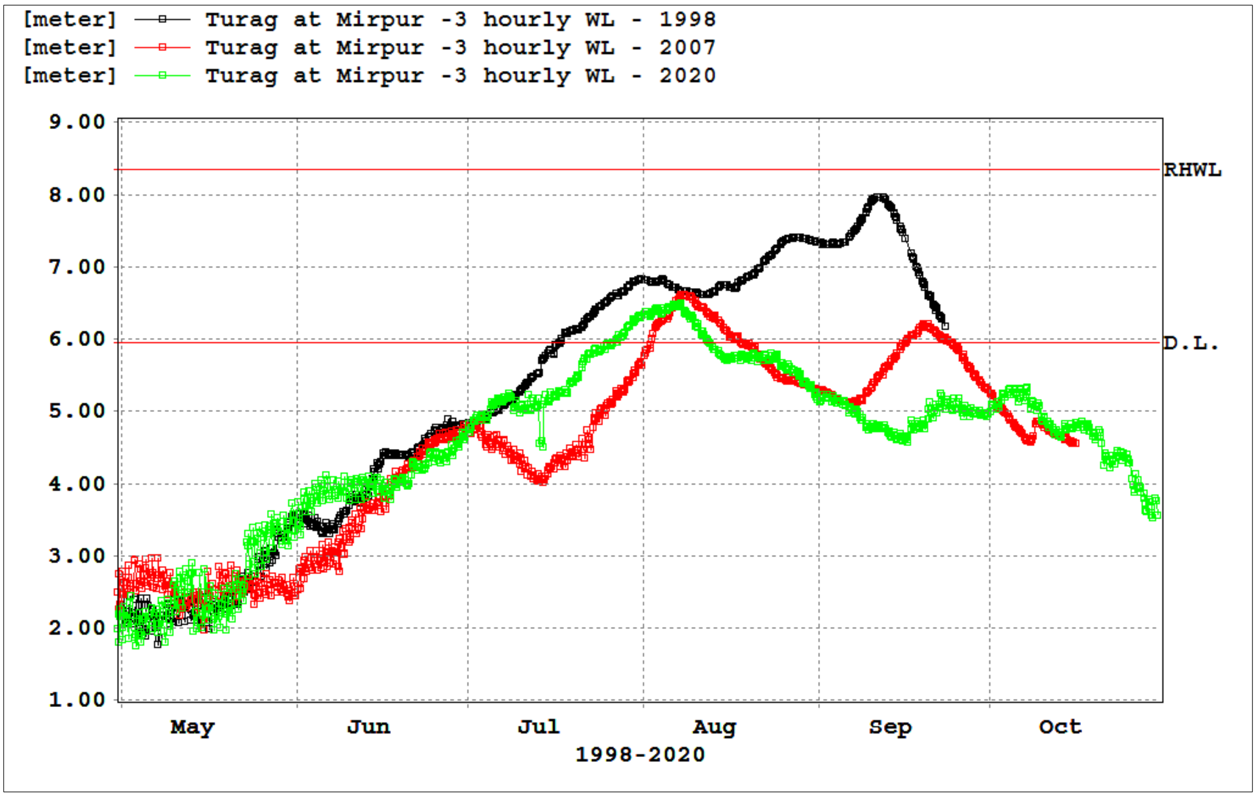


Figure 3.15: Comparison of Hydrograph on Turag at Mirpur

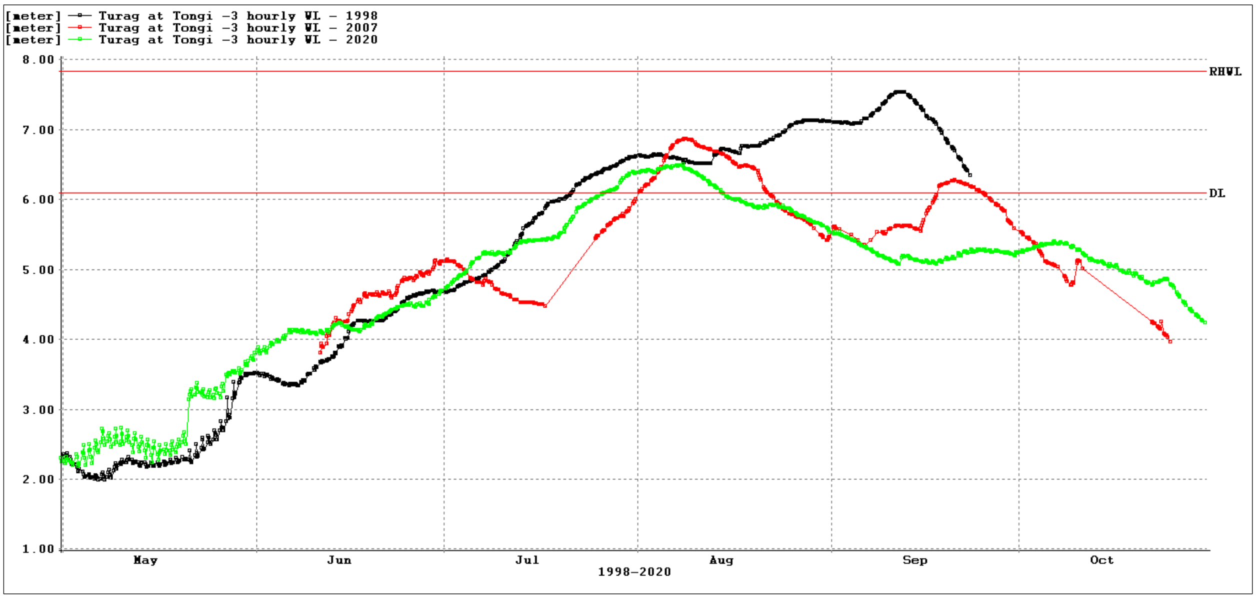


Figure 3.16: Comparison of Hydrograph on Tongi Khal at Tongi

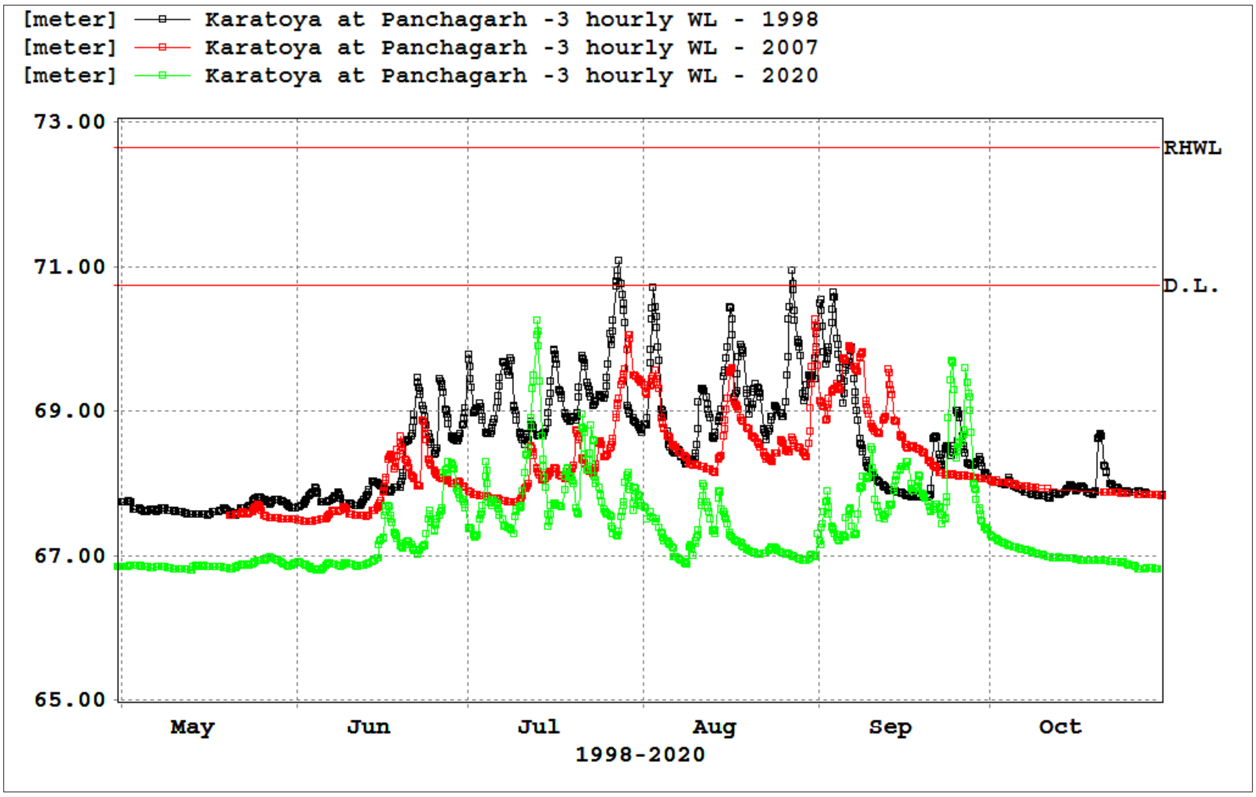


Figure 3.17: Comparison of Hydrograph on Upper Karatoa at Panchagarh

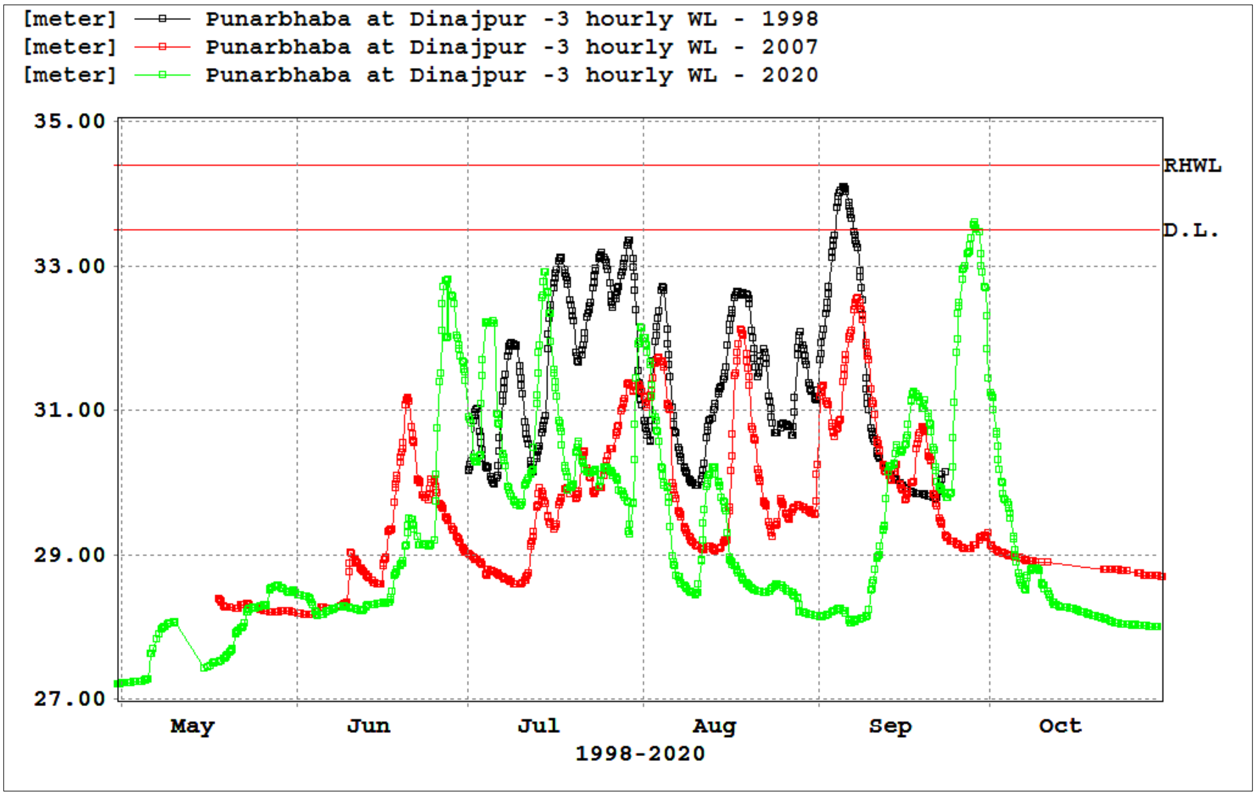


Figure 3.18: Comparison of Hydrograph on Punarbhaba at Dinajpur

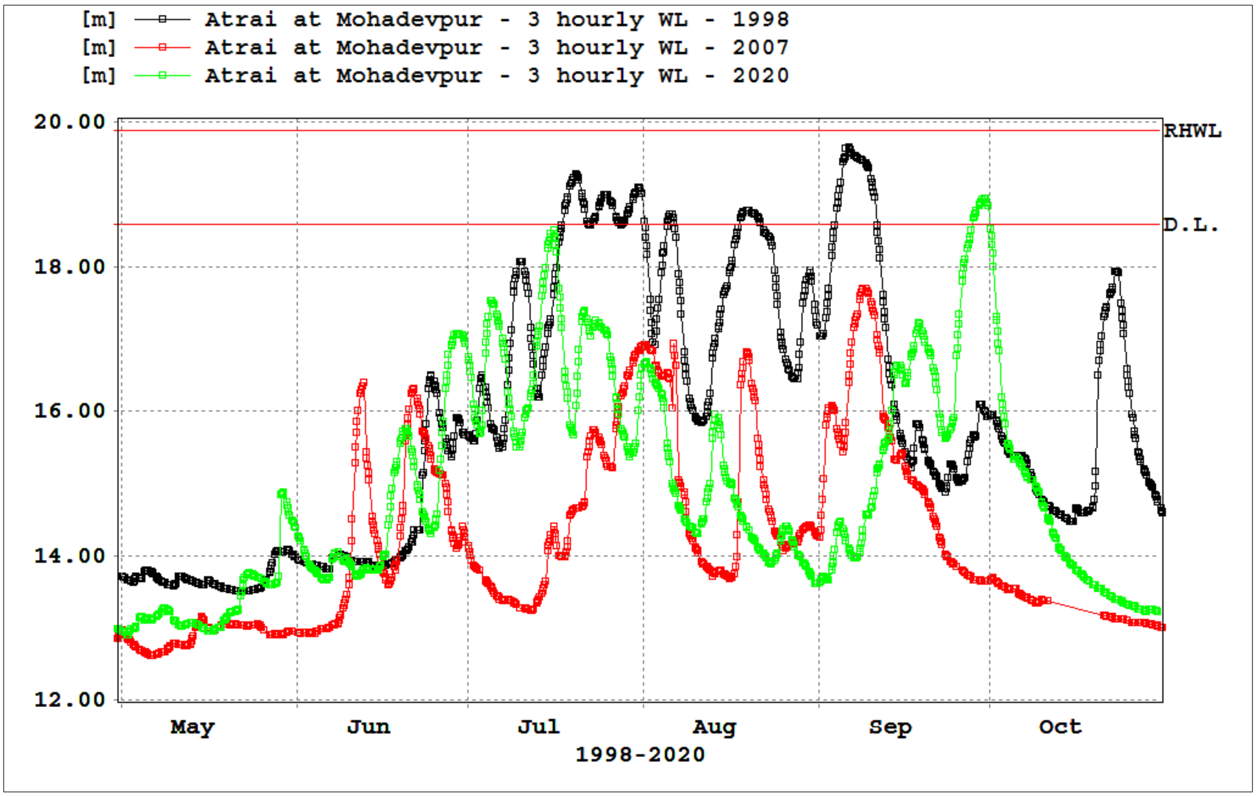


Figure 3.19: Comparison of Hydrograph on Atrai at Mohadevpur

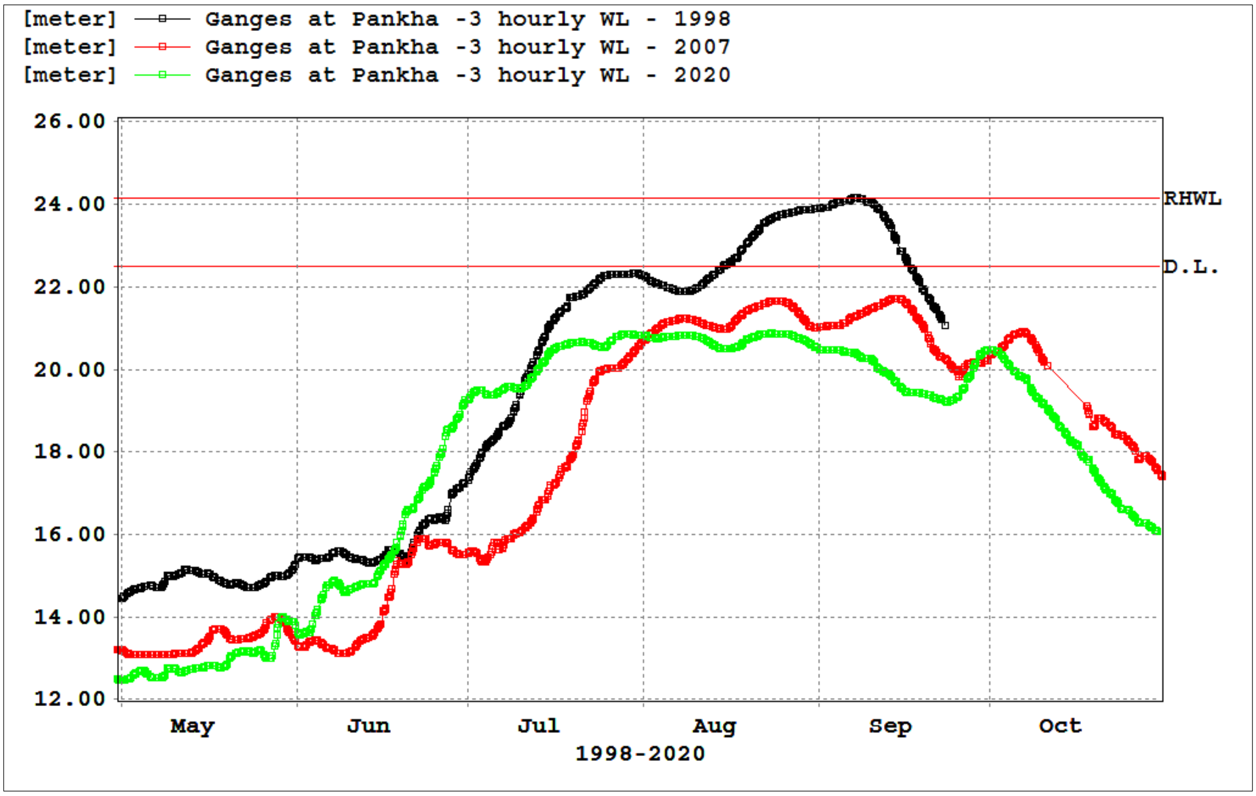


Figure 3.20: Comparison of Hydrograph on Ganges at Pankha

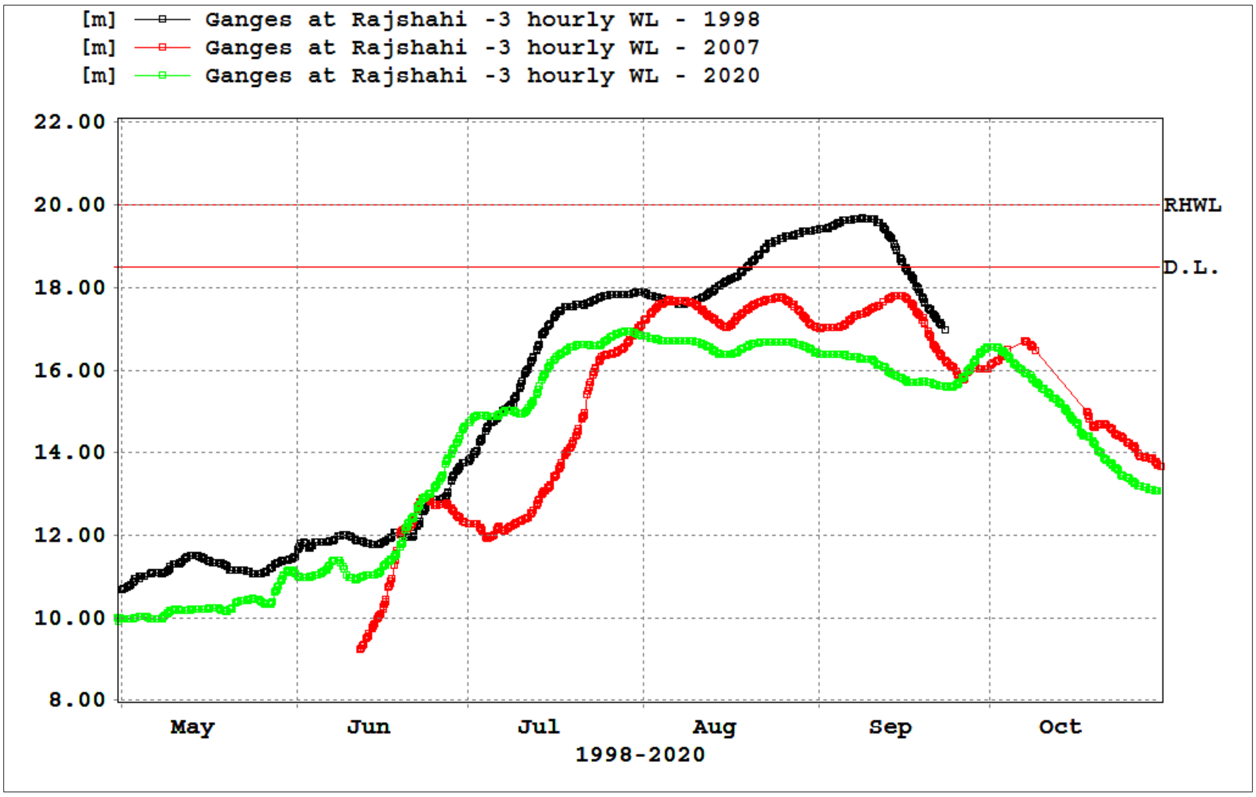


Figure 3.21: Comparison of Hydrograph on Ganges at Rajshahi

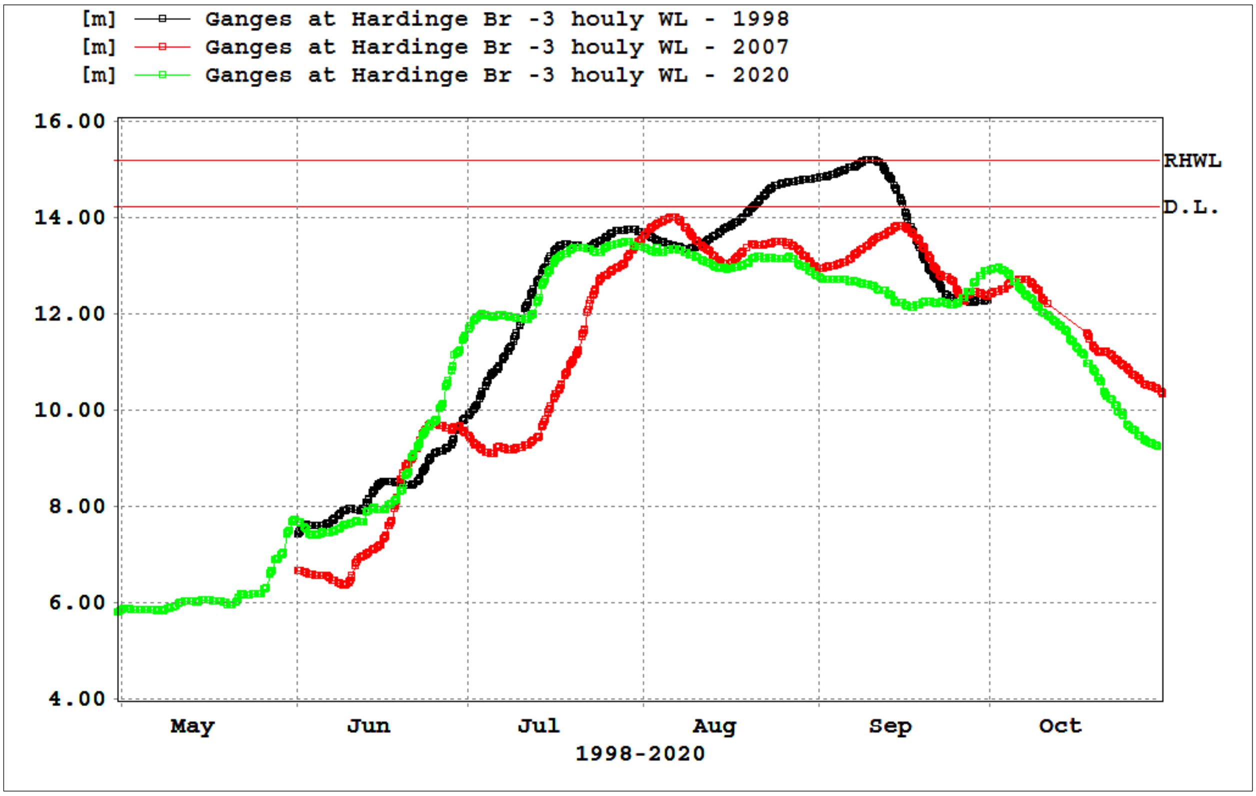


Figure 3.22: Comparison of Hydrograph on Ganges at Hardinge Bridge

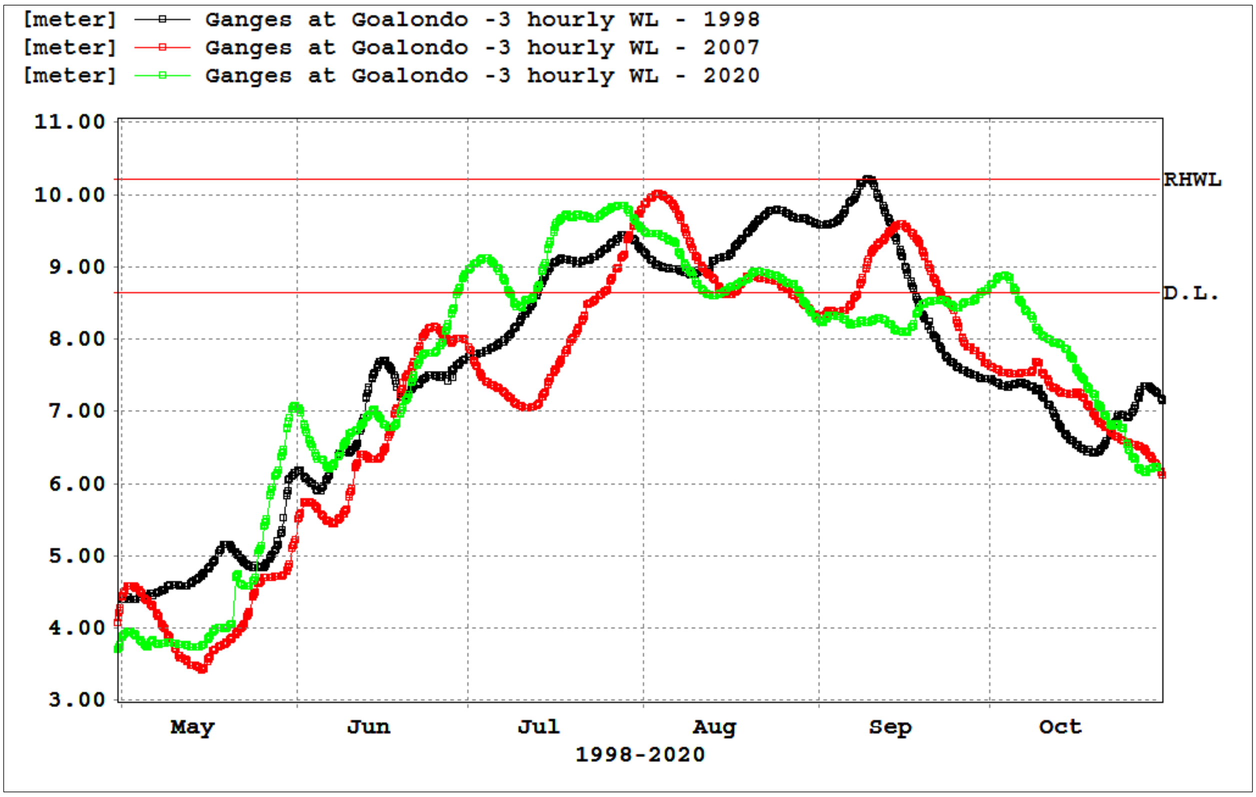


Figure 3.23: Comparison of Hydrograph on Padma at Goalundo

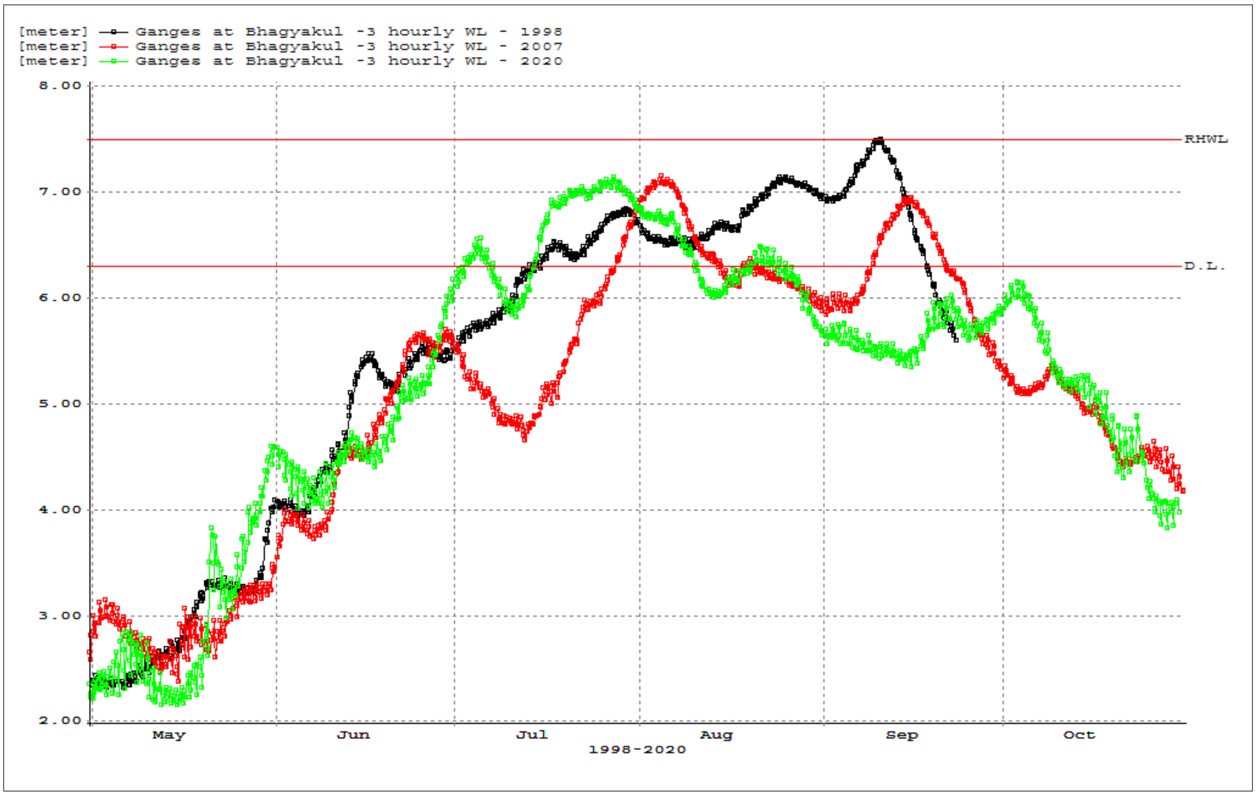


Figure 3.24: Comparison of Hydrograph on Padma at Bhagyakul

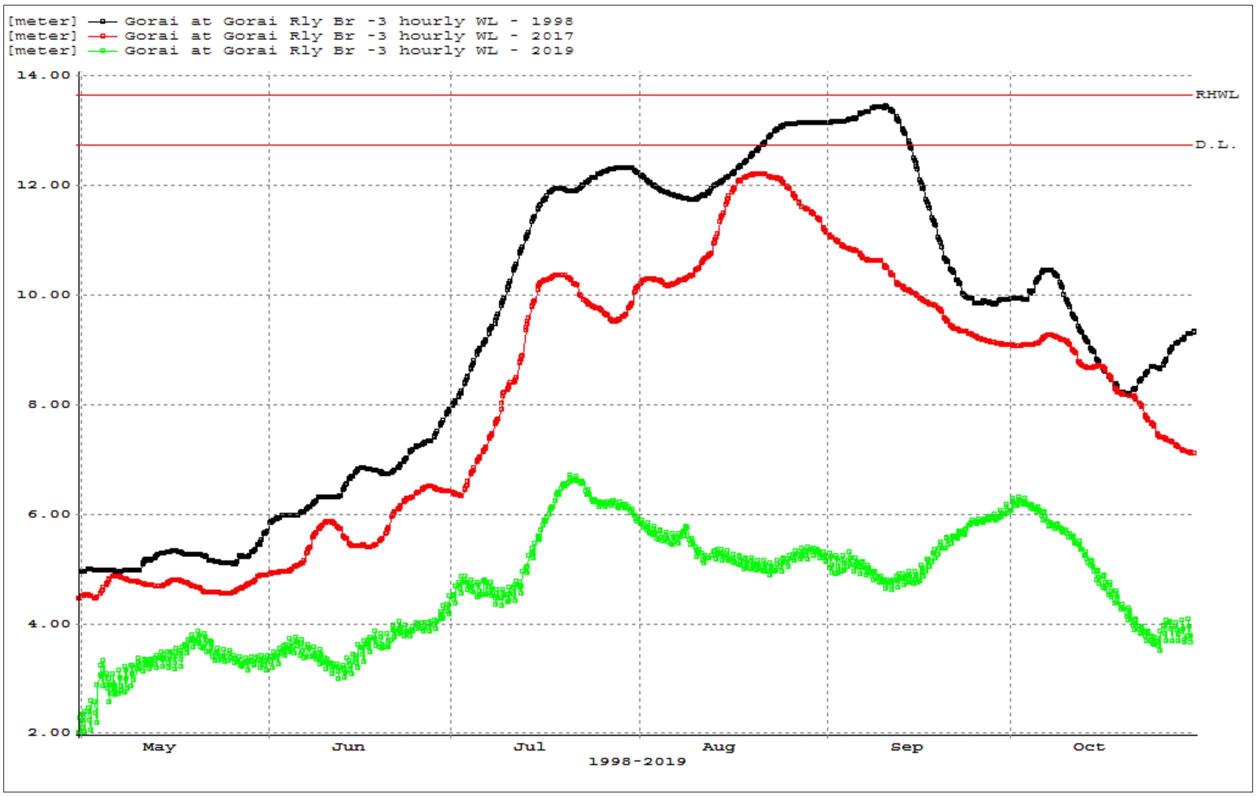


Figure 3.25: Comparison of Hydrograph on Gorai at Gorai Railway Bridge

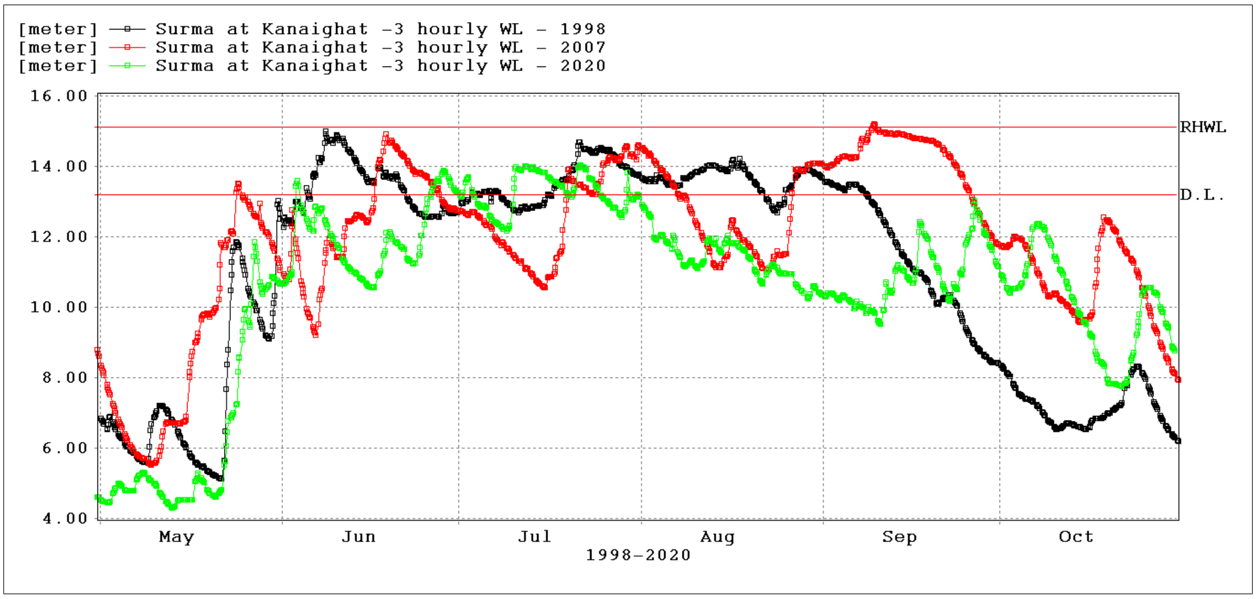


Figure 3.26: Comparison of Hydrograph on Surma at Kanaighat

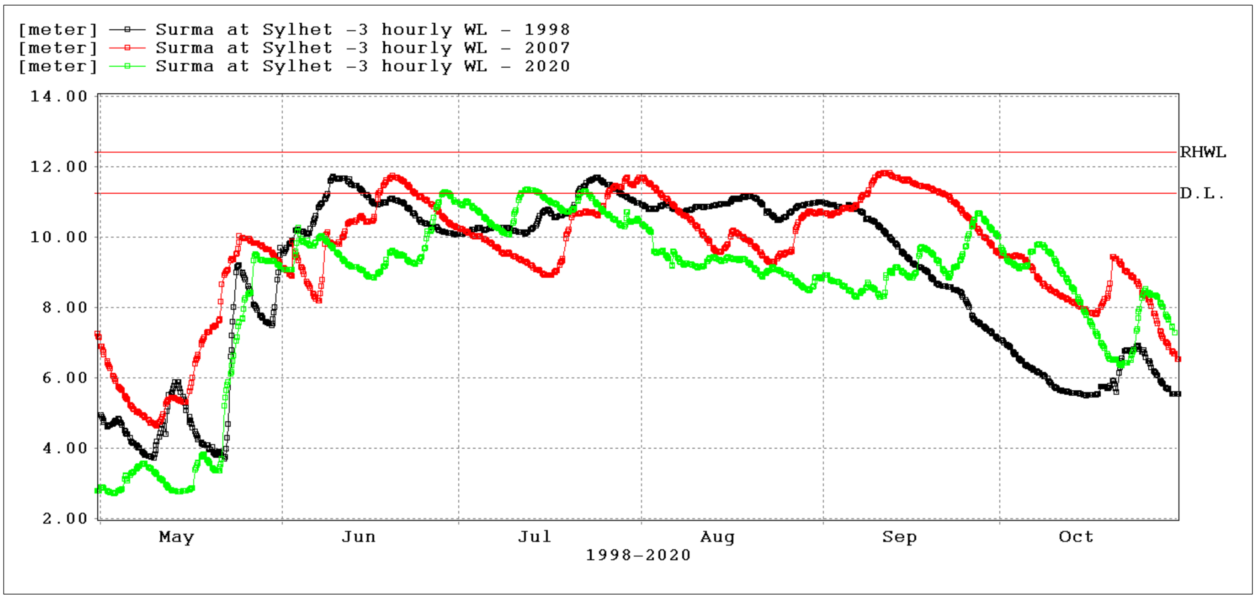


Figure 3.27: Comparison of Hydrograph on Surma at Sylhet

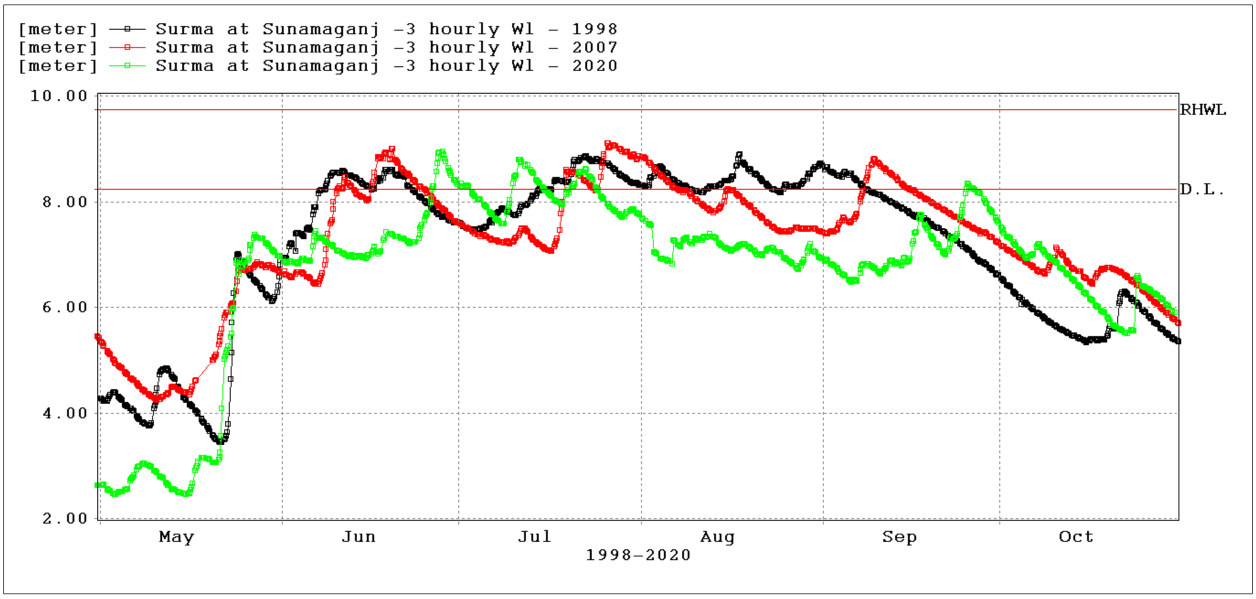


Figure 3.28: Comparison of Hydrograph on Surma at Sunamganj

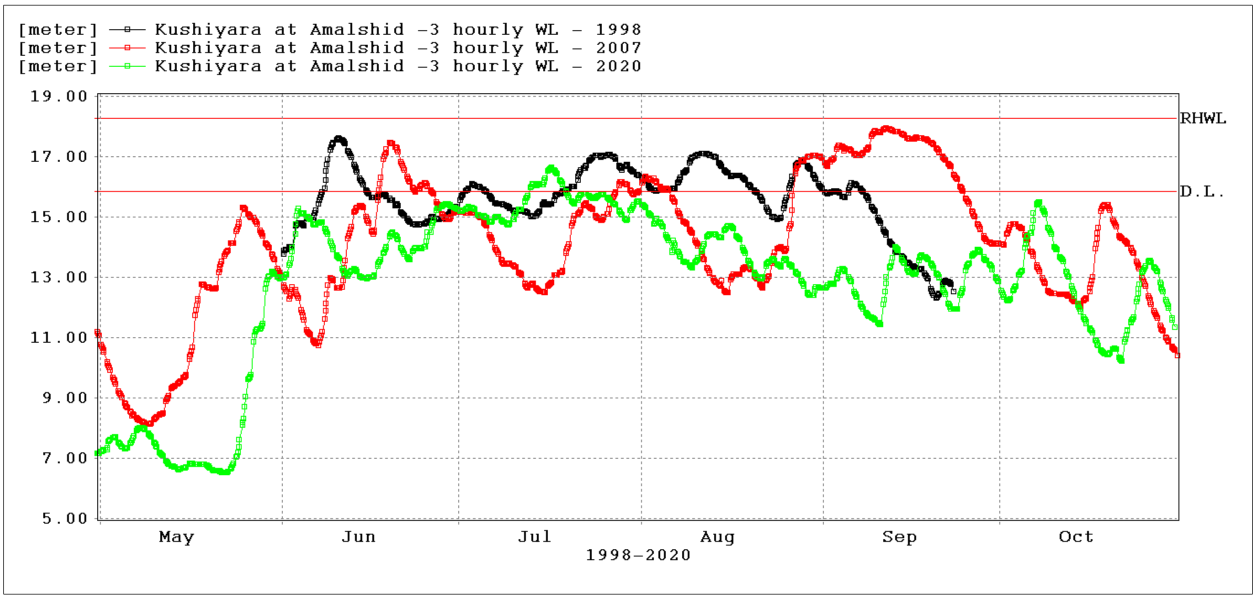


Figure 3.29: Comparison of Hydrograph on Kushiyara at Amalshid

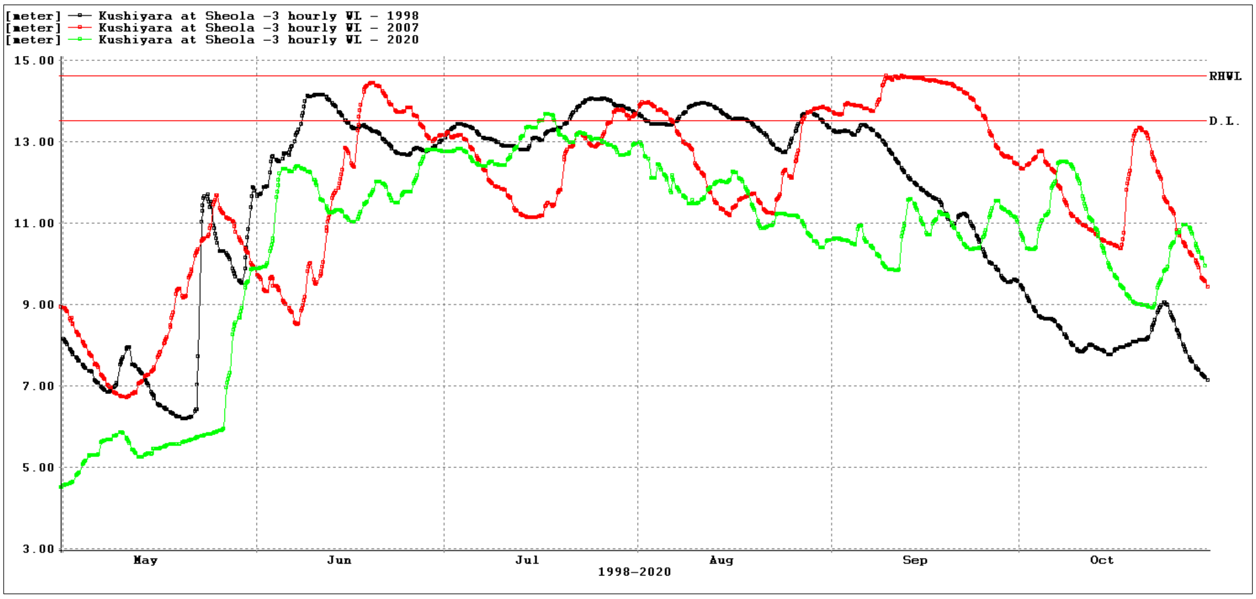


Figure 3.30: Comparison of Hydrograph on Kushiyara at Sheola

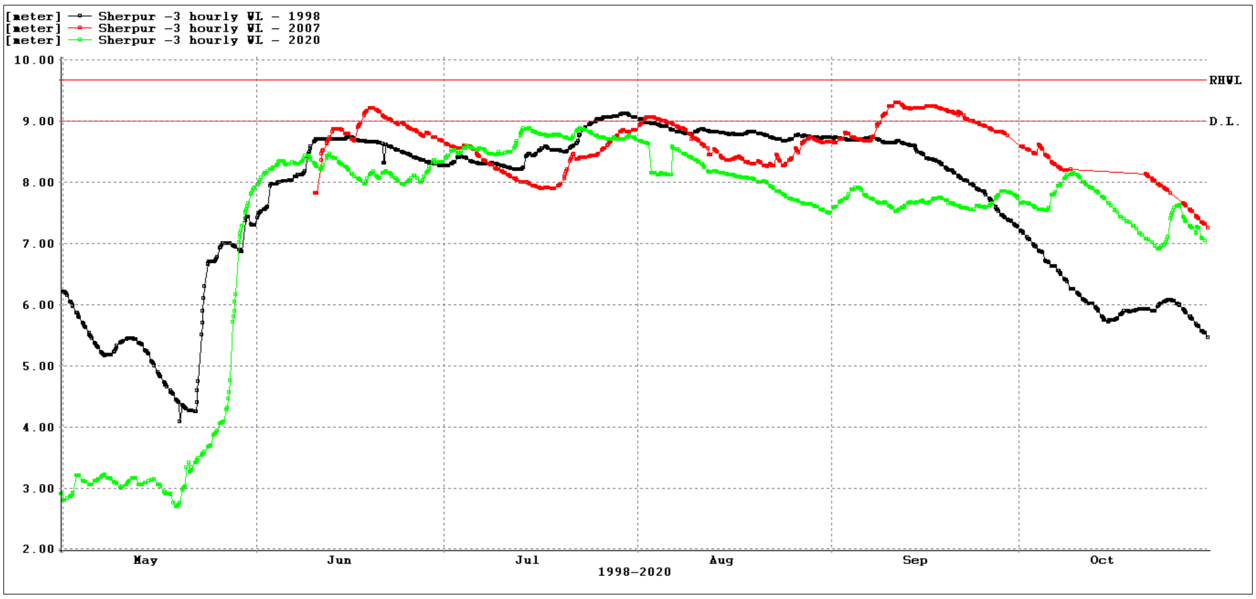


Figure 3.31: Comparison of Hydrograph on Kushiyara at Sherpur

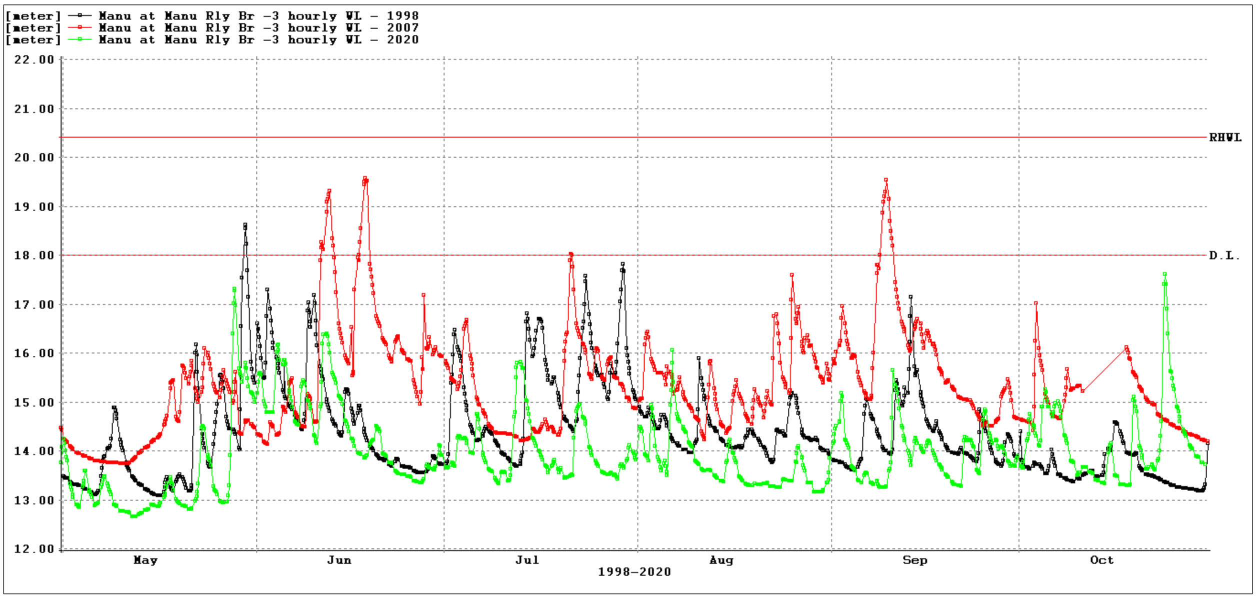


Figure 3.32: Comparison of Hydrograph on Manu at Manu Rail Bridge

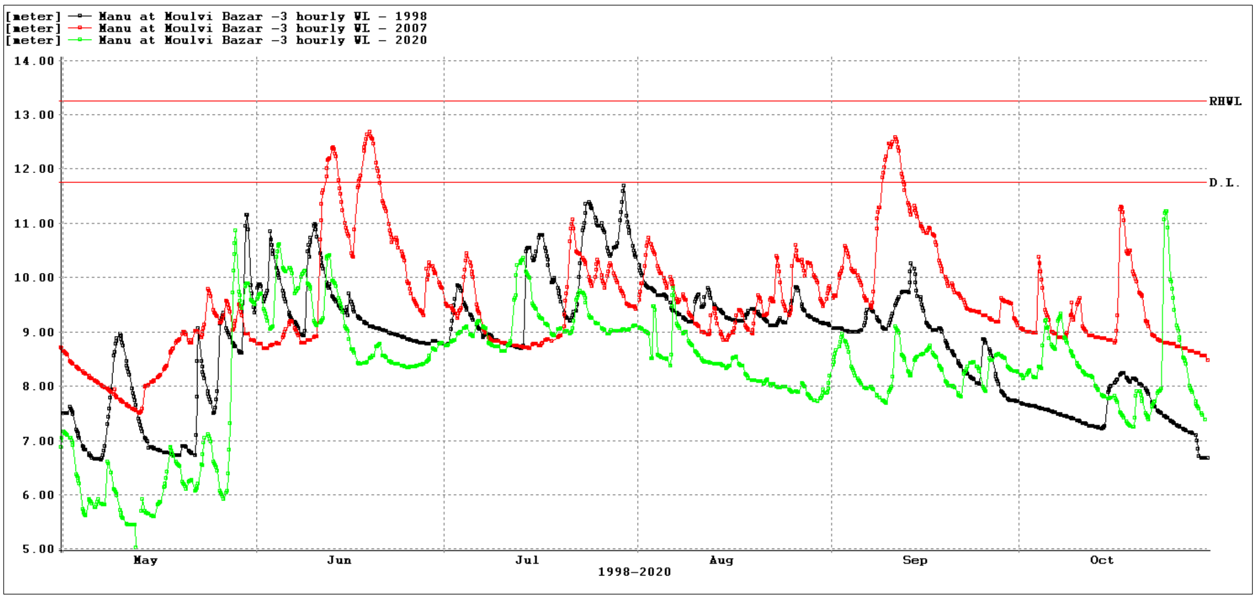


Figure 3.33: Comparison of Hydrograph on Manu at Moulvi Bazar

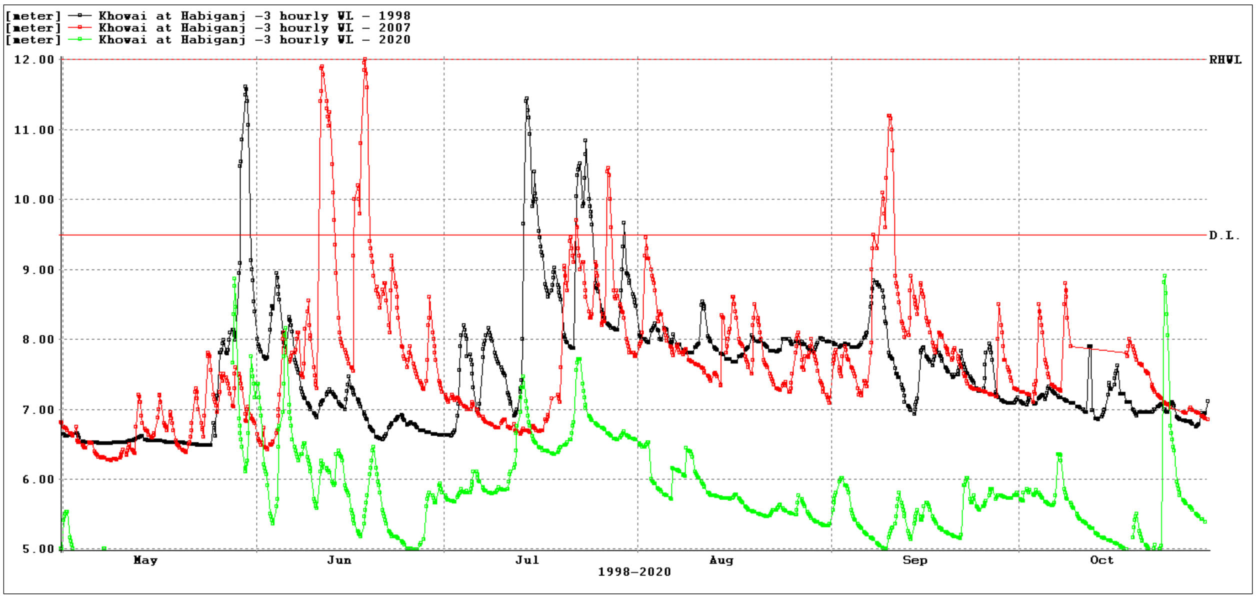


Figure 3.34: Comparison of Hydrograph on Khowai at Habiganj

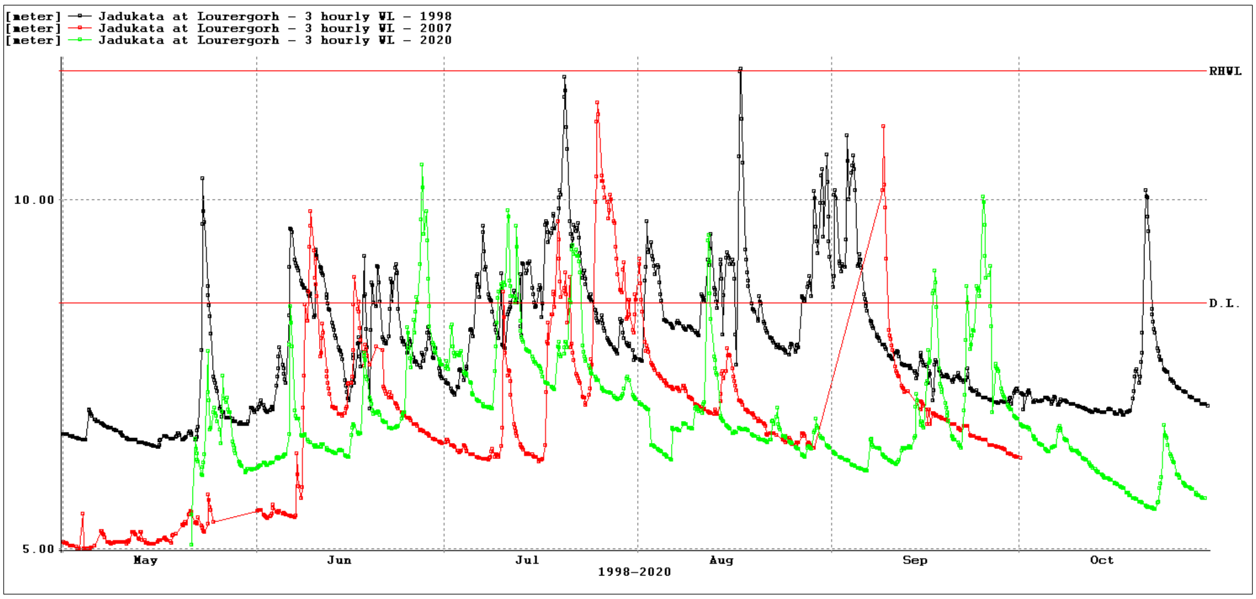


Figure 3.35: Comparison of Hydrograph on Jadukata at Lorergarh

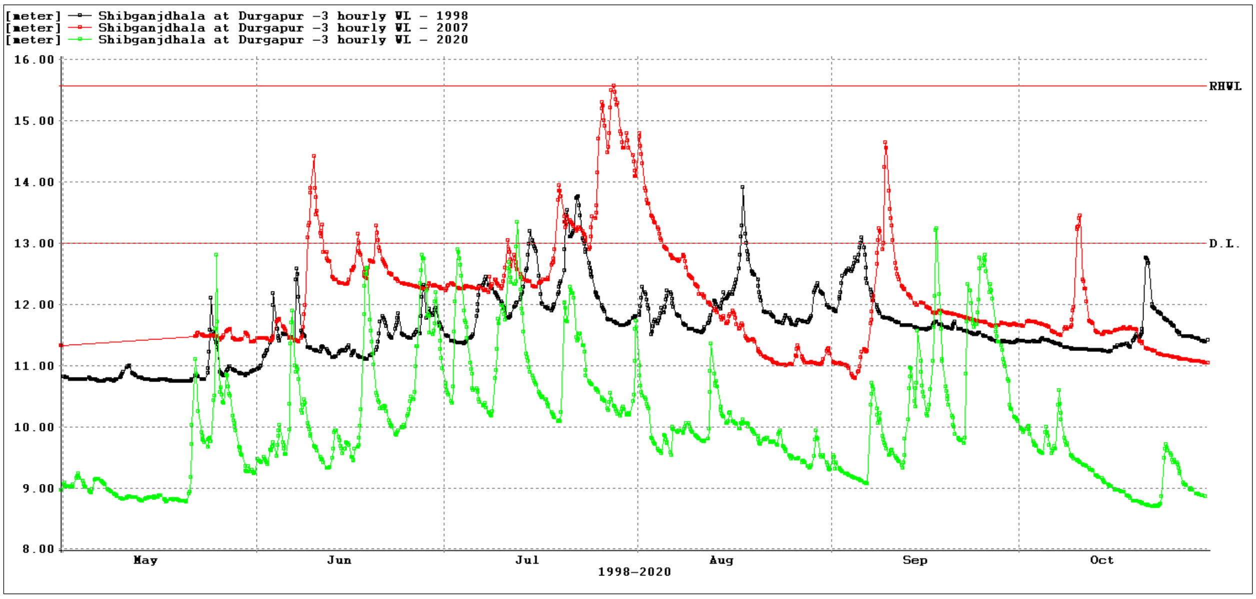


Figure 3.36: Comparison of Hydrograph on Someswari at Durgapur

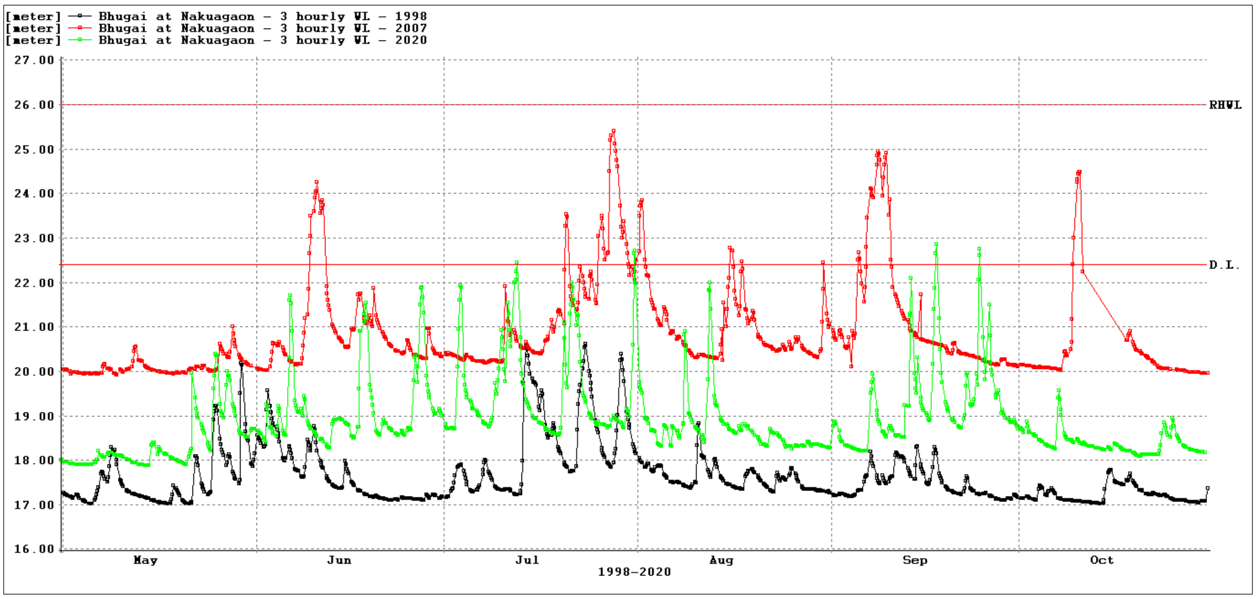


Figure 3.37: Comparison of Hydrograph on Bhugai at Nakuagaon

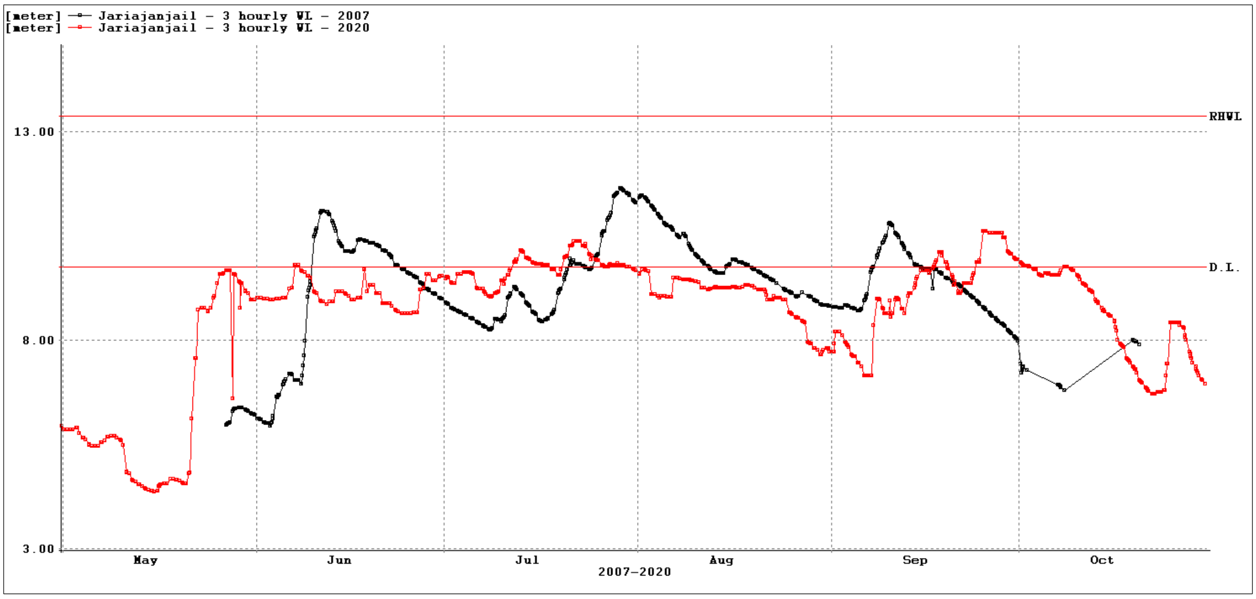


Figure 3.38: Comparison of Hydrograph on Kangsha at Jariajanjail

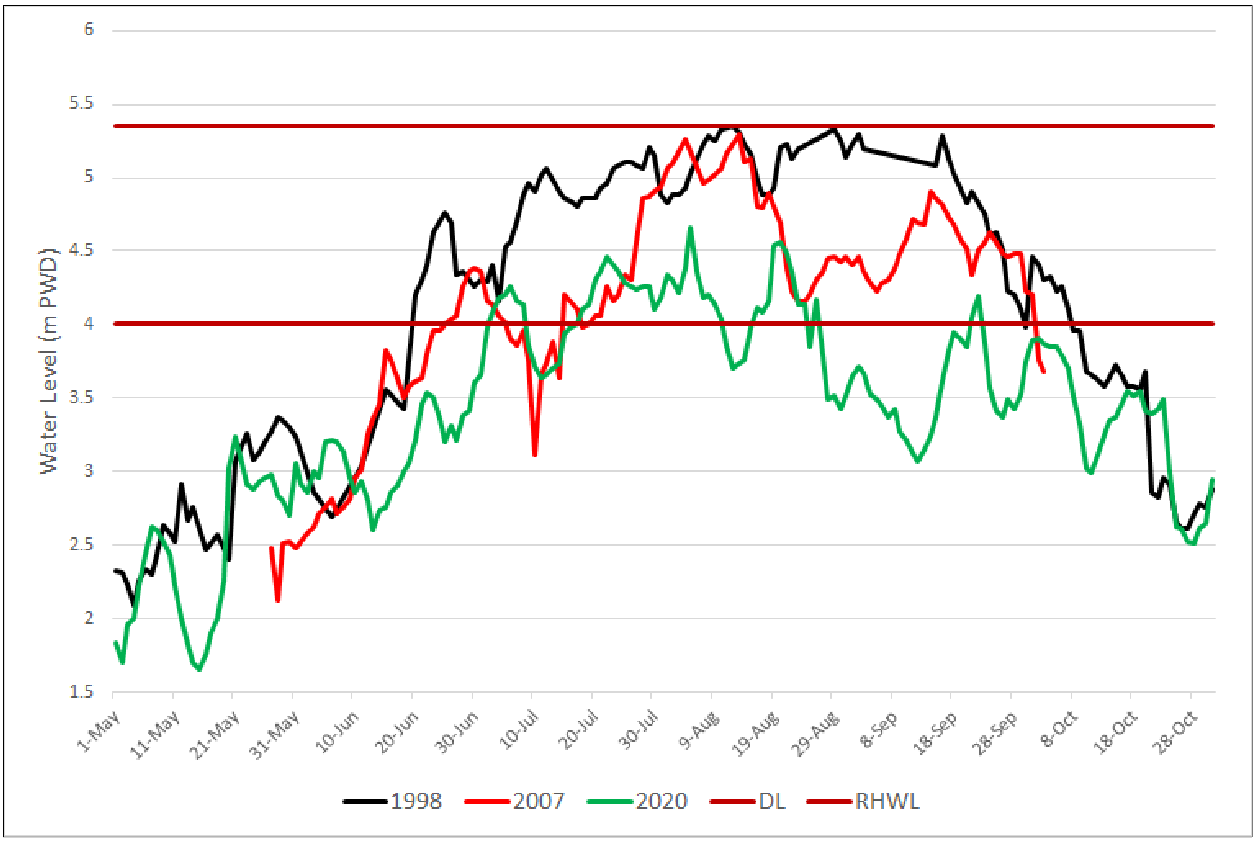


Figure 3.39: Comparison of Hydrograph on Meghna at Chandpur

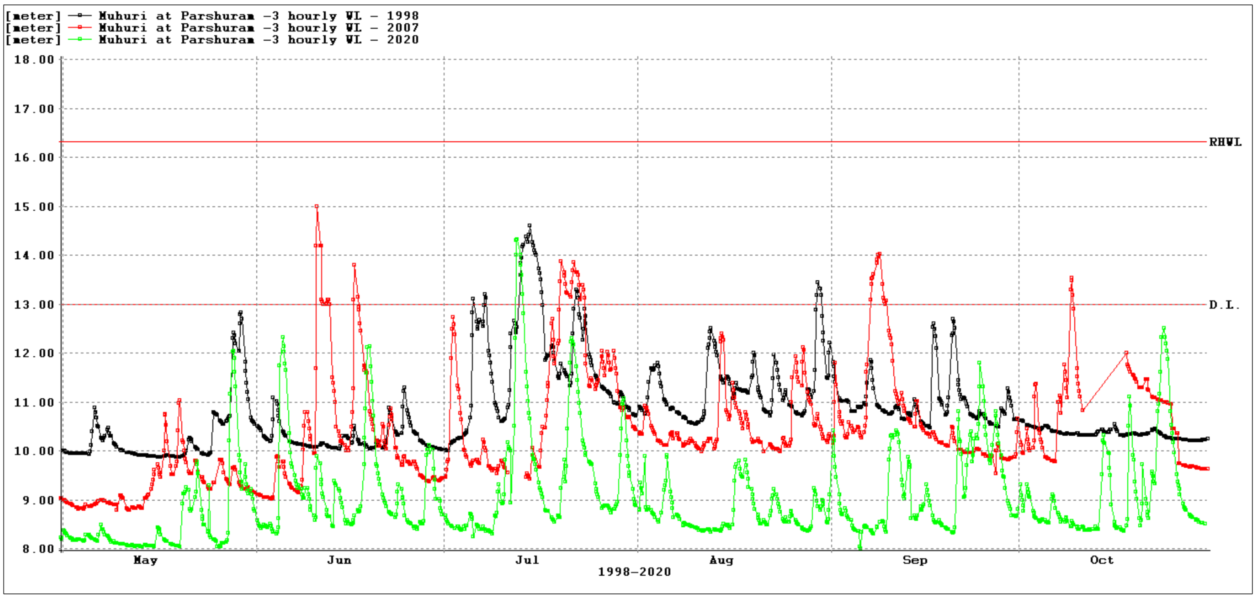


Figure 3.40: Comparison of Hydrograph on Muhuri at Parshuram

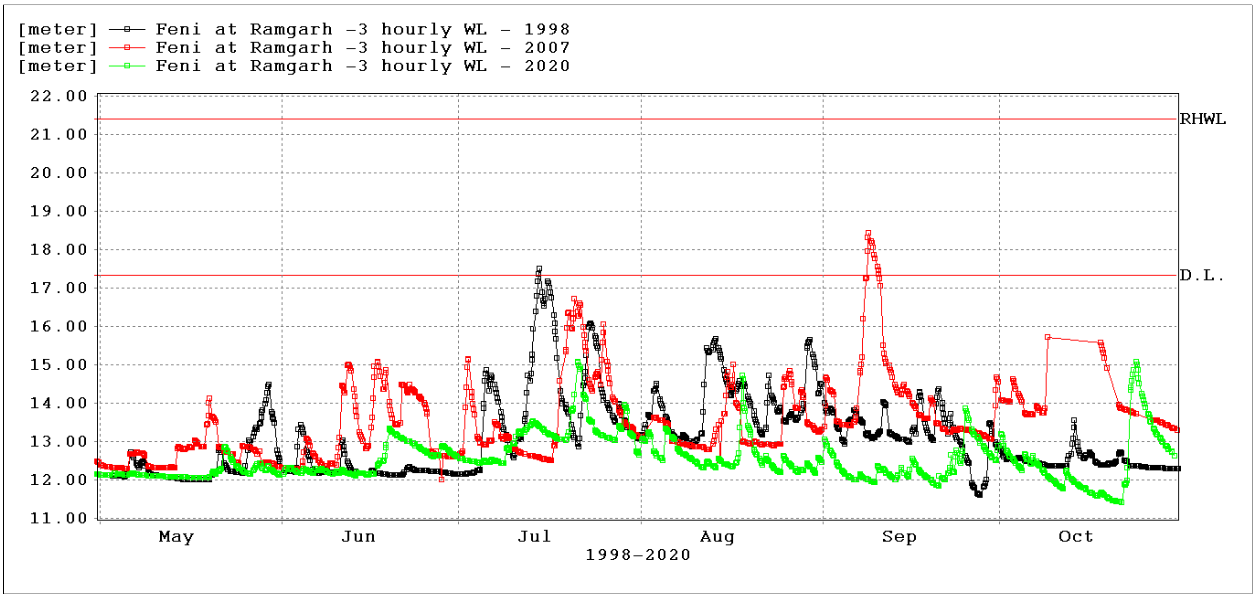


Figure 3.41: Comparison of Hydrograph on Feni at Ramgarh

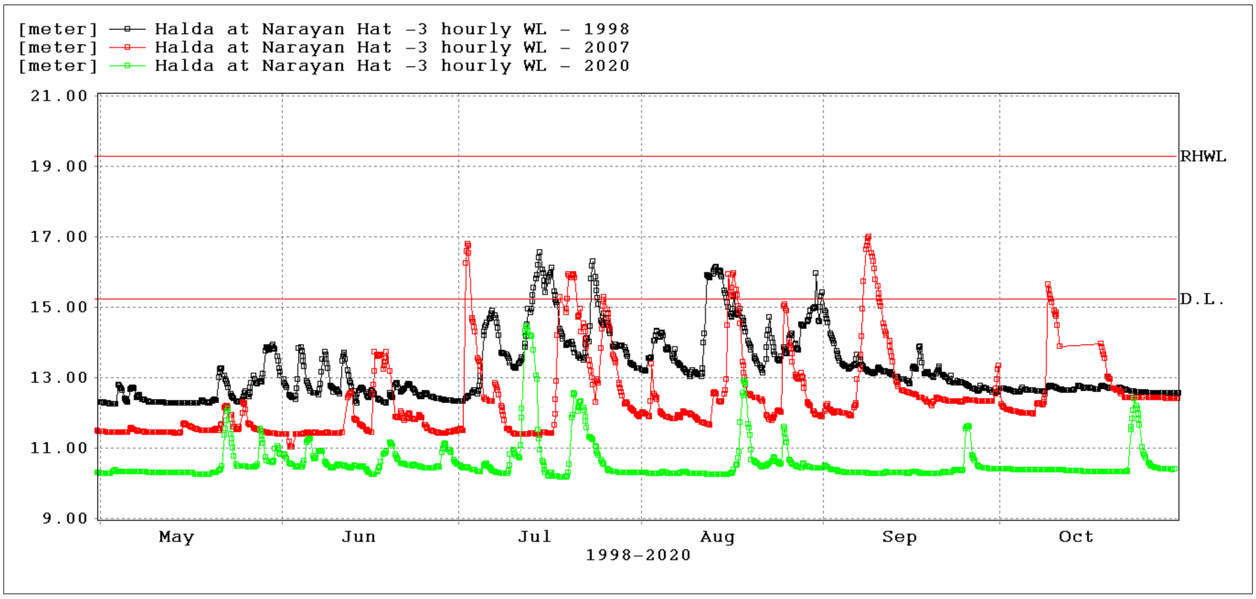


Figure 3.42: Comparison of Hydrograph on Halda at Narayanhat

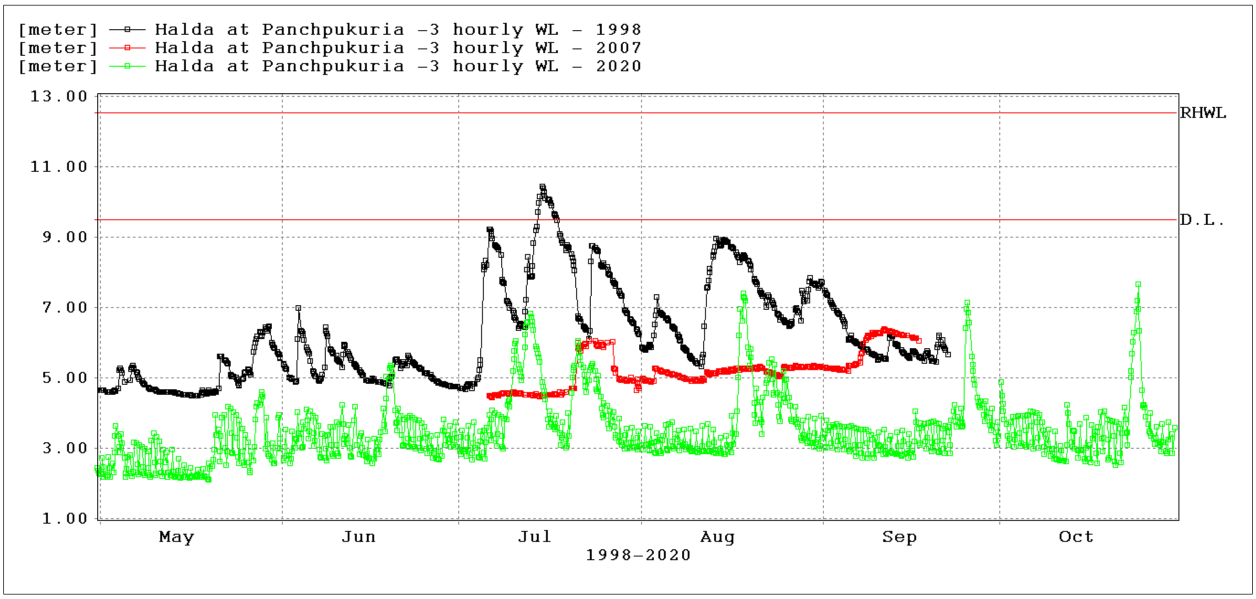


Figure 3.43: Comparison of Hydrograph on Halda at Panchpukuria

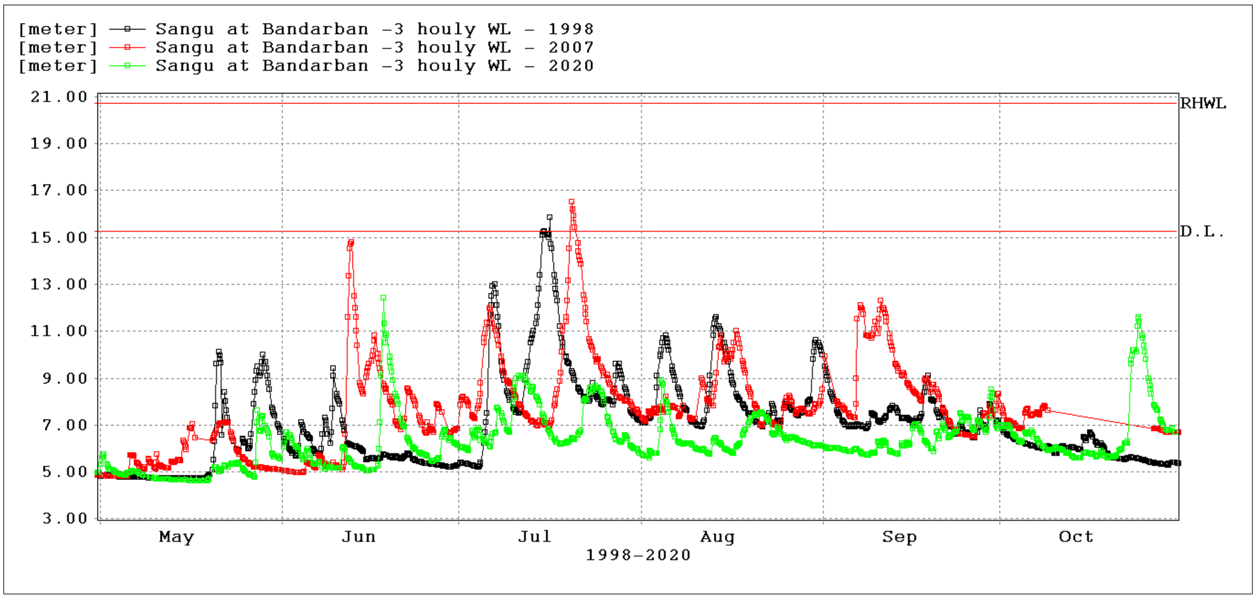


Figure 3.44: Comparison of Hydrograph on Sangu at Bandarban

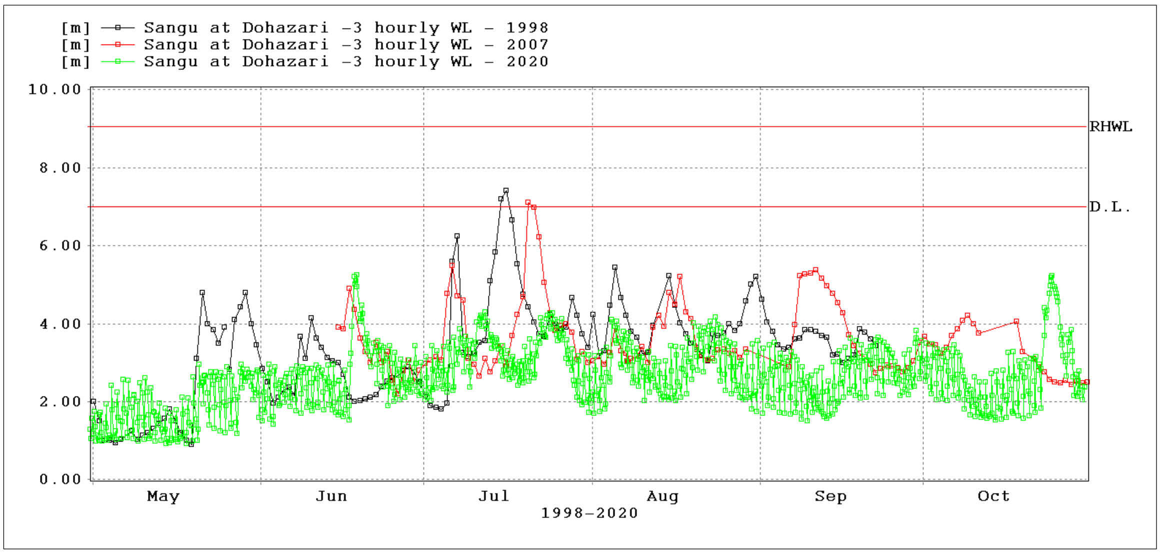


Figure 3.45: Comparison of Hydrograph on Sangu at Dohazari

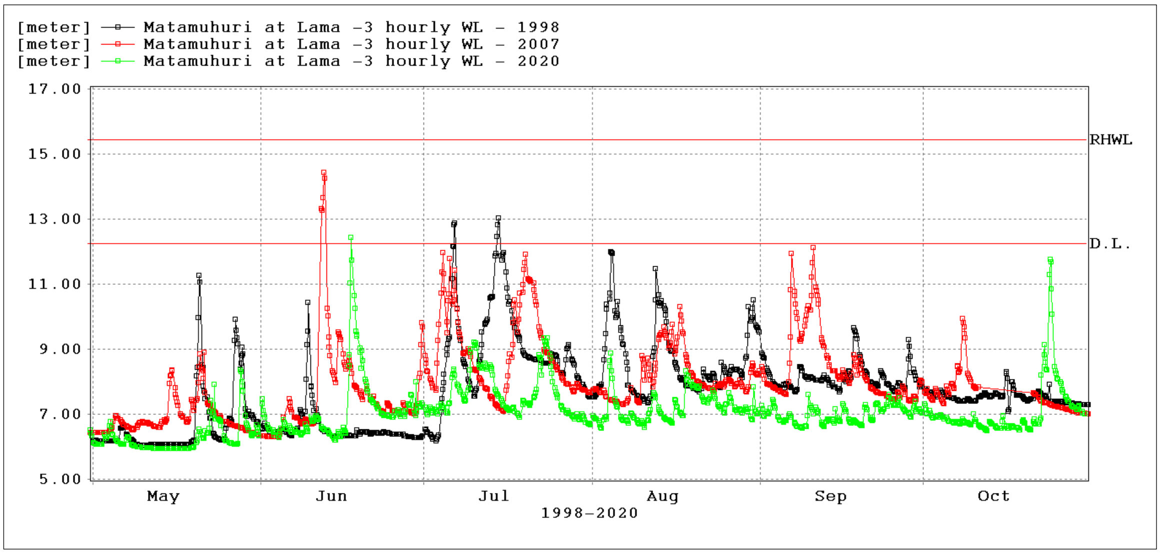


Figure 3.46: Comparison of Hydrograph on Matamuhuri at Lama

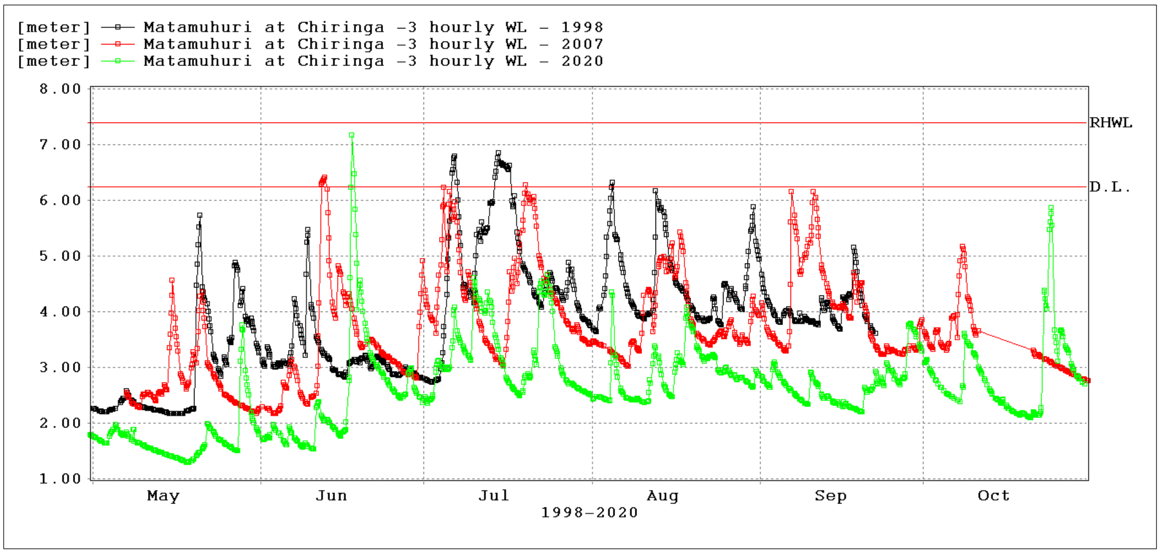


Figure 3.47: Comparison of Hydrograph on Matamuhuri at Chiringa

CHAPTER 4 : FORECAST EVALUATION, 2020

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 in 54 stations during monsoon which is currently continuing 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, Cooperative for American Relief Everywhere (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 SHOUHARDO-II programme with technical support from RIMES. Currently FFWC is generating medium range 10-days probabilistic flood forecast in 37 stations of Ganges-Brahmaputra basin during monsoon.

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:

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

Where,

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

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

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

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

n is the number of *Observed/Forecast* levels

4.2 PRE-DEFINED SCALES TO EVALUATE FORECAST PERFORMANCE

The forecast performances for the monsoon-2020 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, 2020

4.3.1 Deterministic Forecast Performance

For deterministic forecasts, simulations were made up to 120 hours (5-days) in the forecast period. Total 52 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, 94% stations are within the range of Good and Average. For 2-days, 3-days, 4-days and 5-days forecast respectively 81%, 67%, 48% and 31% 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 95%, 91%, 87%, 83% and 78% consistent for 24, 48, 72, 96 and 120 hours of lead time in the monsoon of 2020. Average MAE for 24, 48, 72, 96 and 120 hours of lead time forecasts are 0.08, 0.14, 0.20, 0.25 and 0.30 m respectively.

Table 4.2: Statistics for 24-hours Forecast Performance (Year, 2020)

Sl. No.	Station	MAE (m)	r^2	Performance-24hrs
1	Aricha	0.07	0.99	Good
2	Atrai	0.09	0.97	Good
3	Baghabari	0.04	1.00	Good
4	Bahadurabad	0.05	0.99	Good
5	Baidyar Bazar	0.12	0.92	Good
6	Bhagyakul	0.04	0.99	Good
7	Bhairabbazar	0.05	0.98	Good
8	Bogura	0.20	0.89	Average
9	Chakrahimpur	0.15	0.98	Good
10	Chilmari	0.06	0.99	Good
11	Chapai-Nawabganj	0.06	1.00	Good
12	Demra	0.05	0.99	Good
13	Derai	0.05	0.97	Good
14	Dhaka	0.09	0.96	Good
15	Elasin	0.05	1.00	Good
16	Gaibandha	0.10	0.98	Good
17	Goalondo	0.04	1.00	Good
18	Gorai-RB	0.05	1.00	Good
19	Hardinge-RB	0.05	1.00	Good
20	Hariharpara	0.08	0.97	Good
21	Jagir	0.06	1.00	Good
22	Jamalpur	0.12	0.99	Good
23	Kamarkhali	0.04	1.00	Good
24	Kaunia	0.14	0.68	Not Satisfactory
25	Kazipur	0.05	0.99	Good
26	Khaliajuri	0.04	0.98	Good
27	Kurigram	0.12	0.96	Good
28	Lakhpur	0.06	0.99	Good
29	Markuli	0.07	0.89	Average
30	Mawa	0.04	1.00	Good
31	Meghna Bridge	0.14	0.92	Good
32	Mirpur	0.06	0.98	Good
33	Mohadebpur	0.23	0.95	Not Satisfactory
34	Moulvibazar	0.18	0.79	Average
35	Mymensingh	0.09	0.99	Good
36	Naogaon	0.09	0.99	Good
37	Narayanganj	0.08	0.96	Good
38	Narsingdi	0.06	0.98	Good
39	Nayarhat	0.05	1.00	Good
40	Rajshahi	0.04	1.00	Good
41	Rekabi-Bazar	0.08	0.96	Good
42	Sariakandi	0.05	1.00	Good
43	Serajganj	0.05	0.99	Good
44	Sheola	0.27	0.21	Very Poor
45	Sherpur-Sylhet	0.07	0.94	Good
46	Singra	0.04	0.99	Good
47	Sunamganj	0.11	0.94	Good
48	Sureshswar	0.08	0.95	Good
49	Sylhet	0.12	0.96	Good
50	Talbaria	0.05	1.00	Good
51	Taraghat	0.05	1.00	Good
52	Tongi	0.05	0.99	Good

Table 4.3: Statistics for 48-hours Forecast Performance (Year, 2020)

Sl. No.	Station	MAE (m)	r^2	Performance-48hrs
1	Aricha	0.11	0.97	Good
2	Atrai	0.16	0.93	Average
3	Baghabari	0.07	0.99	Good
4	Bahadurabad	0.12	0.98	Good
5	Baidyar Bazar	0.17	0.87	Average
6	Bhagyakul	0.07	0.99	Good
7	Bhairabbazar	0.09	0.96	Good
8	Bogura	0.38	0.68	Poor
9	Chakrahimpur	0.23	0.95	Not Satisfactory
10	Chilmari	0.12	0.96	Good
11	Chapai-Nawabganj	0.11	1.00	Good
12	Demra	0.09	0.97	Good
13	Derai	0.09	0.94	Good
14	Dhaka	0.15	0.90	Good
15	Elasin	0.09	0.99	Good
16	Gaibandha	0.18	0.95	Average
17	Goalondo	0.08	0.99	Good
18	Gorai-RB	0.08	1.00	Good
19	Hardinge-RB	0.09	1.00	Good
20	Hariharpara	0.12	0.94	Good
21	Jagir	0.11	0.98	Good
22	Jamalpur	0.20	0.96	Average
23	Kamarkhali	0.07	1.00	Good
24	Kaunia	0.18	0.56	Not Satisfactory
25	Kazipur	0.09	0.98	Good
26	Khaliajuri	0.08	0.96	Good
27	Kurigram	0.22	0.90	Not Satisfactory
28	Lakhpur	0.10	0.97	Good
29	Markuli	0.11	0.82	Average
30	Mawa	0.07	0.99	Good
31	Meghna Bridge	0.21	0.87	Not Satisfactory
32	Mirpur	0.11	0.96	Good
33	Mohadebpur	0.40	0.85	Poor
34	Moulvibazar	0.32	0.52	Poor
35	Mymensingh	0.18	0.97	Average
36	Naogaon	0.18	0.95	Average
37	Narayanganj	0.14	0.89	Average
38	Narsingdi	0.09	0.95	Good
39	Nayarhat	0.08	0.99	Good
40	Rajshahi	0.09	1.00	Good
41	Rekabi-Bazar	0.15	0.87	Average
42	Sariakandi	0.10	0.98	Good
43	Serajganj	0.09	0.98	Good
44	Sheola	0.40	0.16	Very Poor
45	Sherpur-Sylhet	0.11	0.88	Average
46	Singra	0.08	0.98	Good
47	Sunamganj	0.22	0.81	Not Satisfactory
48	Sureshswar	0.14	0.85	Average
49	Sylhet	0.25	0.88	Not Satisfactory
50	Talbaria	0.10	0.99	Good
51	Taraghat	0.09	0.99	Good
52	Tongi	0.08	0.98	Good

Table 4.4: Statistics for 72-hours Forecast Performance (Year, 2020)

Sl. No.	Station	MAE (m)	r^2	Performance-72hrs
1	Aricha	0.15	0.96	Good
2	Atrai	0.22	0.89	Not Satisfactory
3	Baghabari	0.10	0.98	Good
4	Bahadurabad	0.19	0.94	Average
5	Baidyar Bazar	0.21	0.81	Not Satisfactory
6	Bhagyakul	0.10	0.98	Good
7	Bhairabbazar	0.12	0.94	Good
8	Bogura	0.54	0.47	Very Poor
9	Chakrahimpur	0.31	0.93	Poor
10	Chilmari	0.19	0.91	Average
11	Chapai-Nawabganj	0.16	0.99	Average
12	Demra	0.12	0.95	Good
13	Derai	0.12	0.89	Average
14	Dhaka	0.19	0.82	Average
15	Elasin	0.12	0.97	Good
16	Gaibandha	0.27	0.90	Not Satisfactory
17	Goalondo	0.11	0.98	Good
18	Gorai-RB	0.12	0.99	Good
19	Hardinge-RB	0.15	0.99	Good
20	Hariharpara	0.15	0.91	Good
21	Jagir	0.16	0.97	Average
22	Jamalpur	0.26	0.94	Not Satisfactory
23	Kamarkhali	0.11	0.99	Good
24	Kaunia	0.23	0.45	Not Satisfactory
25	Kazipur	0.15	0.95	Good
26	Khaliajuri	0.11	0.92	Good
27	Kurigram	0.30	0.82	Not Satisfactory
28	Lakhpur	0.12	0.95	Good
29	Markuli	0.14	0.75	Average
30	Mawa	0.09	0.98	Good
31	Meghna Bridge	0.26	0.84	Not Satisfactory
32	Mirpur	0.14	0.94	Good
33	Mohadebpur	0.54	0.76	Very Poor
34	Moulvibazar	0.42	0.39	Very Poor
35	Mymensingh	0.26	0.95	Not Satisfactory
36	Naogaon	0.29	0.89	Not Satisfactory
37	Narayanganj	0.19	0.82	Average
38	Narsingdi	0.13	0.92	Good
39	Nayarhat	0.12	0.98	Good
40	Rajshahi	0.14	0.99	Good
41	Rekabi-Bazar	0.21	0.76	Not Satisfactory
42	Sariakandi	0.17	0.94	Average
43	Serajganj	0.13	0.95	Good
44	Sheola	0.56	0.15	Very Poor
45	Sherpur-Sylhet	0.14	0.83	Average
46	Singra	0.11	0.96	Good
47	Sunamganj	0.30	0.68	Not Satisfactory
48	Sureshswar	0.20	0.73	Average
49	Sylhet	0.37	0.79	Poor
50	Talbaria	0.15	0.99	Good
51	Taraghat	0.13	0.98	Good
52	Tongi	0.11	0.96	Good

Table 4.5: Statistics for 96-hours Forecast Performance (Year, 2020)

Sl. No.	Station	MAE (m)	r^2	Performance-96hrs
1	Aricha	0.17	0.95	Average
2	Atrai	0.28	0.85	Not Satisfactory
3	Baghabari	0.14	0.97	Good
4	Bahadurabad	0.26	0.89	Not Satisfactory
5	Baidyar Bazar	0.24	0.76	Not Satisfactory
6	Bhagyakul	0.13	0.96	Good
7	Bhairabbazar	0.15	0.92	Good
8	Bogura	0.66	0.31	Very Poor
9	Chakrahimpur	0.37	0.90	Poor
10	Chilmari	0.26	0.86	Not Satisfactory
11	Chapai-Nawabganj	0.21	0.98	Not Satisfactory
12	Demra	0.15	0.93	Good
13	Derai	0.16	0.84	Average
14	Dhaka	0.23	0.74	Not Satisfactory
15	Elasin	0.15	0.96	Good
16	Gaibandha	0.35	0.84	Poor
17	Goalondo	0.16	0.97	Average
18	Gorai-RB	0.16	0.99	Average
19	Hardinge-RB	0.20	0.98	Average
20	Hariharpara	0.18	0.86	Average
21	Jagir	0.21	0.94	Not Satisfactory
22	Jamalpur	0.32	0.92	Poor
23	Kamarkhali	0.14	0.99	Good
24	Kaunia	0.25	0.40	Not Satisfactory
25	Kazipur	0.21	0.91	Not Satisfactory
26	Khaliajuri	0.15	0.88	Average
27	Kurigram	0.37	0.77	Poor
28	Lakhpur	0.15	0.94	Good
29	Markuli	0.18	0.65	Not Satisfactory
30	Mawa	0.12	0.97	Good
31	Meghna Bridge	0.30	0.79	Not Satisfactory
32	Mirpur	0.18	0.91	Average
33	Mohadebpur	0.68	0.66	Very Poor
34	Moulvibazar	0.47	0.32	Very Poor
35	Mymensingh	0.33	0.92	Poor
36	Naogaon	0.42	0.82	Very Poor
37	Narayanganj	0.23	0.74	Not Satisfactory
38	Narsingdi	0.16	0.89	Average
39	Nayarhat	0.15	0.97	Good
40	Rajshahi	0.20	0.98	Average
41	Rekabi-Bazar	0.26	0.66	Not Satisfactory
42	Sariakandi	0.23	0.90	Not Satisfactory
43	Serajganj	0.19	0.91	Average
44	Sheola	0.68	0.15	Very Poor
45	Sherpur-Sylhet	0.17	0.77	Average
46	Singra	0.16	0.93	Average
47	Sunamganj	0.38	0.55	Poor
48	Sureshswar	0.25	0.63	Not Satisfactory
49	Sylhet	0.46	0.69	Very Poor
50	Talbaria	0.19	0.98	Average
51	Taraghat	0.16	0.97	Average
52	Tongi	0.14	0.93	Good

Table 4.6: Statistics for 120-hours Forecast Performance (Year, 2020)

Sl. No.	Station	MAE (m)	r^2	Performance-120hrs
1	Aricha	0.2	0.94	Average
2	Atrai	0.34	0.82	Poor
3	Baghabari	0.16	0.95	Average
4	Bahadurabad	0.32	0.85	Poor
5	Baidyar Bazar	0.26	0.72	Not Satisfactory
6	Bhagyakul	0.17	0.95	Average
7	Bhairabbazar	0.18	0.88	Average
8	Bogura	0.78	0.19	Very Poor
9	Chakrahimpur	0.43	0.86	Very Poor
10	Chilmari	0.32	0.81	Poor
11	Chapai-Nawabganj	0.27	0.98	Not Satisfactory
12	Demra	0.18	0.9	Average
13	Derai	0.19	0.8	Average
14	Dhaka	0.26	0.68	Not Satisfactory
15	Elasin	0.19	0.94	Average
16	Gaibandha	0.4	0.81	Poor
17	Goalondo	0.2	0.95	Average
18	Gorai-RB	0.21	0.98	Not Satisfactory
19	Hardinge-RB	0.26	0.97	Not Satisfactory
20	Hariharpara	0.22	0.83	Not Satisfactory
21	Jagir	0.26	0.92	Not Satisfactory
22	Jamalpur	0.37	0.9	Poor
23	Kamarkhali	0.18	0.98	Average
24	Kaunia	0.25	0.4	Not Satisfactory
25	Kazipur	0.26	0.87	Not Satisfactory
26	Khaliajuri	0.18	0.84	Average
27	Kurigram	0.43	0.71	Very Poor
28	Lakhpur	0.17	0.92	Average
29	Markuli	0.22	0.53	Not Satisfactory
30	Mawa	0.15	0.95	Good
31	Meghna Bridge	0.34	0.76	Poor
32	Mirpur	0.21	0.89	Not Satisfactory
33	Mohadebpur	0.81	0.54	Very Poor
34	Moulvibazar	0.53	0.22	Very Poor
35	Mymensingh	0.38	0.9	Poor
36	Naogaon	0.55	0.75	Very Poor
37	Narayanganj	0.27	0.68	Not Satisfactory
38	Narsingdi	0.19	0.85	Average
39	Nayarhat	0.19	0.95	Average
40	Rajshahi	0.26	0.97	Not Satisfactory
41	Rekabi-Bazar	0.3	0.58	Not Satisfactory
42	Sariakandi	0.29	0.86	Not Satisfactory
43	Serajganj	0.24	0.88	Not Satisfactory
44	Sheola	0.77	0.12	Very Poor
45	Sherpur-Sylhet	0.2	0.69	Not Satisfactory
46	Singra	0.23	0.9	Not Satisfactory
47	Sunamganj	0.44	0.46	Very Poor
48	Sureshswar	0.3	0.55	Not Satisfactory
49	Sylhet	0.53	0.58	Very Poor
50	Talbaria	0.24	0.97	Not Satisfactory
51	Taraghat	0.19	0.96	Average
52	Tongi	0.16	0.91	Average

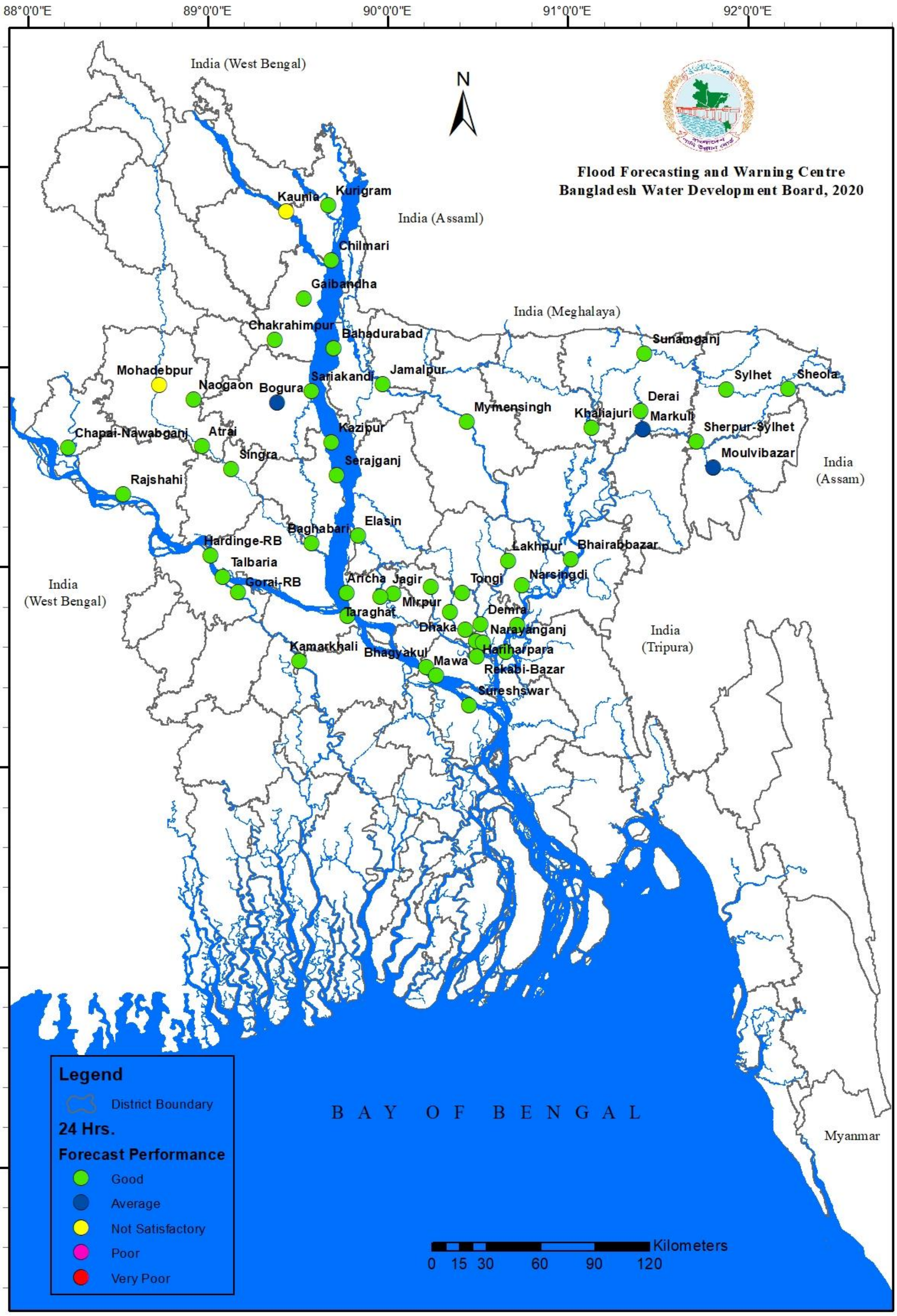


Figure 4.1 : 24-hrs Forecast Evaluation (Year, 2020)

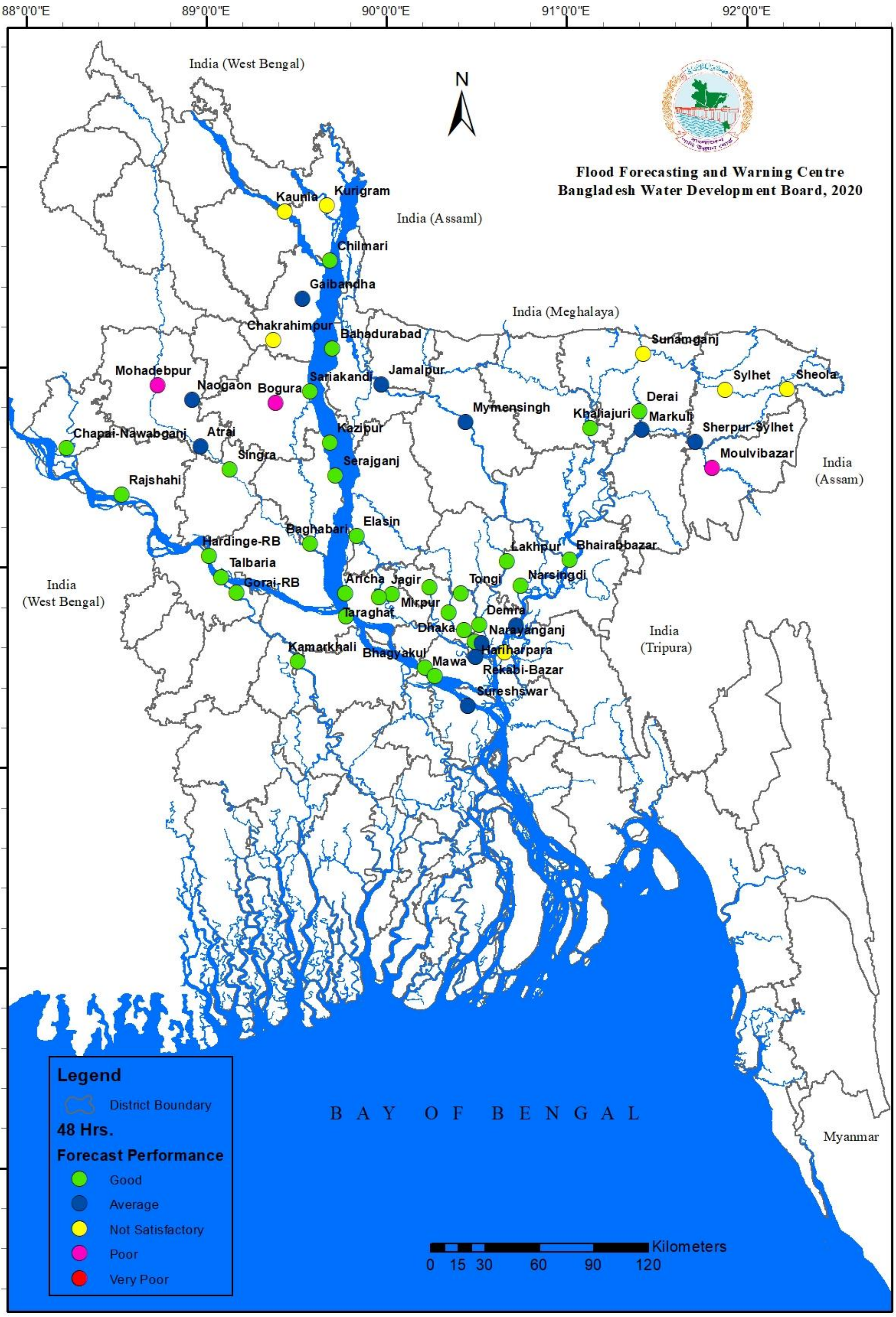


Figure 4.2 : 48-hrs Forecast Evaluation (Year, 2020)

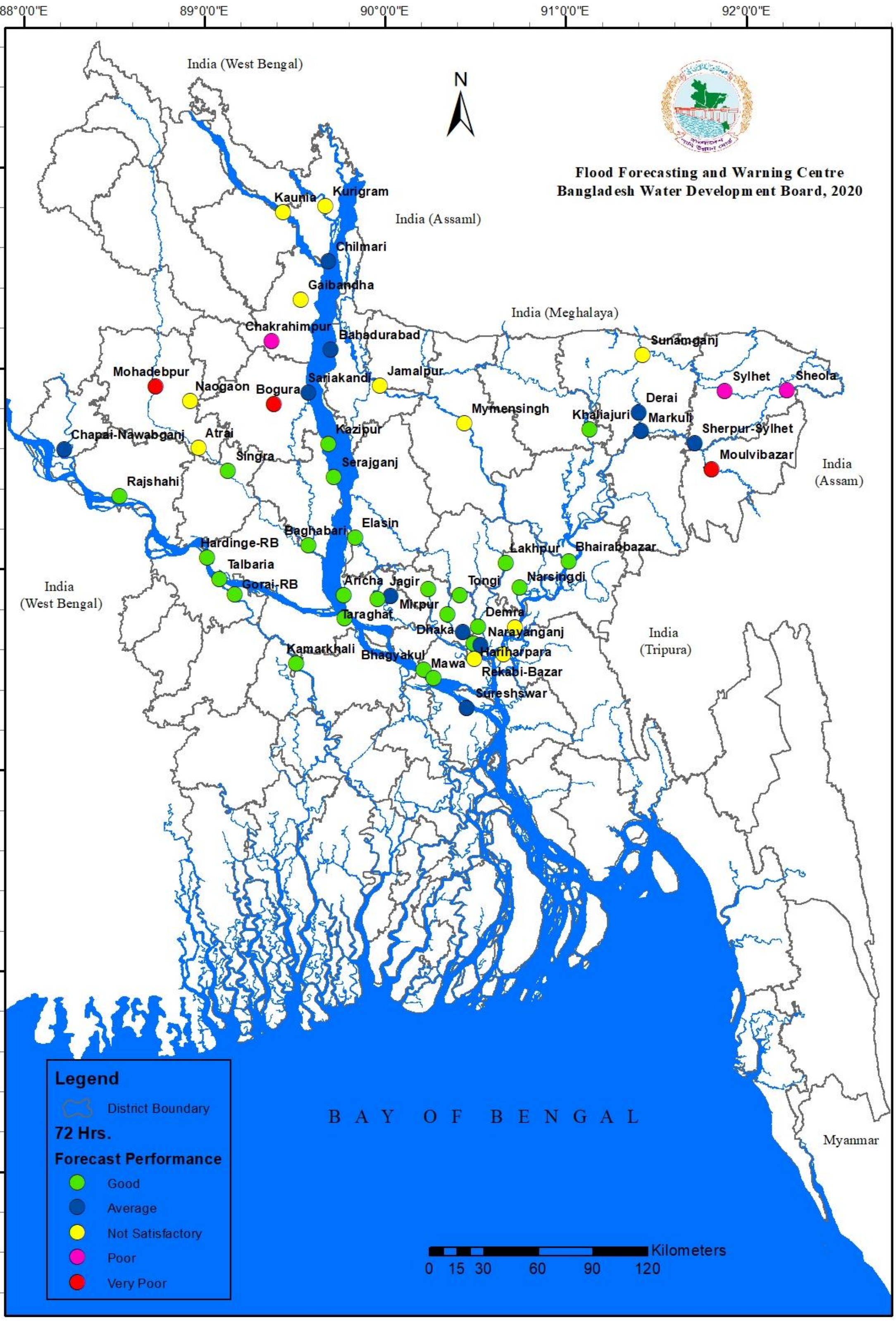


Figure 4.3 : 72-hrs Forecast Evaluation (Year, 2020)

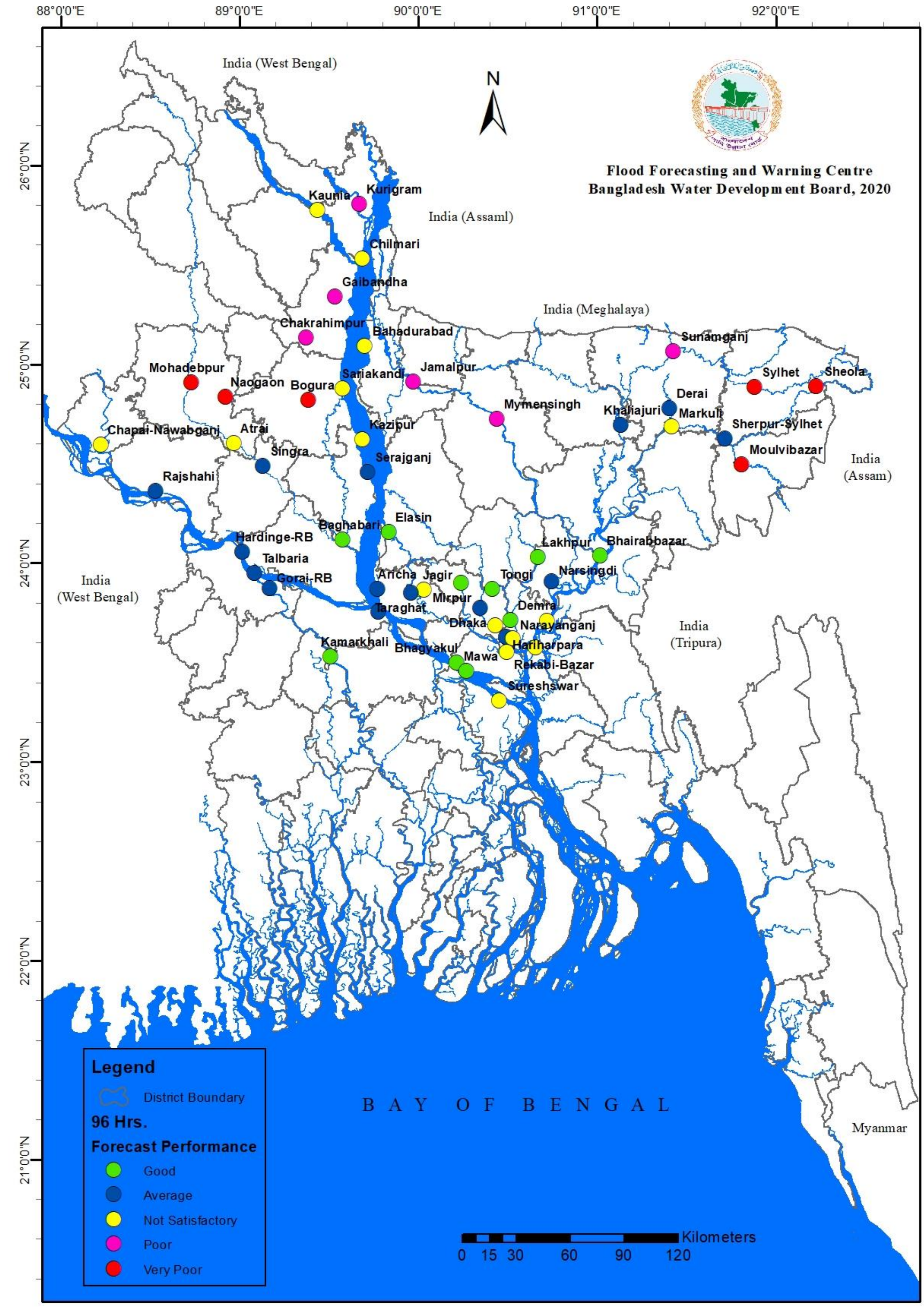


Figure 4.4 : 96-hrs Forecast Evaluation (Year, 2020)

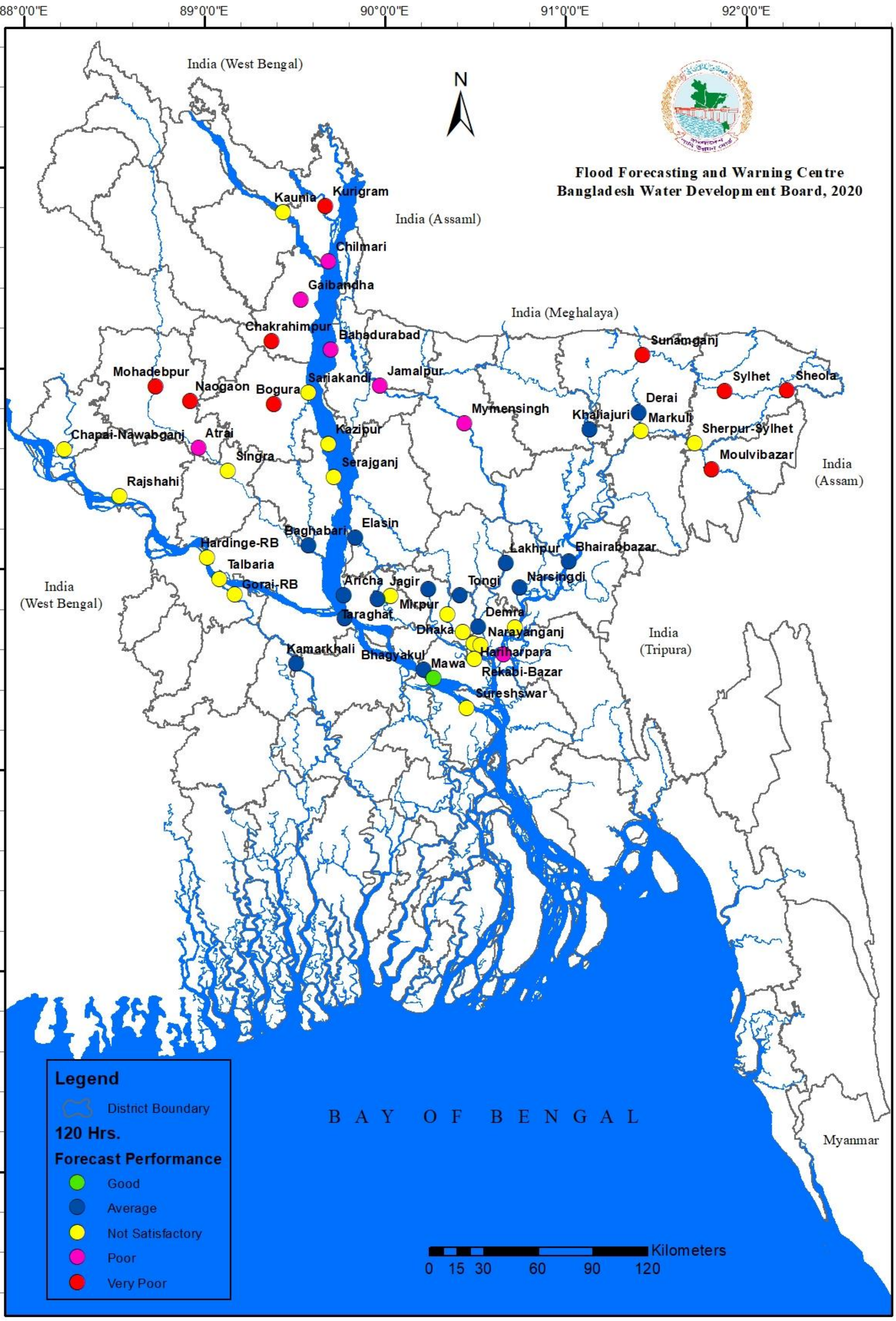


Figure 4.5 : 120-hrs Forecast Evaluation (Year, 2020)

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

Climate Forecast Application Network (CFAN) utilizes ECMWF 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 Flood Forecasting Study (CFAB-FFS) 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 forecast performance based on the MAE, RMSE and r^2 at different time-scale up to 10 days for the 37 number of stations under FFWC system have been presented through Table 4.7 to Table 4.10.

Table 4.7 : Performance of 3-day Probabilistic Forecast (Year, 2020)

	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
Stations	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2
Aricha	0.12	0.17	0.97	0.12	0.17	0.97	0.13	0.17	0.97
Baghbari	0.27	0.38	0.84	0.27	0.37	0.84	0.27	0.37	0.84
Bahadurabad	0.22	0.27	0.91	0.22	0.28	0.91	0.23	0.29	0.92
Bhagyakul	0.11	0.14	0.97	0.11	0.14	0.97	0.11	0.14	0.97
Bhairab Bazar	0.13	0.16	0.97	0.13	0.16	0.97	0.13	0.16	0.97
Chandpur	0.37	0.46	0.41	0.37	0.46	0.41	0.37	0.46	0.41
Demra	0.20	0.24	0.94	0.20	0.24	0.94	0.20	0.24	0.94
Dhaka	0.17	0.22	0.90	0.17	0.22	0.90	0.17	0.22	0.90
Dirai	0.22	0.29	0.69	0.22	0.29	0.69	0.22	0.29	0.69
Elashinghat	0.18	0.24	0.95	0.18	0.24	0.95	0.18	0.23	0.95
Faridpur	0.08	0.11	0.97	0.08	0.11	0.97	0.08	0.11	0.97
Goalondo	0.13	0.17	0.97	0.13	0.17	0.97	0.13	0.17	0.97
Gorai Rly. Bridge	0.23	0.34	0.98	0.23	0.32	0.98	0.22	0.31	0.98
Hardinge Bridge	0.24	0.35	0.97	0.23	0.33	0.97	0.22	0.31	0.97
Jagir	0.20	0.26	0.96	0.21	0.26	0.96	0.21	0.26	0.96
Jamalpur	0.29	0.36	0.94	0.29	0.36	0.94	0.29	0.36	0.94
Kamarkhali	0.18	0.28	0.98	0.18	0.27	0.98	0.18	0.26	0.98
Kanaighat	3.22	3.31	0.63	3.22	3.31	0.63	3.22	3.31	0.63
Kazipur	0.20	0.27	0.90	0.20	0.26	0.90	0.20	0.26	0.90
Madaripur	0.11	0.14	0.96	0.11	0.14	0.96	0.11	0.14	0.96

Stations	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2
Mawa	0.09	0.12	0.98	0.09	0.12	0.98	0.09	0.12	0.98
Mirpur	0.14	0.18	0.95	0.14	0.18	0.95	0.14	0.18	0.95
Mohadevpur	0.76	0.94	0.65	0.76	0.94	0.65	0.76	0.94	0.65
Moulvibazar	1.71	1.87	0.36	1.71	1.87	0.36	1.71	1.87	0.36
Mymensingh	0.38	0.45	0.92	0.38	0.45	0.92	0.38	0.45	0.92
Naogaon	0.36	0.47	0.88	0.36	0.47	0.88	0.36	0.47	0.88
Narayanganj	0.19	0.25	0.87	0.20	0.25	0.87	0.20	0.25	0.87
Narsingdi	0.13	0.16	0.95	0.13	0.16	0.95	0.13	0.16	0.95
RekabiBazar	0.18	0.24	0.85	0.19	0.24	0.85	0.19	0.24	0.85
Sariakandi	0.24	0.30	0.90	0.24	0.29	0.91	0.24	0.29	0.91
Serajganj	0.18	0.23	0.92	0.18	0.23	0.93	0.19	0.24	0.92
Sheola	3.89	3.94	0.72	3.89	3.94	0.72	3.89	3.94	0.72
Sherpur	0.86	0.95	0.88	0.86	0.95	0.88	0.86	0.95	0.88
Sunamganj	0.63	0.78	0.39	0.63	0.78	0.39	0.63	0.79	0.39
Sureshwar	0.16	0.21	0.84	0.16	0.21	0.84	0.16	0.21	0.84
Sylhet	1.80	1.90	0.69	1.80	1.90	0.69	1.80	1.89	0.69
Tongi	0.16	0.19	0.96	0.16	0.19	0.96	0.16	0.19	0.96

Table 4.8 : Performance of 5-day Probabilistic Forecast (Year, 2020)

Stations	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2
Aricha	0.22	0.29	0.92	0.23	0.29	0.92	0.25	0.31	0.92
Baghbari	0.36	0.46	0.76	0.35	0.45	0.76	0.35	0.43	0.76
Bahadurabad	0.35	0.42	0.81	0.38	0.45	0.83	0.42	0.49	0.84
Bhagyakul	0.20	0.25	0.92	0.21	0.25	0.92	0.22	0.26	0.92
Bhairab Bazar	0.20	0.23	0.93	0.20	0.24	0.93	0.20	0.24	0.93
Chandpur	0.51	0.60	0.15	0.51	0.60	0.15	0.51	0.60	0.15
Demra	0.31	0.37	0.88	0.32	0.38	0.88	0.32	0.38	0.88
Dhaka	0.23	0.28	0.87	0.23	0.29	0.87	0.24	0.30	0.87
Dirai	0.29	0.39	0.48	0.29	0.39	0.48	0.29	0.39	0.48
Elashinghat	0.28	0.38	0.88	0.27	0.36	0.88	0.28	0.36	0.88
Faridpur	0.12	0.16	0.94	0.12	0.16	0.94	0.12	0.16	0.94
Goalondo	0.24	0.31	0.91	0.24	0.30	0.91	0.26	0.31	0.91
Gorai Rly. Bridge	0.31	0.43	0.96	0.28	0.39	0.96	0.27	0.36	0.96
Hardinge Bridge	0.31	0.40	0.95	0.29	0.35	0.96	0.27	0.33	0.96
Jagir	0.29	0.37	0.92	0.30	0.37	0.92	0.30	0.37	0.92
Jamalpur	0.41	0.50	0.90	0.43	0.52	0.90	0.45	0.54	0.90
Kamarkhali	0.25	0.35	0.96	0.24	0.33	0.96	0.23	0.31	0.96
Kanaighat	3.32	3.47	0.44	3.32	3.47	0.44	3.32	3.47	0.44
Kazipur	0.35	0.44	0.78	0.35	0.43	0.79	0.36	0.44	0.80

Stations	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2
Madaripur	0.15	0.19	0.92	0.15	0.20	0.92	0.15	0.20	0.92
Mawa	0.20	0.26	0.91	0.20	0.25	0.91	0.21	0.25	0.92
Mirpur	0.20	0.25	0.92	0.21	0.26	0.92	0.22	0.27	0.92
Mohadevpur	0.90	1.09	0.51	0.90	1.09	0.51	0.90	1.09	0.51
Moulvibazar	1.48	1.68	0.22	1.49	1.70	0.23	1.49	1.70	0.23
Mymensingh	0.52	0.62	0.86	0.52	0.62	0.86	0.52	0.62	0.86
Naogaon	0.52	0.66	0.79	0.52	0.66	0.79	0.52	0.66	0.79
Narayanganj	0.28	0.35	0.80	0.29	0.36	0.81	0.30	0.37	0.81
Narsingdi	0.22	0.26	0.90	0.22	0.26	0.90	0.22	0.26	0.90
RekabiBazar	0.26	0.34	0.75	0.28	0.35	0.75	0.28	0.35	0.75
Sariakandi	0.39	0.49	0.80	0.39	0.48	0.81	0.40	0.48	0.81
Serajganj	0.32	0.43	0.83	0.33	0.44	0.84	0.37	0.47	0.84
Sheola	4.25	4.32	0.62	4.25	4.32	0.62	4.25	4.32	0.62
Sherpur	1.18	1.28	0.76	1.18	1.28	0.76	1.18	1.28	0.75
Sunamganj	0.85	1.04	0.20	0.85	1.04	0.20	0.85	1.05	0.19
Sureshwar	0.22	0.28	0.74	0.22	0.28	0.74	0.23	0.29	0.74
Sylhet	2.07	2.19	0.51	2.07	2.19	0.51	2.07	2.19	0.51
Tongi	0.24	0.28	0.92	0.25	0.29	0.92	0.25	0.30	0.92

Table 4.9 : Performance of 7-day Probabilistic Forecast (Year, 2020)

Stations	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2
Aricha	0.34	0.43	0.87	0.36	0.44	0.87	0.40	0.48	0.88
Baghbari	0.44	0.55	0.70	0.41	0.51	0.71	0.41	0.50	0.71
Bahadurabad	0.46	0.54	0.76	0.52	0.61	0.79	0.62	0.71	0.80
Bhagyakul	0.28	0.35	0.88	0.29	0.35	0.88	0.33	0.38	0.88
Bhairab Bazar	0.26	0.31	0.90	0.27	0.32	0.90	0.28	0.33	0.89
Chandpur	0.59	0.67	0.10	0.59	0.67	0.10	0.59	0.67	0.10
Demra	0.40	0.49	0.80	0.42	0.50	0.80	0.44	0.52	0.80
Dhaka	0.27	0.32	0.87	0.29	0.35	0.87	0.32	0.37	0.87
Dirai	0.36	0.49	0.28	0.36	0.49	0.28	0.36	0.49	0.28
Elashinghat	0.37	0.52	0.83	0.37	0.50	0.82	0.42	0.53	0.81
Faridpur	0.16	0.20	0.90	0.16	0.20	0.90	0.16	0.20	0.90
Goalondo	0.34	0.43	0.87	0.35	0.43	0.87	0.38	0.45	0.87
Gorai Rly. Bridge	0.38	0.53	0.93	0.35	0.46	0.93	0.33	0.42	0.93
Hardinge Bridge	0.39	0.53	0.91	0.37	0.48	0.91	0.38	0.47	0.91
Jagir	0.36	0.45	0.89	0.38	0.46	0.89	0.39	0.47	0.89
Jamalpur	0.56	0.68	0.84	0.62	0.72	0.85	0.70	0.80	0.85
Kamarkhali	0.32	0.44	0.93	0.29	0.39	0.93	0.28	0.37	0.93
Kanaighat	3.10	3.30	0.35	3.10	3.30	0.35	3.10	3.30	0.35

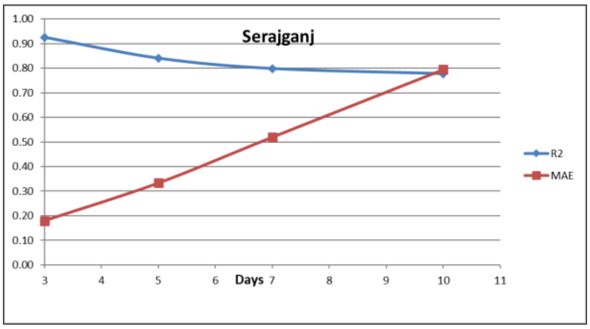
Kazipur	0.46	0.58	0.73	0.47	0.58	0.74	0.52	0.62	0.75
Madaripur	0.20	0.25	0.88	0.21	0.26	0.88	0.22	0.29	0.88
Mawa	0.29	0.37	0.85	0.29	0.35	0.86	0.32	0.36	0.86
Mirpur	0.28	0.35	0.85	0.30	0.37	0.85	0.32	0.39	0.84
Mohadevpur	0.89	1.06	0.52	0.89	1.06	0.52	0.89	1.06	0.52
Moulvibazar	1.31	1.59	0.10	1.31	1.59	0.10	1.30	1.58	0.09
Mymensingh	0.65	0.80	0.77	0.65	0.80	0.78	0.66	0.81	0.78
Naogaon	0.60	0.79	0.71	0.60	0.79	0.71	0.60	0.79	0.71
Narayanganj	0.36	0.43	0.78	0.38	0.45	0.78	0.40	0.47	0.78
Narsingdi	0.29	0.35	0.84	0.29	0.35	0.84	0.29	0.35	0.84
RekabiBazar	0.32	0.39	0.70	0.36	0.44	0.70	0.36	0.44	0.70
Sariakandi	0.49	0.64	0.75	0.50	0.62	0.76	0.55	0.66	0.77
Serajganj	0.46	0.62	0.79	0.52	0.65	0.80	0.62	0.73	0.81
Sheola	4.16	4.27	0.49	4.16	4.27	0.49	4.16	4.27	0.49
Sherpur	1.29	1.39	0.55	1.29	1.39	0.55	1.28	1.39	0.54
Sunamganj	0.88	1.04	0.22	0.87	1.03	0.24	0.88	1.04	0.22
Sureshwar	0.25	0.30	0.73	0.28	0.33	0.73	0.31	0.37	0.73
Sylhet	2.09	2.23	0.41	2.09	2.23	0.41	2.09	2.23	0.40
Tongi	0.33	0.38	0.88	0.34	0.40	0.87	0.36	0.42	0.86

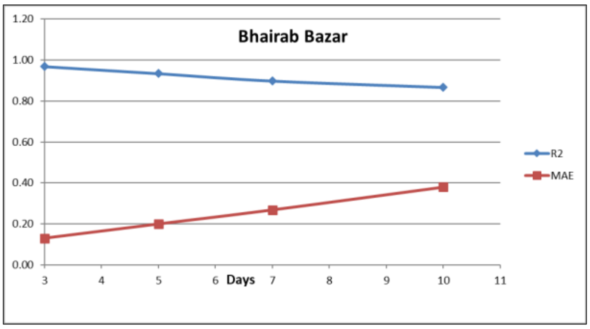
Table 4.10 : Performance of 10-day Probabilistic Forecast (Year, 2020)

Stations	Standard Deviation (-1)			Mean			Standard Deviation (+1)		
	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2	MAE (m)	RMSE (m)	R^2
Aricha	0.45	0.59	0.86	0.51	0.61	0.88	0.63	0.70	0.89
Baghbari	0.50	0.65	0.69	0.50	0.59	0.69	0.54	0.60	0.69
Bahadurabad	0.57	0.70	0.73	0.73	0.83	0.75	0.92	0.99	0.76
Bhagyakul	0.36	0.45	0.87	0.42	0.48	0.87	0.52	0.57	0.88
Bhairab Bazar	0.35	0.40	0.87	0.38	0.43	0.87	0.42	0.48	0.86
Chandpur	0.56	0.64	0.25	0.56	0.64	0.25	0.56	0.64	0.25
Demra	0.54	0.65	0.68	0.58	0.69	0.68	0.63	0.73	0.67
Dhaka	0.32	0.37	0.88	0.38	0.43	0.87	0.44	0.50	0.86
Dirai	0.42	0.55	0.15	0.42	0.55	0.15	0.42	0.55	0.15
Elashinghat	0.48	0.70	0.80	0.53	0.67	0.80	0.64	0.74	0.78
Faridpur	0.22	0.28	0.81	0.22	0.28	0.81	0.22	0.28	0.81
Goalondo	0.44	0.57	0.85	0.48	0.58	0.86	0.58	0.65	0.87
Gorai Rly. Bridge	0.41	0.63	0.88	0.39	0.55	0.88	0.41	0.53	0.88
Hardinge Bridge	0.45	0.70	0.85	0.46	0.64	0.85	0.53	0.66	0.84
Jagir	0.47	0.57	0.85	0.52	0.60	0.85	0.57	0.66	0.85
Jamalpur	0.74	0.89	0.82	0.90	1.04	0.83	1.12	1.23	0.83
Kamarkhali	0.34	0.51	0.90	0.32	0.44	0.90	0.35	0.44	0.90
Kanaighat	2.71	2.95	0.27	2.71	2.95	0.27	2.71	2.95	0.27
Kazipur	0.56	0.73	0.71	0.64	0.76	0.74	0.77	0.88	0.76
Madaripur	0.27	0.33	0.84	0.30	0.37	0.83	0.36	0.43	0.82

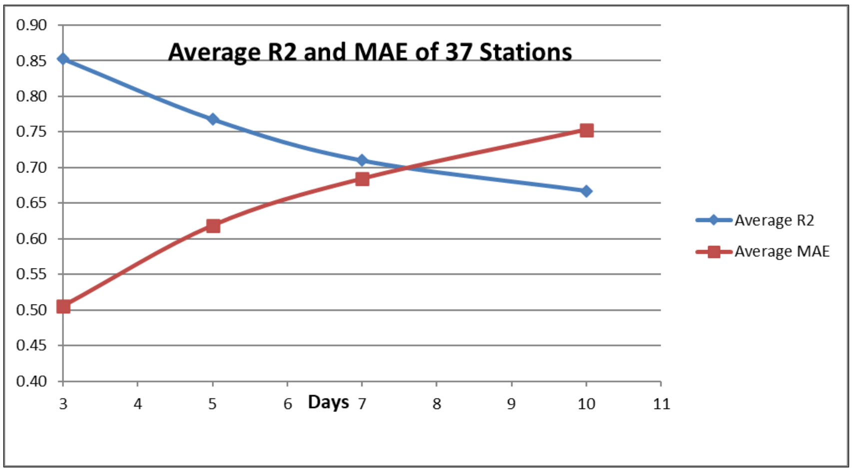
Mawa	0.38	0.44	0.84	0.40	0.44	0.84	0.46	0.50	0.84
Mirpur	0.39	0.47	0.77	0.44	0.52	0.76	0.50	0.59	0.74
Mohadevpur	1.00	1.21	0.48	1.00	1.21	0.48	1.00	1.21	0.48
Moulvibazar	1.12	1.42	0.07	1.12	1.42	0.07	1.11	1.42	0.07
Mymensingh	0.80	1.01	0.68	0.83	1.05	0.69	0.90	1.11	0.70
Naogaon	0.79	1.06	0.51	0.79	1.06	0.51	0.79	1.06	0.51
Narayanganj	0.43	0.50	0.78	0.48	0.55	0.79	0.54	0.60	0.79
Narsingdi	0.41	0.48	0.78	0.41	0.48	0.78	0.41	0.48	0.78
RekabiBazar	0.35	0.43	0.72	0.46	0.55	0.71	0.46	0.55	0.71
Sariakandi	0.59	0.81	0.73	0.66	0.79	0.75	0.78	0.87	0.76
Serajganj	0.64	0.86	0.75	0.80	0.92	0.78	0.98	1.07	0.79
Sheola	3.67	3.87	0.43	3.67	3.87	0.44	3.67	3.87	0.44
Sherpur	1.30	1.44	0.31	1.29	1.43	0.31	1.29	1.43	0.30
Sunamganj	0.81	0.92	0.30	0.81	0.92	0.30	0.83	0.94	0.29
Sureshwar	0.31	0.37	0.73	0.36	0.44	0.72	0.44	0.53	0.71
Sylhet	1.87	2.03	0.37	1.87	2.03	0.37	1.86	2.03	0.37
Tongi	0.45	0.52	0.79	0.50	0.57	0.78	0.54	0.62	0.76

Following charts showing the MAE and r^2 plots for the Serajganj and Bhairabbazar for monsoon 2020 indicate that as the longer is the lead time, the r^2 reduces and MAE increases.





Average of MAE and r^2 of all the 37 probability based flood forecast stations plot also indicate the increasing variability of the forecast and observed with increasing lead time.



CHAPTER 5 : INUNDATION STATUS

Flood inundation is a phenomenon that results from overtopping or overflowing of flood water to the river banks. In our country, this situation at a particular place occurs when the river water level exceeds the danger level of that particular place. During normal flooding, it is expected and observed that flood plain 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. During the pre-monsoon 2020, no flash flooding occurred in the Upper Meghna basin and also the Haor basin therein. In the monsoon 2020, the country experienced severe flooding.

In monsoon 2020, the Brahmaputra basin of the country experienced severe flooding of short to long duration at low lying places. The Teesta river at Dalia and the Gur river at Singra exceeded their recorded highest water levels this year. Along the Padma river in the Ganges basin, the flood was also severe and of long duration. The Atrai river at Atrai in the Ganges basin also exceeded the recorded highest water levels this year. However, the Ganges river this year did not cross DL at any monitoring stations. The Meghna basin experienced severe flash flooding with multiple peaks, the duration of which varied over the basin from short to long. Flash flooding also occurred at some places of the South Eastern Hill basin the duration of which was small however.

This year the flood events were spread throughout the monsoon, starting from the second half of June till first half of October. Simultaneous rise of all the major rivers of the country created countrywide flooding this year which occurred during second half of June till first half of August in 3 spells, and second half of September to first half of October in 2 spells. Flooding persisted in the middle and developed in the South-Western and South-Central coastal parts of the country in between the abovementioned spells during late August due to tidal influences and upstream water rush. As a whole, the flooding occurred in severe scale and the duration varied from short to long at low lying places of Northern, North-Western, North-Central, North-Eastern, Eastern, Central, South-Western and South-Central regions of the country. The South-Eastern region of the country was also affected for small duration during July. In total, 40% of the country got flood inundated this year.

5.1 BASINWISE INUNDATION STATUS

Brahmaputra Basin:

Out of 31 WL monitoring stations in the Brahmaputra basin, at 25 stations WL crossed and remained over their respective DLs in 2020. Flood in the Brahmaputra-Jamuna river this year came in 5 spells between 27th June – 6th July, 11th – 20th July, 20th July – 8th August, 18th – 20th September and 25th September – 4th October. Flood wave in Teesta, the major tributary of the Brahmaputra-Jamuna river, consisted of seven short duration peaks. The first flood peak arrived earlier than Brahmaputra on 20th June, however the following six flood peaks nearly coincided with the Brahmaputra-Jamuna flood spells. The Teesta at

Dalia crossed RHWL on 13th July. Among other rivers the floods of Gur, Atrai and Dhaleswari rivers during the third spell and Gur and Karatoa rivers during the fifth spell stayed for longer even after receding of the Brahmputra-Jamuna flood. The Gur river at Singra also crossed RHWL on 1st October.

The stations that crossed and remained over DLs during these periods are: Dharala at Kurigram for 47 days peaking 103 cm above DL; Teesta at Dalia for 14 days peaking 55 cm above DL (5 cm higher than previously recorded highest) and at Kaunia for 4 days peaking 15 cm above DL; Jamuneswari at Badarganj for 4 days peaking 15 cm above DL; Ghagot at Gaibandha for 38 days peaking 94 cm above DL; Karatoa at Chakrahimpur for 25 days peaking 116 cm above DL; Brahmaputra at Noonkhawa for 28 days peaking 96 cm above DL and at Chilmari for 36 days peaking 103 cm above DL; Jamuna at both Fulchari and Bahadurabad for 40 days peaking 124 cm and 129 cm above DL respectively, at Sariakandi for 55 days peaking 128 cm above DL, at Kazipur for 41 days peaking 122 cm above DL, at Serajganj for 37 days peaking 101 cm above DL and at Aricha for 31 days peaking 80 cm above DL; Atrai at Baghabari for 55 days peaking 114 cm above DL, Gur at Singra for 63 days peaking 111 cm above DL; Dhaleswari at Elashin for 62 days peaking 122 cm above DL; Old Brahmaputra at Jamalpur for 8 days peaking 18 cm above DL; Balu at Demra for 18 days peaking 25 cm above DL; Lakhya at Narayanganj for 25 days peaking 37 cm above DL; Turag at Mirpur for 18 days peaking 56 cm above DL; Tongi Khal at Tongi for 20 days peaking 42 cm above DL; Kaliganga at Taraghat for 26 days peaking 120 cm above DL; Dhaleswari at Jagir for 24 days peaking 106 cm above DL and Banshi at Narayanhat for 11 days peaking 26 cm above DL.

As a result of these events, low-lying areas of Kurigram, Lalmonirhat, Nilphamari, Rangpur, Gaibandha, Bogra, Sirajganj, Natore, Pabna, Jamalpur, Tangail, Manikganj, Dhaka and Narayanganj districts in the Northern, North-Western and North-Central regions of the country experienced moderate to severe flooding of short to long duration during 2020. The basin as a whole experienced flooding throughout the monsoon.

Ganges Basin:

In the Ganges basin, out of 30 WL monitoring stations, 16 stations flowed above DL during 2020. Flood in the Padma river this year came in 4 spells between 29th June – 8th July, 13th July – 11th August, 15th – 28th August and 30th September – 5th October. The middle parts of the basin along the river Padma was mostly affected during the first two flood spells which resulted from combined rise of Ganges and Jamuna, but more prominently due to onrush of floodwater from the Jamuna river. During the third spell, flooding persisted in the middle parts and developed also in the South-Western and South-Central coastal parts of the country, notably along the river Kirtonkhola due to tidal influences and upstream water rush. Duing the fourth spell, significant water came from the upper parts of the basin by Punarbhaba,Tangon, Atrai and Little Jamuna rivers which also created short duration flooding therein. The Atrai river at Atrai crossed RHWL on 16th July.

The stations that crossed and remained over DLs during these periods are: Punarbhaba at Dinajpur for 1 day peaking 10 cm above DL; Tangon at Thakurgaon for 1 day peaking 16 cm above DL; Upper Atrai at Bhusirbandar for 4 days peaking 36 cm above DL; Little Jamuna at Naogaon for 7 days peaking 19 cm above DL; Atrai at Mohadebpur and Atrai for 3 days peaking 35 cm above DL and at Atrai for 28 days peaking 68 cm above DL; Padma at Goalundo for 60 days peaking 119 cm above DL, at Bhagyakul for 41 days peaking 84 cm above DL, at Mawa for 40 days peaking 75 cm above DL and at Sureswar for 9 days peaking 44 cm above DL and Pashure at Khulna and Mongla for 48 and 166 days peaking 39 and 109 cm above DL respectively.

As a result of these events, low-lying areas of Dinajpur, Thakurgaon, Ranpur, Naogaon Rajbari, Faridpur, Manikganj, Dhaka, Munshiganj, Madaripur, Shariatpur, Khulna, Bagerhat, Barisal, Jhalakathi, Patuakhali, Barguna and Pirojpur districts in the Northern, North-Western, Central, South-Western and South-Central regions of the country experienced moderate to severe flooding of short to long duration during 2020. The basin as a whole experienced flooding throughout the monsoon.

Meghna Basin:

During the pre-monsoon (15 March - 15 May), out of 36 WL monitoring stations in the Meghna basin, all stations flowed below respective PMDLs in 2020. No flash flooding occurred in the Upper Meghna basin and also the Haor basin therein.

Out of 29 WL monitoring stations in the Meghna basin, at 15 stations water flowed above their respective monsoon DLs during the year 2020. Flood in the Upper Meghna basin this year came in multiple peaks which were longer than usual, but the major peaks which caused most inundation were centred between June and July. There were 4 major spells in this season. The first one occurred on 3rd June which affected the Surma river at Kanaighat for one day only. The second one occurred between 25th June – 4th July which affected the Surma river reach along with some Meghalayan streams. The third one was the prime peak of the season which started from 9th - 24th July and inundated plains of almost all major river reaches including the Surma-Kushiyara along with most of their major tributaries. The fourth one only affected the Surma river reach at Sunamganj along with some Meghalayan streams in Sunamganj and Netrokona between 24th - 28th September. Flood peak arrived separately in the Titas river after passing of the third peak between 22nd July – 6th August. Due to tidal influences and upstream water rush from the river Padma and Upper Meghna, the Meghna river at Chanpur flowed above normal level duing 3rd – 8th July, 18th July – 10th August, 16th – 26th August and 21st – 22nd September

The stations that crossed and remained over DLs during these periods are: Surma at Kanaighat, Sylhet and Sunamganj for 26, 5 and 20 days peaking 84, 11 and 71 cm above DL respectively; Kushiyara at Amalshid and Sheola for 6 and 3 days peaking 80 and 16 cm above DL respectively; Sarigowain at Sarighat for 12 days peaking 46 cm above DL; Khowai at Ballah for 2 days peaking 24 cm above DL; Old Surma at Derai for 26 days peaking 41 cm above DL; Jadukata at Lorergarh for 15 days peaking 197 cm above DL;

Someswari at Durgapur and Kalmakanda for 2 and 14 days peaking 34 and 38 cm above DL respectively; Bhugai at Nakuagaon for 4 days peaking 45 cm above DL; Titas at B. Baria for 16 days peaking 35 cm above DL and Meghna at Chandpur for 42 days peaking 66 cm above DL and Lower Meghna at Daulatkhan for 41 days peaking 109 cm above DL.

As a result of these events, low-lying areas of Sylhet, Sunamganj, Moulvibazar, Habiganj, Netrokona, Brahmanbaria, Narayanganj, Narsingdi, Chandpur and Bhola districts in the North-Eastern and Eastern regions of the country experienced moderate to severe flooding of short to long duration in 2020. The basin as a whole experienced flooding during throughout the monsoon.

South Eastern Hill Basin:

In the South Eastern Hill basin, 3 out of 9 water level monitoring stations crossed danger levels during monsoon 2020. Flood in the basin this year came in double peaks by Muhuri river between 12^{th} – 13^{th} July and 31^{st} October – 1^{st} November, while in single peak by Matamuhuri river between 17^{th} – 18^{th} June.

The stations that crossed and remained over DLs during these periods are: Muhuri at Parshuram for 4 days peaking 132 cm above DL and Matamuhuri at Lama and Chiringa for 1 and 2 days peaking 19 and 93 cm above DL respectively.

As a result of these events, low-lying areas of Feni, Bandarban and Cox's Bazar districts in the South-Eastern region of the country experienced moderate to severe flash flooding but all of short duration in 2020. The basin experienced flooding during the months of June, July and October only.

5.2 COUNTRYWIDE INUNDATION 2020

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 peaks arrived several times in 2020 which was attenuated during the second half of October. It was observed from monitoring that the Brahmaputra river attained its monsoon peak on 15^{th} July, the Jamuna on 17^{th} July, the Padma on 27^{th} July and the Upper Meghna river on 25^{th} July. From areal coverage perspective, 26^{th} July 2020, was chosen as the peak time of monsoon on which FFWC observed total number of 28 flood monitoring stations above danger levels. Figure 5.1 shows the observed inundation map for 26^{th} of July and then 24, 48, 72, 96 and 120 hours forecasted inundation maps on the day from figures 5.2 to 5.6 respectively. The map on 26^{th} July captures the inundation scenario of the country during monsoon 2020, except relatively small inundations at some places of the North-Eastern, South-Eastern, Northern and North-Western region of the country due to isolated and short-term flood events. Inundated area based on this map is around 59,028 sq-km which is 40% of the country area and is the maximum inundated area found in this flood season. This area excludes the permanent water bodies i.e. perennial streams, lakes, 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.

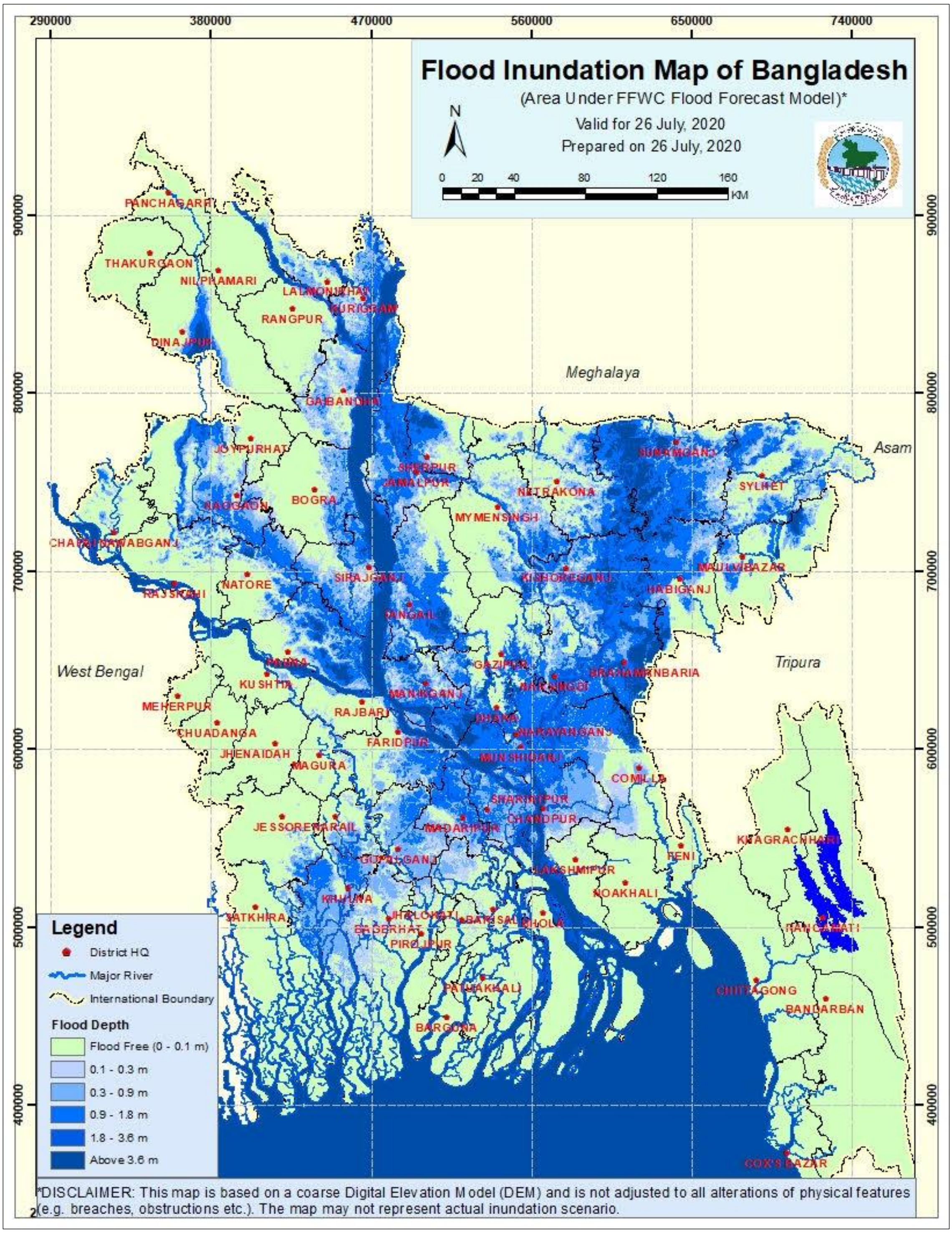


Figure 5.1 : Flood Inundation Map of Bangladesh (on 26th July 2020)

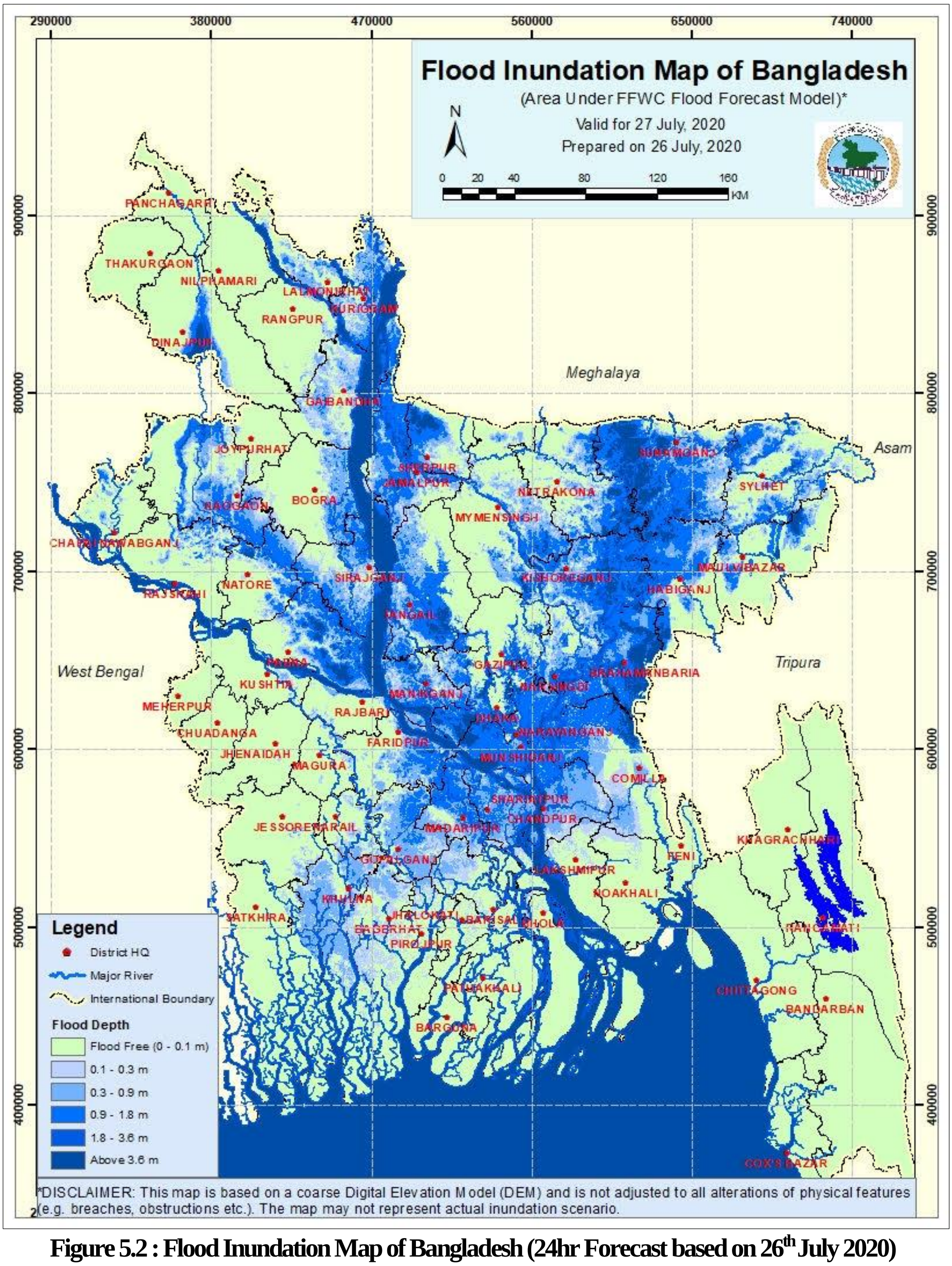


Figure 5.2 : Flood Inundation Map of Bangladesh (24hr Forecast based on 26th July 2020)

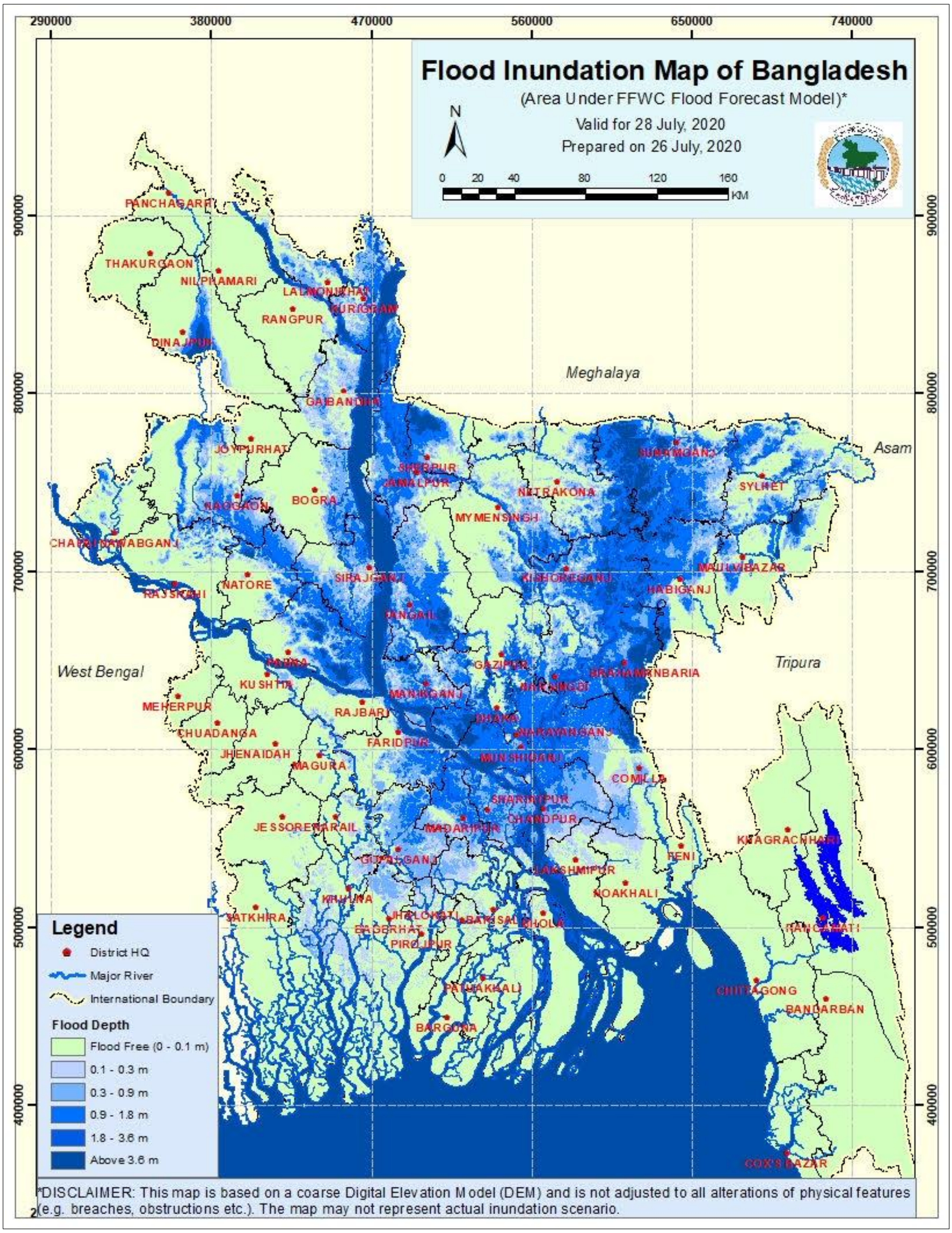


Figure 5.3 : Flood Inundation Map of Bangladesh (48hr Forecast based on 26th July 2020)

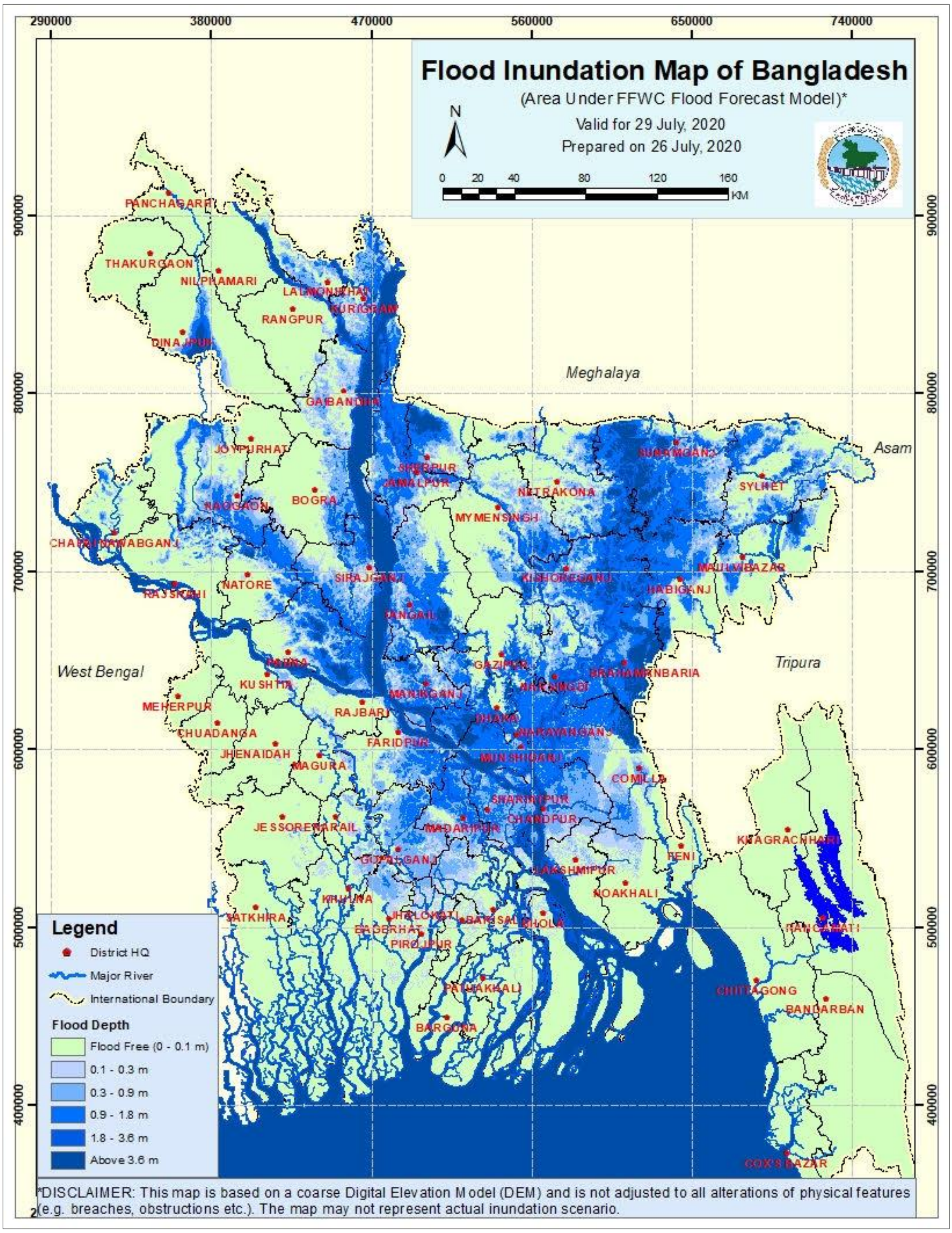


Figure 5.4 : Flood Inundation Map of Bangladesh (72hr Forecast based on 26th July 2020)

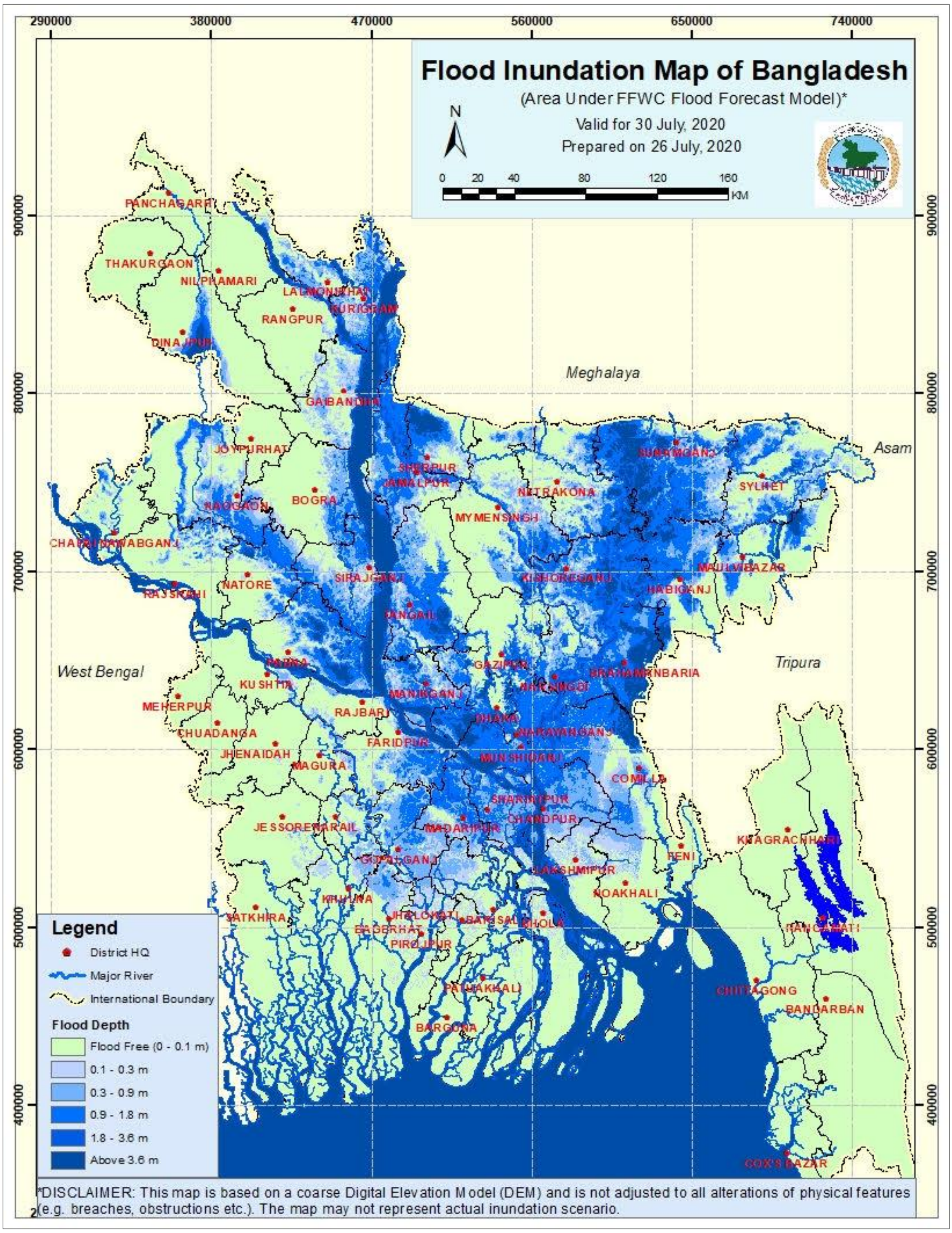


Figure 5.5 : Flood Inundation Map of Bangladesh (96hr Forecast based on 26th July 2020)

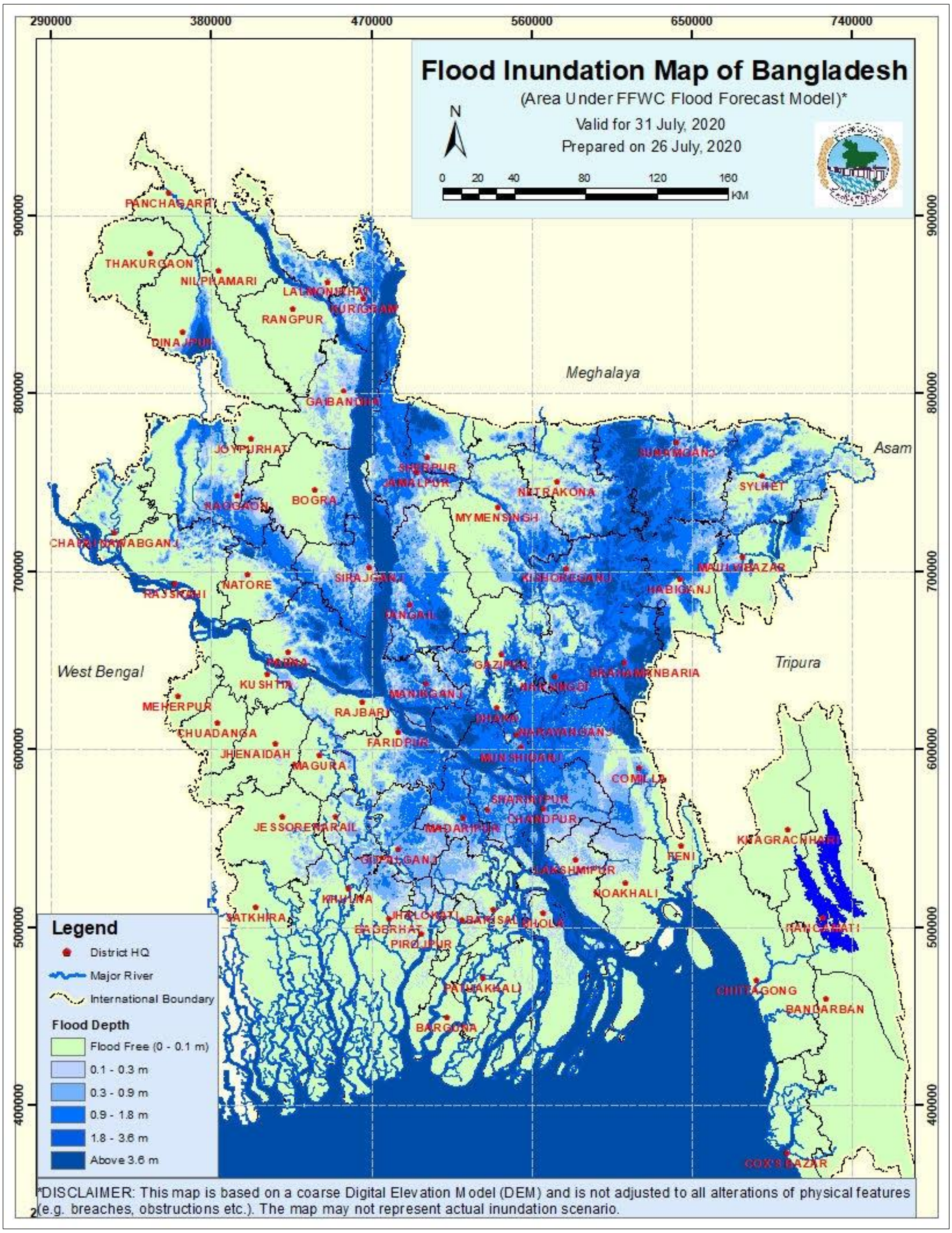


Figure 5.6 : Flood Inundation Map of Bangladesh (120hr Forecast Based on 26th July 2020)

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 2020 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 of the country, but only to be underestimated in South-Western mangrove forest (the Sundarban) and South-Eastern hilly forest areas. Because of non-availability of countrywide daily product, Sentinel-1 data from 24th to 28th of July were used to cover the whole country during peak condition and compared with the FFWC flood map of 26th July, 2020 (Fig 5.7).

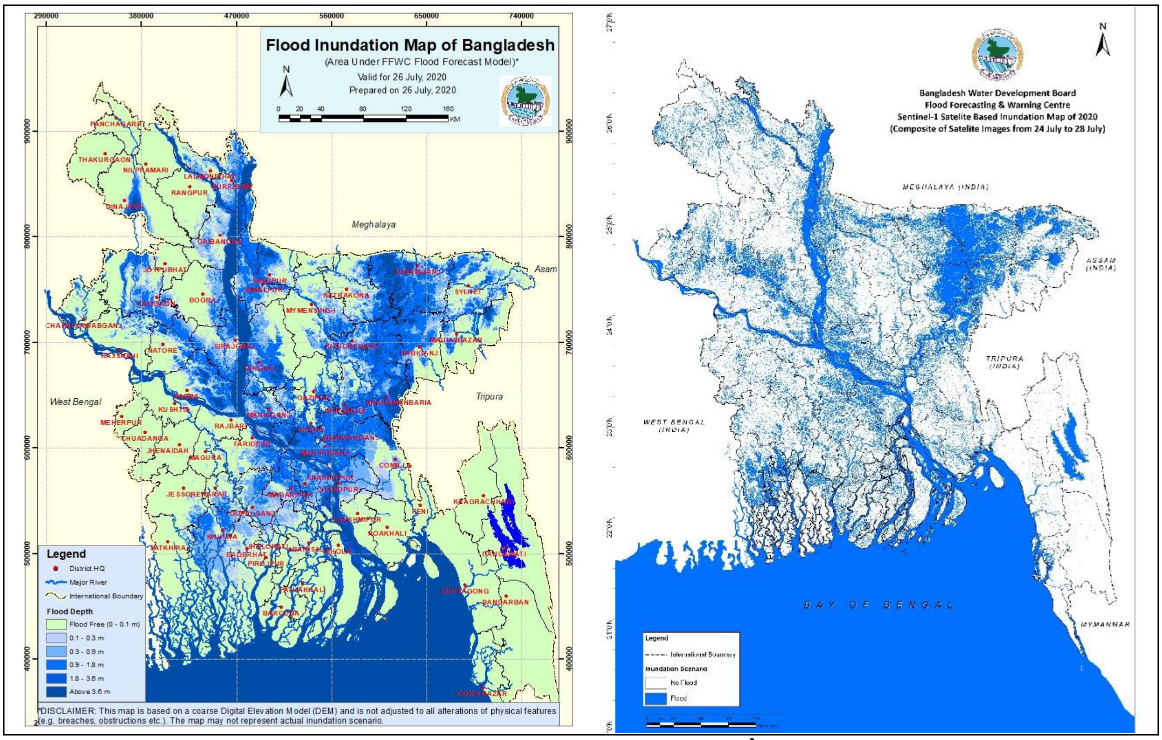


Figure 5.7 : Comparison of FFWC Flood Inundation Map (26th July 2020) with Senitnel-1 based Inundation Map (between 24th -28th July 2020)

Both of the maps are in good agreement in detecting inundated areas in North-Western, North-Central and North-Eastern parts of the country. However, there are spatial variability in the Northern and 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 Northern and Central parts may be an implication of coarse resolution of the DEM along with change in land use.

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.

A significant portion of low lying lands adjacent to Dhaka city corporation got flooded this year. The flooding mainly affected the eastern low lying portion of the Dhaka city periphery. Sentinel-1 image on 25th July was compared with the FFWC flood map of Dhaka city on 29th July, 2020 (Fig 5.8). As observed from both maps, the FFWC flood map generally overestimated the flood of Dhaka city. The FFWC flood map underestimated the flood extents along the western embanment periphery along the Turag river near Mirpur. However, both at the upstream and downstream of Mirpur on Turag and along the Balu river in the eastern portion of Dhaka the FFWC flood map overestimated the extents to considerable degree. Modelled flood extent varied relatively less from the Sentinel-1 observed image along the Tongi khal at north and the Buriganga at south.

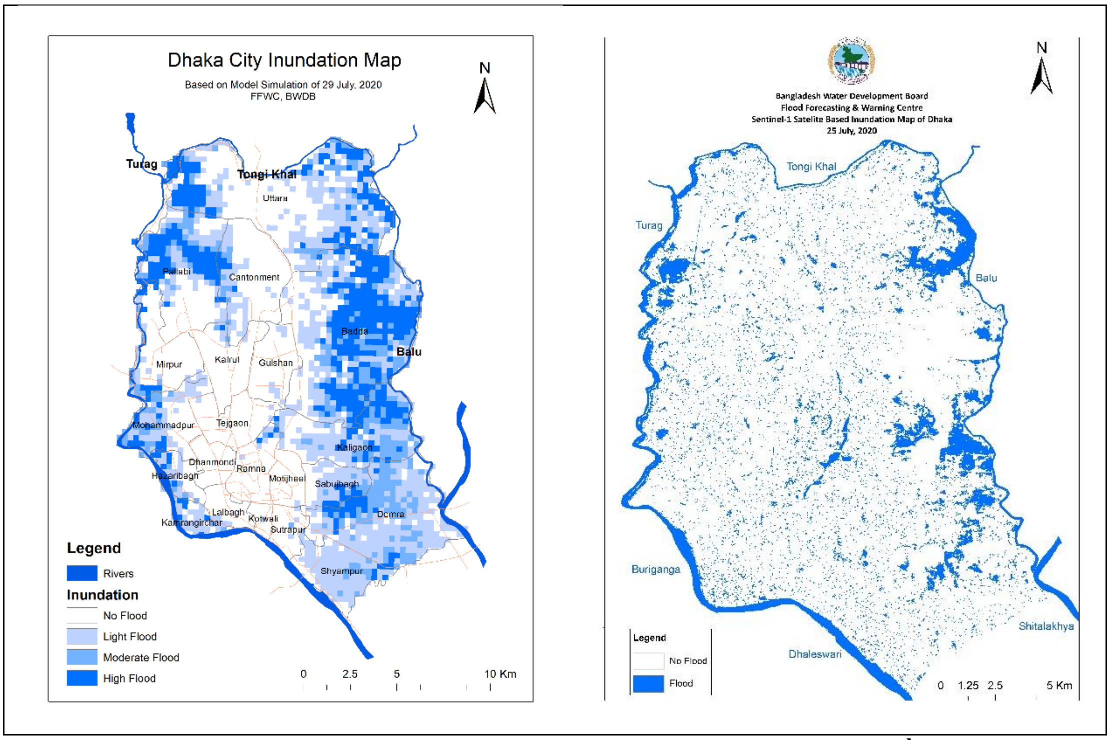


Figure 5.8 : Comparison of FFWC Flood Inundation Map of Dhaka City (29th July 2020) with Senitnel-1 based Inundation Map (25th July 2020)

CHAPTER 6 : CHARACTERISTICS AND SPECIAL EVENTS OF 2020 FLOOD

6.1 General Characteristics

During 2020, the monsoon was more active than normal. Multiple monsoon low pressure/depression in the Bay of Bengal acted as a catalyst behind this. Multiple spells of heavy rainfall events had been observed in the upstream basins and for around all cases the amount of rainfall was higher than last year. Due to greater and frequent rush of upstream water, the flood of 2020 started from the second half of June and continued till first half of October in six spells. The 2020 monsoon flood spells are described in Table 6.1.

Table 6.1: 2020 Monsoon Flood Spells

Spell	Period	Affected Regions	Drivers	Average Rainfall
1	27 June – 6 July	Districts of the Northern region along the Teesta, Brahmaputra-Jamuna and Central region along the Padma	Excessive rainfall in Assam, Meghalaya, Arunachal and Sub-Himalayan West Bengal regions	<u>24 June – 29 June</u> Assam-Meghalaya: 355 mm Arunachal: 475 mm Sub-Himalayan West Bengal: 177 mm
2	11 July – 20 July	Districts of the Northern region along the Teesta, Brahmaputra-Jamuna and Central region along the Padma	Excessive rainfall in Assam, Meghalaya, Arunachal and Sub-Himalayan West Bengal regions	<u>9 July – 14 July</u> Assam-Meghalaya: 360 mm Arunachal: 640 mm Sub-Himalayan West Bengal: 222 mm
3	20 July – 8 August	Low lying areas of the Northern, North-Eastern, Central regions along with surroundings of Dhaka	Excessive rainfall in Assam, Meghalaya, Arunachal and Sub-Himalayan West Bengal regions	<u>19 July – 22 July</u> Assam-Meghalaya: 230 mm Arunachal: 210 mm Sub-Himalayan West Bengal: 95 mm
4	16 August – 25 August	Central region and South-Western, South-Central coastal regions of the country	Upstream rush of water, excessive rainfall in the coastal region due to active monsoon in Bay of Bengal and above normal spring tide during the new moon	<u>20 August – 24 Au;gust</u> Coastal region of the country: 200 mm
5	16 September – 21 September	Districts of the Northern region along the Dharala and Jamuna	Excessive rainfall in Assam, Meghalaya, Arunachal and Sub-Himalayan West Bengal regions	<u>11 September – 16 September</u> Assam-Meghalaya: 200 mm Arunachal: 480 mm Sub-Himalayan West Bengal: 240 mm
6	24 September – 9 October	Districts of the Northern and North-Central region along the Dharala, Teesta, Atrai, Gur and Jamuna	Excessive rainfall in Assam, Meghalaya, Arunachal and Sub-Himalayan West Bengal regions	<u>22 September – 27 September</u> Assam-Meghalaya: 330 mm Arunachal: 360 mm Sub-Himalayan West Bengal: 408 mm

During the 1st spell of the flood, rivers at different stations flowed above DL for around 10 days. After that during the 2nd spell, the northern rivers started crossing DL again from 11th July. The Teesta river at Dalia exceeded the RHWL during this time (53.15 m PWD). At the receding stage of the 2nd spell, heavy rainfall activity started again in the upstream basins due to which the rivers also started rising again before falling below DL. During the 3rd spell, rivers at different stations flowed above DL upto 8th August which resulted in a total flood duration of upto 40 days. WL stayed above DL for more days than even the 1988 flood at many stations on the Brahmaputra-Jamuna, Padma and Meghna rivers including Noonkhawa, Bahadurabad, Goalundo, Bhagyakul, Sureswar, Chandpur.

Table 6.2: Comparison of 2020 Flood with Historical Floods (Days above DL)

Station	Rivers	Districts	1988 (days)	1998 (days)	2020 (days)
Noonkhawa	Brahmaputra	Kurigram	22	29	28
Bahadurabad	Jamuna	Jamalpur	16	66	40
Goalundo	Padma	Rajbari	31	68	60
Bhagyakul	Padma	Munsiganj	29	72	41
Sureswar	Padma	Shariatpur	25	73	43
Chandpur	Meghna	Chandpur	25	44	42

Moreover at Bahadurabad, Kurigram and Gaibandha point the peak WL of 2020 exceeded that of 1988 and 1998. The Padma river at Goalundo point exceeded the peak WL of 1988.

Table 6.3: Comparison of 2020 Flood with Historical Floods (Peak WL)

Sl. No.	Station	Rivers	RHWL (m PWD)	DL (m PWD)	1988	1998	2020
					Peak WL (m PWD)	Peak WL (m PWD	Peak WL (m PWD
1	Kurigram	Dharala	27.84	26.50	27.41	27.22	27.53
2	Dalia	Teesta	53.12	52.60	52.89	52.20	53.15*
3	Gaibandha	Ghagot	22.81	21.70	22.16	22.30	22.64
4	Bahadurabad	Jamuna	21.16	19.50	20.62	20.37	20.79
5	Goalundo	Padma	10.21	8.65	9.83	10.21	9.84

* exceeded RHWL in 2020

Due to upstream rush of water, excessive rainfall and above normal spring tide during the new moon, flood situation developed at low lying places of the Central region and South-Western and South-Central coastal regions during the 4th spell for relatively shorter duration. Following that due to heavy rainfall activity in Arunachal and Sub-Himalayan West Bengal, short duration flood situation developed along the Dharala and Jamuna rivers in the Northern and North-Western regions during the 5th spell. Lastly, during the 6th and final spell of the season, internal drainage congestions developed in the Northern districts due to excessive rainfall in the range of 200-250 mm in one day, which also raised WL of Jamuna, Padma, Dharala, Teesta, Atrai, Gur and Ghagot rivers above DL.

Based on the information of FFWC flood monitoring stations, a maximum numbers of 20 districts were found to be flood affected on 24th July. A sample flood affected district map is shown in Figure 6.1.

Figure 6.1 : Flood Affected District Map based on FFWC Monitoring Stations (1st August, 2020)

6.2 Flood of Dhaka and Surroundings

After many years in 2020, the low lying areas adjacent to the Dhaka city corporation got flooded for long duration. The last major flood event in the area took place in 2007 monsoon. Low lying areas of the districts surrounding Dhaka were also flooded for long duration. With respect to historical events however, the flood of Dhaka and surroundings was less severe in 2020. Comparison of 2020 flood in Dhaka and surroundings with historical flood events are provided in Table 6.4 and 6.5.

Table 6.4: Comparison of 2020 Flood in Dhaka and Surroundings with Historical Floods (Days above DL)

Station	River	RHWL (m PWD)	DL (m PWD)	1988 (Days)	1998 (Days)	2004 (Days)	2007 (Days)	2020 (Days)
Demra	Balu	7.13	5.75	43	73	34	22	17
Narayanganj	Lakhya	6.93	5.5	37	71	36	21	24
Mirpur	Turag	8.35	5.95	35	69	25	26	17
Tongi	Tongi Khal	7.84	6.1	25	65	22	28	19
Taraghat	Kaliganga	10.39	8.4	48	66	21	31	27
Jagir	Dhaleswari	9.96	8.25	28	58	18	25	24
Rekabi Bazar	Dhaleswari	7.66	5.2	26	75	39	45	No flood
Nayarhat	Banshi	8.39	7.3	27	35	14	No Flood	12
Dhaka	Buriganga	7.58	6	22	57	18	No Flood	No flood

Table 6.4: Comparison of 2020 Flood in Dhaka and Surroundings with Historical Floods (Days above DL)

Station	River	RHWL (m PWD)	DL (m PWD)	1988	1998	2004	2007	2020
				Peak WL (m PWD)	Peak WL (m PWD)	Peak WL (m PWD)	Peak WL (m PWD)	Peak WL (m PWD)
Demra	Balu	7.13	5.75	7.09	6.97	6.98	6.27	6.0
Narayanganj	Lakhya	6.93	5.5	6.7	6.93	6.75	6.05	5.87
Mirpur	Turag	8.35	5.95	8.35	7.97	7.29	6.62	6.5
Tongi	Tongi Khal	7.84	6.1	7.84	7.54	7.13	6.87	6.5
Taraghat	Kaliganga	10.39	8.4	10.37	10.21	9.93	9.79	9.58
Jagir	Dhaleswari	9.96	8.25	9.96	9.73	9.50	9.43	9.29
Rekabi Bazar	Dhaleswari	7.66	5.2	6.43	6.87	6.64	6.13	-
Nayarhat	Banshi	8.39	7.3	9.9	8.68	8.09	-	7.58
Dhaka	Buriganga	7.58	6	7.58	7.24	6.68	-	-

6.3 Coastal Floods in the South-Western and South-Central Regions

Due to active monsoon in in the Bay of Bengal, medium to heavy (44-88 mm) along with isolated very heavy rainfall (>100 mm) were observed in the South-Eastern Hills, South-West coastal and South-Central regions starting from 17-18 August. The presence of a low-pressure in North-Central Bay of Bengal being coincident with the new moon created tide 1-2 feet higher than astronomical ones in the sea. The combined effect of upstream rush of water from monsoon floods, excessive rainfall in the coastal regions and above normal spring tide during the new moon made the coastal rivers in the South-Western and South-Central regions rise rapidly during 17-22 August. Maximum number of stations on Kirtonkhola, Tetulia, Payra, Bishkhali, Baleswar, Buriswar, Nayabhangani, Meghna rivers were reported to be flowing above DL in these regions on 22nd August. This created short duration flooding at low lying places of Barisal, Bhola, Barguna, Jhalakathi, Patuakhali, Pirojpur, Khulna, Bagerhat districts in the Barisal and Khulna divisions. The river condition of these districts during this period is presented in Table 6.5.

Table 6.5: River Condition of Coastal Districts of South-Western and South-Central Regions during 20-21 August

Sl. No.	District	River	Station	DL (m PWD)	Highest WL with Date (during 20-21 August)	Above DL (above + / below -) (cm)	Highest WL during Cyclone Amphan (m PWD)	Remarks
1	Barisal	Kirtonkhola	Barisal	2.55	3.07 20/08/2020	+52	2.85	Greater than Highest WL during Amphan
2	Barguna	Bishkhali	Barguna	2.85	3.42 20/08/2020	+57	3.95	
3	Jhalakati	Bishkhali	Bishkhali	2.08	3.28 21/08/2020	+120	2.30	Greater than Highest WL during Amphan
4	Pirojpur	Baleswar	Pirojpur	2.68	3.00 20/08/2020	+32	3.65	
5	Barisal	Kocha	Umedpur	2.65	2.94 21/08/2020	+29	3.33	
6	Patuakhali	Buriswar	Amtali	2.88	3.25 20/08/2020	+37	3.45	
7	Bhola	Lower Meghna	Daulatkhan	3.41	4.50 20/0/2020	+109	3.72	Greater than Highest WL during Amphan
8	Bhola	Tetulia	Bhola Kheya Ghat	2.90	3.56 20/08/2020	+96	3.40	Greater than Highest WL during Amphan
9	Barisal	Nayabhangani	Abupur	2.32	3.50 21/08/2020	+118	2.38	Greater than Highest WL during Amphan
10	Barisal	Dharmaganj	Hijla	2.72	2.94 21/08/2020	+22	2.59	Greater than Highest WL during Amphan
11	Barisal	Torki	Gournadi	3.72	3.07 21/08/2020	-65	2.47	
12	Barisal	Swarupkathi/ Sandhya	Ujipur	3.14	2.94 20/08/2020	-20	-	
13	Khulna	Pashure	Khulna	3.05	3.40 21/08/2020	+35	3.42	
14	Bagerhat	Pashure	Mongla	2.07	3.14 20/08/2020	+103	3.17	

Flood condition prevailed at different places of the abovementioned districts due to the exceedance of river WL by 50 cm to 1 m above DL. Specially the WLs in Barisal, Jhalakathi and Bhola districts exceeded the highest WL during super cyclone Amphan (16-21 May, 2020) which created a severe flood situation therein. As the rainfalls from 22 August decreased the tides also became gradually normal in the following 48 hours.

CHAPTER 7 : RESEARCH AND DEVELOPMENT

7.1 Experimental 15-days Streamflow Forecasting System

A 15 days streamflow forecasting system has been experimentally operationalized this year with technical support from RIMES. The model developed for the Brahmaputra-Ganges-Meghna river basins were calibrated, validated and automated to generated 15 days probabilistic forecast for these three river basins. The system was integrated into FFWC's operational forecasting in June 2020 and it had been used to provide two-week extended outlook for the floods. It is available on FFWC's website: www.ffwc.gov.bd > Forecast and Warning. The monsoon flood during 2020 was captured by the system fourteen days ahead with more than 80% probability. The output from this system was also utilized in 10 days probabilistic water level forecasting. The special flood outlooks issued by FFWC used 15 days probabilistic streamflow forecast and 10 days probabilistic water level forecast to disseminate early warning to the stakeholders. The forecasts were also used during the floodpreparedness planning meeting of the Inter-Ministerial Disaster Management Coordination Committee (IMDMCC) on July 9, 2020 chaired by the State Minister of the Ministry of Disaster Management and Relief. The information were also disseminated to the beneficiaries of SHOUHARDO III program, Supporting Flood Forecast Based Early Action and Learning (SUFAL) project and the concerned lead farmers of Department of Agricultural Extension (DAE).

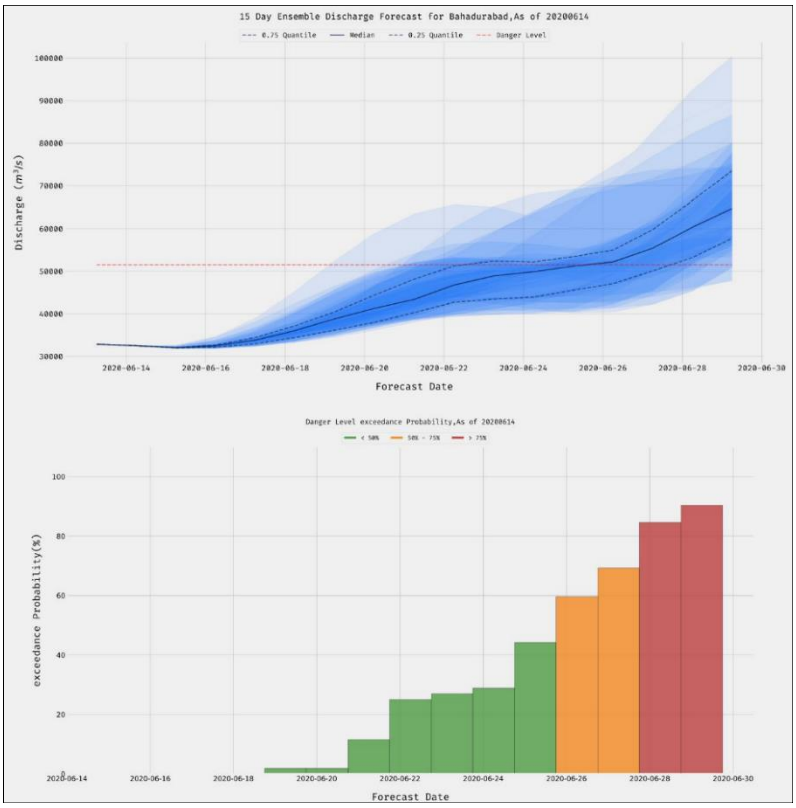
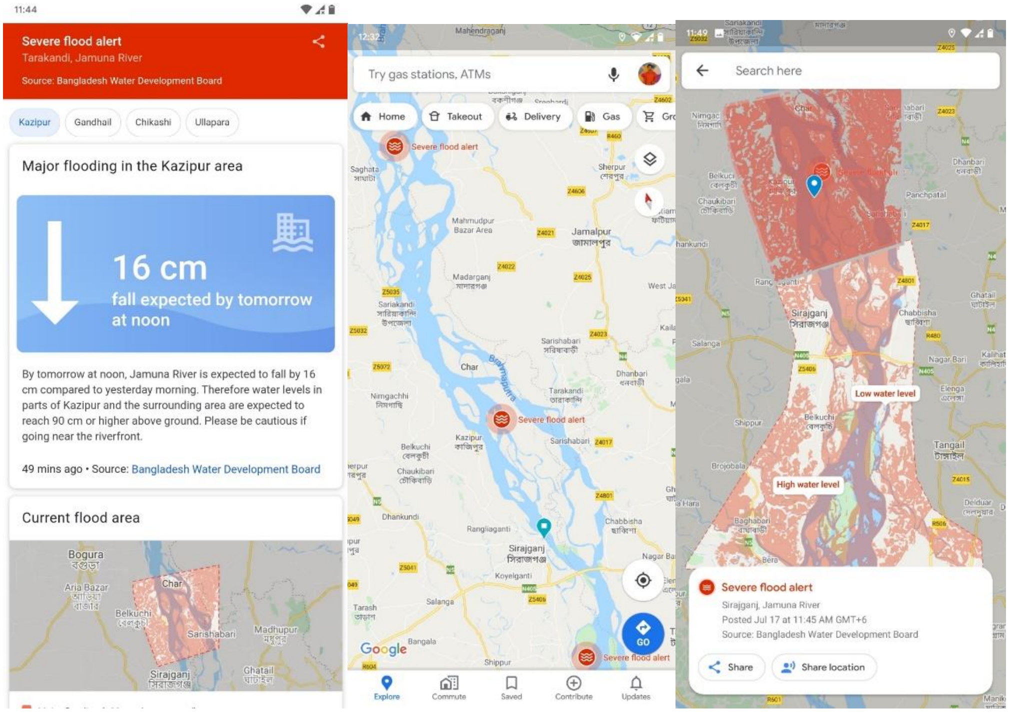


Figure 7.1 : Fifteen Days Forecast for Brahmaputra Basin

7.2 Experimental Operation of Google-BWDB-a2i Flood Forecasting Initiative

Google and BWDB have been officially working together since 2019 with the support from a2i on improving the existing flood forecasting system at local level. The system was proposed to be developed using 5-day deterministic flood forecasts of FFWC, BWDB but additionally with the help of a high-resolution satellite based DEM from Google to develop a more accurate local level flood inundation map. The system would also allow end users to access information on upcoming flood and its magnitude directly from their mobile phone at union level. The districts of Bogra and Sirajganj along the bank of Jamuna had been chosen as pilot districts for this initiative. The process had been set to initiate by synchronizing the 5-day flood forecasts of FFWC, BWDB along with observed water level data to Googles server. After that, Google would produce the high-resolution inundation map which users can see by opening Google map or searching in the Google web. Through intense online collaboration activities among 3 organizations, the system was finally launched in June, 2020 for the 2 pilot districts along the Jamuna.



(a) (b) (c)

Figure 7.2 : Google-BWDB-a2i Flood Forecasting Initiative: a) forecast and warning information in Google search page, b) flood alert visible in Google map, c) forecast inundation map in Google map

The Google-BWDB-a2i flood forecasting initiative have been launched during the flood of 2020 in June. Initially 3 major flood forecasting stations on Jamuna namely the Sariakandi, Kazipur and Serajganj were launched as pilot stations covering the Bogra and Sirajganj districts. After successful implementation, it was in turn expanded for the whole Brahmaputra-Jamuna-Padma river belt from Chilmari in Kurigram to Sureshwar in Shariatpur. The 14 riverine districts of Kurigram, Gaibandha, Bogura, Jamalpur, Serajganj, Tangail, Pabna, Rajbari, Manikganj, Dhaka, Munsiganj, Faridpur, Madaripur and Shariatpur along the Brahmaputra-Jamuna-Padma river belt are now covered within the system. 10

flood forecast stations of FFWC, BWDB cover these 14 districts namely: Sariakandi, Kazipur, Sirajganj, Chilmari, Fulchari, Bahadurabad, Aricha, Goalondo, Bhagyakul and Mawa. The current system includes:

i) Forecasted water level from FFWC, BWDB for the 10 stations published in Google search bar (e.g. user may type ‘Sirajganj floods’) and notified to mobile users through android push notification (location service based).

ii) Forecasted high-resolution inundation map of the 14 districts available through Google map showing the severity of flood in 3 scales; minor, moderate and major

Under the system, over 700,000 warning messages have been sent to local level users through Google alert services using Android push notification. Also, a collaboration of BWDB with BTRC with support from a2i has been going on. This collaboration will directly send SMS text alerts containing warning message and location of nearby flood shelters to people living in the concerned flood areas. This system is currently under process.

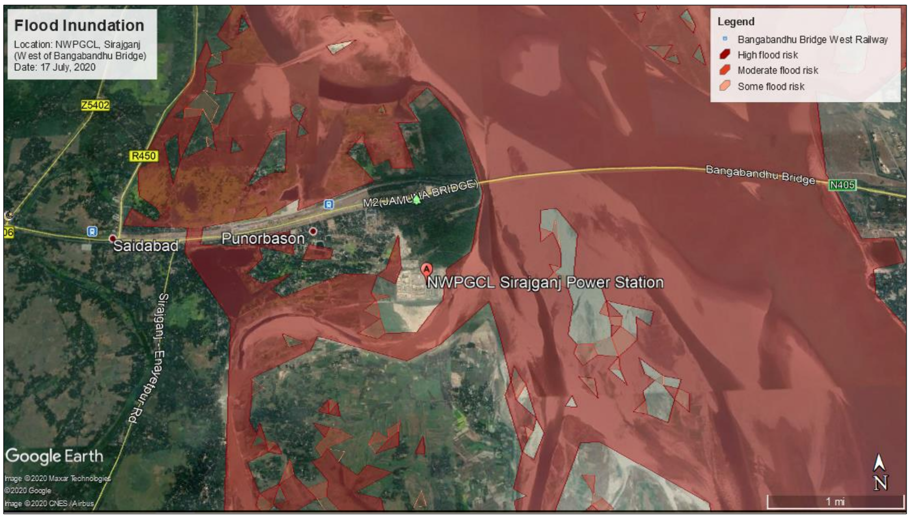


Figure 7.3 : Inundation Map and Flood Situation from Google Earth in Sirajganj

Currently the Brahmaputra-Jamuna and Padma river belt is under coverage of the flood forecasting initiative. Steps to include the Ganges river belt has been taken and will be launched in the next flood season of 2021. This will cover the entire Ganges-Brahmaputra-Jamuna-Padma river system of Bangladesh. Also, the embankment-based forecast system and SMS alert system will hopefully launch in next season. BWDB and a2i will keep this system under continuous monitoring and work together for overcoming the existing challenges and bringing new features and updates to this system. The final target is to increase the accuracy of local level flood forecast and disseminate relevant information in the most user-friendly manner for the targeted river belts. Google will also keep supporting the initiative in near future and it is expected that this will help in improved local level flood forecasting as well as capacity building of BWDB professionals.

7.3 Community based Forecasting Activities

Under the European Civil Protection and Humanitarian Aid Operations (ECHO) funded project SUFAL; RIMES, CARE Bangladesh, Islamic Relief and Concern Worldwide, in collaboration with FFWC, made an effort in reducing the vulnerability of flood-prone populations in the Brahmaputra-Jamuna basin by strengthening impact-based forecasting and early warning to trigger early actions and funding prior to flood events. The project aimed to reduce the impact of floods on communities, improve the effectiveness of emergency preparedness, response, and recovery efforts, and reduce the humanitarian burden. The project made an effort to strengthen flood forecasting EW by facilitating impact-based forecasting to contextualize forecasts and EA by developing an institutionalized mechanism to initiate Forecast based Action (FbA) through Standard Operating Procedures (SOPs). The initiatives under the project are being piloted in selected project unions under Islampur Upazila of Jamalpur, Ulipur Upazila of Kurigram, and Saghata Upazila of Gaibandha and will be scaled up under the second phase of the project.

The initiative produced flood vulnerability maps at sub-district and ward levels through a participatory approach involving the vulnerable communities, disaster management committees. The vulnerability indicators were identified by the humanitarian and disaster

Figure 7.4 : Engr. Md. Nurul Amin, Chief Engineer, Hydrology; Engr. Bidyut Kumar Saha, Superintending Engineer, Processing and Flood Forecasting Circle and Engr. Md. Arifuzzaman Bhuyan, Executive Engineer, FFWC visited Hatia, Ulipur upazila, Kurigram for selection of site for installation of water level monitoring station

management stakeholders. The mapping process also collected exposure data which was used to generate impact and dynamic flood risk maps. The vulnerability and risk information guided the disaster management authorities to prioritize target locations and early actions. The project reviewed local thresholds to trigger early action for floods and identified the need to install a new water level monitoring station. The assessments made by the project were submitted to FFWC, BWDB, and upon approval, two new water level monitoring stations were installed in Hatia and Saghata. FFWC committed in that the maintenance of the gauges will be taken over by FFWC in 2022. Meantime, data from these two gauges have already been incorporated into FFWC's website. Furthermore, the project jointly developed intervention plans with FFWC and DDM; facilitating their input into the process to foster greater Government acceptance and ownership of the project and FbA system.

Figure 7.5 : Engr. Md. Arifuzzaman Bhuyan, Executive Engineer, FFWC and RIMES staff facilitated the Community gauge reader trainings

Community gauge readers were trained by FFWC-BWDB and RIMES in December 2020. These trainings were conducted in three pilot upazilas under Jamalpur, Gaibandha, and Kurigram, and at least one person from each union of three upazilas were selected for gauge reader training. This training aimed at capacity building of community people on adjacent existing and new river gauges, and land gauges in pilot areas, flood forecasting system of Bangladesh, the importance of flood forecasting system in Bangladesh. From the trained gauge readers, two were selected for continuous monitoring of the two newly installed water level monitoring gauges under SUFAL.

In 12 pilot unions under SUFAL, 46 land gauges were installed at the floodplain, considering land elevation and distance from the river bank. Field teams discussed with local DMCs and selected at least 3 sites for land gauge installation at low, medium, and high elevations in each union. These categories will represent a vast area according to their surface level and flood water depth during flood period. These gauges are concrete made and 3 meters in height. Installation work started in November 2020. Flood water level data will be collected during flood period, and dynamic inundation map will be validated for pilot areas.

Local level flood bulletins were disseminated via email from FFWC to the local administration, disaster management officials, NGO representatives, etc. Voice messages were broadcast to more than 8800 recipients, including disaster management committee members, local service providers, community volunteers/representatives, local elites, religious leaders, school teachers, etc. The messages were disseminated simultaneously at different levels minimizing the time lag, and contained information on location specific anticipated flood start date, intensity, duration, possible early actions.

Early action matrices were developed through a participatory process for the local institutions and communities consisting of forecast flood scenarios and corresponding early actions. The matrices were piloted during the 2020 monsoon flood with some adjustments due to COVID situation. With support from the project, the local administration, disaster management committees, and communities took various early actions following the action matrix.

Ahead of the monsoon season simplified 2-trigger mechanism was set in consultation with Department of Disaster Management (DDM) and FFWC. The feasibility of implementing early actions against the backdrop of the COVID-19 pandemic was strongly factored in when setting the triggers. Floods over the 2020 monsoon season were erratic and more intense than normal. The project took early actions ahead of two major flood waves which occurred over the end of June and mid-July. Pre-set early actions were implemented in close consultation and coordination with local Disaster Management Committees (DMCs). Over 200,000 people were supported with forecast, early warning, and risk information, enabling them to take actions timely and ahead of forecasted floods. In addition, an estimated 100,000 people in high-risk locations were supported with various community-based early actions, such as evacuation support, preparation of flood shelters, distribution of temporary shelter materials for families and livestock, distribution of hygiene kits, repairs to tube wells/latrines, distribution of multi-purpose cash grants, building temporary walkways to ensure access around the community and minor repairs to key embankments/evacuation roads to minimize the risk of widespread inundation and damage to households. Implementation of activities was affected by restrictions in movement and organization of official meetings over March until August. In response to the immediate impacts of COVID-19, the project also supported vulnerable communities living in flood-prone locations in May and June ahead of the monsoon season. Response actions focused largely on supporting households with multipurpose cash grants to address the loss of income; and installation of Water, Sanitation and Hygiene (WASH) facilities and awareness raising/hygiene promotion to minimize the risk of transmission in community.

Figure 7.6 : Early Actions during monsoon 2020 supported by SUFAL project

A post-monsoon assessment was conducted in September 2020 to assess the impact of forecast based action during the monsoon of 2020 in SUFAL project areas and identify the gaps and areas of improvement for the implementation of forecast based action. According to the assessment, significant saving/damage avoidance was reported by the household taking early actions and making informed decisions. The early actions helped them save their productive assets and avoid losses of input costs. Average savings per household due to taking early action average cost on household assets were saved around 19,161 BDT per household, 36,552 BDT in livestock and 23,451 BDT in the fisheries sector.

The percentage of damage prevented in agricultural sector has increased to 28% since the flood of 2019. The damage prevented in fisheries has increased significantly by 18 percent in 2020 in compared to that of 2019. The death of family members from waterborne diseases has decreased (except female members) in comparison to the previous flood in 2019. The assessment also revelaed that receving early warning messages with enough lead time to take action has enabled the community to be better prepared compared to the previous years.

7.4 Estimation of Flood Return Period

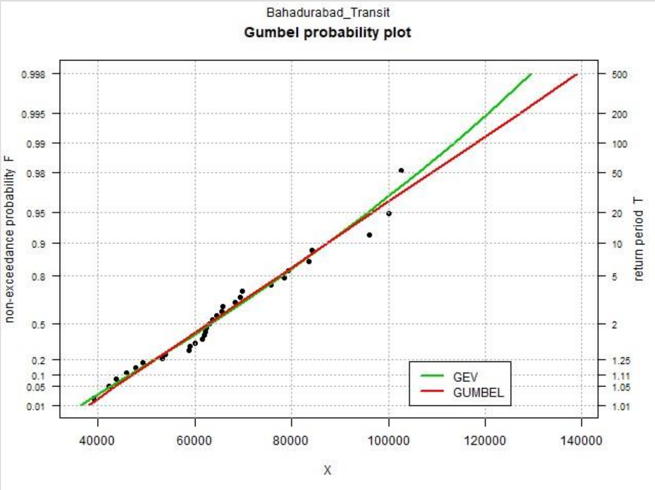
The total flood flow in the country can be considered as the sum of flows from the major rivers– the Brahmaputra-Jamuna, Ganges-Padma and Meghna. Flow of the Brahmaputra, Ganges and Meghna rivers can be represented by observed flow data at Bahadurabad, Hardinge Bridge and Bhairab Bazar respectively. The combined flow of the Brahmaputra-Jamuna and the Ganges can be represented by observed flow data at Baruria. Similarly the combined flow of the Brahmaputra-Jamuna and Ganges-Padma cam be represented by observed flow data at Mawa. Flow at these five locations can be considered as the representative flood flow of the country in a season. Combined flow of the Brahmaputra-Jamuna, Ganges-Padma and the Meghna could not be considered due to unavailability of discharge data at Chandpur. Last 31 years of flow data at Bahadurabad, Hardinge Bridge, Bhairab Bazar, Baruria and Mawa are presented in the following table.

Table 7.1: Observed Flow (in Cumec) at Bahadurabad, Hardinge Bridge, Bhairab Bazar, Baruria and Mawa (1990-2020)

Year	Bahadurabad	Hardinge Bridge	Bhairab Bazar	Baruria	Mawa
1990	64400	49900	11700	83200	-
1991	61500	55100	14100	99000	-
1992	65600	41800	12600	72200	-
1993	59100	44700	**19200**	83300	-
1994	39100	-	9160	81700	88990
1995	84200	-	13400	99800	100000
1996	83485	54488	10900	96500	85605
1997	79270	42465	7825	89965	82324
1998	**102535**	**73091**	14670	**141940**	**100000**
1999	61915	61123	-	92417	96491
2000	69320	52539	12110	87058	85597
2001	49230	53408	11631	86312	71962
2002	69728	40980	16558	80988	-
2003	65684	59876	13229	106286	100000
2004	96106	37706	10571	114128	100000
2005	58767	43620	10787	98047	86075
2006	47666	37254	9464	60358	70984
2007	42241	54217	9133	45751	-
2008	62379	50562	8727	97572	100000
2009	54004	38601	8032	82441	69798
2010	45775	40276	8241	79739	80511
2011	53317	48685	7375	90818	80346
2012	63554	44275	15806	96274	71886
2013	75660	54225	8203	91820	85016
2014	62924	43412	9945	98213	79344
2015	68341	46679	9076	94820	88009
2016	100104	56135	9966	91359	94100
2017	78525	49035	11026	97281	100000
2018	43662	40749	8598	91500	44572
2019	62164	56424	12911	97400	71820
2020	60034	45325	14199	109000	86578

Return period analysis based on the observed flow data at representative stations by Gumbel and Generalized Extreme Value (GEV) distributions is presented graphically below.

BAHADURABAD

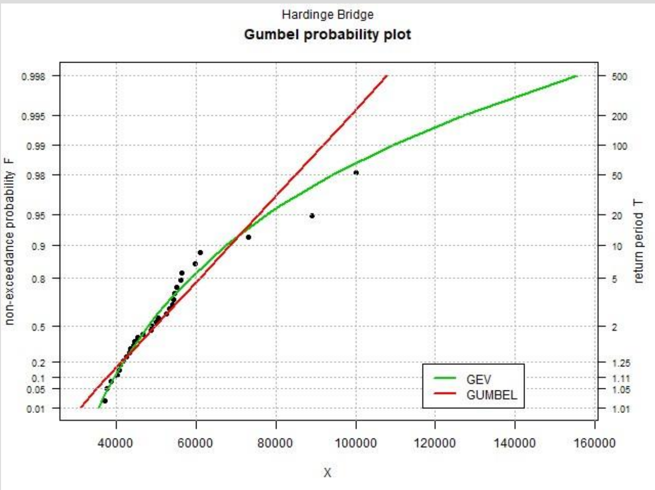


	F	T	GUMBEL	GEV
1	0.800	5	77551.5	78089.8
2	0.900	10	87358.1	87306.7
3	0.950	20	96764.8	95753.9
4	0.960	25	99748.7	98355.7
5	0.980	50	108940.9	106143.0
6	0.990	100	118065.1	113544.3
7	0.995	200	127156.0	120606.8
8	0.998	500	139149.8	129470.4

31 Years of Discharge Data

Figure 7.7: Return Period Analysis by Gumbel Distribution at Bahadurabad

HARDINGE BRIDGE

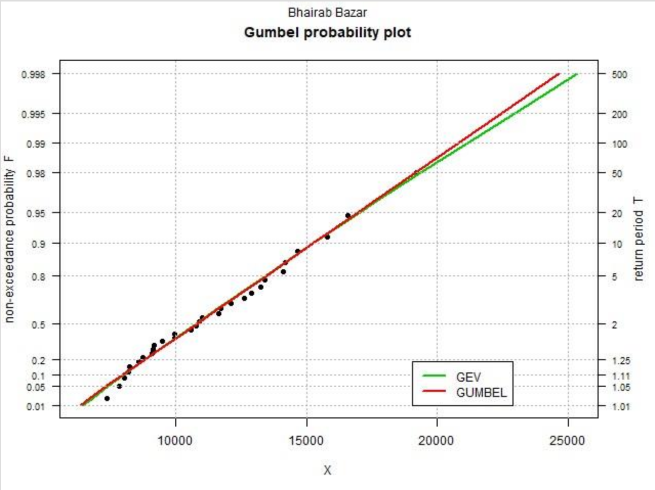


	F	T	GUMBEL	GEV
1	0.800	5	60981.4	58640.4
2	0.900	10	68452.6	67572.4
3	0.950	20	75619.2	77859.1
4	0.960	25	77892.6	81526.4
5	0.980	50	84895.7	94226.9
6	0.990	100	91847.0	109235.6
7	0.995	200	98773.1	127021.6
8	0.998	500	107910.6	155731.0

29 Years of Discharge Data

Figure 7.8 : Return Period Analysis by Gumbel Distribution at Hardinge Bridge

BHAIRAB BAZAR

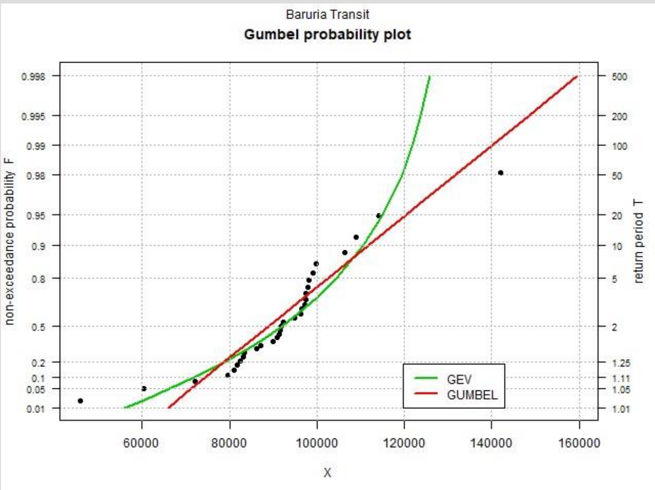


	F	T	GUMBEL	GEV
1	0.800	5	13486.8	13446.8
2	0.900	10	15261.5	15259.9
3	0.950	20	16963.8	17028.8
4	0.960	25	17503.8	17596.0
5	0.980	50	19167.2	19362.3
6	0.990	100	20818.4	21144.1
7	0.995	200	22463.5	22948.1
8	0.998	500	24634.0	25372.7

30 Years of Discharge Data

Figure 7.9 : Return Period Analysis by Gumbel Distribution at Bhairab Bazar

BARURIA

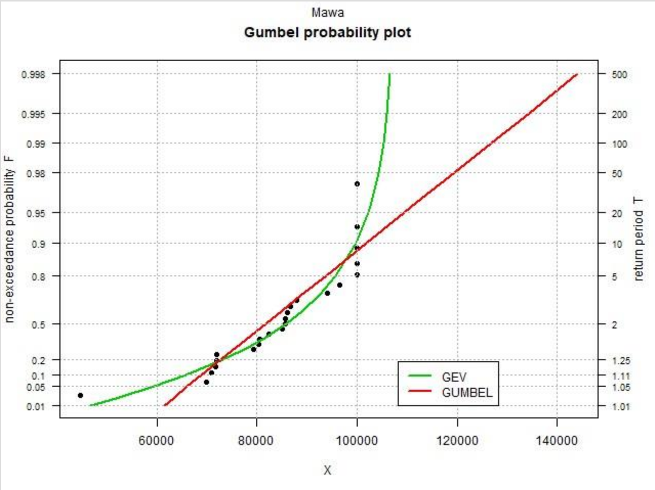


	F	T	GUMBEL	GEV
1	0.800	5	102690	104602
2	0.900	10	111773	110612
3	0.950	20	120486	115082
4	0.960	25	123249	116284
5	0.980	50	131763	119440
6	0.990	100	140214	121900
7	0.995	200	148634	123826
8	0.998	500	159742	125752

31 Years of Discharge Data

Figure 7.10 : Return Period Analysis by Gumbel Distribution at Baruria

MAWA



	F	T	GUMBEL	GEV
1	0.800	5	93812.4	95794.3
2	0.900	10	101827.3	99723.4
3	0.950	20	109515.5	102247.9
4	0.960	25	111954.2	102863.0
5	0.980	50	119466.9	104341.4
6	0.990	100	126924.2	105343.3
7	0.995	200	134354.2	106026.4
8	0.998	500	144156.7	106609.8

25 Years of Discharge Data

Figure 7.11 : Return Period Analysis by Gumbel Distribution at Mawa

Based on the Gumbel distribution, return periods of the 2020 flood are presented in Table 7.2. It should be mentioned that the observed flows in some cases missed the peak due to which the return periods of the 2020 flood tend to be underestimated.

Table 7.2: Return Periods of the 2020 Flood (in years)

Station	River	Return Period
Bahadurabad	Brahmaputra	1.80
Hardinge Bridge	Ganges	1.625
Bhairab Bazar	Meghna	7.00
Baruria	Padma	8.50
Mawa	Padma	4.25

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 parts of Meghna, North and South-Eastern Hill basins are vulnerable to flash flood from the beginning of monsoon 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 and flood inundation maps. The forecast was based on 5-days WL at 54 stations on 28 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 Haor 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 Haor Infrastructure & Livelihood Improvement Project (HILIP) by Local Government Engineering Department (LGED), 3-days experimental flash flood forecast was introduced for the region which has been made operational this year by incorporating BMD generated numerical rainfall forecast. Currently flash flood forecast is being generated at 25 stations within the Upper Meghna basin 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. A new addition since 2018 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.

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 operational 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. Also experimental 15-days probabilistic streamflow forecast for the Brahmaputra-Ganges-Meghna rivers has been launched this year through which the 10-days lead time of medium range forecast can potentially be updated to 15-days in future.

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 then press 5 to 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.

Due to different shortcomings including limited upstream hydro-meteorological information, old & relatively coarse DEM and limited technological development of the centre itself, the services were fully not satisfactory to all corners. Area-inundation forecast based on a coarse DEM and old topographic maps have been indicative. 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.

A major step forward towards improving the inundation mapping is the experimental operarion of Google-BWDB-a2i Flood Forecasting Initiative this year. Google and BWDB have been officially working together since 2019 with the support from a2i on improving the existing flood forecasting system at local level. The system has been developed using 5-day deterministic flood forecasts of FFWC, BWDB but additionally with the help of a high-resolution satellite based DEM from Google to develop a more accurate local level flood inundation map for the Jamuna-Padma river belt. Under the system, over 700,000 warning messages have been sent to local level users through Google alert services using Android push notification which has allowed end users to access information on upcoming flood and its magnitude directly from their mobile phone at union level. An embankment-based forecast system and SMS alert system in connection to this will hopefully launch in future. Also the system is planned to expand step by step for the whole country.

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 2020 through the difficult ongoing Covid-19 pandemic situation.

As a whole the flood of 2020 was a severe one with long duration which affected all the country except the South-Eastern Hill basin for only very short duration. The 2020 flood surpassed the duration of 1988 and 2007 floods at many places in the Northern, North-Western, North-Central and Central regions of Bangladesh along the major rivers, but stayed for shorter duration than 1998. In terms of magnitude the WL of Northern streams excceded that of historical major flood years– notably the Teesta river at Dalia, Gur river at Singra and Atrai river at Atrai exceeding the RHWL. However the flood magnitudes elsewhere were less than that of historical major flood years except at Goalundo on Padma which surpassed the level of 1988 flood. The 2020 flood season characteristically was a more active than normal monsoon. Mostly due to greater and frequent rush of upstream water, the flood of 2020 started from the second half of June and continued till first half of October in six spells stretching the flood duration throughout the monsoon. One notable event of 2020 was the flood of Dhaka and surroundings for long duration which occurred first since 2007. Another notable event was the flood of South-Western and South-Central coastal regions at the middle of monsoon during the second half of August due to upstream rush of water combined with excessive rainfall and above normal spring tide during the new moon. There is a growing concern regarding more coastal flooding in future.

Evaluation indicated that, the accuracy of deterministic flood forecasts issued by FFWC for monsoon-2020 on major rivers were around 95%, 91%, 87%, 83% and 78% consistent on average for 24hrs, 48hrs, 72hrs, 96hrs and 120 hrs 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 40% of the whole country this year (59,028 sq-km approximately) corresponding to severe flooding. Some of the regions experienced severe river bank erosion which continued both during and after the flooding.

Annex-1

5 Days Deterministic Forecast for 24, 48, 72, 96 & 120 Hrs

FFWC, BWDB

SL NO	River	Station	D.L. (meter)	Today 25-07 6:00 AM (meter)	24-hrs forecast 26-07 6:00 AM (meter)	24-hrs +Rise -fall 26-07 6:00 AM (cm)	24-hrs +above -below D.L. 26-07 6:00 AM (cm)	48-hrs forecast 27-07 6:00 AM (meter)	48-hrs +Rise -fall 27-07 6:00 AM (cm)	48-hrs +above -below D.L. 27-07 6:00 AM (cm)	72-hrs forecast 28-07 6:00 AM (meter)	72-hrs +Rise -fall 28-07 6:00 AM (cm)	72-hrs +above -below D.L. 28-07 6:00 AM (cm)	96-hrs forecast 29-07 6:00 AM (meter)	96-hrs +Rise -fall 29-07 6:00 AM (cm)	96-hrs +above -below D.L. 29-07 6:00 AM (cm)	120-hrs forecast 30-07 6:00 AM (meter)	120-hrs +Rise -fall 30-07 6:00 AM (cm)	120-hrs +above -below D.L. 30-07 6:00 AM (cm)
1	Atrai	Mohadevpur	18.59	17.13	16.79	-34	-180	16.39	-41	-220	16.02	-37	-258	15.73	-28	-286	15.67	-6	-292
2	Atrai	Atrai	13.72	13.99	14.05	+6	+33	14.07	+2	+35	14.04	-3	+32	13.98	-5	+26	13.94	-4	+22
3	Atrai	Singra	12.65	13.54	13.59	+5	+94	13.60	+1	+95	13.58	-2	+93	13.54	-4	+89	13.53	0	+88
4	Karatoa-Atrai-GGH	Baghabari	10.40	11.40	11.41	+1	+101	11.41	0	+101	11.42	+1	+102	11.44	+2	+104	11.51	+6	+111
5	Little Jamuna	Naogaon	15.25	15.06	15.01	-5	-24	14.85	-16	-40	14.67	-19	-58	14.53	-14	-72	14.54	0	-71
6	Karatoya	Chakrahimpur	20.15	20.58	20.55	-3	+40	20.47	-8	+32	20.35	-12	+20	20.25	-11	+10	20.18	-6	+3
7	Karatoya	Bogra	16.30	14.73	14.90	+17	-140	14.98	+8	-132	14.99	+1	-131	14.93	-5	-137	14.84	-9	-146
8	Teesta	Kaunia	29.20	28.71	28.45	-26	-75	28.42	-3	-78	28.59	+18	-61	28.93	+34	-27	29.07	+14	-13
9	Ghagot	Gaibandha	21.70	22.45	22.35	-10	+65	22.25	-10	+55	22.25	0	+55	22.35	+10	+65	22.35	0	+65
10	Dharla	Kurigram	26.50	27.15	27.07	-8	+57	26.98	-9	+48	26.98	0	+48	27.05	+8	+55	27.10	+5	+60
11	Brahmaputra	Chilmari	23.70	24.47	24.46	-1	+76	24.45	-1	+75	24.46	+1	+76	24.53	+7	+83	24.64	+11	+94
12	Jamuna	Bahadurabad	19.50	20.60	20.58	-2	+108	20.57	-1	+107	20.57	0	+107	20.62	+5	+112	20.72	+10	+122
13	Jamuna	Sariakandi	16.70	17.87	17.85	-2	+115	17.84	-1	+114	17.84	0	+114	17.87	+3	+117	17.95	+8	+125
14	Jamuna	Kazipur	15.25	16.19	16.17	-2	+92	16.16	-1	+91	16.16	0	+91	16.18	+2	+93	16.27	+9	+102
15	Jamuna	Serajganj	13.35	14.18	14.16	-2	+81	14.14	-1	+79	14.14	0	+79	14.17	+2	+82	14.27	+10	+92
16	Jamuna	Porabari	12.27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Jamuna	Aricha	9.40	10.05	10.05	0	+65	10.06	0	+66	10.08	+2	+68	10.12	+4	+72	10.20	+9	+80
18	Old Brahmaputra	Jamalpur	17.00	16.98	16.97	-1	-3	16.97	0	-3	16.98	+1	-2	17.01	+3	+1	17.05	+4	+5
19	Old Brahmaputra	Mymensingh	12.50	12.10	12.14	+4	-36	12.16	+2	-34	12.19	+2	-31	12.22	+4	-28	12.25	+3	-25
20	Bangshi	Nayerhat	7.30	6.55	6.57	+2	-73	6.59	+3	-71	6.63	+4	-67	6.69	+6	-61	6.75	+6	-55
21	Old Dhalesari	Jagir	8.25	9.05	9.06	+1	+81	9.08	+2	+83	9.11	+2	+86	9.14	+3	+89	9.16	+2	+91
22	Dhaleswari	Kalagachia	4.88	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	Kaliganga	Taraghat	8.40	9.38	9.41	+3	+101	9.43	+2	+103	9.45	+2	+105	9.49	+4	+109	9.52	+3	+112
24	Tongi Khal	Tongi	6.10	6.02	6.04	+2	-6	6.06	+2	-4	6.08	+3	-2	6.13	+4	+3	6.16	+4	+6
25	Turag	Mirpur	5.95	5.90	5.92	+2	-3	5.94	+2	-1	5.97	+3	+2	6.01	+4	+6	6.05	+4	+10
26	Buriganga	Dhaka (Mill Barrack)	6.00	5.12	5.14	+2	-86	5.15	+1	-85	5.18	+2	-82	5.22	+4	-78	5.26	+4	-74
27	Buriganga	Dhaka (Hariharpara)	5.79	5.1	5.12	+2	-67	5.13	+1	-66	5.15	+2	-64	5.19	+4	-60	5.23	+4	-56
28	Balu	Demra	5.75	5.80	5.82	+2	+7	5.83	+1	+8	5.85	+3	+10	5.89	+4	+14	5.93	+4	+18
29	Lakhya	Narayanganj	5.50	5.63	5.65	+2	+15	5.66	+1	+16	5.68	+2	+18	5.72	+4	+22	5.75	+4	+25
30	Dhaleswari	Elashinghat	11.40	12.49	12.49	0	+109	12.48	-1	+108	12.49	0	+109	12.51	+2	+111	12.56	+6	+116
31	Lakhya	Lakhpur	5.80	5.59	5.59	0	-21	5.60	+1	-20	5.62	+2	-18	5.66	+4	-14	5.69	+3	-11
32	Dhaleswari	Rekabi Bazar	5.20	4.92	4.94	+2	-26	4.95	+1	-25	4.97	+2	-23	5.01	+4	-19	5.05	+4	-15
33	Mohananda	Chapai Nawabganj	21.00	20	20.04	+4	-96	20.08	+5	-92	20.14	+5	-86	20.20	+6	-80	20.27	+7	-73
34	Ganges	Rajshahi	18.50	16.68	16.70	+2	-180	16.78	+8	-172	16.88	+10	-162	16.99	+11	-151	17.11	+12	-139
35	Ganges	Hardinge Br	14.25	13.36	13.35	-1	-90	13.40	+5	-85	13.49	+8	-77	13.58	+10	-67	13.71	+12	-54
36	Ganges	Talbaria	12.80	12.88	12.87	-1	+7	12.92	+5	+12	13.00	+9	+20	13.11	+11	+31	13.24	+13	+44
37	Padma	Goalondo	8.65	9.75	9.76	+1	+111	9.76	+1	+111	9.79	+3	+114	9.84	+5	+119	9.93	+9	+128

Note:
1) 24 hrs. rise/fall indicates changes in water levels from today 6 A.M. to 26-7-2020 6:00 A.M.
2) 48 hrs. rise/fall indicates changes in water levels from 26-7-2020 6:00 A.M. to 27-7-2020 6:00 A.M
3) 72 hrs. rise/fall indicates changes in water levels from 27-7-2020 6:00 A.M. to 28-7-2020 6:00 A.M
4) 96 hrs. rise/fall indicates changes in water levels from 28-7-2020 6:00 A.M. to 29-7-2020 6:00 A.M.
5) 120 hrs. rise/fall indicates changes in water levels from 29-7-2020 6:00 A.M. to 30-7-2020 6:00 A.M.
6) "+ above" means water level flowing above danger level, "-below" means water level flowing below danger level.

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A Sample of 5-days Deterministic Forecast Bulletin

Annex-2

FLOOD FORECASTING AND WARNING CENTER, BWDB
RIVER SITUATION AS ON 01-08-2020 AT 09:00 HOURS

SL	RIVER	STATION NAME	RHWL (m PWD)	D.L. (m PWD)	W A T E R L E V E L (m PWD) 31-07-2020	W A T E R L E V E L (m PWD) 01-08-2020	+ Rise - Fall in cm	Above(+) /Below(-) D.L. in cm
	BRAHMAPUTRA BASIN							
1	DHARLA	KURIGRAM	27.84	26.50	26.84	26.95	+ 11	+ 45
2	TEESTA	DALIA	53.12	52.60	52.50	52.50	0	-10
3	TEESTA	KAUNIA	30.52	29.20	28.96	29.00	+ 4	-20
4	JAMUNESWARI	BADARGANJ	33.61	32.15	31.67	32.03	+ 36	-12
5	GHAGOT	GAIBANDHA	22.81	21.70	21.93	21.97	+ 4	+ 27
6	KARATOA	CHAK RAHIMPUR	21.41	20.15	19.72	19.70	-2	-45
7	KARATOA	BOGRA	17.45	16.30	14.75	14.64	-11	-166
8	BRAHMAPUTRA	NOONKHAWA	28.10	26.50	26.34	26.52	+ 18	+ 2
9	BRAHMAPUTRA	CHILMARI	25.07	23.70	23.85	23.96	+ 11	+ 26
10	JAMUNA	FULCHARI	21.35	19.82	20.19	20.20	+ 1	+ 38
11	JAMUNA	BAHADURABAD	21.16	19.50	19.98	20.03	+ 5	+ 53
12	JAMUNA	SARIAKANDI	19.07	16.70	17.25	17.23	-2	+ 53
13	JAMUNA	KAZIPUR	17.47	15.25	15.58	15.52	-6	+ 27
14	JAMUNA	SERAJGANJ	15.12	13.35	13.73	13.69	-4	+ 34
15	JAMUNA	ARICHA	10.76	9.40	9.97	9.81	-16	+ 41
16	GUR	SINGRA	13.67	12.65	13.45	13.40	-5	+ 75
17	ATRAI	BAGHABARI	12.45	10.40	11.29	11.25	-4	+ 85
18	DHALESWARI	ELASIN	12.80	11.40	12.37	12.29	-8	+ 89
19	OLD BRAHMAPUTRA	JAMALPUR	18.00	17.00	16.81	16.69	-12	-31
20	OLD BRAHMAPUTRA	MYMENSINGH	13.71	12.50	12.32	12.20	-12	-30
21	LAKHYA	LAKHPUR	8.70	5.80	5.76	5.79	+ 3	-1
22	BURIGANGA	DHAKA	7.58	6.00	5.28	5.34	+ 6	-66
23	BURIGANGA	HARIHARPARA	7.13	5.79	5.22	5.26	+ 4	-53
24	BALU	DEMRA	7.13	5.75	5.88	5.87	-1	+ 12
25	LAKHYA	NARAYANGANJ	6.93	5.50	5.64	5.60	-4	+ 10
26	TURAG	MIRPUR	8.35	5.95	6.33	6.37	+ 4	+ 42
27	TONGI KHAL	TONGI	7.84	6.10	6.38	6.39	+ 1	+ 29
28	KALIGANGA	TARAGHAT	10.39	8.40	9.41	9.37	-4	+ 97
29	DHALESWARI	JAGIR	9.96	8.25	9.21	9.12	-9	+ 87
30	DHALESWARI	REKABI BAZAR	7.66	5.20	4.98	4.99	+ 1	-21
31	BANSHI	NAYARHAT	8.39	7.30	7.45	7.52	+ 7	+ 22
	GANGES BASIN							
32	KARATOA	PANCHAGARH	72.65	70.75	67.83	67.65	-18	-310
33	PUNARBHABA	DINAJPUR	34.40	33.50	31.96	32.00	+ 4	-150
34	ICH-JAMUNA	PHULBARI	30.47	29.95	27.88	27.87	-1	-208
35	TANGON	THAKURGAON	51.30	50.40	48.28	48.04	-24	-236
36	UPPER ATRAI	BHUSIRBANDAR	41.10	39.62	38.53	37.92	-61	-170
37	MOHANANDA	ROHANPUR	23.83	22.00	21.10	21.00	-10	-100
38	MOHANANDA	CHAPAI-NAWABGANJ	23.01	21.00	20.06	20.04	-2	-96
39	LITTLE JAMUNA	NAOGAON	16.20	15.25	14.66	14.64	-2	-61
40	ATRAI	MOHADEBPUR	19.89	18.59	16.20	16.66	+ 46	-193
41	ATRAI	ATRAI	14.31	13.72	13.65	13.54	-11	-18
42	GANGES	PANKHA	24.14	22.50	20.82	20.81	-1	-169
43	GANGES	RAJSHAHI	20.00	18.50	16.86	16.82	-4	-168
44	GANGES	HARDINGE BRIDGE	15.19	14.25	13.41	13.38	-3	-87
45	GANGES	TALBARIA	14.53	13.50	12.88	12.80	-8	-70
46	PADMA	GOALUNDO	10.21	8.65	9.56	9.48	-8	+ 83
47	PADMA	BHAGYAKUL	7.50	6.30	6.92	6.84	-8	+ 54
48	PADMA	MAWA	7.14	6.10	6.65	6.57	-8	+ 47
49	PADMA	SURESWAR	7.50	4.45	4.56	4.58	+ 2	+ 13
50	GORAI	GORAI RLY BRIDGE	13.65	12.75	12.00	11.93	-7	-82
51	GORAI	KAMARKHALI	9.48	8.20	8.01	7.97	-4	-23
52	ICHAMATI	SAKRA	4.69	3.95	2.87	2.54	-33	-141
53	MATHABHANGA	CHUADANGA	12.67	12.05	9.45	9.40	-5	-265
54	MATHABHANGA	HATBOALIA	15.13	14.50	10.93	10.91	-2	-359
55	KOBADAK	JHIKARGACHA	5.59	5.10	3.81	3.83	+ 2	-127
56	BETNA	KALAROA	4.89	-	4.05	4.06	+ 1	-
57	KUMAR	FARIDPUR	8.76	7.50	5.38	5.37	-1	-213
58	ARIALKHAN	MADARIPUR	5.80	4.20	4.32	4.27	-5	+ 7
59	KIRTONKHOLA	BARISAL	3.20	2.55	1.76	1.72	-4	-83
60	PASHURE	KHULNA	3.48	3.05	2.73	2.28	-45	-77
61	PASHURE	MONGLA	3.28	2.07	2.70	2.34	-36	+ 27

Cont/2

A Sample Flood Bulletin

Annex-3

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; ওয়েবসাইটঃ www.ffwc.gov.bd দূরালাপনিঃ ৯৫৫৩১১৮, ৯৫৫০৭৫৫, ফ্যাক্সঃ ৯৫৫৭৩৮৬

বৃষ্টিপাত ও নদ-নদীর অবস্থা
১৭ শ্রাবণ ১৪২৭ বং/০১ অগাস্ট ২০২০ খৃঃ

এক নজরে নদ-নদীর পরিস্থিতি

- ব্রহ্মপুত্র নদের পানি সমতল বৃদ্ধি পাচ্ছে অপরদিকে যমুনা নদীর পানি সমতল স্থিতিশীল আছে, যা আগামী ২৪ ঘণ্টা পর্যন্ত অব্যাহত থাকতে পারে।
- গঙ্গা-পদ্মা নদীসমূহের পানি সমতল হ্রাস পাচ্ছে, যা আগামী ৪৮ ঘণ্টা পর্যন্ত অব্যাহত থাকতে পারে।
- উত্তর-পূর্বাঞ্চলের আপার মেঘনা অববাহিকার প্রধান নদীসমূহের পানি সমতল হ্রাস পাচ্ছে, যা আগামী ৪৮ ঘণ্টায় হ্রাস পেতে পারে।
- ঢাকা জেলার আশেপাশের নদীসমূহের পানি সমতল স্থিতিশীল আছে, যা আগামী ২৪ ঘণ্টা পর্যন্ত অব্যাহত থাকতে পারে।
- আগামী ২৪ ঘণ্টায় গাইবান্ধা, বগুড়া, জামালপুর, নাটোর, সিরাজগঞ্জ, টাঙ্গাইল, মানিকগঞ্জ, মুন্সিগঞ্জ, ফরিদপুর, মাদারীপুর, চাঁদপুর, রাজবাড়ি, ব্রাহ্মণবাড়িয়া, শরীয়তপুর এবং ঢাকা জেলার বন্যা পরিস্থিতির উন্নতি হতে পারে।
- আগামী ২৪ ঘণ্টায় কুড়িগ্রাম ও নারায়ণগঞ্জ জেলার বন্যা পরিস্থিতি স্থিতিশীল থাকতে পারে।
- আগামী ২৪ ঘণ্টায় ঢাকা সিটি কর্পোরেশন সংলগ্ন নিম্নাঞ্চল সমূহের বন্যা পরিস্থিতি স্থিতিশীল থাকতে পারে।

নদ-নদীর অবস্থা (আজ সকাল ০৯:০০ টা পর্যন্ত)

পর্যবেক্ষণাধীন পানি সমতল স্টেশন	১০১	গেজ পাঠ পাওয়া যায়নি	**০০**
বৃদ্ধি	৩০	বন্যা আক্রান্ত জেলার সংখ্যা	**১৭**
হ্রাস	৬৯	**বিপদসীমার উপরে নদীর সংখ্যা**	**১৯**
অপরিবর্তিত	০২	**বিপদসীমার উপরে স্টেশনের সংখ্যা**	**২৭**

অপর পৃষ্ঠার দ্রষ্টব্য

A Sample Flood Situation Summary

Annex-4

Flood Forecasting and Warning Center, Bangladesh Water Development Board

Web: www.ffwc.gov.bd, Email: ffwcbwdb@gmail.com

Medium Range 1-10 days Probabilistic Forecast

Forecast As of July 15, 2020

Outlook for Next 10 Days:

- Water level in Brahmaputr-Jamuna river system may continue to rise during the next 24 hours and then remain steady till 20th July. As a result, the flood situation in Kurigram, Bogra, Gaibandha, Jamalpur, Sirajganj, Tangail and Manikganj may remain unchanged during next 5 days.
- Water level in Brahmaputra-Jamuna river system may again start rising after 20th July and reach peak around 25th. Flood situation in the above mentioned districts are likely to deteriorate after 20th July. As a result, the ongoing flood in the above mentioned districts may continue towards the end of July.
- Ganges-Padma River may steadily rise. Water level at Goalondo station at Rajbari District, Bhagyakul station at Munshiganj and Sureshwar station at Shariatpur district may continue to rise during the next 5 days. As a result, flood situation is likely to continue in the low lying areas of these districts during next 10 days. Water level may exceed danger level at Sureshwar station in Shariatpur district during next 24 hours.
- Rivers around Dhaka city may rise. No probability of flooding is forecasted in the rivers around Dhaka city

For viewing interactive hydrographs of the Medium Range forecast please visit:
http://ffwc.gov.bd/index.php/hydrograph/medium-range-1-10-days-forecast

আগামী ১০ দিনের সম্ভাব্য পূর্বাভাস

- ব্রক্ষপুত্র-যমুনা নদীর পানি সমতল আগামী ২৪ ঘন্টায় বাড়তে পারে এবং তারপর ২০ জুলাই নাগাদ স্থিতিশীল হতে পারে। যার ফলে আগামী ৫ দিন কুড়িগ্রাম, বগুড়া, গাইবান্ধা, সিরাজগঞ্জ, জামালপুর, টাঙ্গাইল এবং মানিকগঞ্জ জেলার সার্বিক বন্যা পরিস্থিতি প্রায় অপরিবর্তিত থাকতে পারে।
- ব্রক্ষপুত্র-যমুনা নদীর পানি সমতল আগামী ২০ জুলাই এর পর পুনরায় বাড়তে পারে এবং ২৫ জুলাই নাগাদ সর্বোচ্চ পর্যায়ে পৌছাতে পারে। যার ফলে উপরোল্লিখিত জেলাসমূহে ২০ শে জুলাই এর পর বন্যা পরিস্থিতির অবনতি হতে পারে এবং চলমান বন্যা পরিস্থিতি জুলাই মাসের শেষ পর্যন্ত অব্যাহত থাকতে পারে।
- গঙ্গা-পদ্মা নদীর পানি সমতল বাড়তে পারে। আগামী ৫ দিন রাজবাড়ী জেলার গোয়ালন্দ পয়েন্ট, মুন্সিগঞ্জ জেলার ভাগ্যকূল পয়েন্ট এবং শরীয়তপুর জেলার সুরেশ্বর পয়েন্টে পানি সমতল বাড়তে পারে। যার ফলে জেলাসমূহের নিম্নাঞ্চলে বন্যা পরিস্থিতি আগামী ১০ দিন পর্যন্ত স্থায়ী হতে পারে। শরীয়তপুরের সুরেশ্বর পয়েন্টে পানি সমতল আগামী ২৪ ঘন্টার মধ্যে বিপদসীমা অতিক্রম করতে পারে।
- ঢাকার চারপাশের নদীসমূহের পানি সমতল বাড়তে পারে। ঢাকার চারপাশের নদীসমূহের অববাহিকায় বিপদসীমা অতিক্রমের সম্ভাবনা নেই।

১০ দিনের সম্ভাব্যতা ভিত্তিক পূর্বাভাসের ইন্টার‍্যাক্টিভ হাইড্রোগ্রাফ দেখতে ভিজিট করুন:
http://ffwc.gov.bd/index.php/hydrograph/medium-range-1-10-days-forecast

Developed With Technical and Implementation Support from Regional Integrated Multi-Hazard Early Warning System (RIMES)

A Sample Medium Range 1-10 days Probabilistic Forecast Outlook

Annex-5

Forecast made on: 15-07-2020 (Page 1/5)

Water Level in [m]			today	1-day forecast	2-day forecast	3-day forecast	4-day forecast	5-day forecast	6-day forecast	7-day forecast	8-day forecast	9-day forecast	10-day forecast	Forecast type
			15-07	16-07	17-07	18-07	19-07	20-07	21-07	22-07	23-07	24-07	25-07	
River	Station	D.L	0600	0600	0600	0600	0600	0600	0600	0600	0600	0600	0600	
Jamuna	Bahadurabad	19.50	20.74	20.76	20.78	20.78	20.79	20.84	20.98	21.17	21.36	21.52	21.65	Upper Range
				20.75	20.75	20.73	20.71	20.70	20.75	20.89	21.03	21.14	21.26	Lower Range
				20.75	20.77	20.76	20.75	20.77	20.87	21.03	21.21	21.38	21.50	Mean
Jamuna	Sariakandi	16.70	17.82	17.86	17.88	17.89	17.90	17.94	18.04	18.21	18.41	18.62	18.82	Upper Range
				17.86	17.87	17.86	17.84	17.83	17.86	17.96	18.10	18.21	18.32	Lower Range
				17.86	17.87	17.87	17.87	17.89	17.95	18.09	18.26	18.43	18.59	Mean
Jamuna	Kazipur	14.85	16.19	16.27	16.30	16.31	16.33	16.37	16.50	16.73	17.00	17.26	17.52	Upper Range
				16.26	16.28	16.27	16.25	16.24	16.27	16.39	16.57	16.74	16.89	Lower Range
				16.27	16.29	16.29	16.29	16.31	16.39	16.56	16.80	17.04	17.24	Mean
Jamuna	Serajganj	13.35	14.03	14.14	14.18	14.20	14.21	14.26	14.41	14.66	14.95	15.21	15.45	Upper Range
				14.14	14.15	14.15	14.13	14.11	14.15	14.29	14.49	14.67	14.84	Lower Range
				14.14	14.17	14.18	14.17	14.19	14.28	14.48	14.74	14.98	15.18	Mean
Jamuna	Aricha	9.40	9.65	9.79	9.82	9.86	9.89	9.92	10.00	10.14	10.34	10.57	10.77	Upper Range
				9.79	9.81	9.84	9.84	9.84	9.86	9.93	10.05	10.17	10.27	Lower Range
				9.79	9.82	9.85	9.87	9.88	9.93	10.04	10.19	10.38	10.54	Mean
Ganges-Padma	Hardinge Bridge	14.25	12.85	12.76	12.81	12.86	12.90	12.95	13.09	13.27	13.49	13.67	13.77	Upper Range
				12.76	12.80	12.84	12.87	12.90	12.95	13.00	13.10	13.20	13.27	Lower Range
				12.76	12.80	12.85	12.89	12.93	13.01	13.16	13.32	13.46	13.55	Mean

Developed With Technical and Implementation Support from Regional Integrated Multi-Hazard Early Warning System (RIMES)

A Sample Medium Range 1-10 days Probabilistic Forecast Bulletin

Annex-6

নির্বাহী প্রকৌশলীর দপ্তর
বন্যা পূর্বাভাস ও সতর্কীকরণ কেন্দ্র
বাংলাদেশ পানি উন্নয়ন বোর্ড
ওয়াপদা ভবন (৯ম তলা), মতিঝিল বা/এ, ঢাকা-১০০০।
ফোনঃ ৯৫৫৩১১৮, ৯৫৫০৭৫৫; ফ্যাক্সঃ ৮৮-০২-৯৫৫৭৩৮৬
ই-মেইলঃ ffwcbwdb@gmail.com; ffwc05@yahoo.com
ওয়েবসাইটঃ www.ffwc.gov.bd

Office of The Executive Engineer
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WAPDA Building (8th Floor), Motijheel C/A, Dhaka 1000.
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E-mail : ffwcbwdb@gmail.com; ffwc05@yahoo.com
Website: www.ffwc.gov.bd

বন্যা পূর্বাভাস সম্পর্কিত সংক্ষিপ্ত প্রতিবেদন

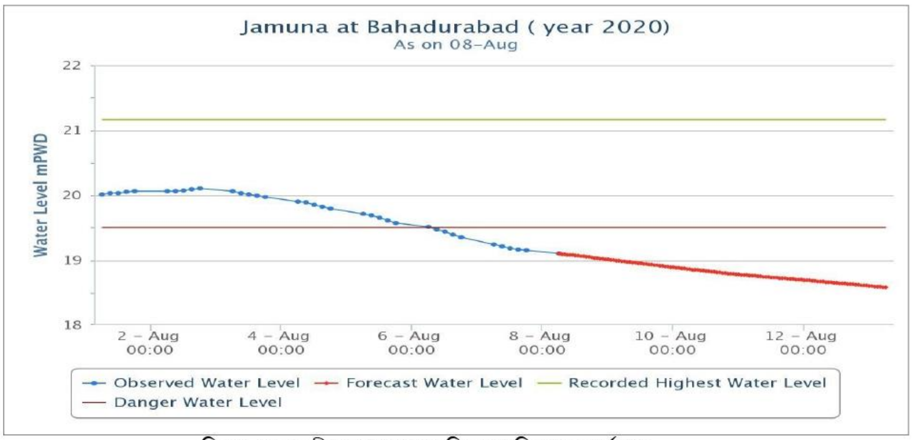
০৮.০৮.২০২০

আগস্ট মাসের প্রারম্ভ থেকে বাংলাদেশ ও উজানের অববাহিকাসমূহে ভারী বৃষ্টিপাত প্রবণতা কমে আসায় দেশের সার্বিক বন্যা পরিস্থিতির ক্রমাগত উন্নতি পরিলক্ষিত হচ্ছে। দেশের মধ্যাঞ্চলের নদীসমূহের পানি সমতল কিছুটা ধীর গতিতে হ্রাস পেলেও বন্যা পরিস্থিতি উন্নতির প্রবণতা লক্ষ্য করা যাচ্ছে। আগামী ২ সপ্তাহের জন্য দেশের সম্ভাব্য বন্যা পরিস্থিতির অববাহিকাভিত্তিক ধারণাগত পূর্বাভাস নিম্নে প্রদত্ত হলো:

ব্রহ্মপুত্র অববাহিকাঃ

ব্রহ্মপুত্র অববাহিকার প্রধান নদ-নদীসমূহের পানি সমতল বর্তমানে হ্রাস পাচ্ছে এবং ব্রহ্মপুত্র-যমুনা নদী আরিচা ব্যতীত উজানের সবগুলো পয়েন্টে বিপদসীমার নিচ দিয়ে প্রবাহিত হচ্ছে। দেশের উত্তরাঞ্চলের বন্যা পরিস্থিতি বর্তমানে স্বাভাবিক হয়ে এসেছে। চলতি সপ্তাহে ব্রহ্মপুত্র অববাহিকার অবশিষ্ট পয়েন্টগুলোতে পানি সমতল বিপদসীমার নিচে নেমে আসতে পারে এবং এর ফলে দেশের উত্তর-মধ্যাঞ্চলের বন্যা পরিস্থিতিও স্বাভাবিক হয়ে আসতে পারে। দেশের উত্তরাঞ্চলের ধরলা ও তিস্তা নদীসমূহের পানি সমতল চলতি সপ্তাহে বৃদ্ধি পেতে পারে তবে উক্ত সময়ে পানি সমতল বিপদসীমা অতিক্রম করে বন্যা পরিস্থিতি সৃষ্টি হওয়ার সম্ভাবনা ক্ষীণ। তৎপরবর্তী সপ্তাহে (১৫-২২ আগস্ট) অববাহিকার নদীসমূহের পানি সমতল হ্রাস প্রবণতা কিছুটা ধীর হয়ে এসে স্থিতাবস্থা প্রাপ্ত হতে পারে তবে বিপদসীমার নিচে অবস্থান করবে এবং নতুন করে বন্যা পরিস্থিতি সৃষ্টি হওয়ার সম্ভাবনা নেই।

ঢাকা শহর ও তদসংলগ্ন এলাকার শীতলক্ষ্যা, বালু, তুরাগ, টঙ্গি, কালীগঙ্গা, ধলেশ্বরী ও বংশী নদীর পানি সমতল আগস্ট মাসের প্রথম সপ্তাহে স্থিতিশীল থাকলেও বর্তমানে হ্রাস পাচ্ছে। চলতি সপ্তাহে উক্ত নদীসমূহের পানি সমতল হ্রাস পাওয়া অব্যাহত থাকার সম্ভাবনার প্রেক্ষিতে রাজধানী ঢাকা ও আশেপাশের এলাকার বন্যা পরিস্থিতি স্বাভাবিক হয়ে আসতে পারে। চলতি মাসে রাজধানী ঢাকা ও আশেপাশের এলাকায় নতুন করে বন্যা পরিস্থিতি সৃষ্টি হওয়ার সম্ভাবনা নেই।



চিত্র-১: যমুনা নদী বাহাদুরাবাদে ৫ দিনের পানি সমতল পূর্বাভাস

পৃষ্ঠা-১ (চলমান)

A Sample 2-Weeks Special Flood Outlook

Annex-7

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-2019 (Morning)

Station Name	River Name	Experimental DL (PM) (mMSL)	RHWL (PM) (mMSL)	15-April-2019 Observed 9:00 AM (mMSL)	Forecast 9:00 PM (mMSL)	12-Hr R/F (cm)	16-April-2019 Forecast 9:00 AM (mMSL)	24-Hr R/F (cm)	Forecast 9:00 PM (mMSL)	36-Hr R/F (cm)	17-April-2019 Forecast 9:00 AM (mMSL)	48-Hr R/F (cm)	Forecast 9:00 PM (mMSL)	60-Hr R/F (cm)	18-April-2019 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 Operational 3-days Flash Flood Forecast Bulletin for the NE Region

Annex-8

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 IN HAOR REGION AS ON APRIL 30, 2019

- ***The major rivers in the North-Eastern region of the Country are in rising trend.***
- ***According to the information of Bangladesh Meteorological Department and Indian Meteorological Department, there is chance of medium to heavy rainfall in places of the North-Eastern part of the Country and adjoining parts of Assam, Meghalaya and Tripura states of India in next 48 hours.***
- ***Water level of the major rivers in the North-Eastern region of the Country; the Surma, Kushiyara and Jadukata may rise rapidly in next 24 hours but will remain below danger level.***

Stations above Danger Levels (As on 30 April 2019, 09:00 am): Nil

Station name	River	Today is Water Level (meter)	Rise(+)/Fall(-) (cm) during last 24 hours	Danger Level (meter)	Above Danger Level (cm)
-	-	-	-	-	-

RAINFALL

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

Station	Rainfall(mm)	Station	Rainfall(mm)
Lorergarh	97.0	Sylhet	70.0
Kanaighat	58.0	Chattak	56.0

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

Station	Rainfall(mm)	Station	Rainfall(mm)
Cherrapunji	133.0	Slichar	33.0

General River Condition

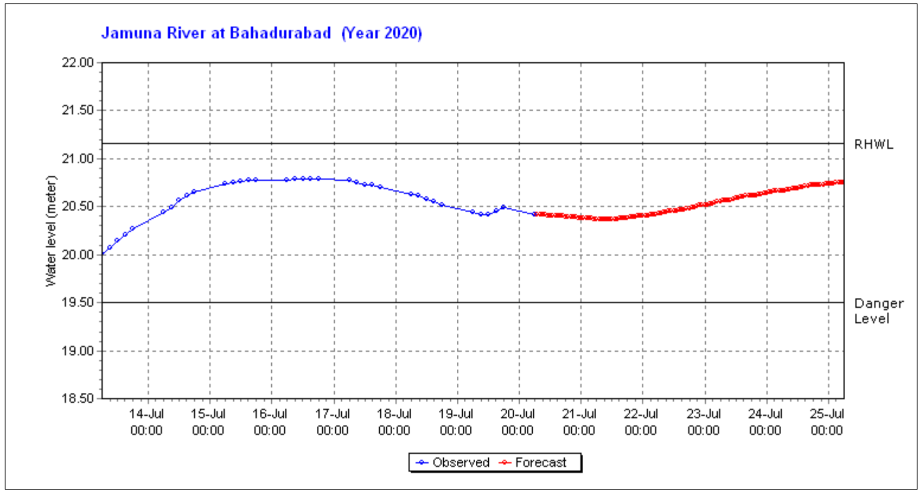
Monitored Water Level Station	39	Inactive Gauge	01
Rise	32	Gauge Reading Missing	02
Fall	04	Total Not Reported	03
Steady	0	Above Danger Level	0

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

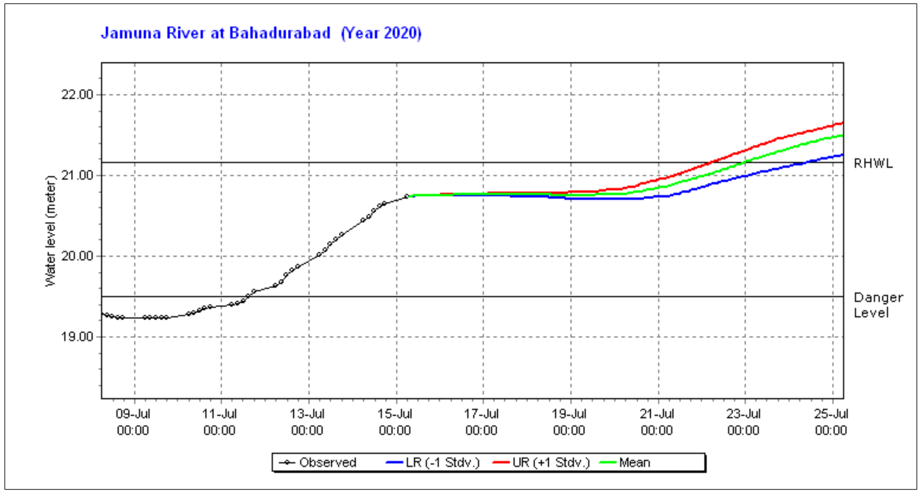
(Md. Arifuzzaman Bhuyan)
Executive Engineer
Duty Officer, FFWC, BWDB.
Cell no: 01715040144

Sample Flash Flood Outlook for the NE region

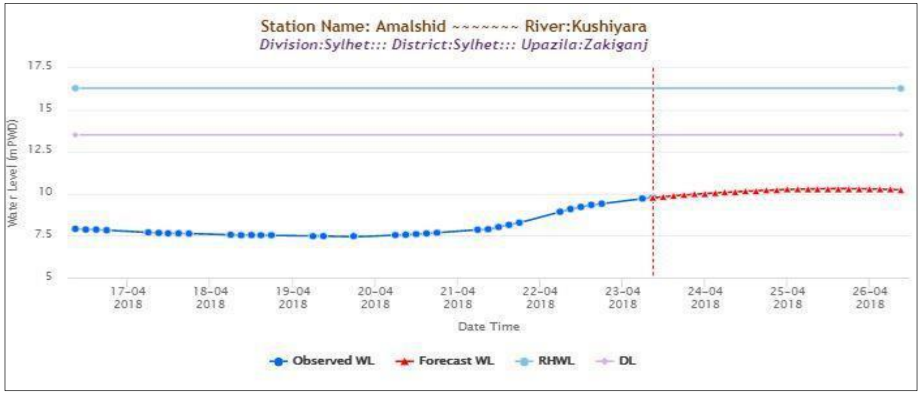
Annex-9



Sample Hydrograph of 5-days Deterministic Forecast



Sample Hydrograph of 10-days Probabilistic Forecast



Sample Hydrograph of 3-days Deterministic Flash Flood Forecast

Flood Forecasting and Warning Centre
Bangladesh Water Development Board
Pani Bhaban (Level-2, Block-G)
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