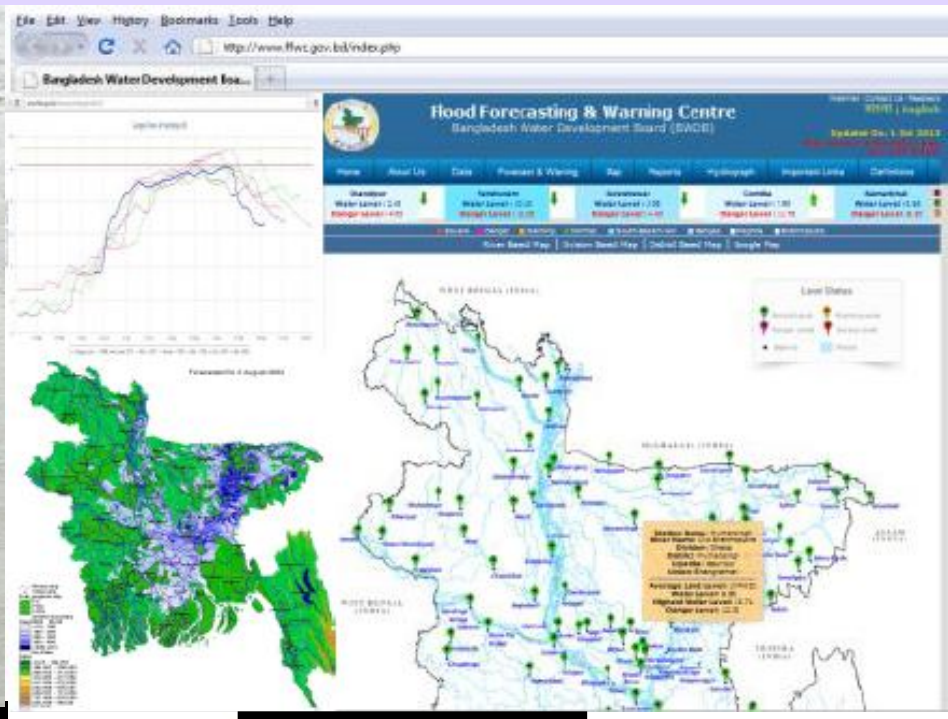
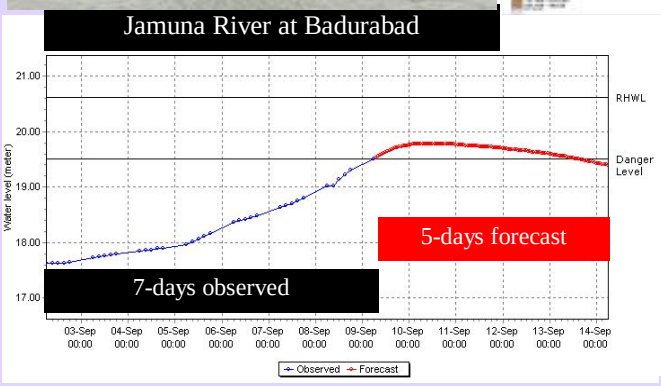
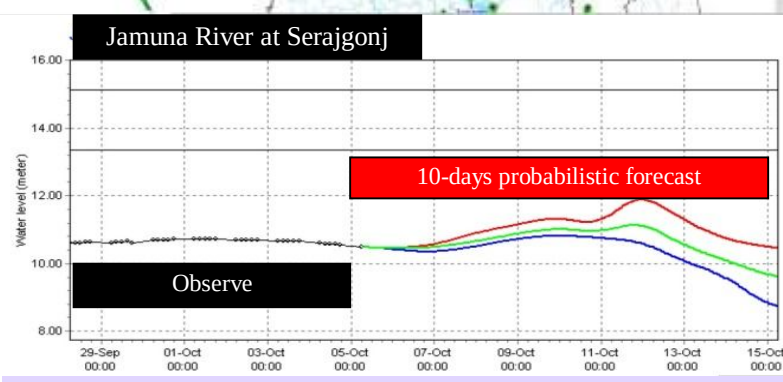
# ANNUAL FLOOD REPORT 2013




**FLOOD FORECASTING & WARNING CENTRE**

**PROCESSING & FLOOD FORECASTING CIRCLE**

**BANGLADESH WATER DEVELOPMENT BOARD**

**Annual Flood Report 2013**

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# TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES

# PREFACE

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

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

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

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

The services of Flood Information Centers (FICs) established at the Division Offices of BWDB, Gauge Reader's, Wireless operators, local communities and other support service providers are gratefully acknowledged. The FFWC is also grateful to the print and electronic news media and those who helped in disseminating the flood information and warning messages during flood 2013. A number of NGOs have been working in different areas for dissemination of the flood warning message generated by the FFWC at community and grass root level (Union and Village), this enables flood preparedness at local level.

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

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

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

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

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

Finally, I sincerely thank and acknowledge my colleagues of the FFWC whose earnest and sincere co-operation made it possible to publish this Annual Flood Report-2013.

(Md. Amirul Hossain)
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# Executive Summary

The characteristics of flood of 2013, is a representative one in respect of duration and magnitude. During the monsoon 2013, the flood was not severe one, duration was short in the north (along the Brahmaputra-Jamuna River) and short to moderate in the part of north east. Duration of flooding in the central part(along the Padma river) was moderate. Duration of flooding in the south west, in the part of Satkhira and Khulna districts was prolong, due to slow drainage or very low carrying capacity of rivers, specially Kobodak, Haribhanga & Shibsa river system. Water Level of Kobodak River at Jhikorgacha flowed above danger level for 120 days. As a whole, the monsoon 2013 was a normal flood year. The evaluation indicated that the accuracy of deterministic flood forecasts issued by FFWC is around 91.6%, 86.3% and 80.2% for 24hrs, 48hrs and 72 hrs respectively for the monsoon of 2013.

The country as a whole received 14.1% less rainfall than normal during the monsoon-2013 (May to October). The Brahmaputra, Meghna and South Eastern Hill basins received 39.8%, 9.9% and 12.4% less rainfall and the Ganges basin received 7.8% more rainfall than the normal value respectively. During the monsoon-2013 all the basins recorded more rainfall than their respective normal during October month. The Meghna and South Eastern hill Basins recorded more rainfall than the normal value in May, it was due to the tropical Cyclone Mahasen that hit Bangladesh coast in 16 May 2013. Basin wise monthly percent less(-) or more(+) rainfall than the normal is presented in the following table.

| Month | Brahmaputra basin | Ganges basin | Meghna basin | South East Hill basin |
|---|---|---|---|---|
| May | -30.69% | 66.35% | 60.94% | 66.07% |
| June | -34.8% | -20.9% | -34.02% | -25.45% |
| July | -37.6% | -11.6% | -22.8% | -34.2% |
| August | -17.4% | +14.56% | -12.5% | -17.0% |
| September | -57.3% | -4.7% | -32.9% | 0.3% |
| October | 11.62% | 155% | 21.21% | 18.33% |

*BWDB Data 2013*

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

Notable improvents have been made during monsoon 2013 are extended lead time of flood forecsaat from 3-days to 5-days, structure based flood forecast for few projects, more user friendly-upgarded-easy to operate web-site with bangla flood warning message and mobile based dissemination system known as Interactive Voice Response (IVR).

During the monsoon-2013, maximum flooded area was 10.6% of the whole country (15,650 sq-km approximately). Some of the regions experienced river bank errosion and flash flood. The part of south west area flooded for prolong period.

**List of Abbreviations**

| | |
|---|---|
| ADG | Additional Director General |
| ADPC | Asian Disaster Preparedness Centre |
| BWDB | Bangladesh Water development Board |
| BMD | Bangladesh Meteorological Department |
| CB | Cell Broadcast |
| CDMP | Comprehensive Disaster Management Programme |
| CEGIS | Centre for Environmental Geographical Information Services |
| CFAB | Climate Forecast Application Bangladesh |
| CARE | Cooperative for American Relief Everywhere |
| CFAN | Climate Forecast Application Network |
| DG | Director General |
| DL | Danger Level |
| DDM | Department of Disaster Management |
| DHI | Danish Hydraulic Institute |
| ECMWF | European Centre for Medium-Range Weather Forecasts |
| DEM | Digital Elevation Model |
| DAE | Department of Agriculture Extension |
| FFWC | Flood Forecasting and Warning Centre |
| GM | General Model |
| GBM | Ganges Brahmaputra Meghna |
| IWM | Institute of Water Modelling |
| IVR | Interactive Voice Response |
| MAE | Mean Absolute Error |
| MoFDM | Ministry of Food and Disaster Management |
| MoWR | Ministry of Food Water Resources |
| NGO | Non-Government Organization |
| MSL | Mean Sea Level |
| RIMES | Regional Integrated Multi-hazard Early Warning System |
| SOD | Standing Order on Disaster |
| SSB | Single Site Band |
| SPARRSO | Space Research and Remote Sensing Organization |
| UNDP | United Nations Development Porgramme |
| USAID | United States Agency for International Development |
| WL | Water Level |

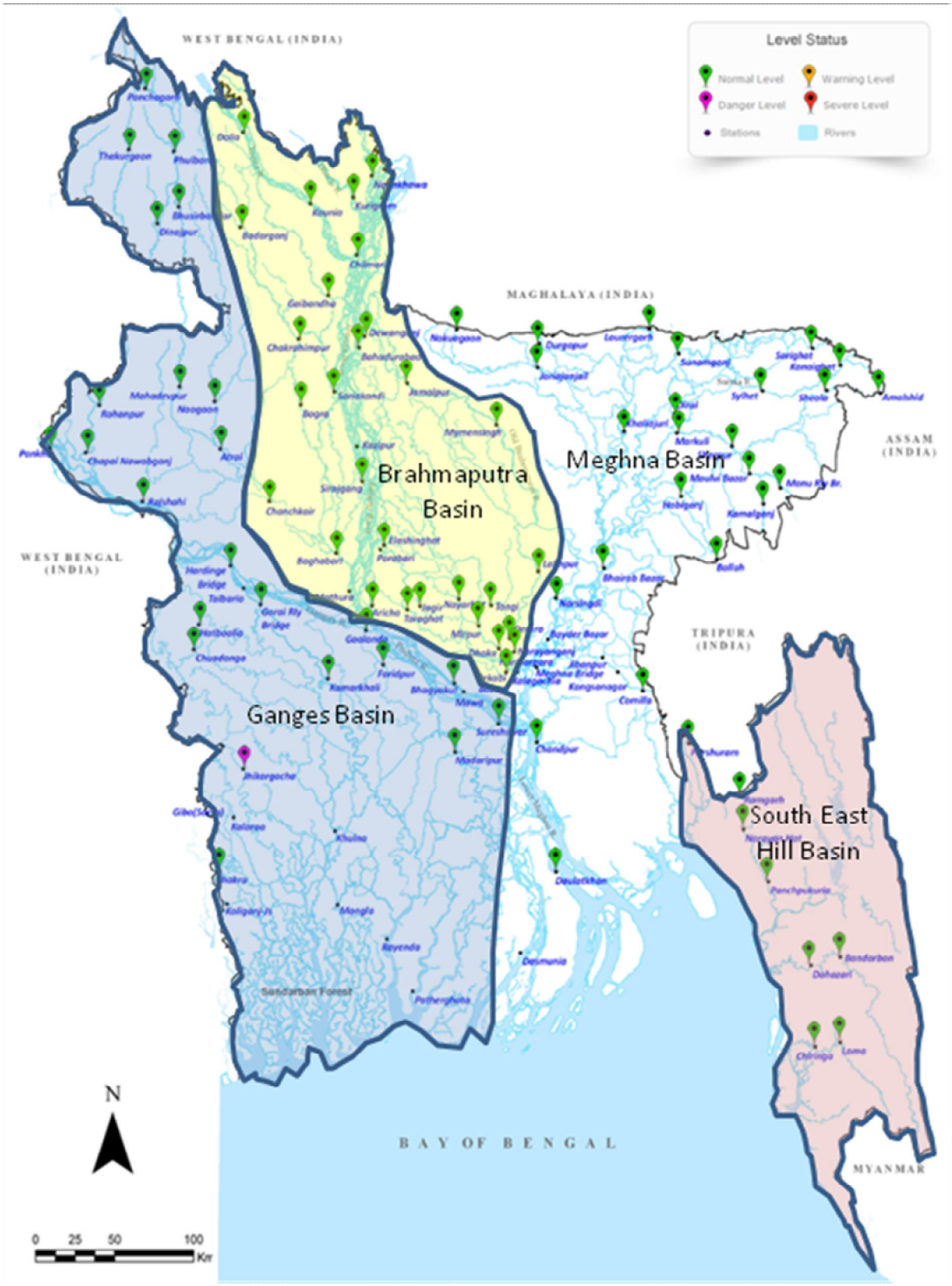



**Figure 1 : Basin Map of Bangladesh with Water Level Gauge Stations**

# CHAPTER 1: INTRODUCTION

## 1.1. THE PHYSICAL SETTING

Bangladesh lies approximately between 20°30' and 26°40' north latitude and 88°03' and 92°40' east longitude. It is one of the biggest active deltas in the world with an area of about 1,47,570 sq-km. The country is under sub-tropical monsoon climate, annual average precipitation is 2,300 mm, varying from 1,200 mm in the north-west to over 5,000 mm in the north-east. India borders the country in west, north and most part of east. The Bay of Bengal is in the south, Myanmar borders part of the south-eastern area. It has 405 rivers including 57 transboundary rivers, among them 54 originated from India including three major rivers the Ganges, the Brahmaputra and the Meghna (*Ref. Bangladesher Nod Nodi, BWDB, August 2011*). Three rivers originated from Myanmar. Monsoon flood inundation of about 20% to 25% area of the country is assumed beneficial for crops, ecology and environment, inundation of more than that causing direct and indirect damages and considerable inconveniences to the population.

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

## 1.2. THE RIVER SYSTEM

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

The Brahmaputra (Jamuna) river above Bahadurabad has a length of approximately 2,900 km and a catchment area about 5,83,000 sq-km. Started from the glaciers in the

northernmost range of the Himalayas and flows east far above half its length across the Tibetan plateau. In the complex mountain terrain bordering north-east India and China it bends through a series of gorges and is joined by a number of major tributaries, e.g., the Dihang and the Luhit before entering its broad valley section in Assam. This stretch is about 720 km long to the border of Bangladesh and throughout most of this, the course is braided. This braided channel is continued to the confluence with the Ganges.

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

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

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

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

Between the Surma and Kushiyara, there are many internal draining depressions (haors), meandering flood channels and abandoned river courses, which are widely flooded every monsoon season. The two rivers rejoined at Markuli and flow via Bhairab as the Meghna to join the Padma at Chandpur. The major tributaries of any size outside the Sylhet basin

are the Gumti and the Khowai River, which rises in Tripura and other hilly streams from Meghalaya and Assam of India to join the Meghna.

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

## 1.3. ACTIVITIES OF FFWC

The importance of the flood forecasting and warning is recognized as a vital non-structural measures to aid the mitigating the loss of lives, crops and properties caused by the annual flood occurrence. The Flood Forecasting and Warning Centre, under the Directorate of Processing and Flood Forecasting Circle, Hydrology, BWDB carries out monitoring of 85 (73 previous and 12 added in 2013) representative water level stations and 56 rainfall stations throughout the country. The principal outputs are the daily statistical bulletin of floods, river situation, a descriptive flood bulletin, forecast for 24, 48, 72, 96 and 120 hours at (38+16) 54 monitoring points, special flood report along with different graphical and statistical presentation during the monsoon season. The Centre is also involved in preparation of flood status report at national level, weekly bulletin during dry season bulletin, monthly and annual flood reports. The Centre is responsible as a focal point in respect of flood from the month of April to November as per Government order for generating flood forecast & warning that are issued with the flood bulletin and also provide support services to DDM, BMD and SPARRSO during cyclonic disaster.

**OUTPUTS of the FFWC**

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

Step by step development has been made in the flood forecasting and warning services in Bangadesh, started from 1972. Before 1990, forecast for six locations viz. Bahadurabad, Serajgonj, Aricha, Goalondo, Bhagyakul and Hardinge Bridge on the Padma – Brahmaputra –Jamuna river system were issued by Co-axial correlation, Gauge to Gauge relation and Muskingum-Cunge Routing Model. After the devastating flood of 1987 and catastrophic flood of 1988, it was deeply realized that the forecast formulation should be introduced in the process of river modelling. In view of the above, the simulation model MIKE11 developed by Danish Hydraulic Institute (DHI) was installed at FFWC and a special version of MIKE11 FF conceptual Hydrodynamic model is in operation for forecast formulation.

The General Model (GM) developed under MIKE11 was adapted to real time operation in which boundary extended near to the Indian border on all main rivers. A supermodel now is in operational at FFWC covering entire flood affected area of Bangladesh, except coastal zone, the southern part. The Supermodel covers about 82,000 $km^2$ of entire country, except the coastal zone of the country. The area covered under the supermodel is divided into 107 numbers of sub-catchments. It includes 195 river branches, 207 link channels, 40 Broad Crested Weirs. The total river length modeled is about 7300 km. Model operation and data base management is being done with a well-managed server based (Widows 2000) LAN–Operating System installed with desk top PCs at the FFWC.

**Flood Forecasting & Warning Services: Brief History**

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

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

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

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

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

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

From 2012 - Strengthening and Improvement of FFWS
- FF at 54 locations on 29 rivers with Extended Lead Time upto 5-days
- Structure based FF for 4-selected projects upto 5-days lead time
- Improved and more user friendly web-site with Bangla language
- IVR system for dissemination based on mobile phone introduced
- Improved LAN and display

## 1.4. OPERATIONAL STAGES BEFORE FORECAST MODEL RUN

*Data Collection:* The real time hydrological data (85 WL stations and 56 rainfall stations) is collected by SSB wireless, fixed & mobile telephone from the BWDB hydrological network. WL for non-tidal stations are collected five times daily at 3 hourly intervals during day time from 6:00 AM to 6:00 PM, and for tidal stations collected hourly. Rainfall is collected daily period beginning at 9 AM. The data collections at FFWC are usually

completed by 10:30 A.M. Limited WL, rainfall and forecasts of upper catchments from Indian stations are also collected through internet, e-mail, and from BMD.

*Essential Information's:* Estimation of WL at the model boundaries and rainfall for the catchments are required input to the model upto the time of Forecast (24, 48, 72, 96 & 120hrs). For the rainfall estimation, satellite images from NOAA and IMD is used. In addition a dedicated land line radar link with BMD (Bangladesh Meteorological Department) provided frequent (five minutes interval) rainfall information.

*Forecast Calculation:* Collected/observed WL and rainfall data are given input to the computer database and checked. The WL and rainfall estimation has to be prepared. During monsoon (June to October) WL of few stations of upper catchments of Ganges, Brahmaputra, Teesta, Dharala and Barak rives has been received since 2010 from CWC India through e-mail. The basis for WL estimation is considering trend Hydrograph extrapolated upto the period of forecast from previous few days data, response characteristics of rivers, effect of rainfall on WL and Indian available WL & forecasts data. Rainfall estimation based on previous 2-day's rainfall and analysis of information collected. After input required data and boundary-estimated data to the model, model run started. It takes about 30 to 40 minutes time to complete the calculations.

Daily forecast bulletin is prepared upto 5 days for important locations and region-wise flood warning messages. The bulletins are disseminated to more than 600 recipients including different ministries, offices(central & district level), individuals, print & electronic news media, development partners, research oraganisations, NGO's etc. including President's & Prime Minister's Secretariat. Whenever, the forecast river stage cross the DL, the concern field offices and limited key officials are informed through mobile SMS. Interactive Voice Response (IVR) through mobile has been initiated since July 2011 through Teletalk and from 2013 all the mobile operators started the IVR.

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

**Mode of Dissemination**

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

## 1.5. NATURE AND CAUSES OF FLOODING

### 1.5.1. CAUSATIVE FACTORS

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

in the east. Long periods of steady rainfall persisting over several days are common during the monsoon, but sometimes local high intensity rainfall of short duration also occurs.

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

- *The geographic location and climatic pattern:* Bangladesh is located at the foot of the highest mountain range in the world, the Himalayas, which is also the highest precipitation zone in the world. This rainfall is caused by the influence of the south-west monsoon. Cherapunji, highest rainfall in the world, is located a few kilometers north east of the Bangladesh border
- *The confluence of three major rivers, the Ganges, the Brahmaputra and the Meghna:* the runoff from their vast catchment (about 1.72 million km²) passes through a small area, only 8% of these catchments lie within Bangladesh. During the monsoon season the amount of water entering Bangladesh from upstream is greater than the capacity of the rivers to discharge in to the sea.
- *Bangladesh is a land of rivers:* there are about 310 major and minor rivers in the country. The total annual runoff of surface water flowing through the rivers of Bangladesh is about 12,000 billion cubic meters.
- *Man-made environment:* the construction of embankments in the upstream catchments reduces the capacity of the flood plains to store water. The unplanned and unregulated construction of roads and highways in the flood plain without adequate opening creates obstructions to flow.
- *The influence of tides and cyclones*: the frequent development of low pressure areas and storm surges in the Bay of Bengal can impede drainage. The severity of flooding is greatest when the peak floods of the major rivers coincide with these effects.
- *Long term environmental changes:* climate changes could influence the frequency and magnitude of flooding. A higher sea level will inhibit the drainage from the rivers to the sea and increase the impact of tidal surges. Deforestation in hilly catchments causes more rapid and higher runoff, and hence more intense flooding.

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

### 1.5.2. STATISTICS OF FLOODING

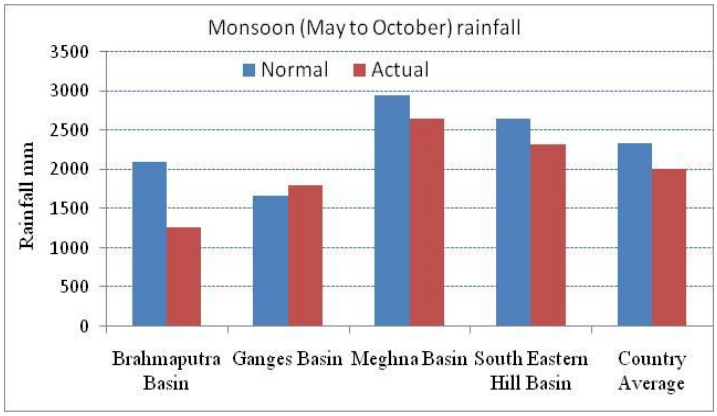
Many parts of the Asia during monsoon frequently suffer from severe floods. Some parts of India and Bangladesh experience floods almost every year with considerable damage. The floods of 1954, 1955, 1974, 1987, 1988, 1998, 2004 and 2007 all caused enormous damages to properties and considerable loss of life. The floods of 1987, 1988 1998, 2004 and 2007 flood caused heavy damage. During the monsoon 2013, the flood was not a severe one and stayed for short duration in all the four basins, the Brahmaputra, the

Ganges, the Meghna and South Eastern Hill Basin. In the South Western part of the country experienced prolong flooding in few stations, longer than the previous flood years, specially part of Khulna, Jessore and Satkhira districts. During the monsoon-2013 other flood affected districts (part of full, on the low-lying areas) are of Kurigram, Lalminiorhat, Gaibandha, Bogra, Rangpur, Serajgonj, Tangail, Jamalpur and Narayangonj, Munshigonj, Madaripur, Sariatpur, Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, Brahmmanbaria, Habigonj, Chittagong, Bandarban and Cox's Bazar. Percent of total area of Bangladesh affected by the flood are available since 1954 is presented in Table 1.1.

**Table 1. 1 :Year-wise Flood Affected Area in Bangladesh**

| Year | Flood Affected area | | Year | Flood affected area | | Year | Flood affected area | |
|---|---|---|---|---|---|---|---|---|
| | Sq-Km | % | | Sq-Km | % | | Sq-Km | % |
| 1954 | 36,800 | 25 | 1975 | 16,600 | 11 | 1995 | 32,000 | 22 |
| 1955 | 50,500 | 34 | 1976 | 28,300 | 19 | 1996 | 35,800 | 24 |
| 1956 | 35,400 | 24 | 1977 | 12,500 | 8 | **1998** | **1,00,250** | **68** |
| 1960 | 28,400 | 19 | 1978 | 10,800 | 7 | 1999 | 32,000 | 22 |
| 1961 | 28,800 | 20 | 1980 | 33,000 | 22 | 2000 | 35,700 | 24 |
| 1962 | 37,200 | 25 | 1982 | 3,140 | 2 | 2001 | 4,000 | 2.8 |
| 1963 | 43,100 | 29 | 1983 | 11,100 | 7.5 | 2002 | 15,000 | 10 |
| 1964 | 31,000 | 21 | 1984 | 28,200 | 19 | 2003 | 21,500 | 14 |
| 1965 | 28,400 | 19 | 1985 | 11,400 | 8 | 2004 | 55,000 | 38 |
| 1966 | 33,400 | 23 | 1986 | 6,600 | 4 | 2005 | 17,850 | 12 |
| 1967 | 25,700 | 17 | 1987 | 57,300 | 39 | 2006 | 16,175 | 11 |
| 1968 | 37,200 | 25 | **1988** | **89,970** | **61** | **2007** | **62,300** | **42** |
| 1969 | 41,400 | 28 | 1989 | 6,100 | 4 | 2008 | 33,655 | 23 |
| 1970 | 42,400 | 29 | 1990 | 3,500 | 2.4 | 2009 | 28,593 | 19 |
| 1971 | 36,300 | 25 | 1991 | 28,600 | 19 | 2010 | 26,530 | 18 |
| 1972 | 20,800 | 14 | 1992 | 2,000 | 1.4 | 2011 | 29,800 | 20 |
| 1973 | 29,800 | 20 | 1993 | 28,742 | 20 | 2012 | 17,700 | 12 |
| 1974 | 52.600 | 36 | 1994 | 419 | 0.2 | 2013 | 15,650 | 10.6 |

# CHAPTER 2 : RAINFALL SITUATION




During the monsoon-2013 (May to Oct), the country experienced as a whole 14.1% less rainfall than normal. The Brahmaputra, Meghna & South Eastern Hill basins received 39.8%, 9.9% and 12.4% less rainfall than the normal value respectively and only the Ganges Basin received 7.8% more rainfall than the normal value. Comparison of the basin and country average of normal and actual rainfall for the monsoon-2013 (May to October) is presented in the bar chart. Considering monthly value, all the basins except the Ganges basin recorded less rainfall than their respective normal during May-October period. All basins received more rainfall than their normal rainfall during the month of October. The Ganges Basin experienced more rainfall than its normal during May, August and October-2013. 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 2013 over the four Basins**

| Month | Brahmaputra Basin(mm) | | Ganges Basin(mm) | | Meghna Basin(mm) | | South Eastern Hill Basin(mm) | | Monsoon average (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Normal | Actual | Normal | Actual | Normal | Actual | Normal | Actual | Normal | Actual |
| May | 315.4 | 218.6 | 191.8 | 319.0 | 491.0 | 790.3 | 290.4 | 482.26 | 2342.0 | 2010.9 |
| June | 433.5 | 267.3 | 327.0 | 258.7 | 621.0 | 409.8 | 599.8 | 447.14 | | |
| July | 496.1 | 182.9 | 397.8 | 301.4 | 650.5 | 443.0 | 728.5 | 417.2 | | |
| August | 339.7 | 264.2 | 337.8 | 392.6 | 537.9 | 470.4 | 536.9 | 445.58 | | |
| Sept | 353.4 | 153.4 | 298.7 | 274.2 | 449.2 | 301.4 | 317.9 | 319.0 | | |
| October | 155.6 | 173.7 | 120.1 | 258.8 | 194.7 | 236.0 | 183.4 | 217.0 | | |
| Total | 2093.7 | 1260.1 | 1673.2 | 1804.7 | 2944.3 | 2650.8 | 2656.9 | 2328.2 | | |
| %More/ Less | 39.8% less | | 7.8% more | | 9.9% less | | 12.4% less | | 14.1% less | |

Rainfall situation of the country for the monsoon-2013(May to September) is described in the following sections.

## 2.1 MAY

**Important Rainfall Information for May 2013**

**Monthly Maximum at Sheola 1354.0 mm**

**1-day maximum at Ramgarh: 172.0 mm**

**10-day maximum at Comilla: 646.0 mm**

The country, as a whole, experienced rainfall more than normal during the month of May 2013. The Ganges, the Meghna and the South Eastern Hill recorded 66.35%, 60.94% and 66.07% more rainfall than their respective monthly normal value. The Brahmaputra basin experienced 30.69% less rainfall than normal in this month. The summery of rainfall situation of the country during May 2013 is shown in the Table 2.2.

**Table 2. 2** : Summary of the rainfall situation during the month of May 2013

| Basin: | Brahmaputra | Ganges | Meghna | South Eastern Hill |
|---|---|---|---|---|
| No of Stations: | 12 | 12 | 11 | 11 |
| Average Rainfall (mm) of the basin: | 218.58 | 319.0 | 790.27 | 482.26 |
| %More(+)/Less(-) than the Normal: | -30.69% | 66.35% | 60.94% | 66.07% |
| Number of Stations above Normal Rainfall: | 1 | 9 | 10 | 10 |
| Highest 1-day Maximum Rainfall with Stations: | Gaibandha (130mm) | Khulna (150mm) | Comilla (155mm) | Ramgarh (172mm) |
| Number of Rain Fed Flood* Stations: | 0 | 3 | 9 | 4 |

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

In Brahmaputra basin, out of 12 rainfall monitoring stations, all the stations except Dhaka received less rainfall than their normal. At Comilla and Chandpur the recorded rainfall exceeded the previous maximum value. The Basin received 30.69% less rainfall than their normal during the month May 2013.

In Ganges basin, out of 12 rainfall monitoring stations, all the stations except Dinajpur, Naogaon and Kushtia received more rainfall than their normal value of the month May 2013. At Barisal, Khulna, Patuakhali and Satkhira the recorded rainfall exceeded the previous maximum value. The basin as a whole received 66.35% more rainfall than the normal during the month of May-2013.

In the Meghna basin, out of 11 rainfall monitoring stations, all the stations except one received more rainfall than their normal value of the month. At Coox's Bazar the recorded rainfall exceeded the previous maximum value. The Basin received 60.94% more rainfall than their monthly normal during the month of May 2013.

In the South Eastern Hill basin, all the stations except one received more rainfall than their normal value of the month. The Basin received 66.07% more rainfall than their monthly normal during the month of May 2013.

Considering 10-day maximum rainfall of 300 mm as a rain-fed flood index, as many as 16 stations were crossed the threshold value in this month. At Barisal, Patuakhali, Khulna, Satkhira, Comilla, Chandpur and Coox's Bazar the recorded rainfall exceeded the previous maximum monthly value. Along the coastal zones and in the North east the country recorded more rainfall due to the influence of tropical Cyclone Mahasen. On May 16, Mahasen hit southern Bangladesh, through Patuakhali, bringing heavy rains and winds up to 95 km/h (60 mph). In some areas, more than a month's worth of rain fell over two weeks as a result flash floods hit in few locations of south eastern zone. Special information centre was opened at the FFWC for monitoring the Cyclone Mahasen. The track of Cyclone Mahasen is presented in Annex-1.

The Isohyets of the actual rainfall of the month of May-2013 is shown in the Figures 2.1.

## 2.2 JUNE

**Important Rainfall Information for June, 2013**
**Maximum, at Sunamganj : 911.0 mm**
**1-day maximum, at Cox's Bazar : 191 mm**
**10-day maximum, at Cox's Bazar: 532.0 mm**

The country, as a whole, recorded less rainfall than normal during the month of June-2013. The Brahmaputra, the Ganges, the Meghna and South Eastern Hill basins recorded 34.8%, 20.9%, 34.02% and 25.45% less rainfall than their respective monthly normal rainfall during the month of June-2013. The summery of the rainfall situation for June 2013 is shown in the Table 2.3.

Table 2. 3: Summary of the rainfall situation during the month of June 2013

| Basin: | Brahmaputra | Ganges | Meghna | South Eastern Hill |
|---|---|---|---|---|
| No of Stations: | 12 | 12 | 11 | 11 |
| Average Rainfall (mm) of the basin: | 267.3 | 258.66 | 409.77 | 447.14 |
| %More(+)/Less(-) than the Normal: | -34.8% | -20.9% | -34.02% | -25.45% |
| Number of Stations above Normal Rainfall: | 1 | 2 | 1 | 1 |
| Highest 1-day Maximum Rainfall with Stations: | Dhaka 125.0 mm | Khulna 140mm | Sylhet 171.0mm | Cox's Bazar 191mm |
| Number of Rain Fed Flood* Stations: | 1 | 1 | 3 | 5 |

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

In Brahmaputra basin, out of 12 rainfall monitoring stations, all were recorded less rainfall than the normal except Dhaka station. The Basin received 34.8% less rainfall than their normal during the month June 2013.

In the Ganges basin, out of 12 rainfall monitoring stations, only 2 stations namely Panchagarh, and Khulna recorded more rainfall than the normal value and all the other rainfall monitoring stations recorded less rainfall than their normal value of the month. One day maximum rainfall of 140mm was recorded at Khulna. The 10-day consecutive maximum rainfall of 309.2 was recorded at Panchagarh. The basin received 20.9% less rainfall than their monthly normal rainfall during the month of June 2013.

In the Meghna basin, out of 11 rainfall monitoring stations, all were recorded less rainfall than the normal value except Comilla, where recorded rainfall was more than the normal rainfall of the month June-2013. One day maximum of 171mm & 10-day consecutive maximum rainfall of 485mm was recorded at Sylhet. The Meghna basin as a whole received 34.02% less rainfall than the normal rainfall during the month of June-2013.

In the South Eastern Hill basin, all the rainfall monitoring stations received less rainfall than their normal rainfall for the month of June-2013, except Lama. One day maximum of 191.0 mm was recorded at Cox's Bazar. The 10-day consecutive maximum rainfall of 532.0mm was also recorded at Cox's Bazar. The basin as a whole recorded 25.45% less rainfall than the normal rainfall during the month of June 2013.

The Isohyets of the actual rainfall of the month of June-2013 are shown in the Figure 2.2.

## 2.3 JULY

**Important Rainfall Information for July 2013**
**Maximum at Sunamganj: 997 mm**
**1-day maximum at Lama: 229 mm**
**10-day maximum at Panchagarh: 687.6 mm**

The country, as a whole, experienced rainfall less than normal during the month of July 2013. The Brahmaputra, the Ganges, the Meghna and the South Eastern Hill basins received 37.6%, 11.6%, 22.8% and 34.2% less rainfall than their respective monthly normal value. The summery of the rainfall situation of the country during the month of July 2013 is shown in the Table 2.4.

Table 2. 4: Summary of the rainfall situation during the month of July 2013

| Basin: | Brahmaputra | Ganges | Meghna | South Eastern Hill |
|---|---|---|---|---|
| No of Stations: | 12 | 12 | 11 | 11 |
| %More(+)/Less(-) than the Normal: | -37.6% | -11.6% | -22.8% | -34.2% |
| Number of Stations above Normal Rainfall: | 0 | 3 | 1 | 1 |
| Highest 1-day Maximum Rainfall with Stations: | Rangpur 153.0 mm | Khulna 170.0mm | Comilla 200.0mm | Lama 229.0mm |
| Number of Rain Fed Flood* Stations: | 1 | 1 | 2 | 2 |
| Name of Rain Fed Flood* Stations: | Dalia | Panchagarh | Comilla Sunamganj | Lama Cox's Bazar |

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

In Brahmaputra basin, all the stations received less rainfall than their normal. The Basin received 37.6% less rainfall than their normal during the month July 2013. Monthly 1-day maximum rainfall of 153mm was recorded at Rangpur.

In the Ganges basin, as a whole received 11.6% less rainfall than its normal during the month of July-2013. One day maximum rainfall of 170mm at Khulna and 10-day consecutive maximum rainfall of 687.6mm was recorded at Panchagarh. This rainfall along with upstream inflow caused local flood at Panchagarh.

In Meghna basin, all the stations except Comilla (Normal 465mm, Actual 649mm) recorded less rainfall than their normal value of the month. The Basin recorded 22.8% less rainfall than their normal during the month of July 2013. One day maximum rainfall of 200mm & 10-day consecutive maximum rainfall of 518mm was recorded at Comilla.

The South Eastern Hill basin, as a whole received 34.2% less rainfall than its normal value during the month of July 2013. One day maximum rainfall of 229mm and 10-day consecutive maximum rainfall of 525mm was recorded at Lama. The 10-days cumulative rainfall caused local flood at the area.

A map with isohyets of the actual rainfall of July-2013 is shown in the Figure 2.3.

## 2.4 AUGUST

**Important Rainfall Information for August 2013**
**Maximum at Cox's Bazar : 1064.4 mm**
**1-day maximum at Cox's Bazar: 334 mm**
**10-day maximum at Cox's Bazar: 853.4 mm**

The intensity of rainfall in the Ganges, the Brahmaputra, the Meghna and the South Eastern Hill basin was moderate at most of the places during the month of August 2013. Out of 4 hydrological basins 3 received less rainfall and one received more rainfall than their respective monthly normal rainfall in this month. The Brahmaputra, the Meghna and the South Eastern Hill basin received 17.4%, 12.5% and 17.0% less and the Ganges basin received 14.56% more monthly rainfall than their respective normal rainfall of the month.

**Table 2. 5:** Summary of the rainfall situation during the month of August 2013

| Basin: | Brahmaputra | Ganges | Meghna | South Eastern Hill |
|---|---|---|---|---|
| No of Stations: | 12 | 12 | 11 | 11 |
| Basin average rainfall at August, 2013(mm): | 264.2 | 392.55 | 470.4 | 445.58 |
| %More(+)/Less(-) than Normal: | -17.4% | +14.56% | -12.5% | -17.0% |
| No. of Stations above Normal Rainfall: | 3 | 6 | 3 | 3 |
| Highest 1-day Maximum Rainfall Stations: | Dewanganj (95 mm) | Panchagarh (135 mm) | Sunamganj (165 mm) | Cox's Bazar (334 mm) |
| No of Rain Fed Flood* Stations: | 0 | 2 | 4 | 4 |

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

The above table shows that 3 out of 12 rainfall monitoring stations in the Brahmaputra basin; 6 out of 12 rainfall stations in the Ganges basin; 3 out of 11 rainfall stations in the Meghna basin and 3 out 11 stations in South Eastern Hill the basin received more rainfall than their monthly normal rainfall. Among all monitoring stations, Cox's Bazar in the South Eastern Hill basin are the daily highest rainfall recorded stations.

The Table 2.5 shows that all 2 stations in the Ganges basin, 4 stations in the Meghna Basin and 4 stations in the South Eastern Hill basin received more than 300 mm rainfall in consecutive 10-day period. It may be mentioned that 300 mm or more rainfall in consecutive 10-day period may cause rain fed flood in the locality.

The Isohyets of the actual rainfall of the month of August-2013 is shown in the Figure 2.4.

## 2.5 SEPTEMBER

**Important Rainfall Information for September 2013**
**Maximum at Khulna : 633.0 mm**
**1-day maximum at Panchagarh : 147.5 mm**
**10-day maximum at Chandpur: 362.0 mm**

The country, as a whole, experienced rainfall less than the normal value except the South Eastern Hill basin during the month, September 2013. Among the four hydrological basins of the country, the Brahmaputra, the Ganges and the Meghna

basins received 57.3%, 4.7%, and 32.9% less rainfall basin received and South Eastern Hill basin received 0.3% more rainfall than their respective monthly normal rainfall during the September 2013. Table 2.6 represents the summary of rainfall situation all through the country during the month of September 2013.

**Table 2. 6:** Summary of the rainfall situation during the month of September 2013

| Basin: | Brahmaputra | Ganges | Meghna | South Eastern Hill |
|---|---|---|---|---|
| No of Stations: | 12 | 12 | 11 | 11 |
| Basin average rainfall at September,2013(mm): | 153.4 | 274.2 | 301.4 | 319.0 |
| %More(+)/Less(-) than Normal: | -57.3% | -4.7% | -32.9% | 0.3% |
| No. of Stations above Normal Rainfall: | 0 | 5 | 3 | 5 |
| Highest 1-day Maximum Rainfall Stations: | Gaibandha (64 mm) | Panchagarh (147.5 mm) | Chandpur (144 mm) | Sandwip (117 mm) |
| No of Rain Fed Flood* Stations: | 0 | 2 | 1 | 1 |

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

The above table shows that 5 out of 12 stations in the Ganges basin, 3 out of 11 stations in the Meghna and 5 out 11 stations in South Eastern Hill the basin received more rainfall than their monthly normal rainfall. Among all monitoring stations, Panchagarh in the Ganges basin is the daily highest rainfall recipient station.

The table also shows that all the two stations in the Ganges basin, one station in the Meghna basin and one station in the South Eastern Hill basin received more than 300 mm rainfall in 10-day period. As a result, some parts of Kurigram, Lalmonirhat, Jamalpur, Rangpur, Panchagarh, Khulna, Sunamganj were affected by rain feed flood during the month of September 2013. It is to be mentioned here that 300 mm or more rainfall in 10-Day period may cause rain fed flood.

The Isohyets of actual rainfall for September-2013 is shown in the Figure 2.5.

## 2.6 OCTOBER

**Important Rainfall Information for October 2013**

**Monthly Maximum at Sunamganj : 627.0 mm**

**1 day maximum at Dinajpur: 251.5 mm**

**10 day maximum at Sunamganj: 479.0 mm**

All the four hydrological basins of the country received more rainfall than their monthly normal in October-2013. The Brahmaputra, the Ganges, the Meghna and the South Eastern Hill Basins received 11.62 %, 155%, 21.21% and 18.33% more rainfall than their monthly normal rainfall respectively during October-2013. At Dinajpur the 1-day maximum rainfall recorded 251.5mm in October 2013. The summary of the rainfall for the month of October-2013 is presented in Table 2.7

**Table 2. 7:** Summary of Rainfall for the month of October-2013

| Basin: | Brahmaputra | Ganges | Meghna | South Eastern Hill |
|---|---|---|---|---|
| No of Stations: | 12 | 12 | 11 | 11 |
| Average Rainfall (mm) of the basin: | 173.7 | 258.8 | 236.0 | 217.0 |
| %More(+)/Less(-) than the Normal: | 11.62% | 155% | 21.21% | 18.33% |
| Number of Stations above Normal Rainfall: | 5 | 12 | 8 | 6 |
| Highest 1-day Maximum Rainfall with Stations: | Rangpur 205.0 mm | Dinajpur 251.5 mm | Sylhet 192 mm | Bandarban 115.0mm |
| Number of Rain Fed Flood* Stations: | 0 | 2 | 2 | 0 |

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

In Brahmaputra basin, out of 12 rainfall monitoring stations, at 5 stations recorded more rainfall than the normal and the other 7 stations received less rainfall than their normal. The Basin received 11.62% more rainfall than their normal during the month October 2013.

In Ganges basin, out of 12 rainfall monitoring stations, all stations recorded more rainfall than the normal rainfall of the month. At Khulna the recorded rainfall exceeded the previous monthly max value. The basin as a whole received 155% more rainfall than the normal during the month of October-2013.

In the Meghna basin, out of 11 rainfall monitoring stations, 8 stations namely Kanaighat, Sylhet, Sunamganj, Sheola, Habiganj, Bhairab Bazar, Comilla and Chandpur recorded more rainfall than the normal value of the month and all the other 3 stations received less rainfall than their normal value of the month. The Basin received 21.21% more rainfall than their monthly normal during the month of October 2013.

In the South Eastern Hill basin, 6 rainfall monitoring stations received more rainfall than their normal rainfall and they were Bandarban, Rangamati, Lama, Chittagong, Swandip and Cox's Bazar. The other stations received less rainfall than their normal values. The Basin as a whole recorded 18.33% more rainfall than the normal rainfall during the month October 2013.

A map with the Isohyets of actual rainfall for the month of October-2013 is shown in the Figure 2.6.

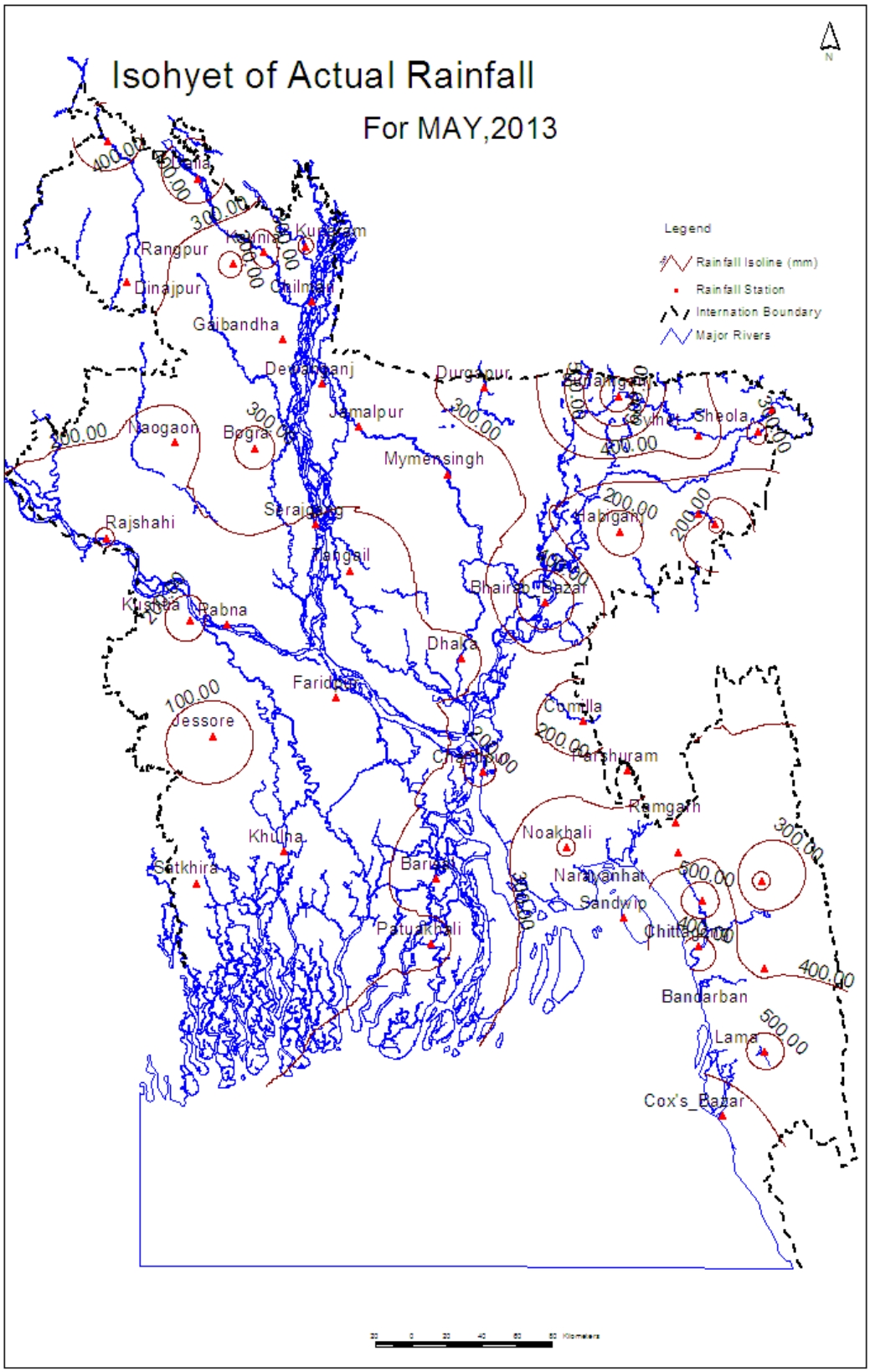



Figure 2.1 : Isohyets of Actual Rainfall (May 2013)

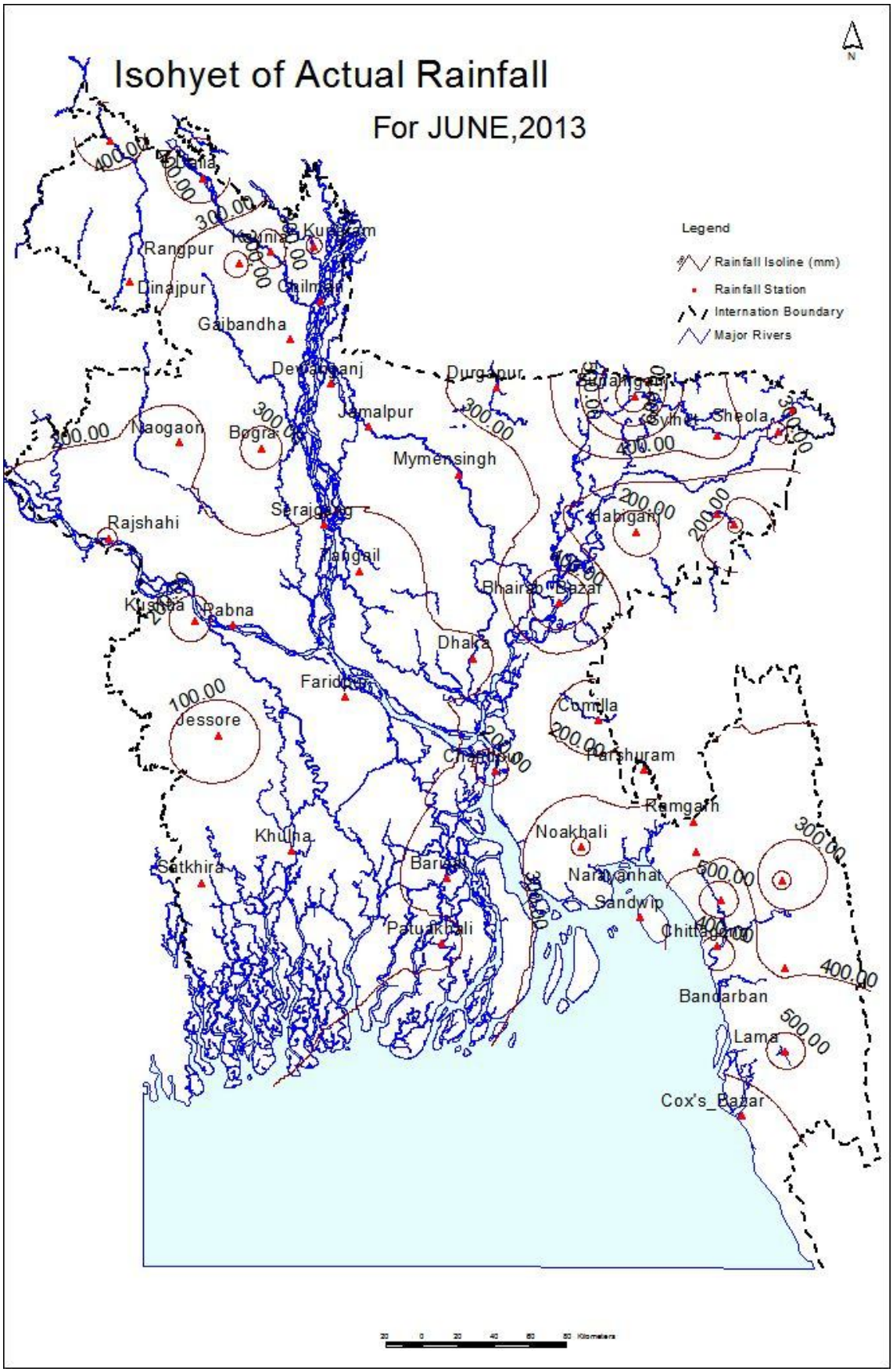



Figure 2.2 : Isohyets of Actual Rainfall (June 2013)

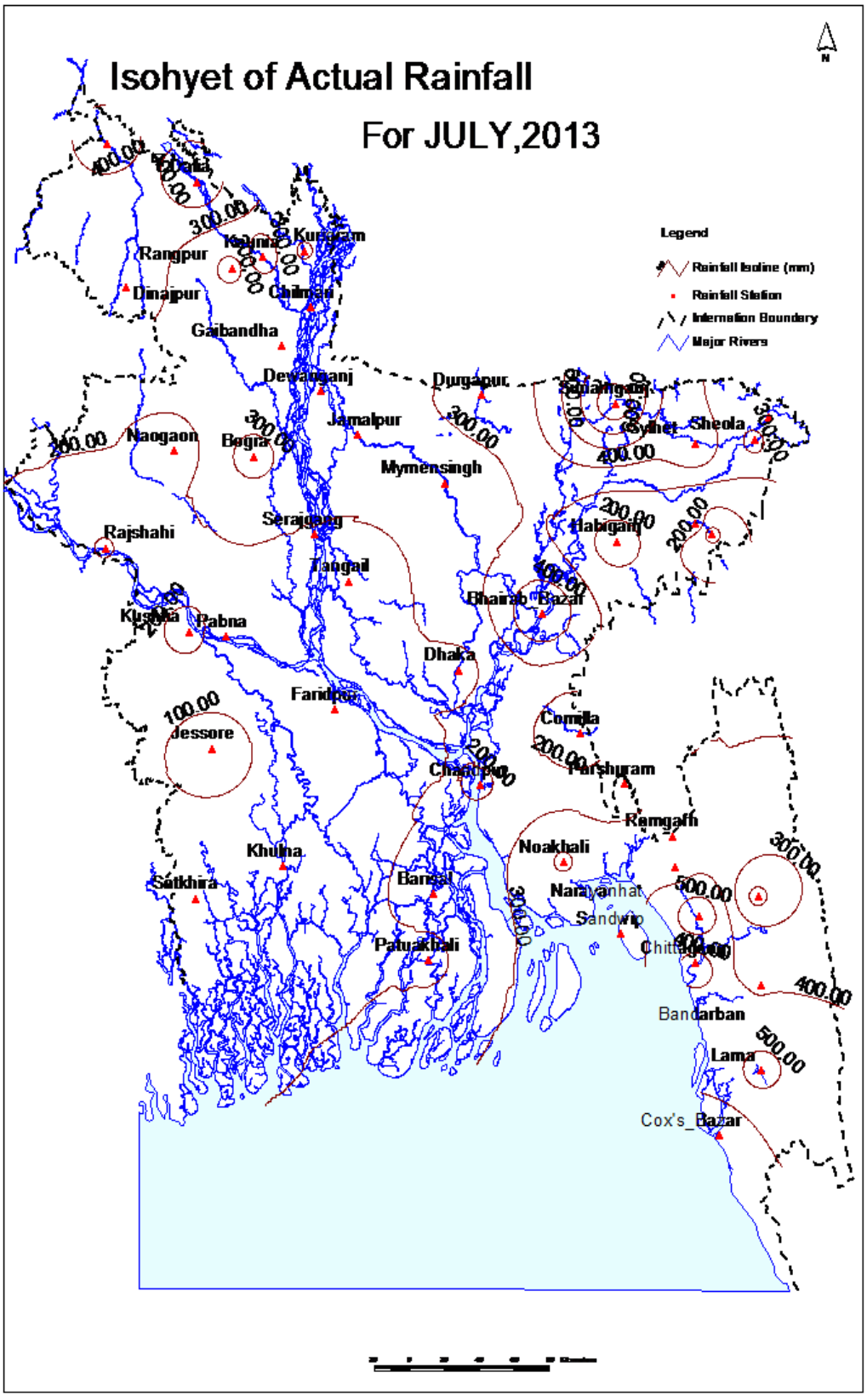



Figure 2.3 : Isohyets of Actual Rainfall (July 2013)

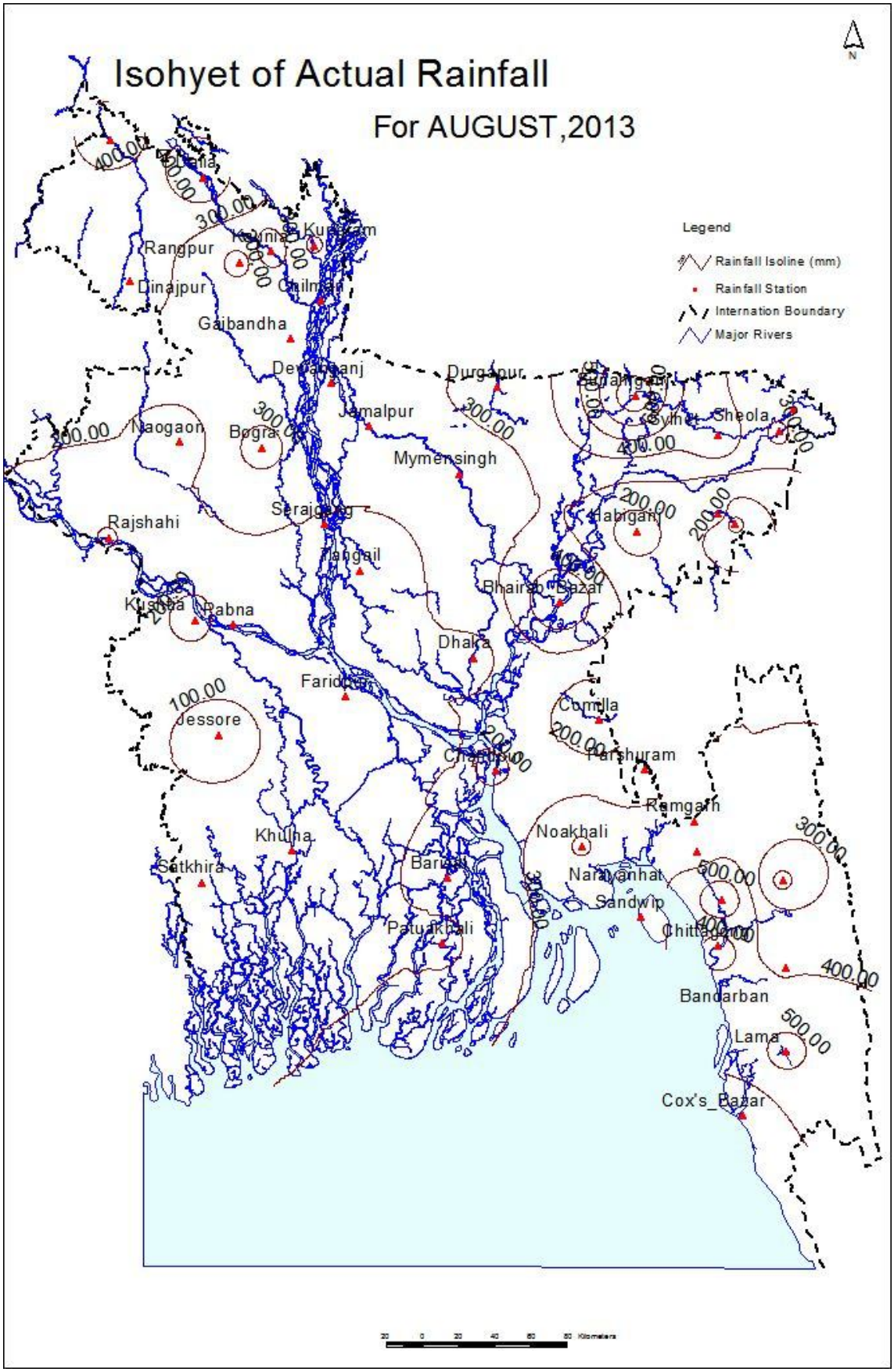



Figure 2.4 : Isohyets of Actual Rainfall (August 2013)

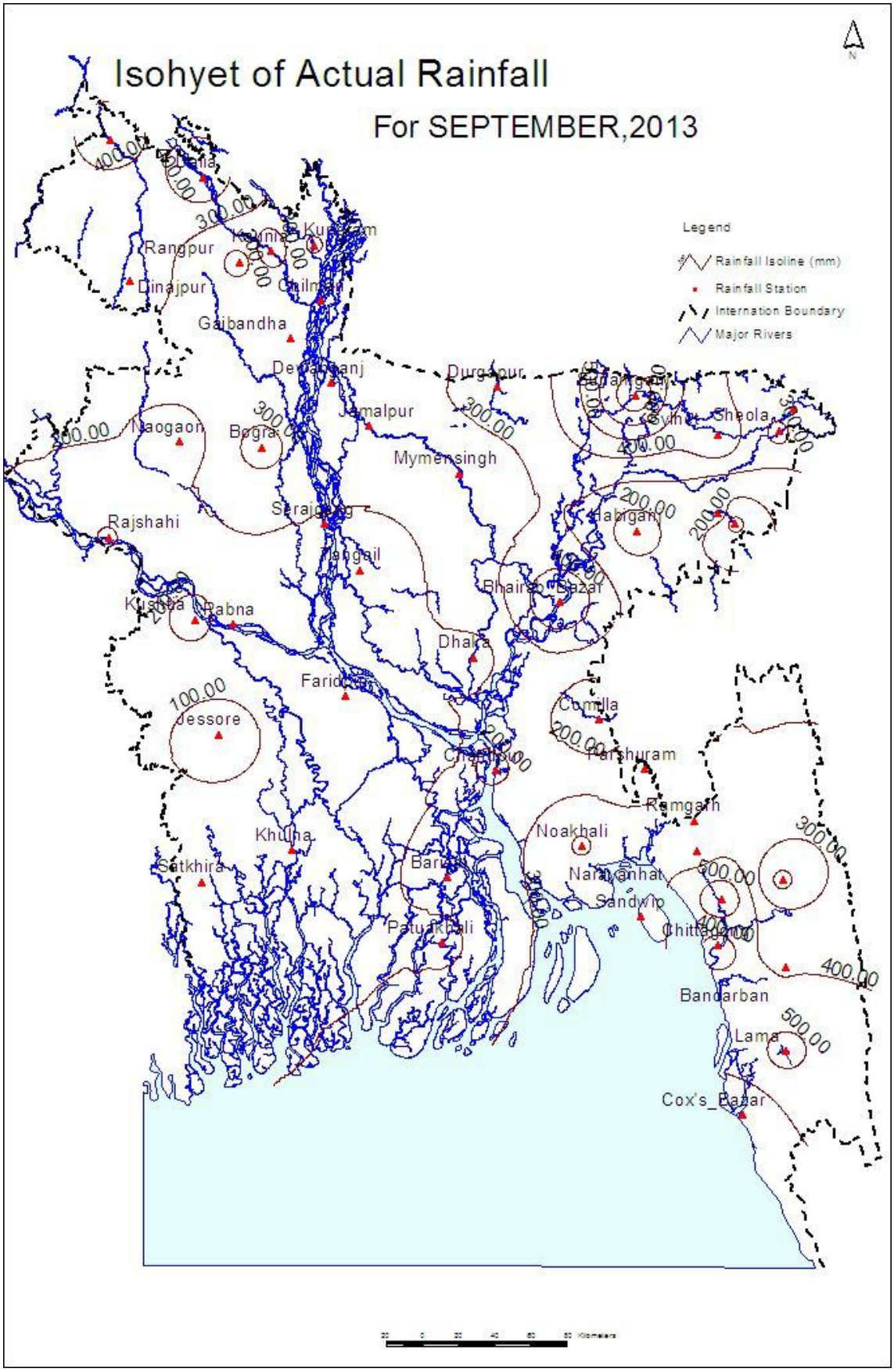



Figure 2.5 : Isohyets of Actual Rainfall (September 2013)

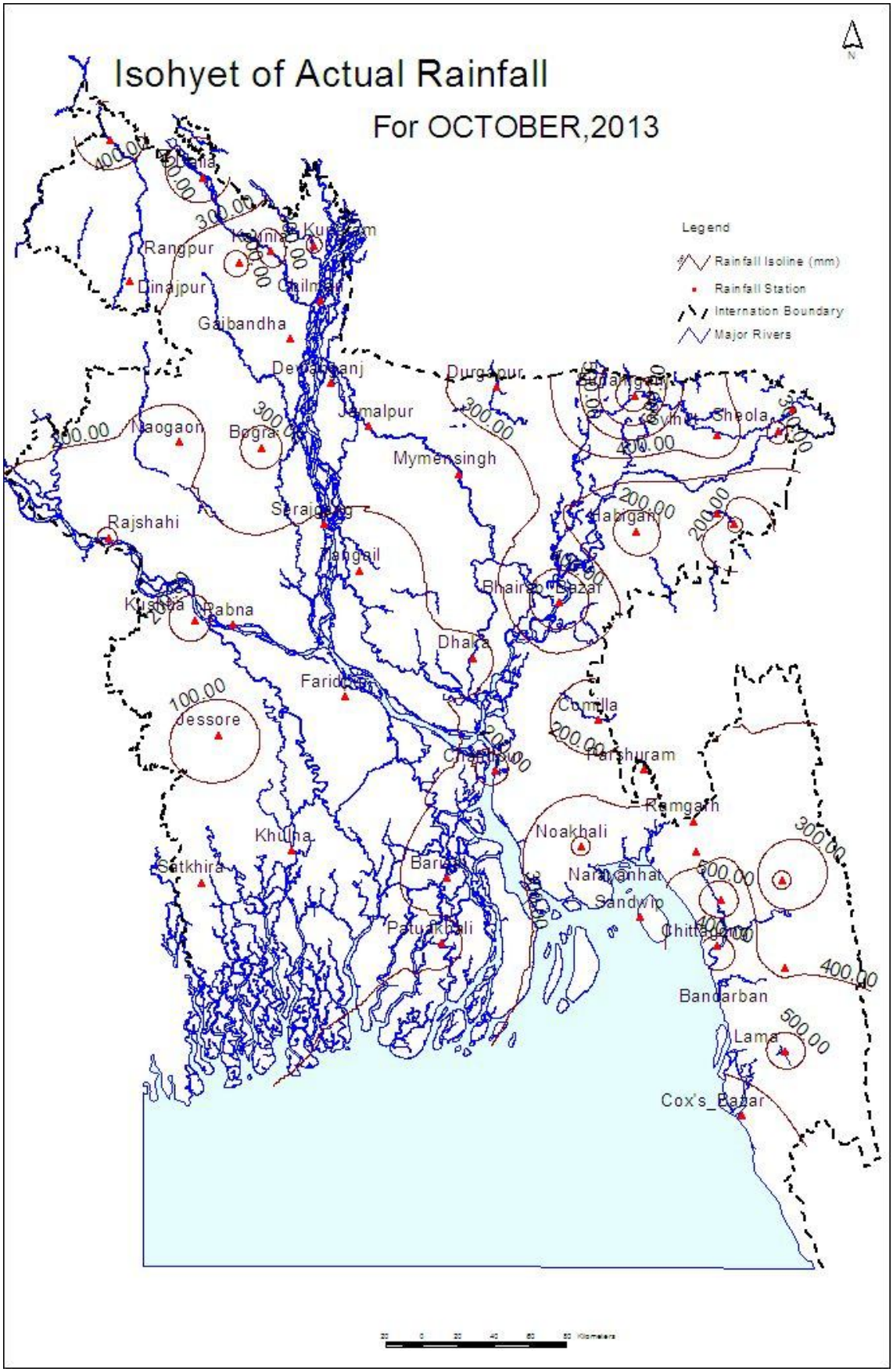



Figure 2.6 : Isohyets of Actual Rainfall (October 2013)

# CHAPTER 3: RIVER SITUATION

During the monsoon 2013, the flood was not a severe one and stayed for short duration in all the four basins, the Brahmaputra, the Ganges, the Meghna and South Eastern Hill Basin, except few stations of the south west part of the country. At Jhikorgacha water level monitoring station of the South Western part of the country experienced prolong flooding, longer than the previous flood years, specially part of Jessore, Khulna districts and large part of Satkhira district. The prolonged flood affected Upozillas are Keshobpur, Kalaroa, Tala, Monirumpur and Stakhira Sadar. Water Level at Jhikargacha on Kobadak flowed above the danger level for continuous 120 days. Basin wise WL situation is described in the following sections.

## 3.1 THE BRAHMAPUTRA BASIN

Out of 23 Water Level (WL) monitoring stations in this basin, at 7 stations river WL was crossed their respective Danger Levels (DL), these are Kurigram on Dharla for 3 days, Dalia on Teesta for 7 days in the second week of July and Bahadurabad on Jamuna river for 8 days and Serajgonj on Jamuna for 3 days, Aricha on Jamuna for 5 days, Sariakandi on Jamuna for 5 days and Gaibandha on Ghagot river for 4 days in the 1$^{st}$ and 2$^{nd}$ week of September. As a result, low-lying areas of Kurigram, Lalminiorhat, Gaibandha, Bogra, Rangpur, Serajgonj, Tangail, Jamalpur and Narayangonj districts were flooded for short period. A comparative statement of WL for current year 2013 and historical events of 1988 and 1998 for the Brahmaputra Basin is shown in the Table 3.1. The details of the river situation in this basin are described in the following sections:

### *The Dharla at Kurigram*

The WL of Dharla river at Kurigram registered its monsoon peak during the monsoon 2013, in July. It crossed the DL once during the monsoon 2013 and flowed above DL for 3 days. WL at Kurigram attained peak of 26.68mPWD on 11$^{th}$ July at 6:00 hours, which was 18cm above the DL (26.50 m).

### *The Teesta at Dalia and Kaunia*

The Teesta river is flashy in nature. The WL of river Teesta showed several peaks during the monsoon both at Dalia and Kaunia. At Dalia WL crossed its DL mark for 4 times during the monsoon (twice in July and two times in September), highest peak on 10$^{th}$ July for one day only with peak of 52.70mPWD, which was 30cm above its DL (52.40m). At Dalia it flowed above DL for 7 days. At Kaunia WL of the river Teesta did not cross the DL during the mosoon-2013, attained the peak of 29.05m on 10$^{th}$ July which was 95cm below the DL(30.0m) at this point.

### *The Ghagot at Gaibandha*

The WL of Ghagot river at Gaibandha crossed DL once during the monsoon 2013. It flowed above the DL for 4 days between 9$^{th}$ July to 12$^{th}$ July with peak of 22.17 m on 10$^{th}$ July, which was 47cm above its DL(21.70m).

***The Jamuneswari at Badargonj***

The Jamuneswari at Badargonj didn't cross the DL and attained the peak of 30.85mPWD(DL 32.16m) on 12th July at 6:00 hours. During the whole monsoon this station was recorded with other several low peaks.

***The Brahmaputra at Noonkhawa and Chilmari***

The river Brahmaputra at Noonkhawa and Chilmari observed sharp rise and fall at several times throughout the monsoon but didn't cross its DL. At Noonkhawa WL of the Brhamaputra river attained the peak of 26.56mPWD on 10th September at 09:00 hours, which was 69cm below the DL (27.25mPWD) at this point. At Chilmari the peak WL of the Brahmaputra river was recorded 23.92mPWD on the 10th July-2013, which was 8cm below its DL(24.00m).

***The Jamuna at Bahadurabad, Sariakandi, Serajgonj and Aricha***

The WL of river Jamuna at Bahadurabad, Sariakandi, Serajgonj & Aricha demonstrated similar trends as Brahmaputra at Noonkhawa and Chilmari. At Bahadurabad the Jamuna flowed above DL two times for 8 days from 11th July to 13th July and again 9th September to 13th September, with the peak of 19.91mPWD on 11th September, which is 41cm above the DL(19.50m) at this point. At Sariakandi the Jamuna flowed above the DL from 9th September to 13th September, for 5 days, with a peak of 17.18mPWD on 11th September 6:00 hours, which was 48 cm above the DL (16.70 m). At Serajgonj the Jamuna flowed above DL in September for 3 days with peak of 13.51mPWD, on 11th September at 18:00hrs, which is 16cm above the DL(13.35m). At Aricha the WL of the Jamuna river crossed the DL with peak WL of 9.7mPWD on 11th September, which was 30cm above the DL(9.40m) and remained above DL for 5 days.

***The Old Brahmaputra at Jamalpur and Mymensingh***

The WL of the Old Brahmaputra river at Jamalpur and Mymensingh showed rise and fall during the monsoon, but remained below the respective DLs at both the stations. At Jamalpur the peak WL recorded of 15.80mPWD on 12th September which is 120cm below the DL at this point(DL 17.0m). At Mymensingh the peak WL recorded was 10.12mPWD on 16th September, which was 238cm below the DL (12.5m) at this point.

***The Lakhya at Narayangonj***

The WL of Lakhya river at Narayangonj showed a similar trend to that of the Buriganga but didn't cross the respective DL. It attained its monsoon peak of 5.17mPWD thrice on 10th, 12th and 13th September, which 33cm below the DL (DL 5.50m).

***The Rivers around Dhaka***

Stations near or around Dhaka city like Buriganga at Dhaka, and the Turag at Mirpur attained the peak of the monsoon during the August and September in this year, mostly at end of the month. Flowed below their respective DLs. The Buriganga at Dhaka, the Balu at Demra and the Turag at Mirpur recoded their highest peak of 4.92 mPWD (DL 6.0m) on 12th September, 5.31m (DL 5.75m) on 8th July, 5.16mPWD (DL 5.94m) on 23th August-2013 respectively.

***The Kaliganga at Taraghat***

The WL of Kaliganga river at Taraghat showed a trend similar to that of the Buriganga at Dhaka. The river at this station remained below the DL throughout the season with peak of 7.89 m on 14th September, which was 51 cm below its DL(8.40 m) at Taraghat.

Comparative hydrographs for the year of 2013, 2007 & 1998 of few stations of the Brahmaputra basin are shown in Figures 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 3.10, 3.11, 3.12 and 3.13.

**Table 3. 1 :** Comparison of Water Level of 2013 and Historical Events of 1988 & 1998 of Some Important Stations in the Brahmaputra Basin.

| Sl. No | River | Station | Recorded Maximum (m) | Danger Level (m) | Peak of the year (m) | | | Days above Danger level | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2013 | 1998 | 1988 | 2013 | 98 | 88 |
| 1 | Dharla | Kurigram | 27.66 | 26.50 | 26.68 | 27.22 | 27.25 | 3 | 30 | 16 |
| 2 | Teesta | Dalia | 52.97 | 52.40 | 52.7 | 52.20 | 52.89 | 7 | - | 8 |
| 3 | Teesta | Kaunia | 30.52 | 30.00 | 29.05 | 29.91 | 30.43 | - | - | 38 |
| 4 | Jamuneswari | Badargonj | 33.00 | 32.16 | 30.85 | 33.00 | 32.80 | - | 6 | 5 |
| 5 | Brahmaputra | Noonkhawa | 28.10 | 27.25 | 26.56 | 27.35 | NA | - | - | NA |
| 6 | Brahmaputra | Chilmari | 25.06 | 24.00 | 23.92 | 24.77 | 25.04 | - | 22 | 15 |
| 7 | Ghagot | Gaibandha | 22.81 | 21.70 | 22.17 | 22.30 | 22.20 | 4 | 51 | 17 |
| 8 | Jamuna | Bahadurabad | 20.62 | 19.50 | 19.91 | 20.37 | 20.62 | 8 | 66 | 27 |
| 9 | Jamuna | Serajgonj | 15.12 | 13.35 | 13.51 | 14.76 | 15.12 | 3 | 48 | 44 |
| 10 | Jamuna | Aricha | 10.76 | 9.40 | 9.7 | 10.76 | 10.58 | 5 | 68 | 31 |
| 11 | Old Br.putra | Jamalpur | 18.00 | 17.00 | 15.8 | 17.47 | 17.83 | - | 31 | 8 |
| 12 | Old Br.putra | Mymensingh | 14.02 | 12.50 | 10.12 | 13.04 | 13.69 | - | 33 | 10 |
| 13 | Buriganga | Dhaka | 7.58 | 6.00 | 4.92 | 7.24 | 7.58 | - | 57 | 23 |
| 14 | Lakhya | Narayangonj | 6.71 | 5.50 | 5.27 | 6.93 | 6.71 | - | 71 | 36 |
| 15 | Turag | Mirpur | 8.35 | 5.94 | 5.16 | 7.97 | NA | - | 70 | NA |
| 16 | Tongi Khal | Tongi | 7.84 | 6.08 | 5.32 | 7.54 | NA | - | 66 | NA |

## 3.2 THE GANGES BASIN

In this basin out of 22 WL monitoring stations, 9 stations exceeded their respective DLs, during the monsoon 2013. The rivers flowed above DL are Ganges at Pankha for 5 days and at Rajshahi at for 7 days, Padma at Goalondo for 5 days and at Bhagyakul for 7 days, Gorai at Kamarkhali for 13 days, Karatoa at Panchgarh for 1 day, Mohananda at Chapai-Nawabgonj for 8 days, Tangon at Thakurgaon for 1 day and Kobodak at Jhikorgacha for 120 days. Punarbhaba at Dinajpur was touched the DL for one day. The low lying areas of Chapai-Nawabgonj, Rajshahi, Kustia, Magura, Rajbari, Faridpur, Panchagr, Thakurgain, Dinajpur, Manikgonj, Munshigonj, Sariatpur and Noagaon districts was affected by normal flooding during the month of August and September for short ot medium periods. Part of Satkhira, Jessore and Khulna districts was affected by prolong flooding during the September-October due to very poor drainage condition along with very high rainfall during September-October. It may be mentioned that, a moderate duration of flooding situation was prevailing around the Bhagyakul and Goalundo. All other rivers flowed

below their respective DLs. A comparative statement of WL for 2013 and historical events of 1998 & 1988 for the Ganges Basin is shown in the Table 3.2. The details of the river WL situation in this basin are described below:

***The Karatoa at Panchgarh***

The karatoa river at Panchgarh showed a sharp rise and fall during the monsoon and crossed the DL for one day on 10th July 18:00 hours with a peak flow of 70.80 mPWD, which was 5 cm above the respective DL (70.75 m)

***The Punarbhaba at Dinajpur***

The WL of river Punarbhaba at Dinajpur showed sharp rise and fall during the monsoon, but did not cross the DL in the flood season of 2013. The peak WL of 33.5mPWD was recorded on 11th July, which was at the same level of its DL (33.50m).

***The Tangon at Thakurgaon***

The Tangon river is flashy in nature and showed various small peaks during the monsoon and crossed its respective Danger Level for one day with height peak of 51.11mPWD on 8th July 6:00 hours, which was 71 cm above the Danger level (50.40 m).

***The Upper Atrai at Bhusirbandar and Atrai at Modevpur***

The WL of river Upper Atrai at Bhusirbandar (Upazila – Chirirbandar, District –Dinajpur) also showed similar trend of Punarbhaba, did not cross the DL. It had a peak value of WL 39.19mPWD on 8th July at 06:00hour, which was 43cm below the DL(39.62m). The Atrai at Mohadevpur (Noagaon District) also flowed below the DL with peak of 18.54mPWD on 14th July, which is 106cm above the DL(19.6m).

***The Mohananda at Chapai-Nawabgonj***

This river showed a gradual increase in water level throughout the monsoon and crossed the DL on 3rd September to 10th September, stayed above DL for 8 days. Then the water level started to decrease and in decreased for rest of the monsoon. It attained its peak of 21.25m on 7th September at 6:00 hours, which was 25cm above its DL (DL21.00m) at Chapai-Nawabgonj.

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

The river at Pankha showed a gradual rise in the whole season of flood in 2013 and crossed the respective DL in the first week of September and remained above DL for 5 days. At Pankha the peak of 22.66m during the day of 6th of September, which was 16 cm below the DL (22.50m) at this point. At Rajshahi, the Ganges showed nearly similar trend as at Pankha and flowed above its respective DL for 7 days in the beginning of the month of September. It attained its peak of 18.70m on 7th September at 6:00 hours, which was 20cm above its DL (DL18.50m) at Rajshahi. At Hardinge Bridge, water level did not cross the respective Danger Level and it attained its peak of 14.13m on 7th September, which was 12 cm below its DL (14.25m) at this point.

***The Ganges/ Padma at Goalundo***

At Goalondo river WL started to rise in month of September and it flowed above the DL for 5 days from 9th September to 13th September. The WL of the river Padma at Goalondo attained its yearly peak of 8.97mPWD on the 12th September, which was 32 cm above its DL (8.65m) at this point.

***The Padma at Bhagyakul***

The river Padma has tidal influence at this point. At Bhagyakul, the WL of river Padma crossed the DL on 8th to 14th September for 7 days. The WL of the river attained its highest yearly peak water level of 6.65 mPWD on 11th September, which was 35cm above the DL (6.30m) at Bhagyakul.

***The Gorai at Gorai Railway Bridge and Kamarkhali***

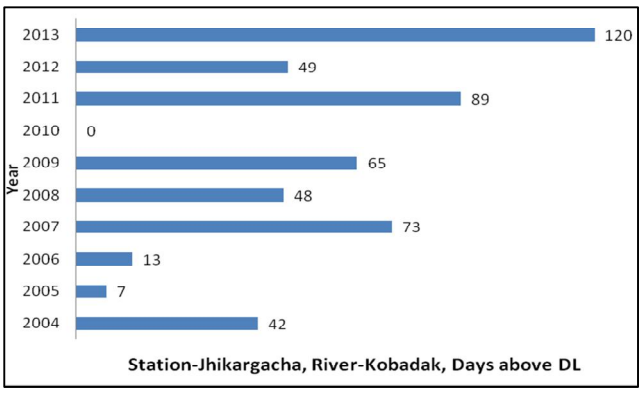
The WL of river Gorai at Gorai Railway Bridge and Kamarkhali showed steady rise during July to September in the monsoon-2013. The WL of river Gorai did not cross the DL at Gorai Railway Bridge. The WL of the river attained its highest yearly peak of 12.24 mPWD on 8th of September, which was 51cm below the DL (12.75m) at Gorai Rail Bridge. Gorai river at Kamarkhali crossed the DL twice in this reporting monsoon. It crossed the respective DL at 21st August and Remained above it for 5 days and again crossed the DL at 3rd September to 10th September for 8 days. The WL of the river attained its highest yearly peak of 8.36 mPWD on 8th of September, which was 16cm above the DL (8.20m) at Kamarkhali station.

***The Arialkhan at Madaripur***

At Madaripur the WL of the river Arialkhan showed similar trend of rise and fall of the river Padma. The WL of Arialkhan at Madaripur flowed below the DL. The WL attained its highest peak of 3.61 m on the 12th of September, which was 56cm below the DL (4.17m) at Madaripur.

***Kobodak at Jhikorgacha***

A prolong flooding situation was prevailed along the Kobodak river from end of the August to the middle of the December. At Jhikorgacha, the WL flowed above the DL for continuous 120 days with a peak of 4.92mPWD on 8th October, which was 81cm above the DL(4.11m) at this point. As a result, part of Satkhira, Khulna and Jessore districts were flooded for prolong period, most affected affected Upozillas are Keshobpur, Kalaroa, Tala, Monirumpur and Stakhira Sadar. This is due to the poor drainage condition and more rainfall in the region. At Jhikorgacha, the WL of river Kobodak crossed the DL on 21st August and remained above the DL till 15th of December. From the figure, it may be seen that, except 2010, the Kobodak flowed above its DL at Jhikorgacha in every year since 2004, and the trend of flood days in the area is increasing.



Comparative hydrographs for few important stations for the year of 2013, 2007 & 1998 of the Ganges basin are shown in figures 3.14 to 3.20.

**Table 3 2 :**Comparison of Water Level of 2013 and Historical Events of 1988 & 1998 of Some Important Stations in Ganges Basin.

| Sl. No | River | Station | Recorded Maximum (m) | Danger Level (m) | Peak of the year (m) | | | Days above Danger Level | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2013 | 1998 | 1988 | 2013 | 98 | 88 |
| 1 | Punarbhaba | Dinajpur | 34.40 | 33.50 | 33.5 | 34.09 | 34.25 | - | 3 | 4 |
| 2 | Ganges | Pankha | 22.97 | 22.50 | 22.66 | 24.14 | NA | 5 | 66 | NA |
| 3 | Ganges | Rajshahi | 20.00 | 18.50 | 18.7 | 19.68 | 19.00 | 7 | 28 | 24 |
| 4 | Ganges | Hardinge Bridge | 15.04 | 14.25 | 14.13 | 15.19 | 14.87 | - | 27 | 23 |
| 5 | Padma | Goalundo | 10.01 | 8.50 | 8.97 | 10.21 | 9.83 | 5 | 68 | 41 |
| 6 | Padma | Bhagyakul | 7.58 | 6.00 | 6.65 | 7.50 | 7.43 | 7 | 72 | 47 |
| 7 | Gorai | Gorai Rail Bridge | 13.65 | 12.75 | 12.24 | 13.45 | 13.65 | - | 25 | 25 |
| 8 | Gorai | Kamarkhali | 9.48 | 8.20 | 8.36 | NA | NA | 13 | NA | NA |
| 9 | Arialkhan | Madaripur | 5.80 | 4.17 | 3.61 | NA | NA | - | NA | NA |
| 10 | Kobodak | Jhikorgacha | 5.59 | 4.11 | 4.92 | NA | NA | 120 | NA | NA |

## 3.3 THE MEGHNA BASIN

Many rivers of this basin entered from the hilly catchment of India and are flashy in nature. Out of 20 WL monitoring stations in the Meghna basin, at 8 stations flowed above their respective DLs, these are Kanaighat on Surma River, Amalshid and Sheola on Kushyara River, Manu Railway Bridge on Manu river, Habigonj and Bullah on Khowai river, Kamalgonj on Dhalai river and Nakuakaon on Bhugai river for less than 1 day (Manu at Manu Railway Bridge) to 13 days (Sheola on Kushiyara River). As a result, floods of short to moderate duration was experienced in the districts of Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, and Habigonj during the monsoon 2013.

Comparative statement of WL and days flowed above the DL for 2013 and historical events of 1998 and 1988 for this basin for selected stations are shown in Table 3.3.

***The Surma at Kanaighat***

As a flashy river, WL of the river Surma at Kanaighat (Sylhet district) showed several peaks during the monsoon-2013. WL flowed above its DL at Kanaighat during 1$^{st}$ and 3$^{rd}$ week of August and 1$^{st}$ week of September and flowed total 7 days above DL. It attained its highest peak of 13.67mPWD on 18$^{th}$ August at 12:00 hours, which was 47cm above the DL(13.20 m) at Kanaighat.

***Surma at Sylhet***

The WL of river Surma at Sylhet didn't cross the DL, though it showed the similar trend as Kanaighat. It attained the monsoon with peak WL of 10.58mPWD on 18$^{th}$ August, which was 67cm below its DL (11.25m).

***The Surma at Sunamgonj***

The WL of the river Surma at Sunamgonj didn't flow above the DL in this monsoon-2013. The WL of Surma at Sunamgonj recorded its highest peak of 7.96mPWD on 10th July, which was 29cm below its DL (8.25m).

***The Kushiyara at Amalshid***

The river at this point observed several peaks during the monsoon 2013. It flowed above DL for 10 days. In July it crossed the DL on 17th 18.00hours and stayed for one day, again in August it crossed the DL at 7th 18.00hours and stayed for just few hours and then crossed its respective DL on 15th August and continued for 9 days till 22nd August. It attained the yearly peak of 16.94mPWD on 18th August at 15:00 hrs, which was 109cm above the DL (15.85mPWD) at Amalshid.

***The Kushiyara at Sheola and Sherpur***

The Kushiyara river at Sheola and Sherpur (Sylhet district) observed similar rise and fall as of Amalshid. At Sheola it flowed above the DL for 2 days in month of July and for 11 days during August (total 13 days). In July it crossed the Dl for 2 days in 18th and 19th, again crossed the DL in August twice from 15th to 22nd and 26th to 28th. It attained its highest peak of 14.31 mPWD on 18th August at 12:00hrs, which was 81 cm above its DL (13.50 m). At Sherpur the river flowed with a gradual rise and fall trend but didn't cross the DL in this monsoon. It attained its yearly highest peak of 8.91mPWD on 20th August, which was 9cm below its DL (9.00 m).

***The Manu at Manu Railway Bridge and Moulvi Bazar***

As a flashy river, the WL of the river Manu at Manu Railway Bridge and at Moulvibazar observed several peaks during the monsoon-2013. The WL of Manu river crossed the DL at Manu Railway Bridge for 12hrs at 9th May (peak 17.84mPWD, which is 77 cm above the DL). At Moulvibazar the WL of Manu didn't cross the DL, flowed with peak of 11.63mPWD, which was 12cm below its DL(11.75m) at this point.

***The Someswari at Durgapur***

As the flashy river the Durgapur in Netrokona district, showed several peaks during the monsoon 2013, but remained below its DL. It attained monsoon highest peak of 12.38mPWD on 6th October at 18:00hours, which was 62cm below its DL (13.0 m).

***The Kangsha at Jariajanjail***

As flashy river the Kangsha at Jariajanjail in Netrokona district showed several peaks during the monsoon 2013, but remained below its DL. It attained its yearly highest peak of 9.3mPWD on 6th September at 15:00hours, which was 45cm below its DL (9.75m).

***The Bhugai at Nakuagaon***

As flashy river the Bhugai at Nakuagaon in Sherpur district recorded sharp rise & fall with several peaks during the monsoon 2013. It flowed above its DL for 3 hours at 6th October due to heavy rainfall. It attained monsoon highest peak of 22.66mPWD at 6th October 18.00 hours, which was 26cm above its DL (22.40m) at this point.

***The Khowai at Habigonj and Bullah***

As the flashiest river in Bangladesh, the Khowai at Habigonj showed several peaks during the monsoon 2013, The WL at Habigonj crossed its DL for 1 day in month of September. The WL recorded its yearly highest peak of 10.00 m on 6th September, which was 50 cm above its DL (9.50m). At Ballah the WL of Khowai flowed above the DL for 2 days from 5th September to 6th September with peak of 22.8m on 1st June at 15:00 hours, which is 116cm above the DL (21.64m).

***The Dhalai at Kamalgonj***

The WL of the flashy river Dhalai at Kamalgonj flowed above its DL thrice for 3 days in month of May, June and August in a short duration with monsoon peak of 20.5mPWD on 15th August at 18:00hours, which was 23cm above its DL(19.82m) at this point.

***The Meghna at Bhairab Bazar***

The WL of the Upper Meghna river at Bhairab Bazar flowed below its DL during the monsoon 2013, without much ups and downs from July to September. The peak WL recorded of 5.52mPWD on 11th September at 12:00 hours, which was 48cm below of its DL(6.0m) at this point.

Comparative hydrographs for few stations the year of 2013, 2007 & 1998 of rivers of the Meghna basin are shown in figures 3.21 to 3.36.

**Table 3. 3:** Comparison of Water Level of 2013 and Historical Events of 1988 & 1998 of Some Important Stations in Meghna Basin.

| Sl. No | River | Station | Recorded Maximum (m) | Danger Level (m) | Peak of the year (m) | | | Days above Danger level | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2013 | 1998 | 1988 | 13 | 98 | 88 |
| 1 | Surma | Kanaighat | 15.58 | 13.20 | 13.67 | 15.00 | 15.10 | 7 | 73 | 75 |
| 2 | Surma | Sylhet | 11.95 | 11.25 | 10.58 | 11.72 | 11.95 | - | 14 | 21 |
| 3 | Surma | Sunamgonj | 9.46 | 8.25 | 7.96 | 8.90 | 9.03 | - | 56 | 62 |
| 4 | Kushiyara | Amalshid | 18.28 | 15.85 | 16.94 | 17.60 | 17.50 | 10 | 54 | 65 |
| 5 | Kushiyara | Sheola | 14.60 | 13.50 | 14.31 | 14.14 | 14.09 | 13 | 37 | 80 |
| 6 | Kushiyara | Sherpur | 9.68 | 9.00 | 8.91 | NA | NA | - | NA | NA |
| 7 | Jariajanjail | Kangsha | 13.37 | 9.75 | 9.30 | NA | NA | - | NA | NA |
| 8 | Manu | Manu Railway Bridge | 20.42 | 17.07 | 17.84 | 18.63 | 18.95 | 0.5 | 6 | 66 |
| 10 | Manu | Moulvi Bazar | 15.50 | 11.75 | 11.63 | 11.68 | 13.01 | - | - | 25 |
| 11 | Khowai | Habigonj | 12.00 | 9.50 | 11.5 | 11.44 | 11.06 | 1 | 8 | 14 |
| 12 | Upper Meghna | Bhairab Bazar | 7.66 | 6.25 | 5.52 | 7.33 | 7.66 | - | 68 | 68 |
| 13 | Gumti | Comilla | 13.56 | 11.75 | 10.86 | 12.79 | 11.80 | - | 17 | 17 |

## 3.4 THE SOUTH EASTERN HILL BASIN

The South Eastern Hill basin is constituted with the basin areas of the hilly rivers like the Muhuri, the Halda, the Sangu, the Matamuhuri and the Feni in the South Eastern Part of the country. The WL of the rivers Muhuri, Halda and Matamuhuri crossed their respective DLs for 1 day during this monsoon-2013. As a result, a short duration flood occurred at Parshuram on Muhuri, Narayanhat on Halda river and Chiringa on Matamuhuri river during the monsoon 2013. As a result, low lying areas of Chittagong, Bandarban and Cox's Bazar were slightly affected by the flood for very short duration. All other rivers of this basin flowed below their respective DLs. The details of WL of different river are described in following sections. A comparative statement of water level and days flowed above the DLs for the monsoon-2013 and historical events of 1998 and 1988 for this basin are shown in the Table 3.4.

***The Muhuri at Parshuram***

The Muhuri river in Feni, Noakhali district is a flashy one flowed above the DL for one day at 28th July-2013. It attained its highest peak 13.23m on 28th July, which was 23cm above its DL (13.00 m).

***The Halda at Narayanhat***

As it is a flashy river, the WL of the river Halda (a flashy river) at Narayanhat under Hathazari upzilla also showed several peaks during this monsoon. It crossed danger mark 2 times during the monsoon-2013, for less than one day on 28th June and for one day on 28th July with peak of 16.32 mPWD (monsoon peak) on 28th July, which was 107 cm above the DL(15.25 m) at Narayanhat. The WL of the river Halda at Narayanhat flowed above the DL for 2 days in the monsoon-2013.

***The Halda at Panchpukuria***

The river here observed several peaks like Narayanhat, but flowed below its DL during the monsoon 2013. At Panchpukuria it attained its highest peak of 7.28mPWD on 28th June at 6:00 hours, which was 222cm below its DL (9.50 m).

***The Sangu at Bandarban and Dohazari***

It is a flashy river, showed several peaks. The river flowed below the DL at Bandarban but crossed the DL at Dohazari in this monsoon-2013. At Bandarban the peak recorded was 11.8 mPWD on 30th June at 18:00 hours, which was 345 cm above its DL (15.25m). At Dohazari the highest peak was recorded 5.5m on 30th June at 06:00 hours, which was 150 cm above its danger mark (7.00 m) at this point.

***The Matamuhuri at Lama and Chiringa***

The river observed several peaks DL in the monsoon-2013. At Lama the peak recorded was 12.16m on 18th August at 12:00 hours, which was 09cm below its DL(12.25m). At Chiringa recorded highest peak of 6.36m on 18th August at 12:00 hours, which was 61 cm above the DL (5.75 m), flowed above the DL for less than one day on 29th June and 30th June, less than one day on 28th July and a whole day on 18th August in this monsoon-2013.

***The Feni at Ramgarh***

The WL of river Feni at this point observed several peaks and flowed below its DL during the monsoon-2013. The highest peak WL attained by the river was 14.78 m on 30th August 6:00 hours , which was 259cm below its DL (17.37m) at this point.

**Table 3. 4 :** Comparison of Water Level of 2013 and Historical Events of 1988 and 1998 of Some Important Station in South Eastern Hill Basin.

| Sl. No | River | Station | Recorded Maximum (m) | Danger Level (m) | Peak of the year (m) | | | Days above Danger level | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2013 | 98 | 88 | 2013 | 98 | 88 |
| 1 | Muhuri | Parshuram | 15.03 | 13.00 | 13.23 | 14.60 | 12.42 | 1 | 9 | 48 |
| 2 | Halda | Narayanhat | 18.05 | 15.25 | 16.32 | 16.57 | NA | 2 | 21 | NA |
| 3 | Halda | Panchpukuria | 11.55 | 9.50 | 7.28 | 10.44 | 10.05 | - | 4 | 6 |
| 4 | Sangu | Bandarban | 20.38 | 15.25 | 11.8 | 15.25 | 16.80 | - | 1 | 3 |
| 5 | Sangu | Dohazari | 9.05 | 7.00 | 5.50 | 7.42 | NA | - | 2 | NA |
| 6 | Matamuhuri | Lama | 15.45 | 12.25 | 12.16 | 13.05 | 12.18 | - | 2 | - |
| 7 | Matamuhuri | Chiringa | 6.83 | 5.75 | 6.36 | 6.85 | NA | 3 | 5 | NA |
| 8 | Feni | Ramgarh | 21.41 | 17.37 | 14.78 | 17.50 | NA | - | 1 | NA |

Comparative hydrographs for the year of 2013, 2007 and 1998 of few stations of the South Eastern Hill Basin are shown in Figures 3.37 to 3.42.

## 3.5 RECORDED HIGHEST WATER LEVEL

The peak water level of all the water level monitoring stations under FFWC with the date during the monsoon 2013 s shown in the following table.

**Table 3.5: Recorded Peak Water Level with Date during the monsoon 2013**

| SL No | River name | Station | Peak WL-2013 (m) | Date |
|---|---|---|---|---|
| | **BRAHMAPUTRA BASIN** | | | |
| 1 | DHARLA | KURIGRAM | 26.68 | 11/07/2013 |
| 2 | TEESTA | DALIA | 52.70 | 10/07/2013 |
| 3 | TEESTA | KAUNIA | 29.05 | 10/07/2013 |
| 4 | JAMUNESWARI | BADARGANJ | 30.85 | 12/07/2013 |
| 5 | GHAGOT | GAIBANDHA | 22.17 | 10/09/2013 |
| 6 | KARATOA | CHAK RAHIMPUR | 19.33 | 19/10/2013 |
| 7 | KARATOA | BOGRA | 13.25 | 18/10/2013 |
| 8 | BRAHMAPUTRA | NOONKHAWA | 26.56 | 10/09/2013 |
| 9 | BRAHMAPUTRA | CHILMARI | 23.92 | 10/09/2013 |
| 10 | JAMUNA | BAHADURABAD | 19.91 | 11/09/2013 |
| 11 | JAMUNA | SERAJGONJ | 13.51 | 11/09/2013 |
| 12 | JAMUNA | ARICHA | 9.70 | 11/09/2013 |
| 13 | OLD BRAHMAPUTRA | JAMALPUR | 15.80 | 12/09/2013 |
| 14 | OLD BRAHMAPUTRA | MYMENSINGH | 10.12 | 16/09/2013 |
| 15 | BURIGANGA | DHAKA | 4.92 | 12/09/2013 |
| 16 | BALU | DEMRA | 5.31 | 08/09/2013 |
| 17 | LAKHYA | NARAYANGONJ | 5.27 | 13/09/2013 |
| 18 | TURAG | MIRPUR | 5.16 | 23/08/2013 |
| 19 | TONGI KHAL | TONGI | 5.32 | 12/09/2013 |
| 20 | KALIGANGA | TARAGHAT | 7.89 | 14/09/2013 |
| 21 | DHALESWARI | JAGIR | 7.16 | 16/09/2013 |
| 22 | DHALESWARI | REKABI BAZAR | 4.83 | 10/09/2013 |

| SL No | River name | Station | Peak WL-2013 (m) | Date |
|---|---|---|---|---|
| 23 | BANSHI | NAYARHAT | 5.26 | 15/09/2013 |
| | **GANGES BASIN** | | | |
| 24 | KARATOA | PANCHAGARH | 70.8 | 10/07/2013 |
| 25 | PUNARBHABA | DINAJPUR | 33.5 | 11/07/2013 |
| 26 | ICH-JAMUNA | PHULBARI | 28.48 | 16/10/2013 |
| 27 | TANGON | THAKURGAON | 51.11 | 08/07/2013 |
| 28 | UPPER ATRAI | BHUSIRBANDAR | 39.19 | 11/07/2013 |
| 29 | MOHANANDA | ROHANPUR | 21.40 | 08/09/2013 |
| 30 | MOHANANDA | CHAPAI-NAWABGANJ | 21.25 | 07/09/2013 |
| 31 | LITTLE JAMUNA | NAOGAON | 14.00 | 14/07/2013 |
| 32 | ATRAI | MOHADEBPUR | 18.54 | 14/07/2013 |
| 33 | GANGES | PANKHA | 22.66 | 06/09/2013 |
| 34 | GANGES | RAJSHAHI | 18.70 | 07/09/2013 |
| 35 | GANGES | HARDINGE BRIDGE | 14.13 | 07/09/2013 |
| 36 | PADMA | GOALONDO | 8.97 | 11/09/2013 |
| 37 | PADMA | BHAGYAKUL | 6.65 | 11/09/2013 |
| 38 | GORAI | GORAI RAIL BRIDGE | 12.24 | 08/09/2013 |
| 39 | GORAI | KAMARKHALI | 8.36 | 08/09/2013 |
| 40 | ICHAMATI | SAKRA | 3.55 | 26/06/2013 |
| 41 | MATHABHANGA | CHUADANGA | 9.57 | 08/09/2013 |
| 42 | MATHABHANGA | HATBOALIA | 12.45 | 11/09/2013 |
| 43 | KOBADAK | JHIKORGACHA | 4.92 | 08/10/2013 |
| 44 | KUMAR | FARIDPUR | 4.89 | 12/09/2013 |
| 45 | ARIALKHAN | MADARIPUR | 3.61 | 12/09/2013 |
| | **MEGHNA BASIN** | | | |
| 46 | SURMA | KANAIGHAT | 13.67 | 18/08/2013 |
| 47 | SURMA | SYLHET | 10.58 | 18/08/2013 |
| 48 | SURMA | SUNAMGONJ | 7.96 | 10/07/2013 |
| 49 | KUSHIYARA | AMALSHID | 16.94 | 18/08/2013 |
| 50 | KUSHIYARA | SHEOLA | 14.31 | 18/08/2013 |
| 51 | KUSHIYARA | SHERPUR | 8.91 | 20/08/2013 |
| 52 | SARIGOWAIN | SARIGHAT | 12.56 | 06/10/2013 |
| 53 | MANU | MANU RAILY BRIDGE | 17.84 | 09/05/2013 |
| 54 | MANU | MOULVI BAZAR | 11.63 | 09/05/2013 |
| 55 | KHOWAI | BALLAH | 23.39 | 09/05/2013 |
| 56 | KHOWAI | HABIGONJ | 11.50 | 09/05/2013 |
| 57 | DHALAI | KAMALGONJ | 20.50 | 15/08/2013 |
| 58 | BHUGAI | NAKUAGAON | 22.66 | 06/10/2013 |
| 59 | JADUKATA | LORERGARH | 8.94 | 27/06/2013 |
| 60 | SOMESWARI | DURGAPUR | 12.38 | 06/10/2013 |
| 61 | KANGSHA | JARIAJANJAIL | 9.3 | 06/09/2013 |
| 62 | MEGHNA | BHAIRAB BAZAR | 5.52 | 11/09/2013 |
| 63 | GUMTI | COMILLA | 10.86 | 09/05/2013 |
| 64 | GUMTI | DEBIDDAR | 7.06 | 06/09/2013 |
| 65 | MEGHNA | CHANDPUR | 3.81 | 24/08/2013 |
| | **SOUTH EASTERN HILL BASIN** | | | |
| 66 | MUHURI | PARSHURAM | 13.23 | 28/07/2013 |
| 67 | HALDA | NARAYAN HAT | 16.32 | 28/07/2013 |
| 68 | HALDA | PANCHPUKURIA | 7.28 | 28/07/2013 |
| 69 | SANGU | BANDARBAN | 11.80 | 30/06/2013 |
| 70 | SANGU | DOHAZARI | 5.50 | 30/06/2013 |
| 71 | MATAMUHURI | LAMA | 12.16 | 18/08/2013 |
| 72 | MATAMUHURI | CHIRINGA | 6.36 | 18/08/2013 |
| 73 | FENI | RAMGARH | 14.78 | 30/08/2013 |

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

| Sl. No. | River | Station | Danger Level (m) | Recorded highest WL (m) before 2013 flood (date) | WL (Date) Exceeding previous Highest WL (m) |
|---|---|---|---|---|---|
| 1 | Dharla | Kurigram | 26.50 | 27.66 (14.07.96) | - |
| 2 | Teesta | Dalia | 52.40 | 52.97 (29.07.72) | - |
| 3 | Teesta | Kaunia | 30.00 | 30.52 (06.01.68) | - |
| 4 | Brahmaputra | Noonkhawa | 27.25 | 28.10 | - |
| 5 | Brahmaputra | Chilmari | 24.00 | 25.07 (23.08.62) | - |
| 6 | Jamuna | Bahadurabad | 19.50 | 20.62 (30.08.88) | - |
| 7 | Jamuna | Serajgonj | 13.35 | 15.12 (30.08.88) | - |
| 8 | Jamuna | Aricha | 9. 40 | 10.76 (02.09.88) | - |
| 9 | Old Brhamaputra | Jamalpur | 17.00 | 18.00 (31.07.54) | - |
| 10 | Old Brhamaputra | Mymensingh | 12.50 | 13.71(1.09.88) | - |
| 11 | Buriganga | Dhaka | 6.00 | 7.58 (04.09.68) | - |
| 12 | Lakhya | Narayangonj | 5.50 | 6.93 (10.09.98) | - |
| 13 | Turag | Mirpur | 5.94 | 8.35 (10.09.88) | - |
| 14 | Tongi Khal | Tongi | 6.08 | 7.84 (01.09.62) | - |
| 15 | Kaliganga | Taraghat | 8.38 | 10.37(2.09.88) | - |
| 16 | Punarbhaba | Dinajpur | 33.50 | 34.40 | - |
| 17 | Padma | Pankha | 21.50 | 24.14 (07.09.97) | - |
| 18 | Padma | Rajshahi | 18.50 | 20.00(13.09.1910) | - |
| 19 | Padma | H- Bridge | 14.25 | 15.19 (10.09.98) | - |
| 20 | Padma | Goalundo | 8.50 | 10.21 (03.08.08) | - |
| 21 | Padma | Bhagyakul | 6.00 | 7.58 | - |
| 22 | Gorai | Gorai Rly Br | 12.75 | 13.65 (02.09.98) | - |
| 23 | Surma | Kanaighat | 13.20 | 15.58(26.06.12) | - |
| 24 | Surma | Sylhet | 11.25 | 12.44 (19.07.04) | - |
| 25 | Surma | Sunamgonj | 8.25 | 9.75 (20.07.04) | - |
| 26 | Kushiyara | Amalshid | 15.85 | 18.28 (08.06.74) | - |
| 27 | Kushiyara | Sheola | 13.50 | 14.60 (09.09.08) | - |
| 28 | Manu | Manu Rly Br | 18.00 | 20.42 (23.05.02) | - |
| 29 | Manu | Moulvi Bazar | 11.75 | 13.25 (8.06.93) | - |
| 30 | Khowai | Habigonj | 9.50 | 12.00 (18.06.07) | - |
| 31 | Upper Meghna | Bhairab Bazar | 6.25 | 7.78 (24.07.04) | - |
| 32 | Gumti | Comilla | 11.75 | 13.56 (23.07.93) | - |
| 33 | Muhuri | Parshuram | 13.00 | 16.33 (13.09.04) | - |
| 34 | Halda | Narayanhat | 15.25 | 19.30 (13.08.99) | - |
| 35 | Halda | Panchpukuria | 7.00 | 12.54(27.06.03) | - |
| 36 | Sangu | Bandarban | 15.25 | 20.7 (12.07.97) | - |
| 37 | Sangu | Dohazari | 5.75 | 9.05 | - |
| 38 | Matamuhuri | Lama | 12.25 | 15.46 (12.08.99) | - |
| 39 | Matamuhuri | Chiringa | 5.75 | 7.03 (10.07.97) | - |
| 40 | Feni | Ramgarh | 17.37 | 21.42 (11.07.68) | - |

**WL - Water Level**

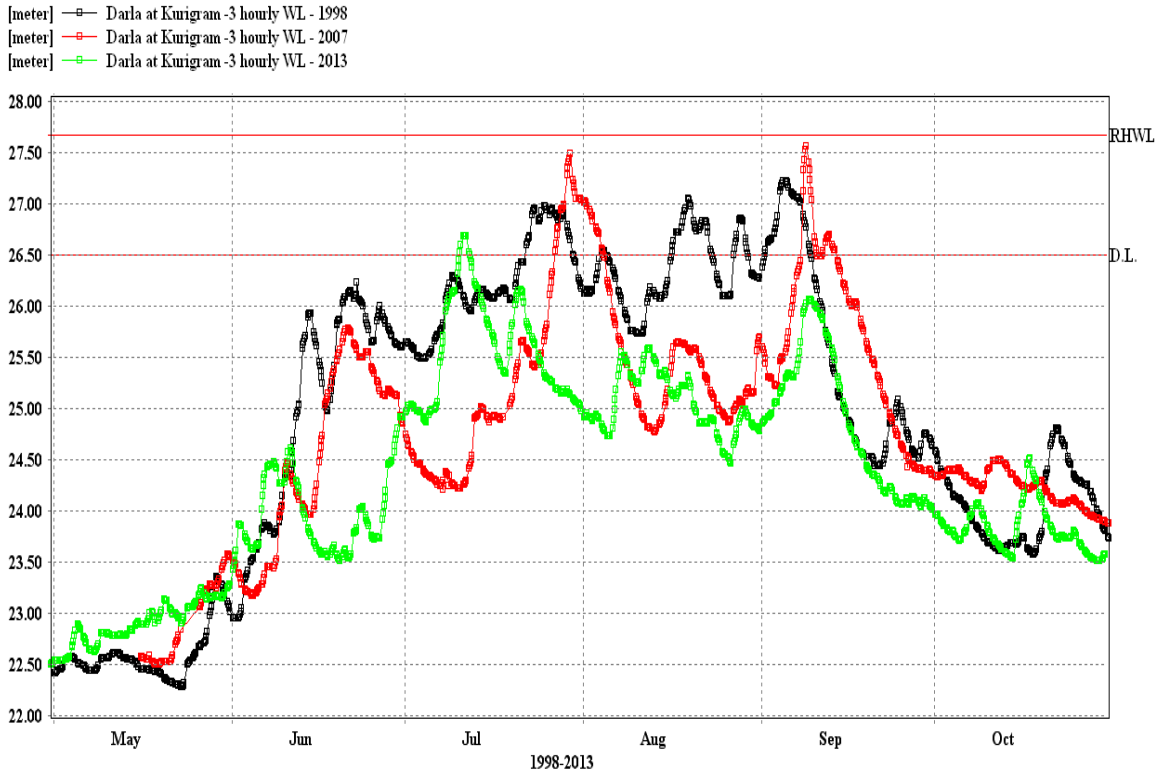



Figure 3.1 : Comparison of Hydrograph on Dharla at Kurigram

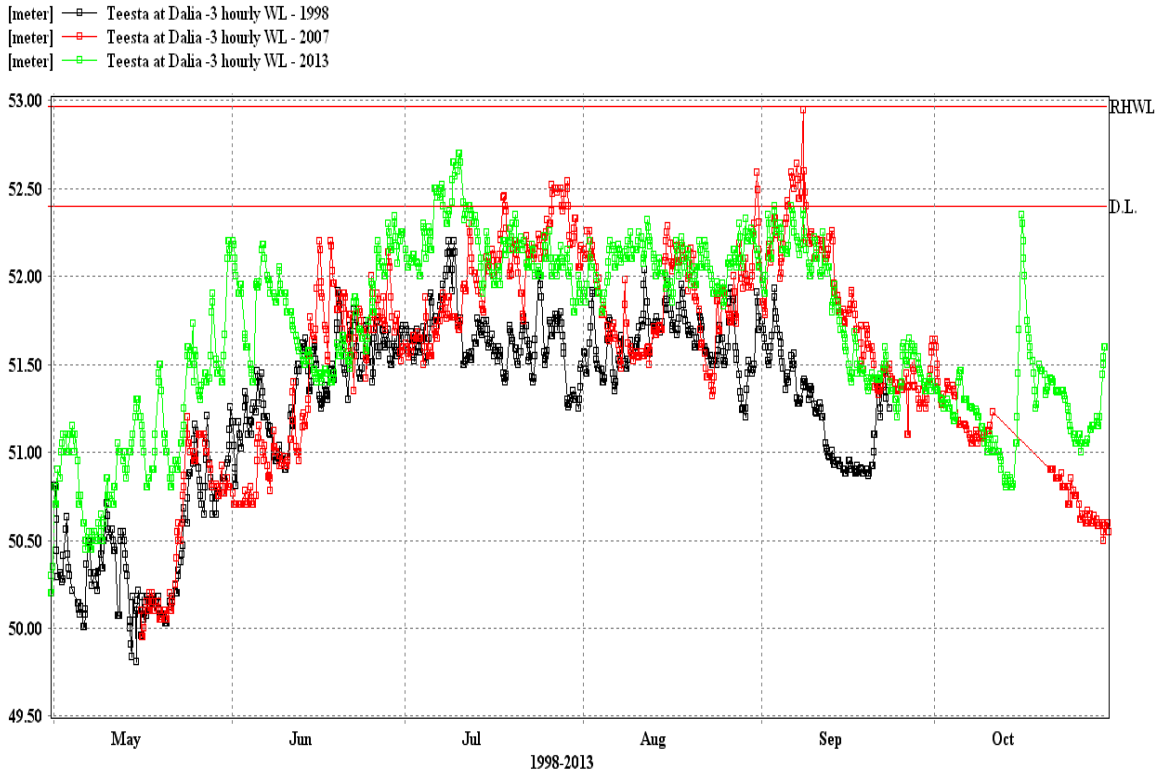



Figure 3.2 : Comparison of Hydrograph on Teesta at Dalia

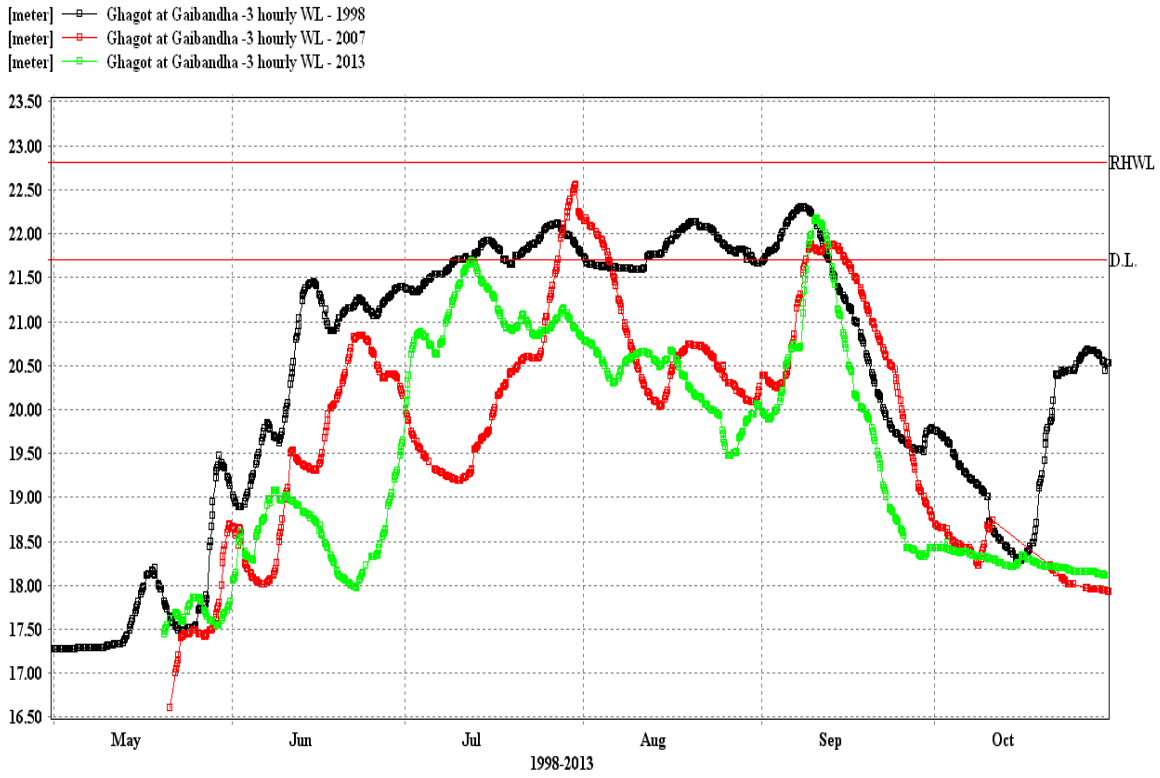



Figure 3.3 : Comparison of Hydrograph on Ghagot at Gaibandha

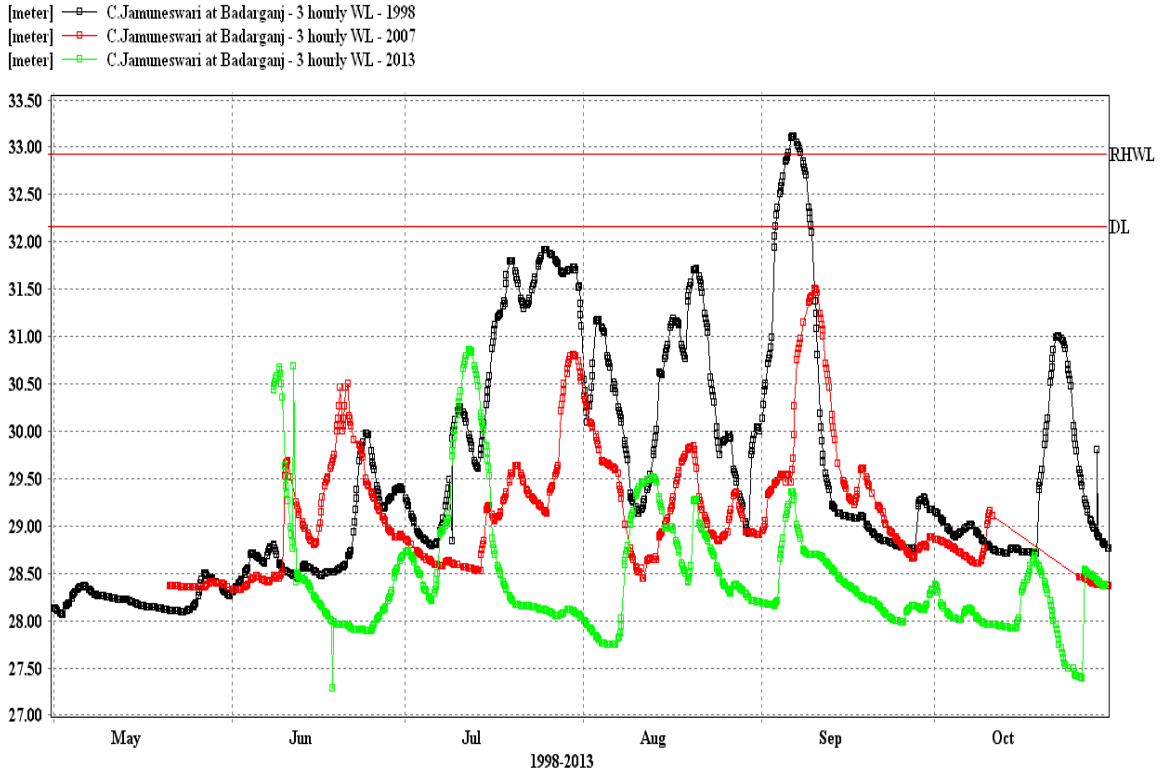



Figure 3.4 : Comparison of Hydrograph on Jamunesweri at Badargonj

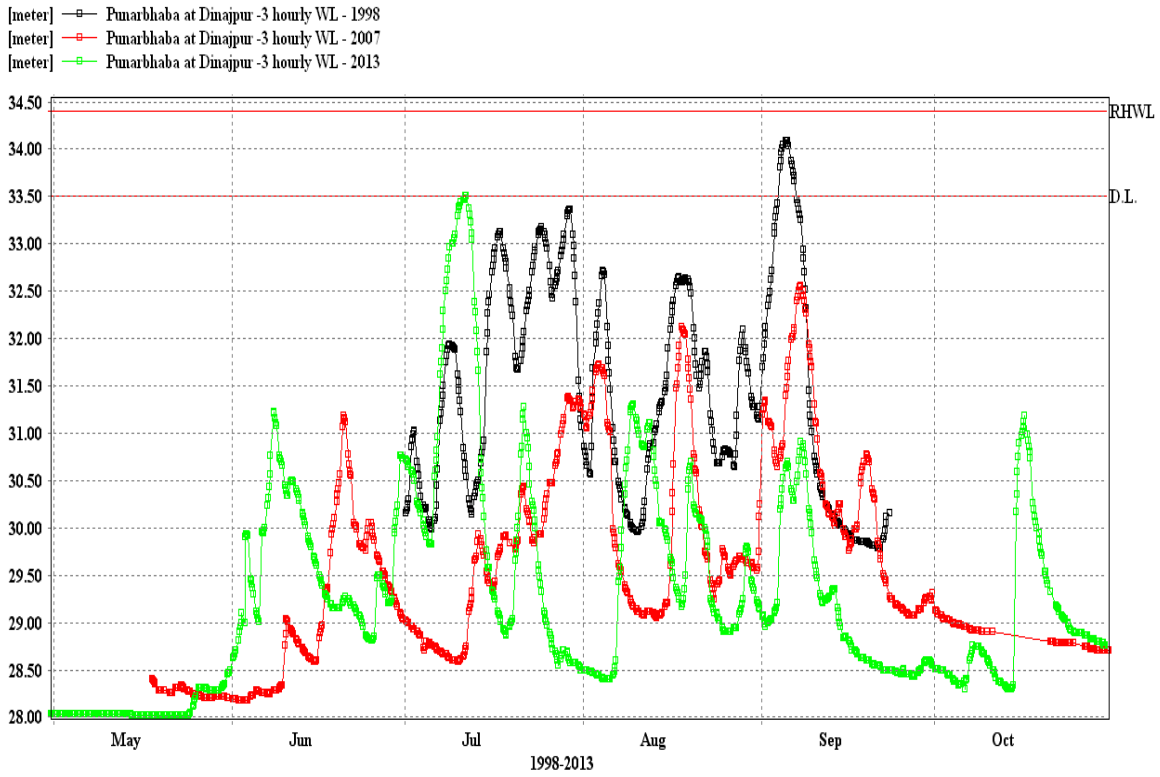



Figure 3.5 : Comparison of Hydrograph on Punurbhoba at Dinajpur

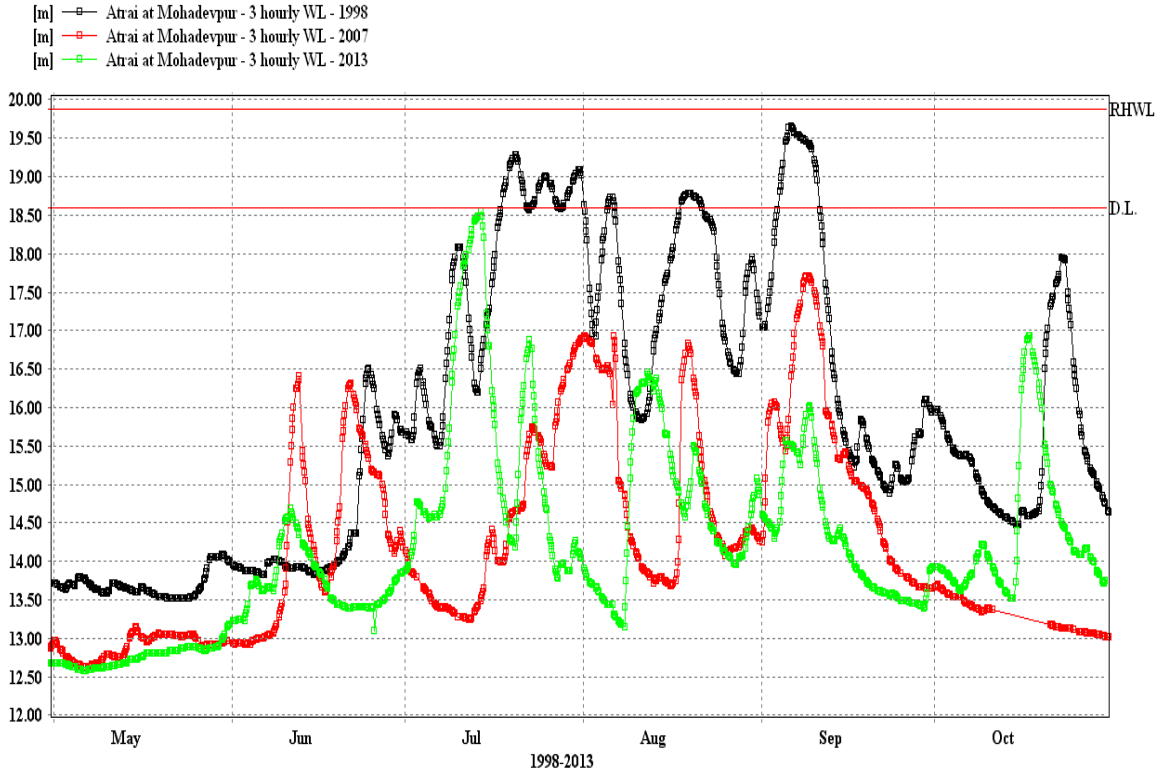



Figure 3.6 : Comparison of Hydrograph on Atrai at Mohadevpur

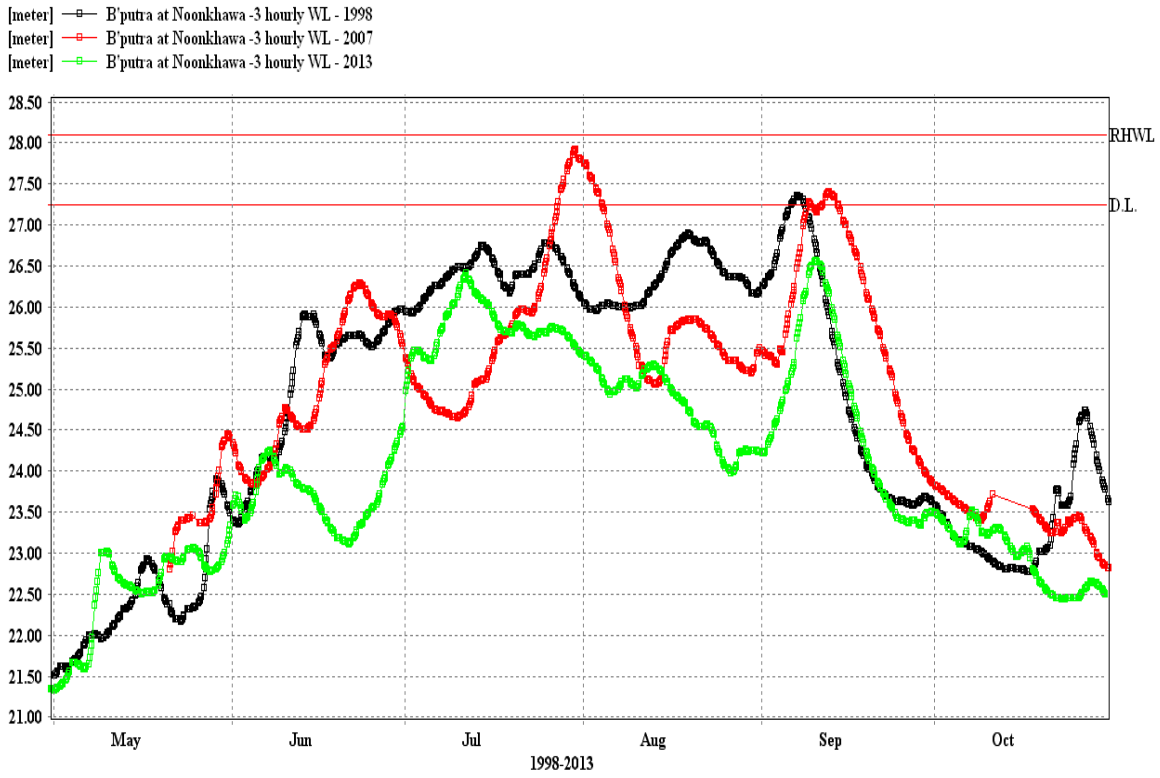



Figure 3.7 : Comparison of Hydrograph on Brahmaputra at Noonkhawa

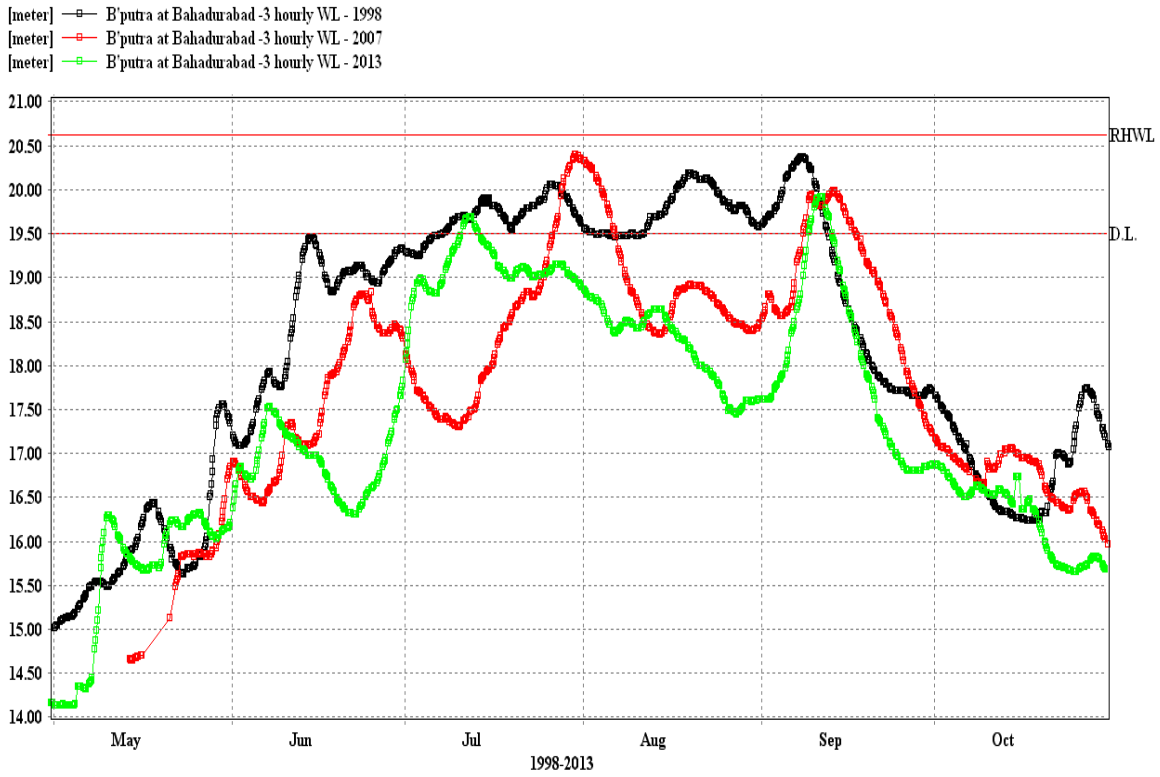



Figure 3.8 : Comparison of Hydrograph on Brahmaputra at Bahadurabad

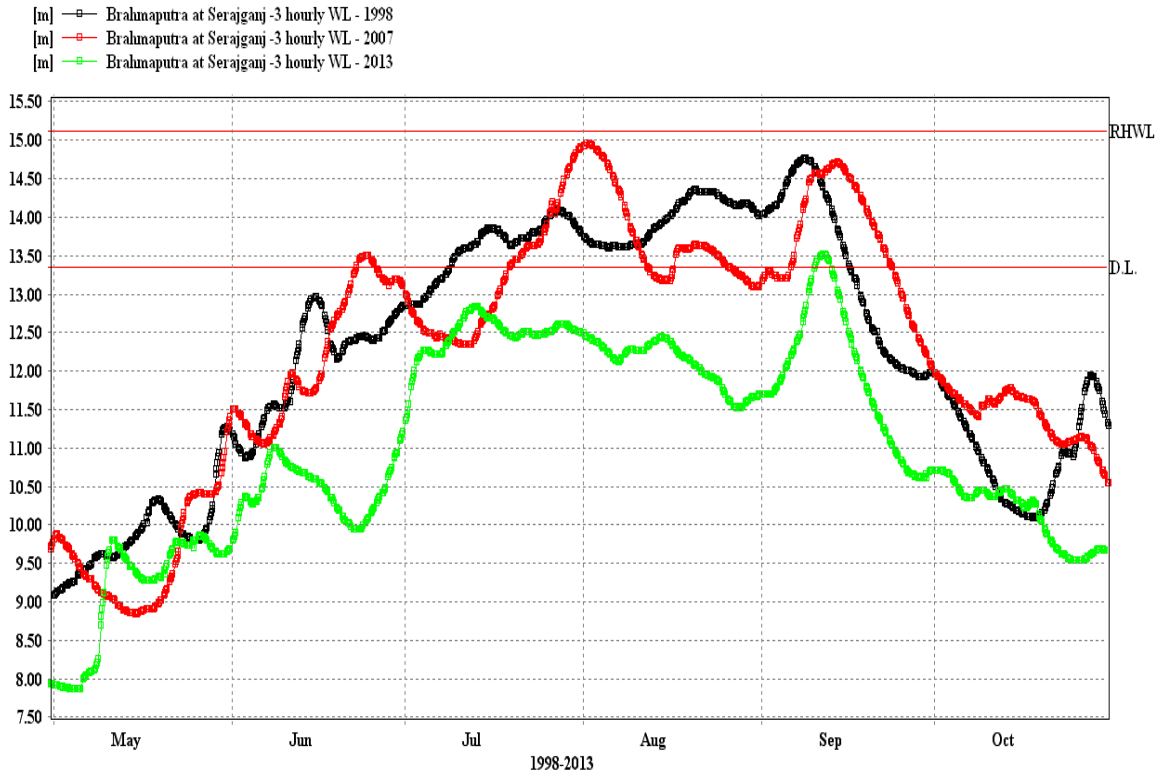



Figure 3.9 : Comparison of Hydrograph on Jamuna at Serajgonj

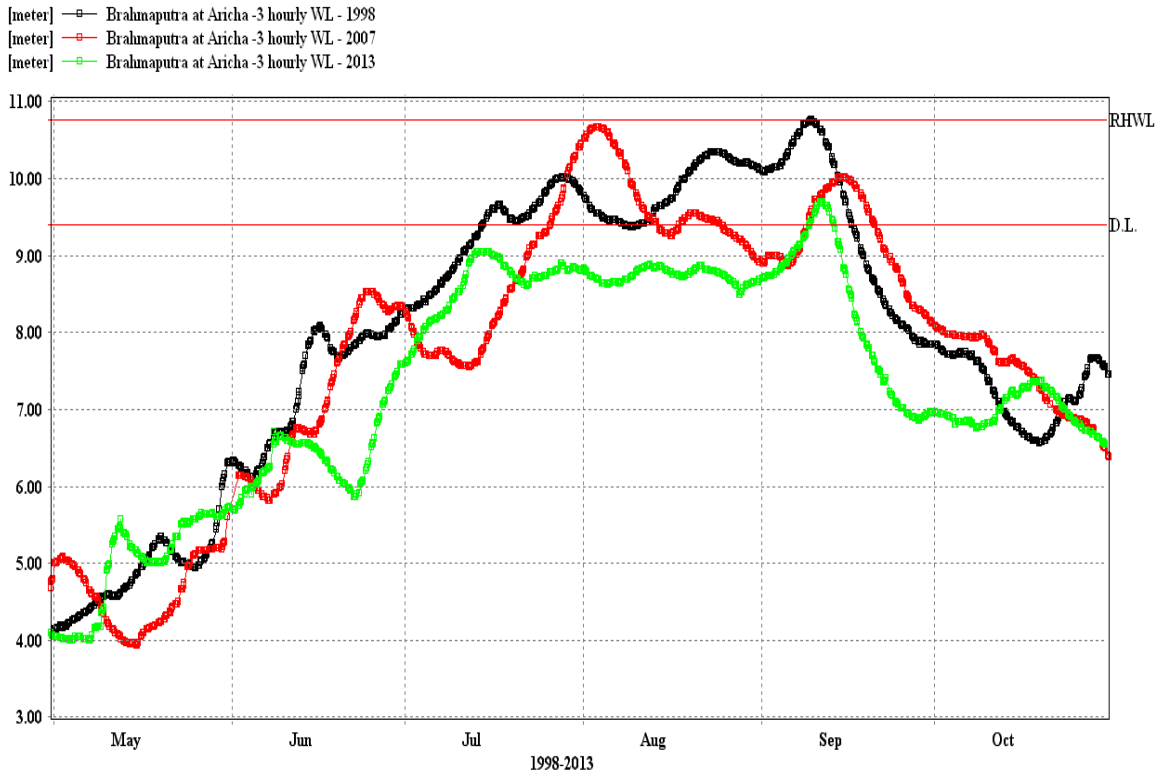



Figure 3.10 : Comparison of Hydrograph on Jamuna at Aricha

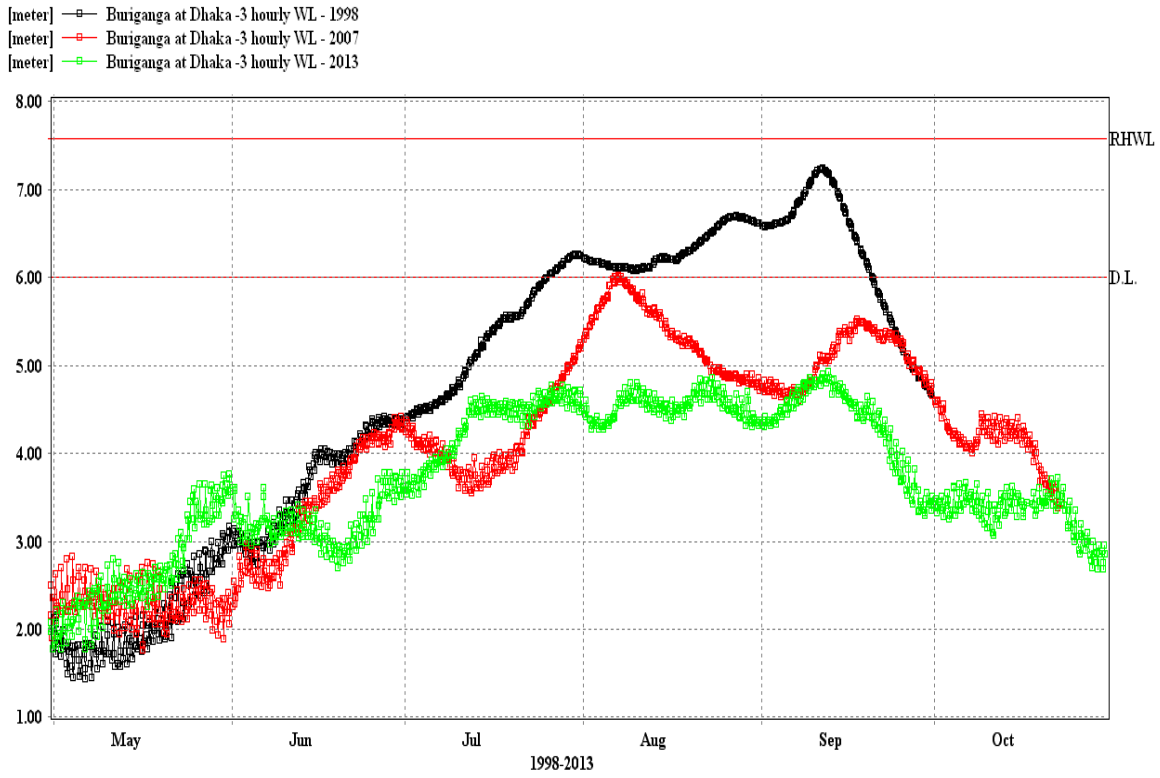



Figure 3.11 : Comparison of Hydrograph on Buriganga at Dhaka(Milbarak)

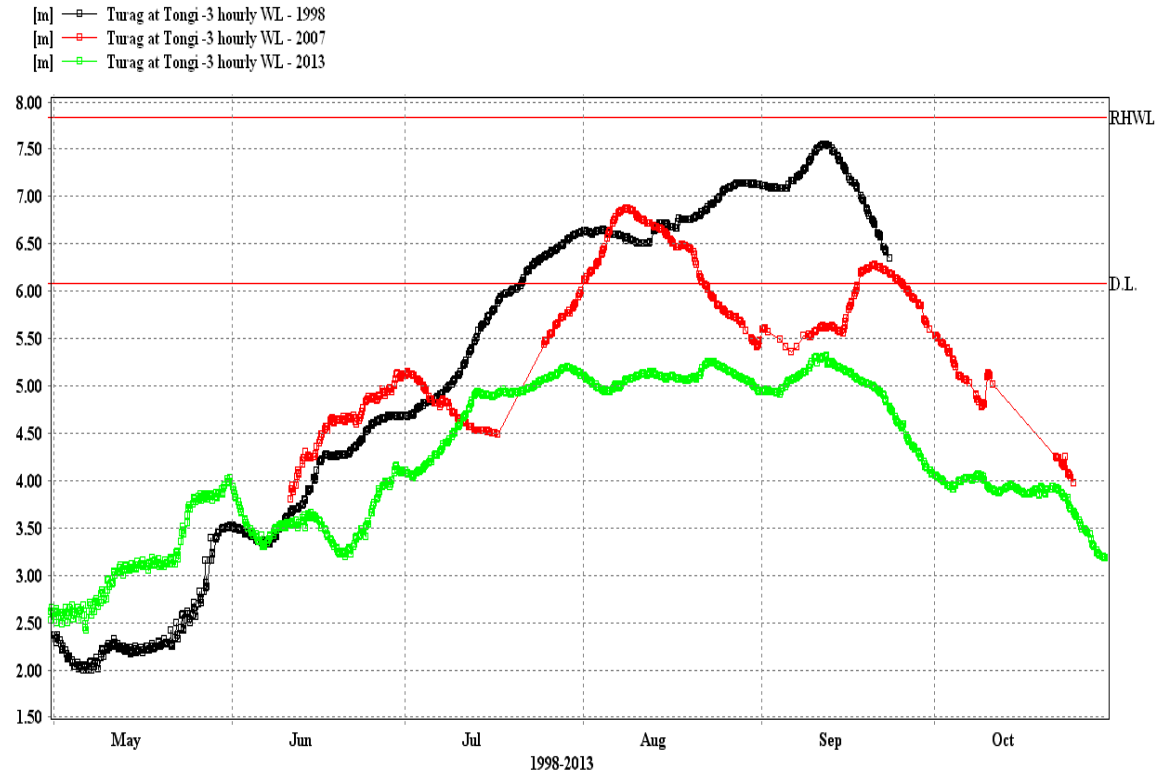



Figure 3.12 : Comparison of Hydrograph on Tongi Khal at Tongi

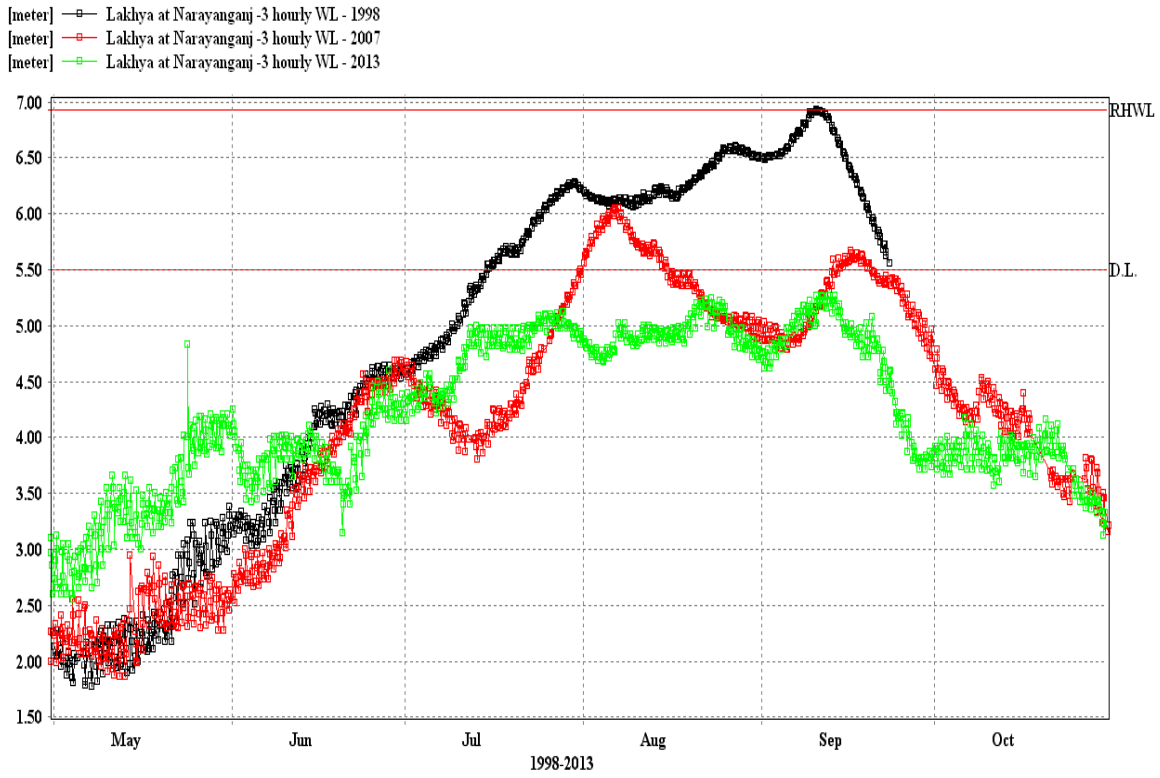



Figure 3.13 : Comparison of Hydrograph on Lakhya at Narayangonj

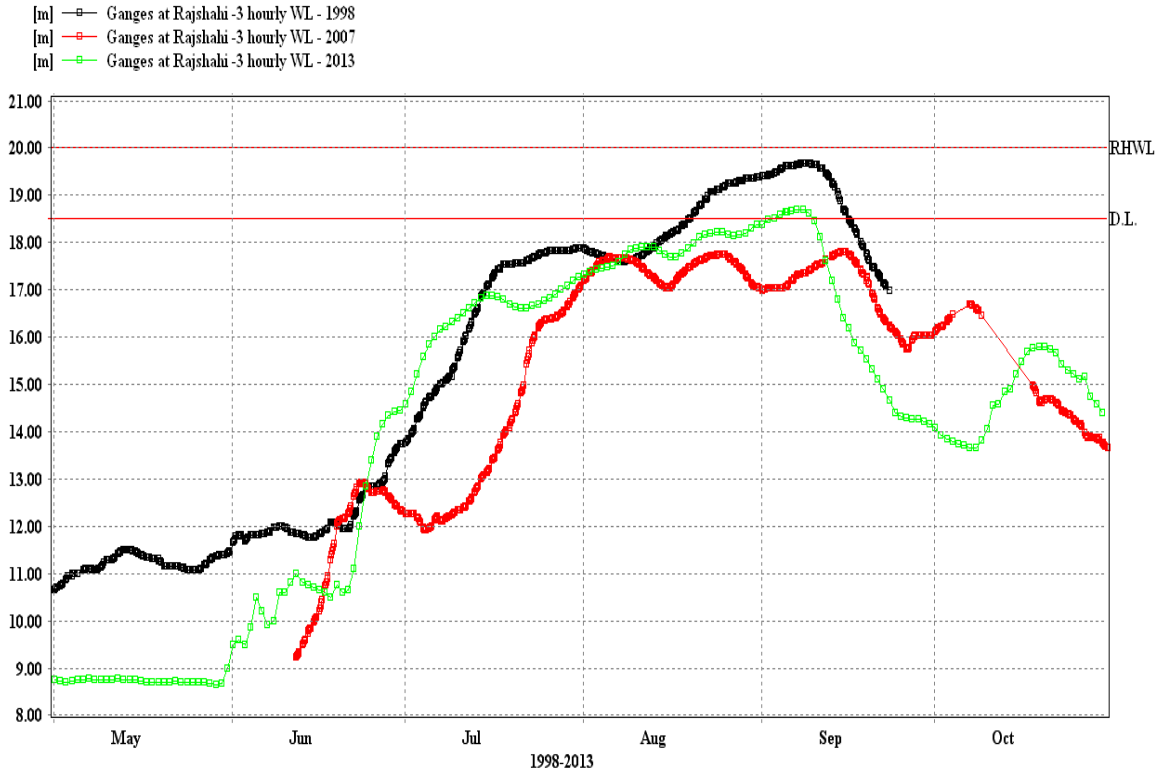



Figure 3.14 : Comparison of Hydrograph on Ganges at Rajshahi

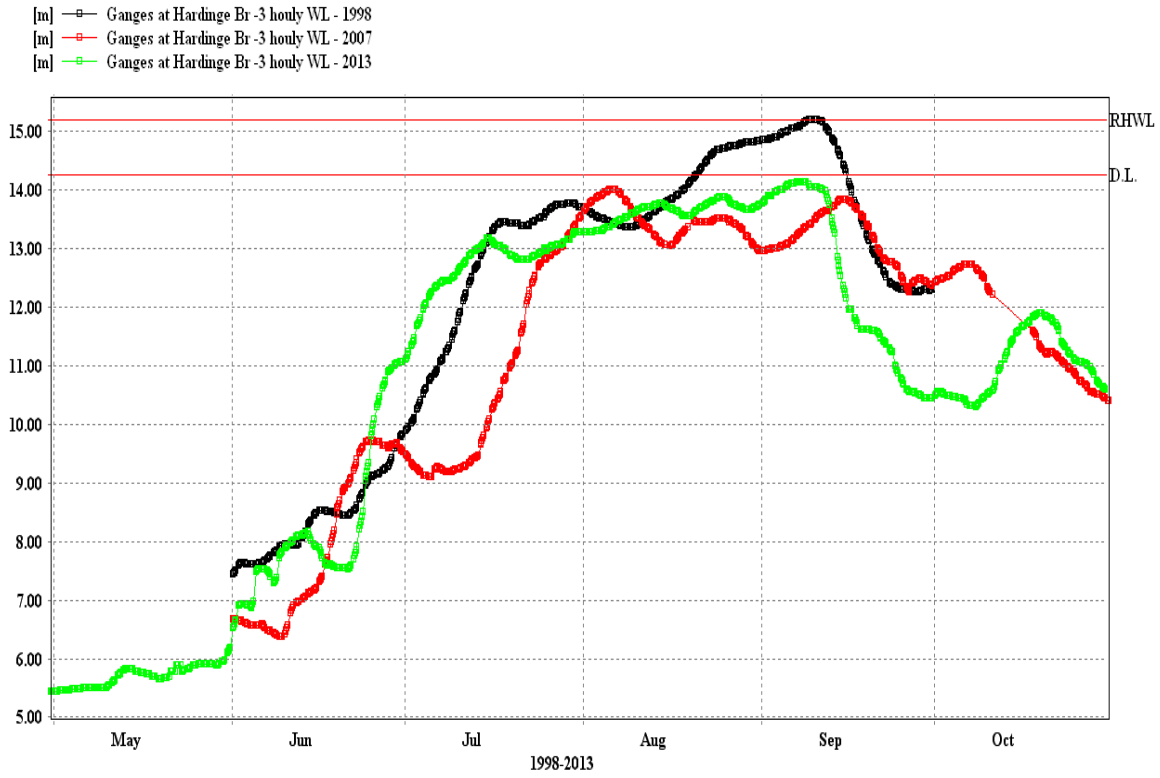



Figure 3.15 : Comparison of Hydrograph on Ganges at Hardinge Bridge

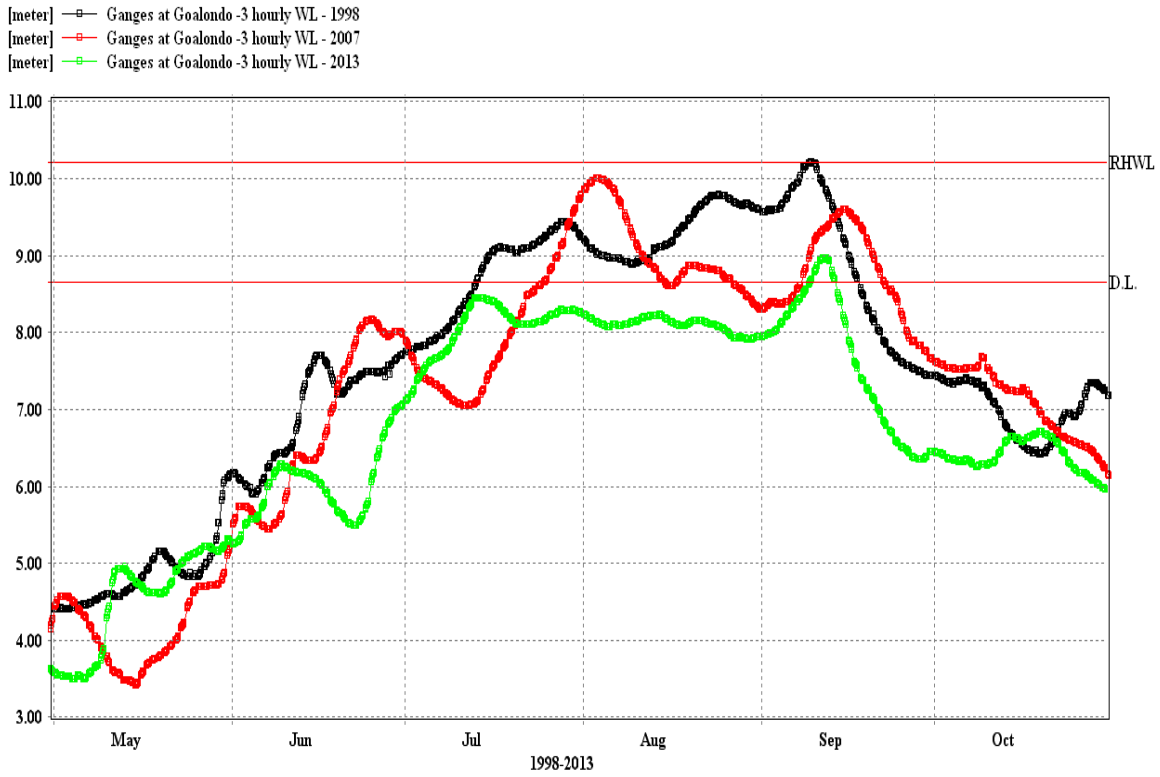



Figure 3.16 : Comparison of Hydrograph on Padma at Goalondo

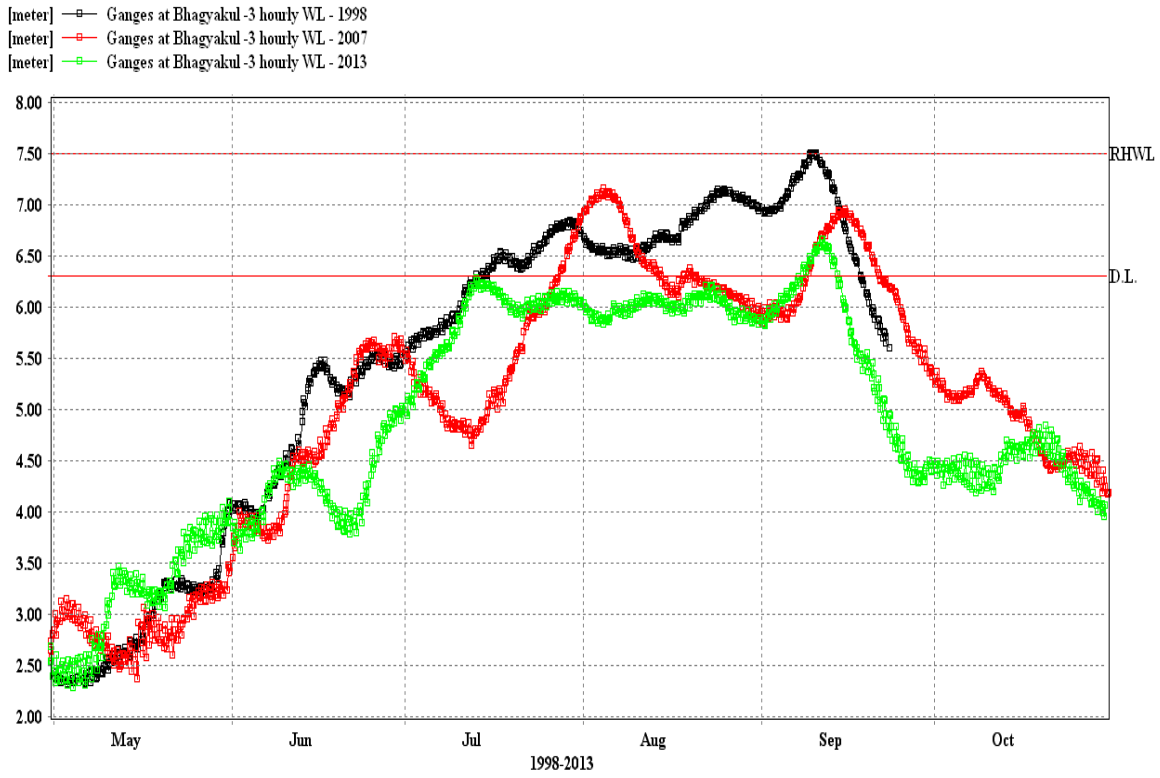



Figure 3.17 : Comparison of Hydrograph on Padma at Bhagyakul

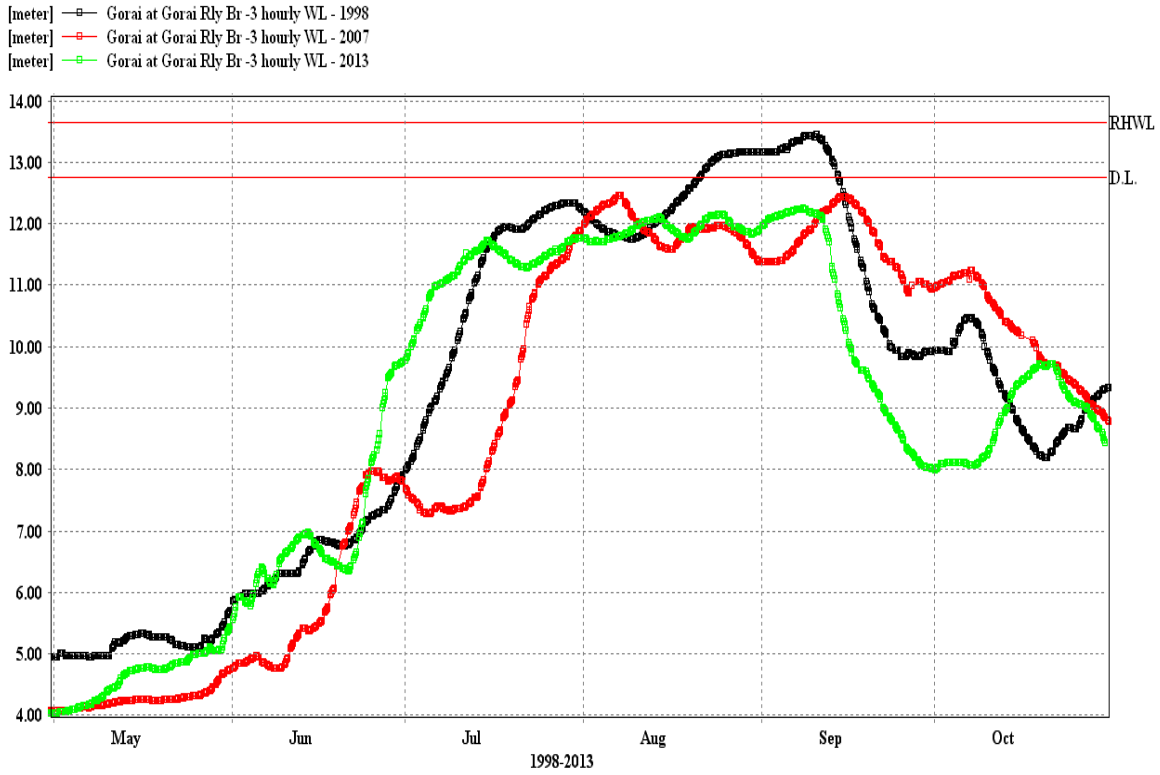



Figure 3.18 : Comparison of Hydrograph on Gorai at Gorai Railway Bridge

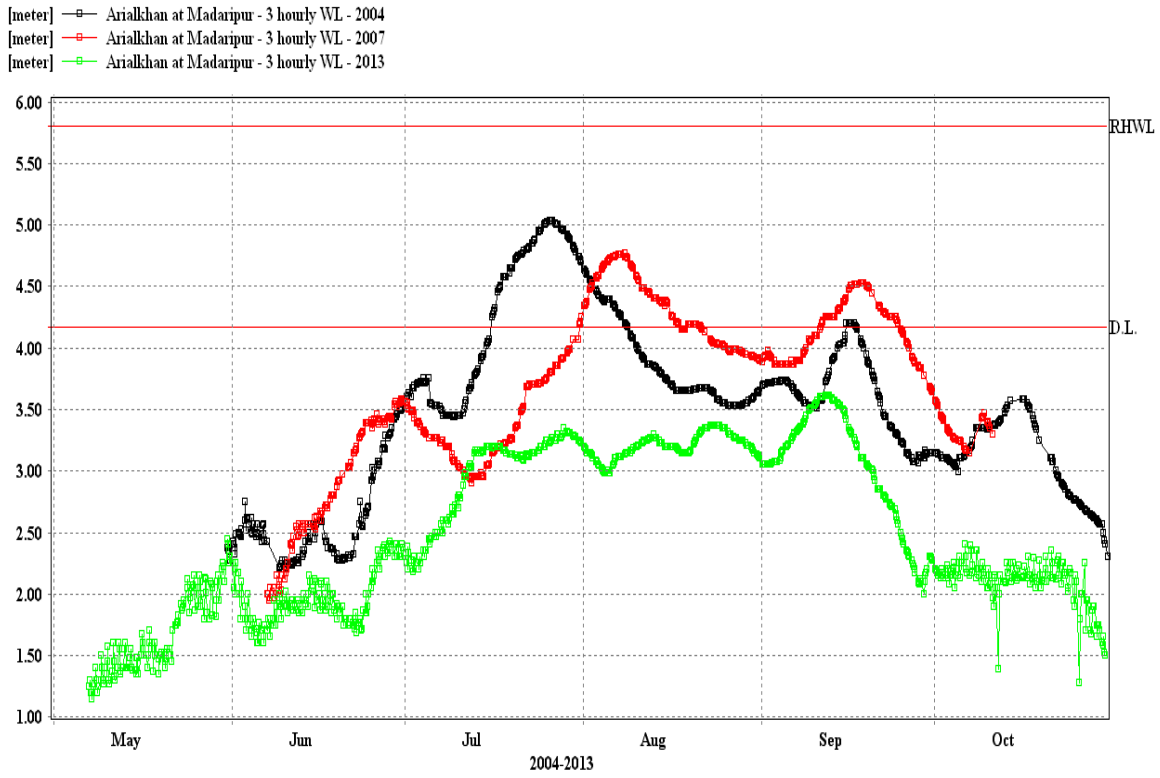



Figure 3.19 : Comparison of Hydrograph on Arialkhan at Madaripur

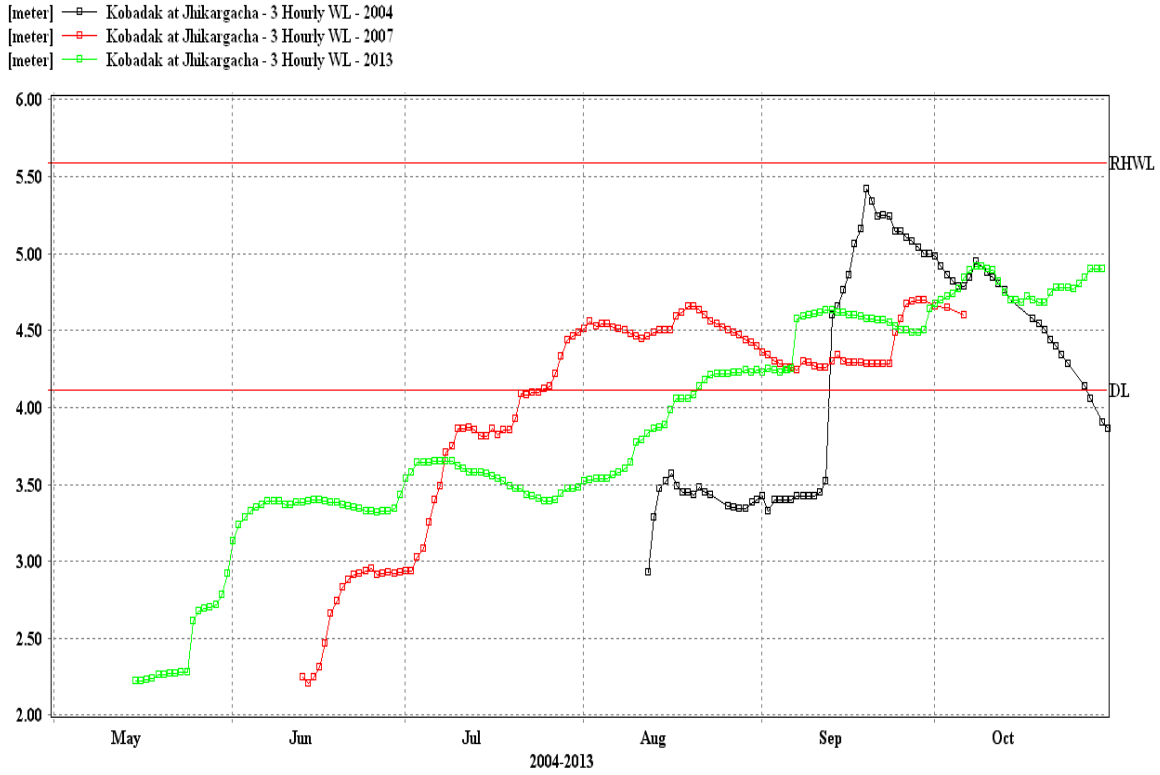



Figure 3.20 : Comparison of Hydrograph on Kobodak at Jhikorgacha

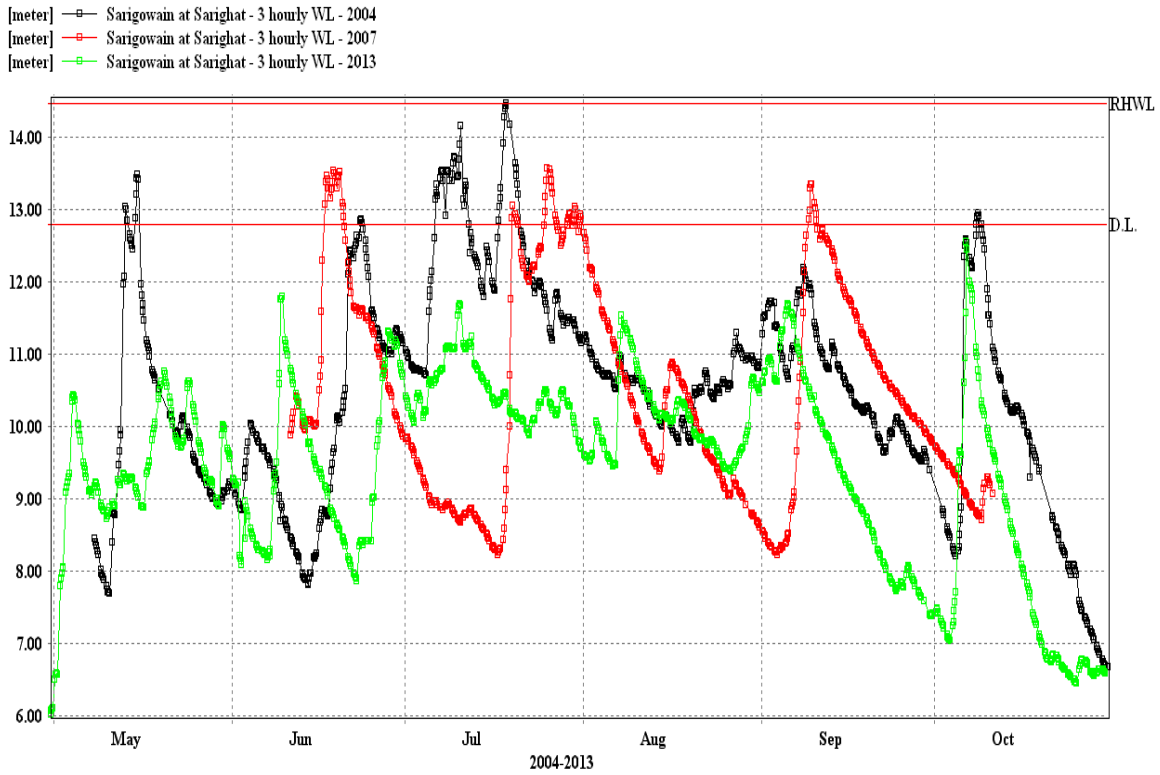



Figure 3.21 : Comparison of Hydrograph on Sarigoain at Sarighat

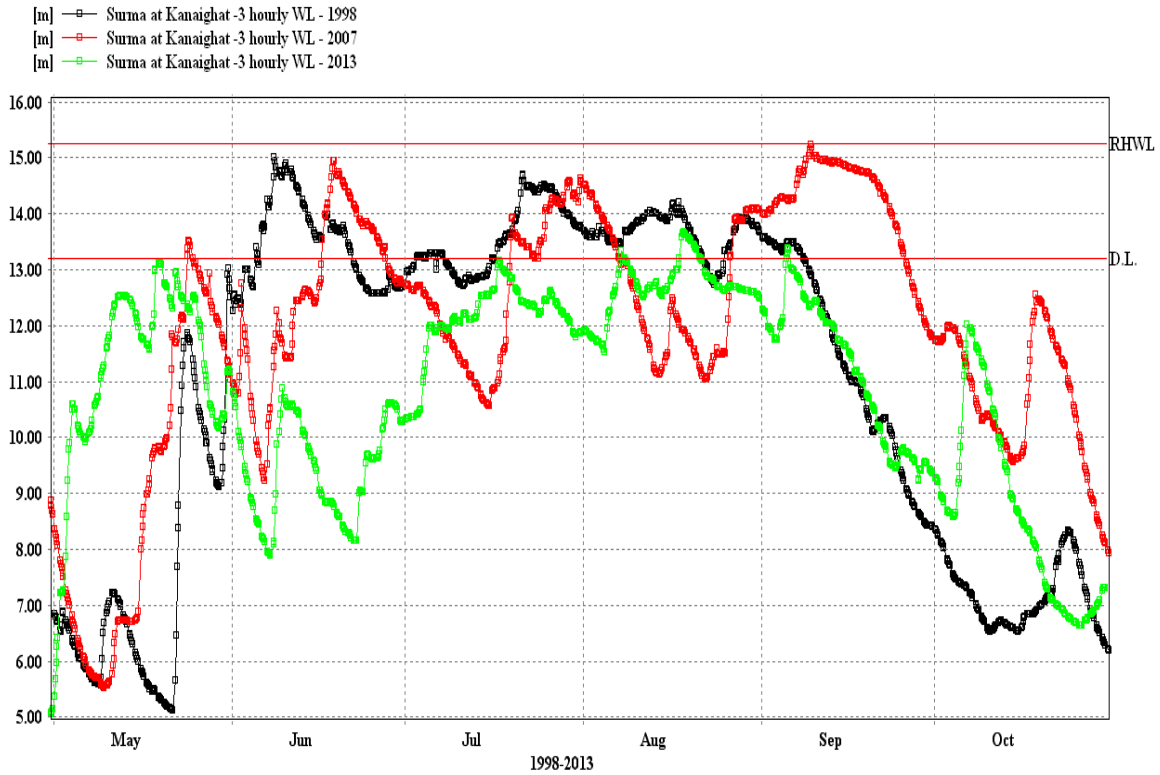



Figure 3.22 : Comparison of Hydrograph on Surma at Kanaighat

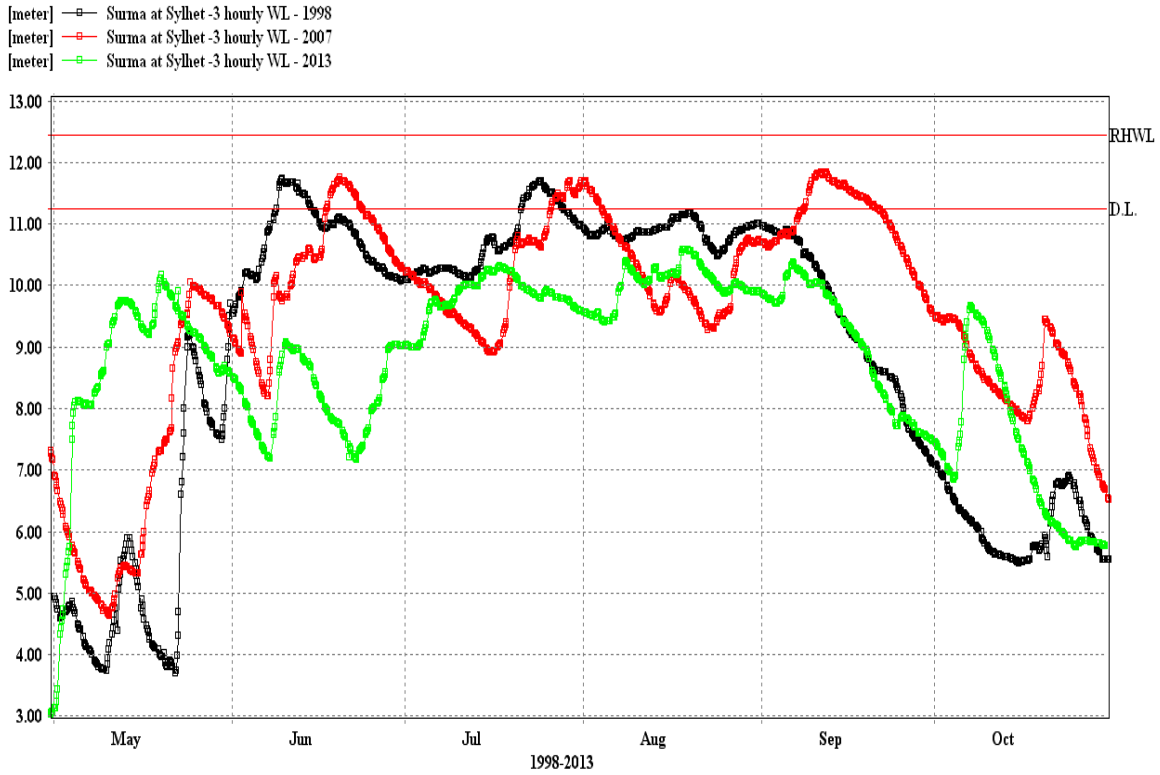



Figure 3.23 : Comparison of Hydrograph on Surma at Sylhet

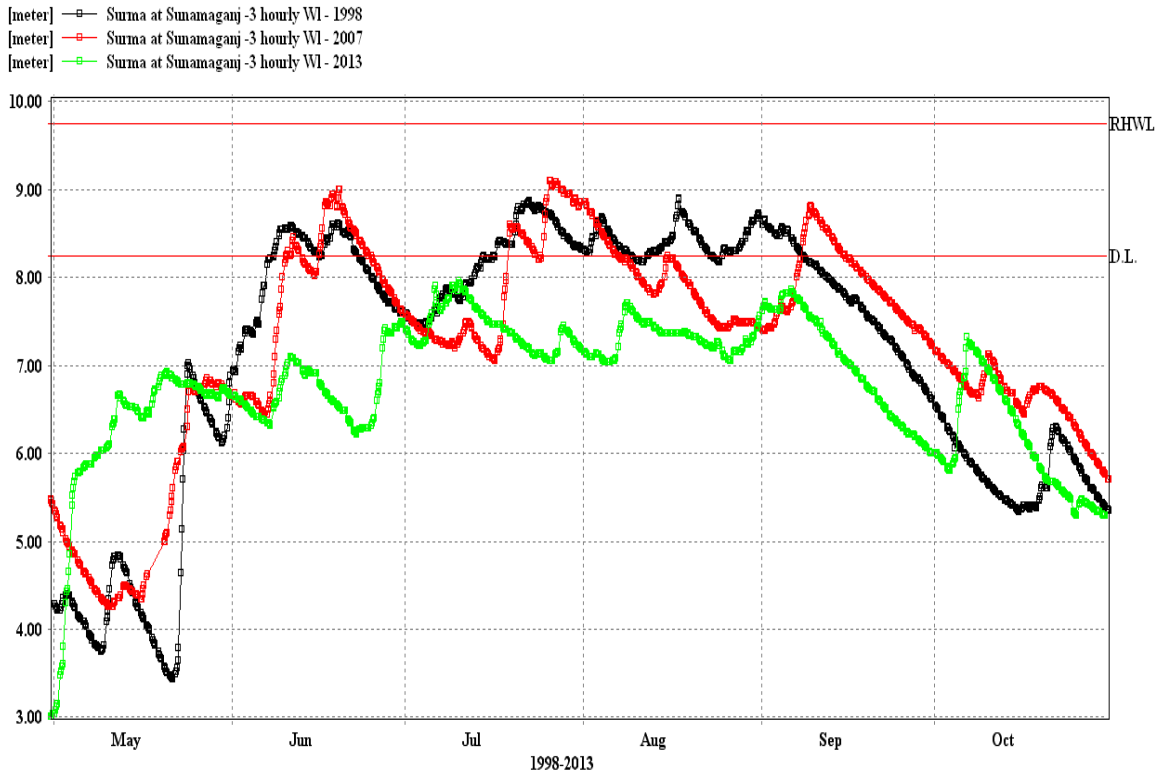



Figure 3.24 : Comparison of Hydrograph on Surma at Sunamgonj

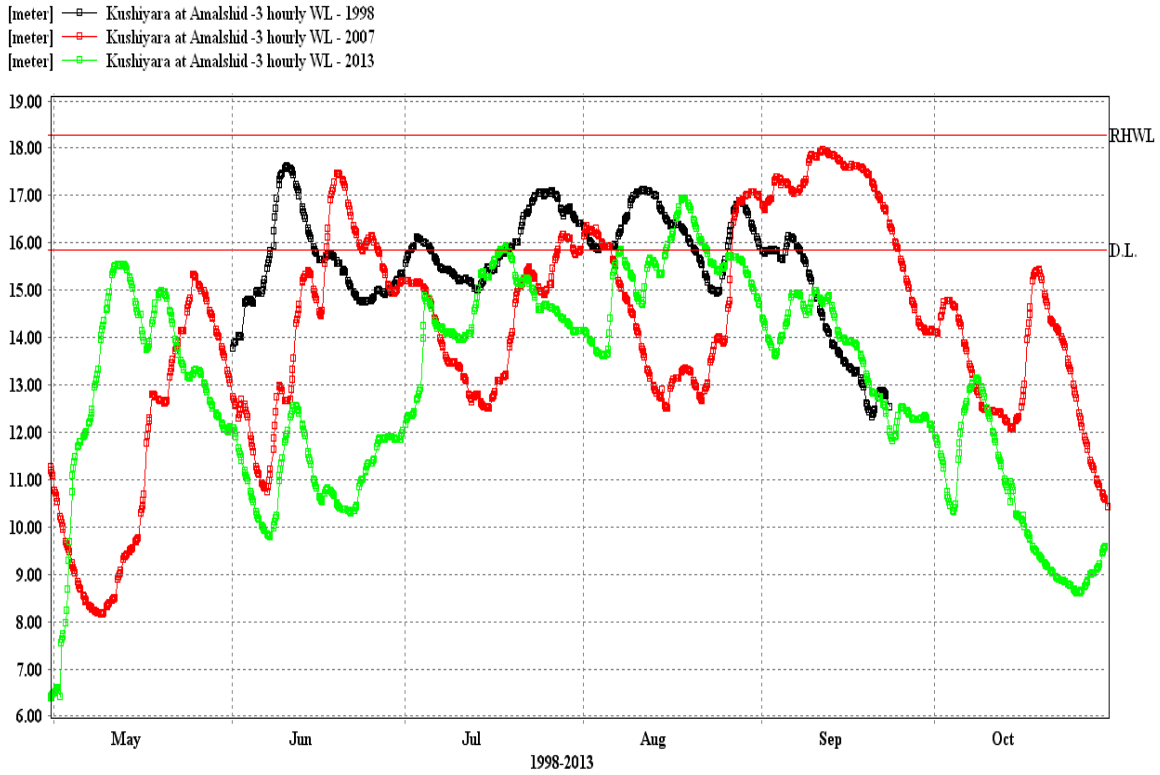



Figure 3.25 : Comparison of Hydrograph on Kushiyara at Amalshid

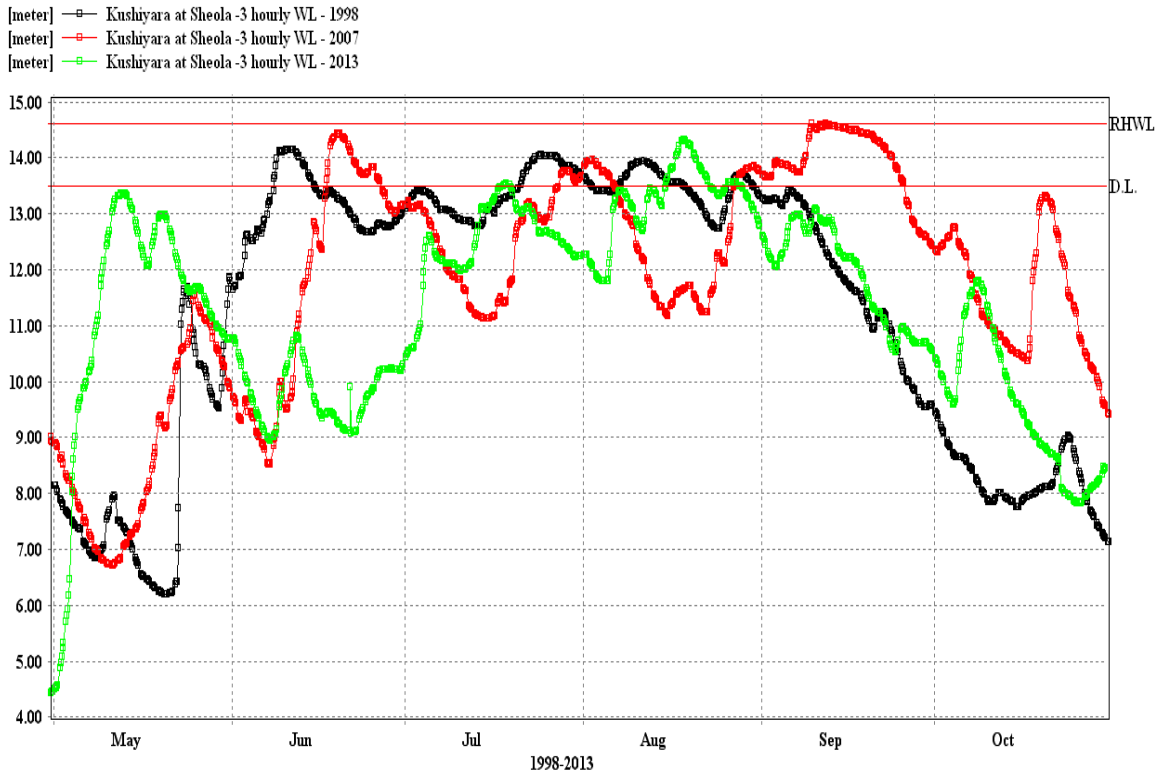



Figure 3.26 : Comparison of Hydrograph on Kushiyara at Sheola

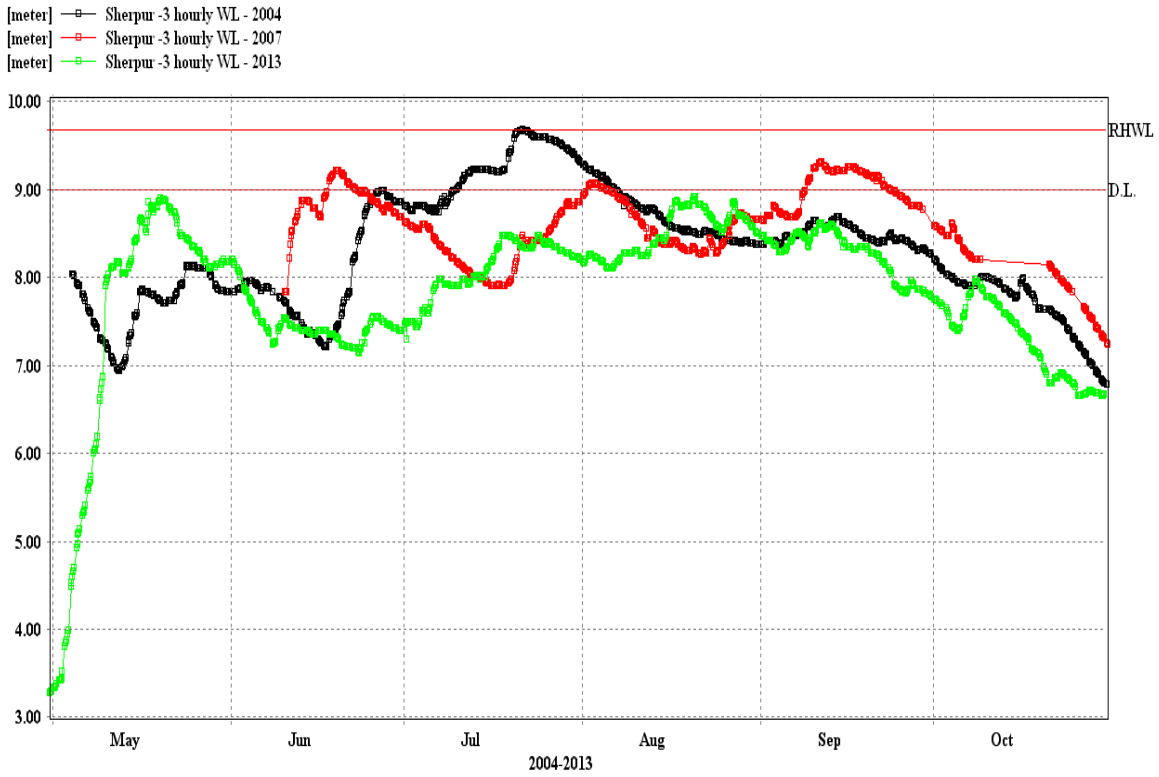



Figure 3.27 : Comparison of Hydrograph on Kushiyara at Sherpur

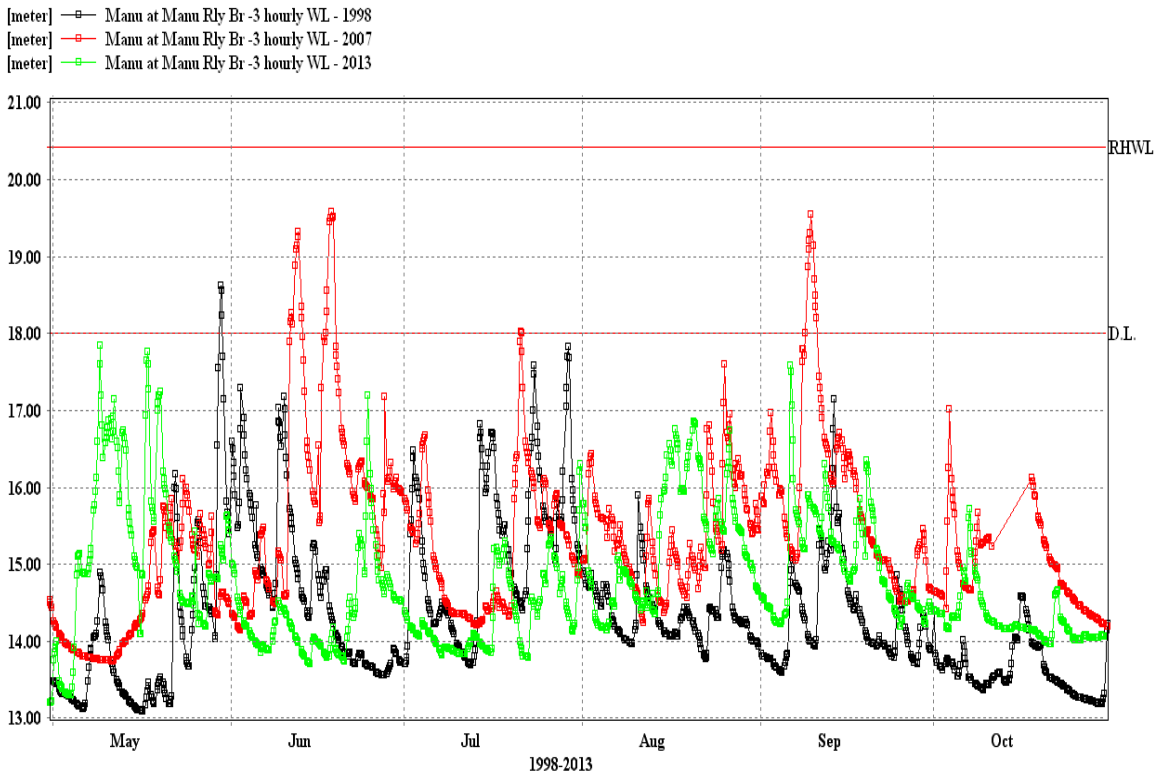



Figure 3.28 : Comparison of Hydrograph on Manu at Manu Rail Bridge

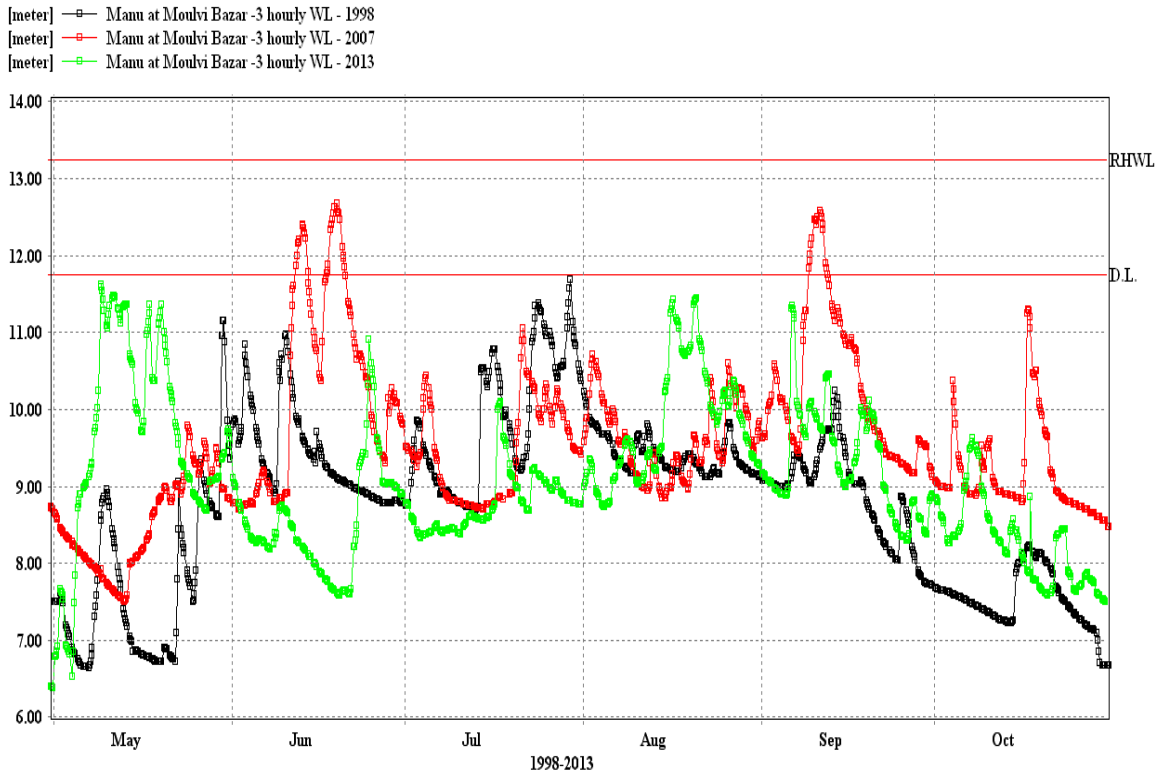



Figure 3.29 : Comparison of Hydrograph on Manu at Moulvibazar

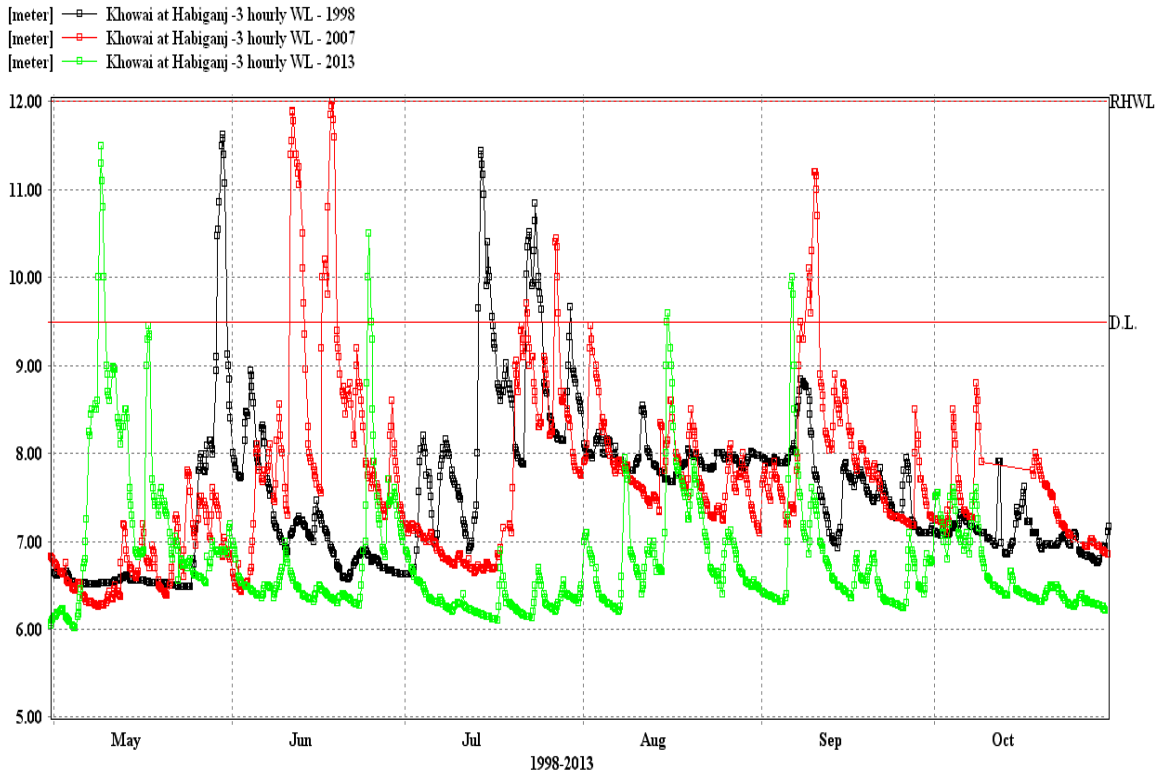



Figure 3.30 : Comparison of Hydrograph on Khowai at Habigonj

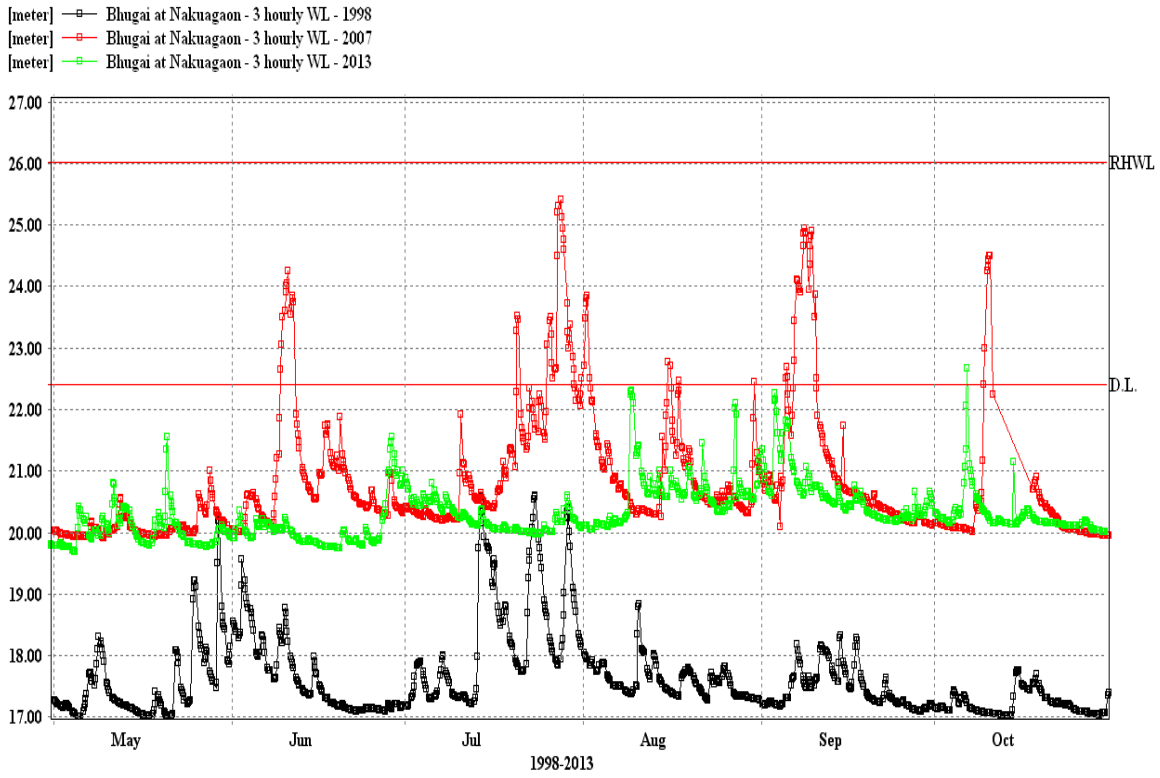



Figure 3.31 : Comparison of Hydrograph on Bhugai at Nokuagaon

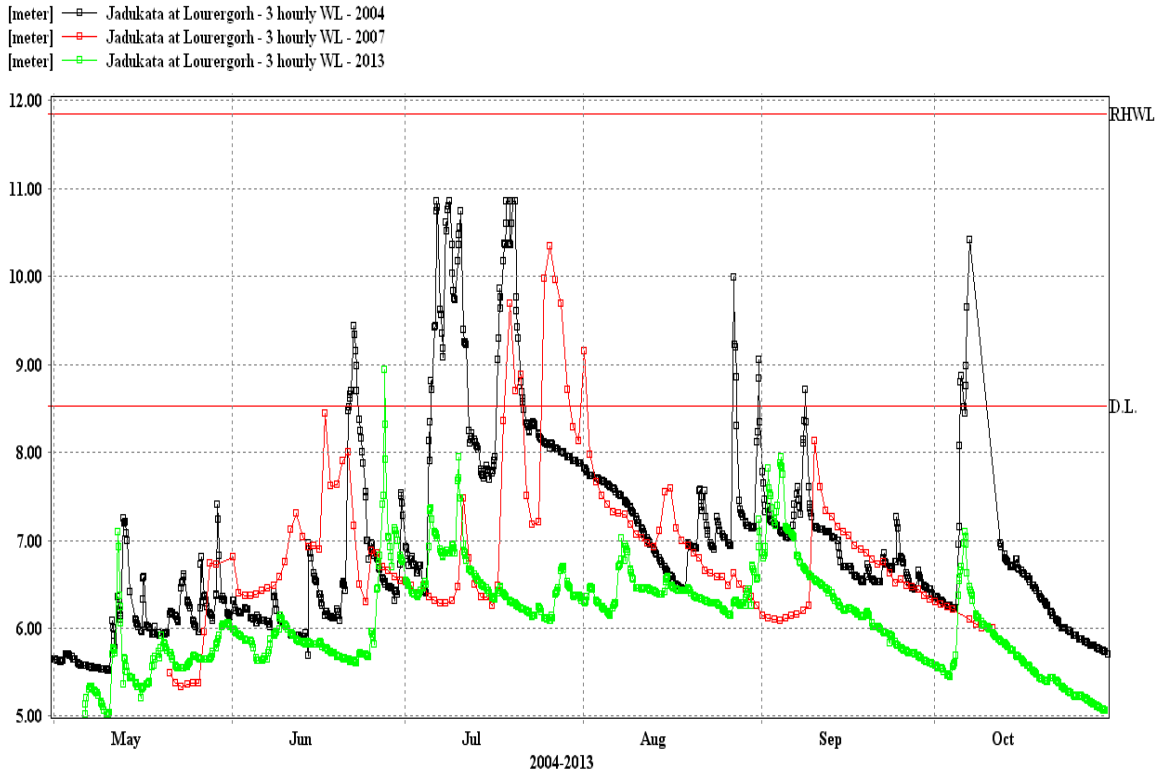



Figure 3.32 : Comparison of Hydrograph on Jadukata at Lorerghor

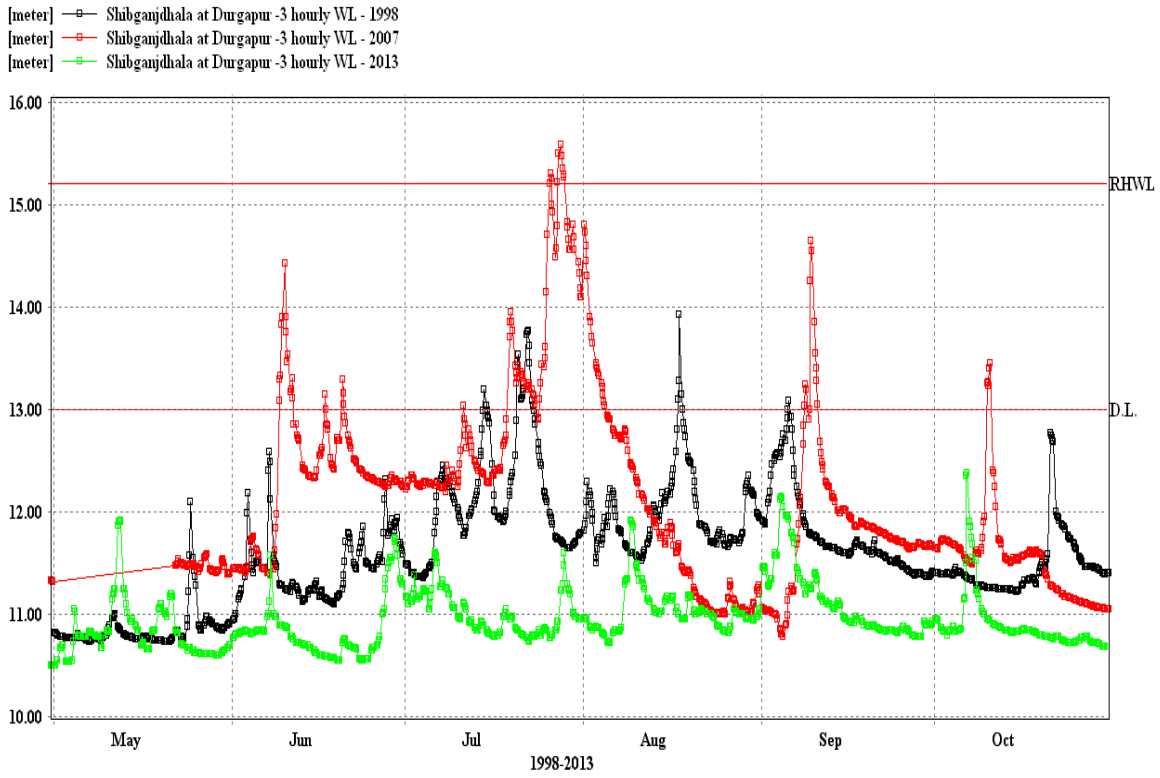



Figure 3.33 : Comparison of Hydrograph on Someswari at Durgapur

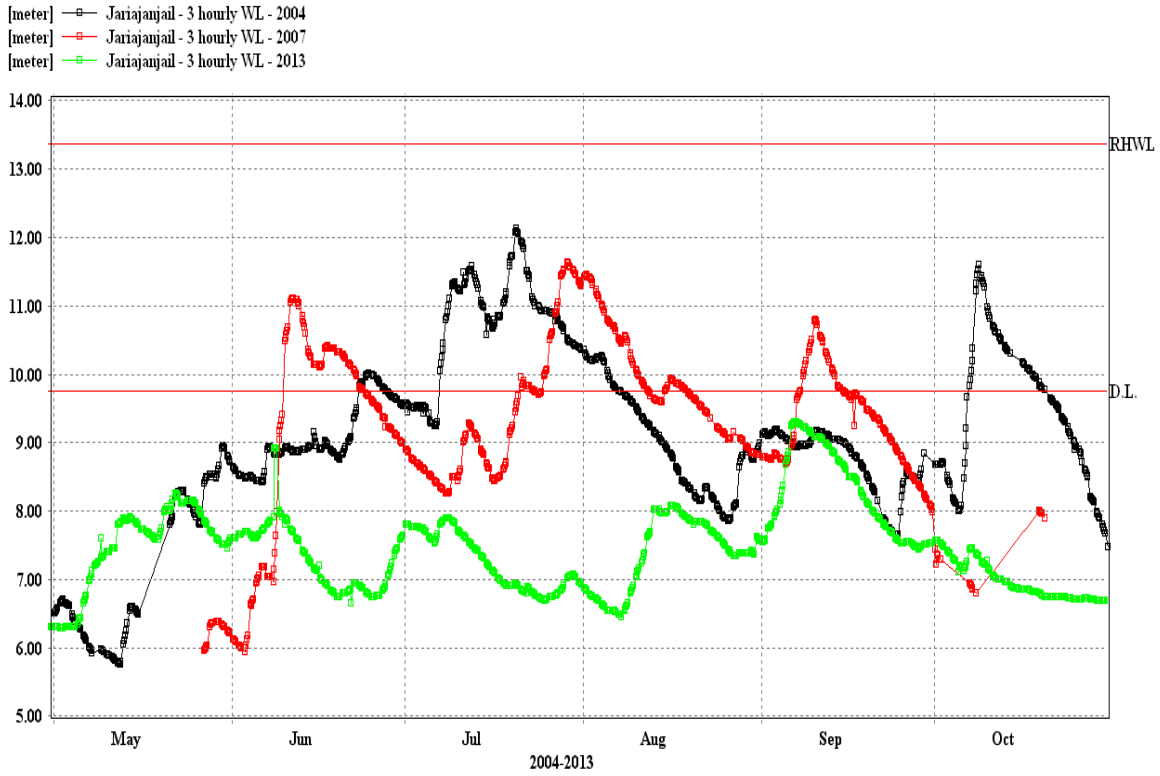



Figure 3.34 : Comparison of Hydrograph on Kangsha at Jariajanjail

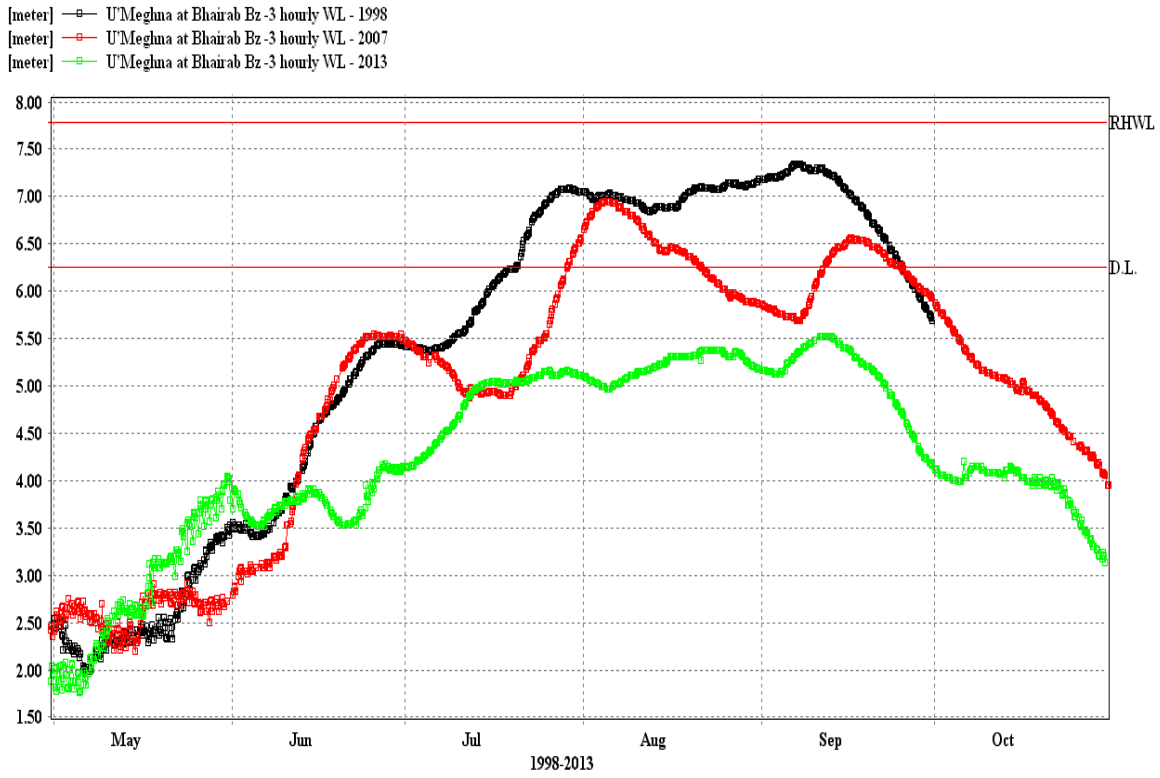



Figure 3.35 : Comparison of Hydrograph on Upper Meghna at Bhairab Bazar

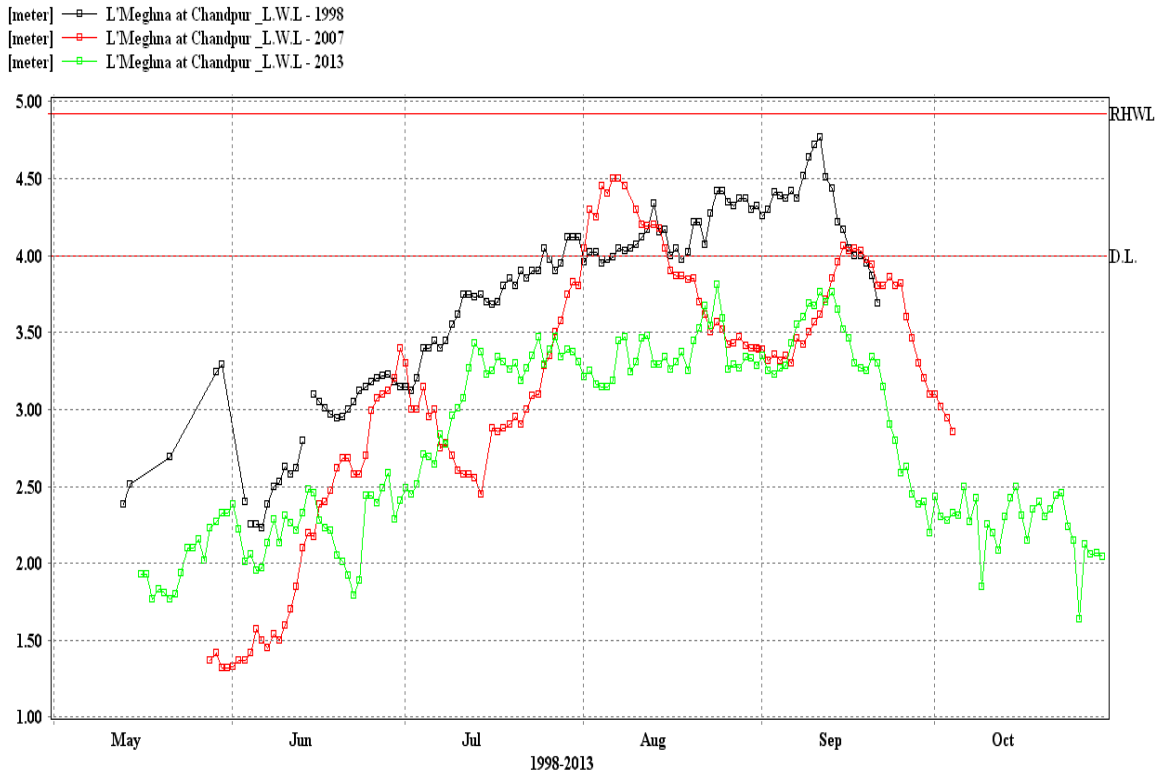



Figure 3.36 : Comparison of Hydrograph on Lower Meghna at Chandpur

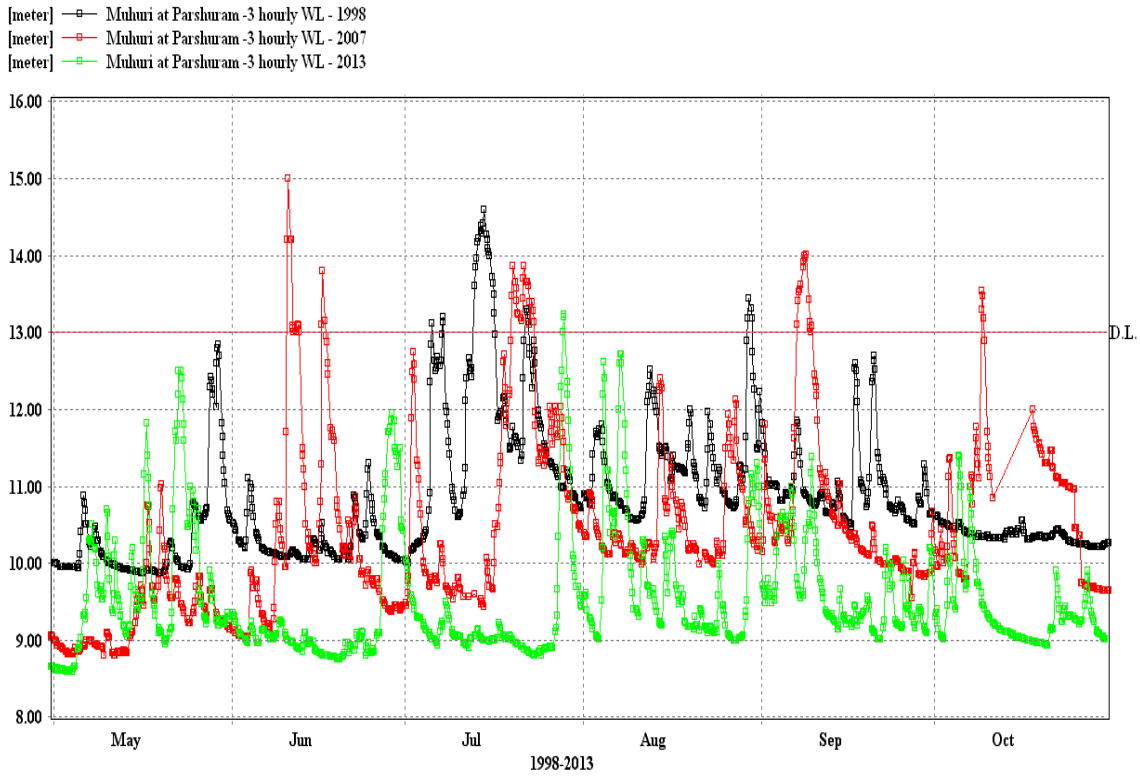



Figure 3.37 : Comparison of Hydrograph on Muhuri at Parshuram

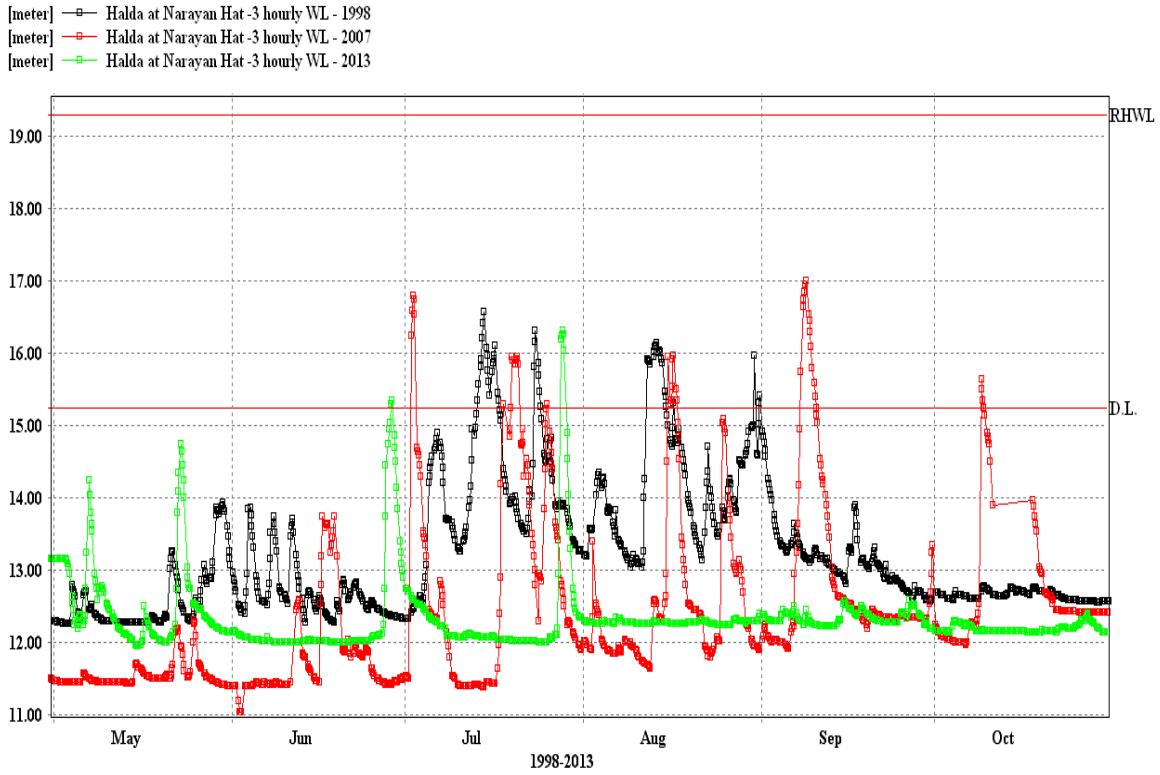



Figure 3.38 : Comparison of Hydrograph on Halda at Narayanhat

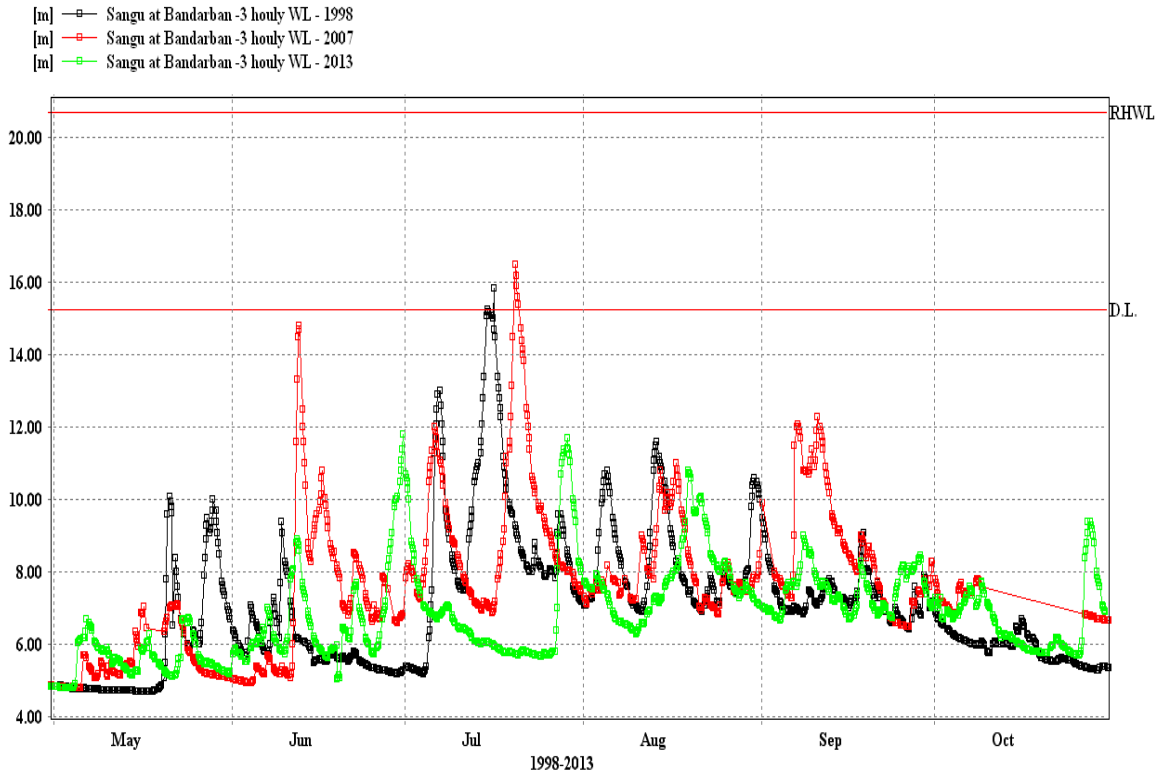



Figure 3.39 : Comparison of Hydrograph on Sangu at Bandarban

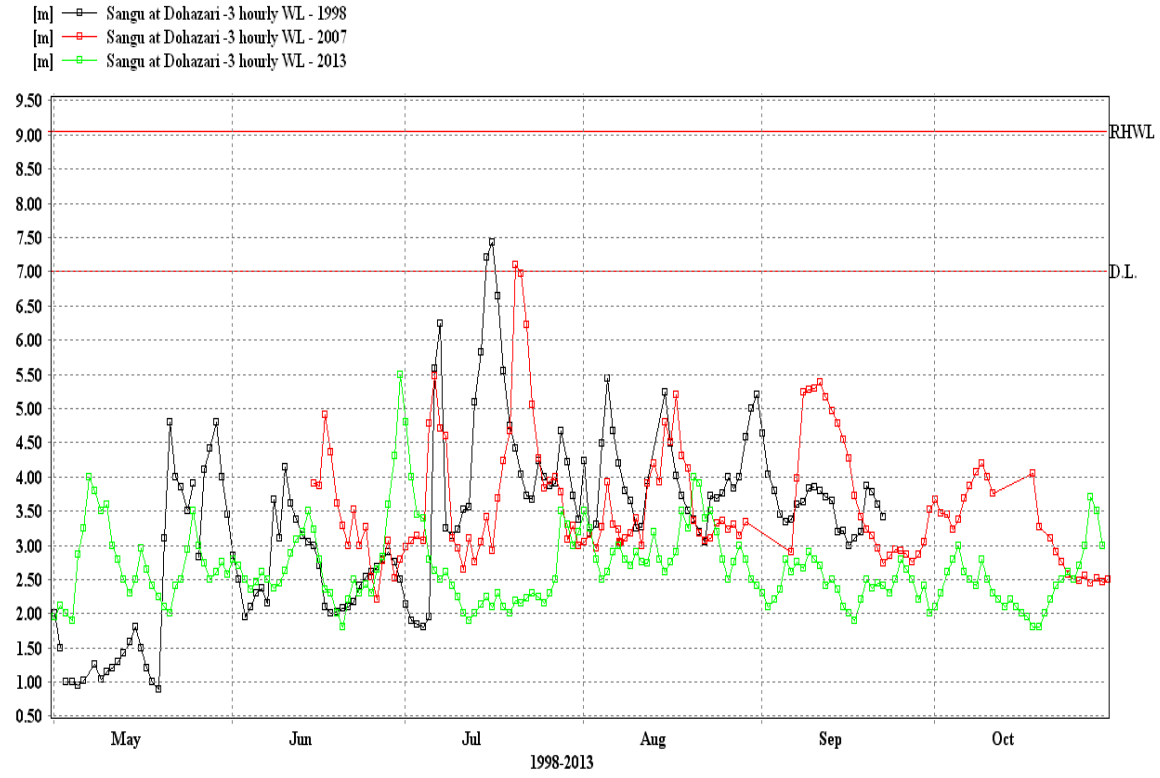



Figure 3.40 : Comparison of Hydrograph on Sangu at Dohazari

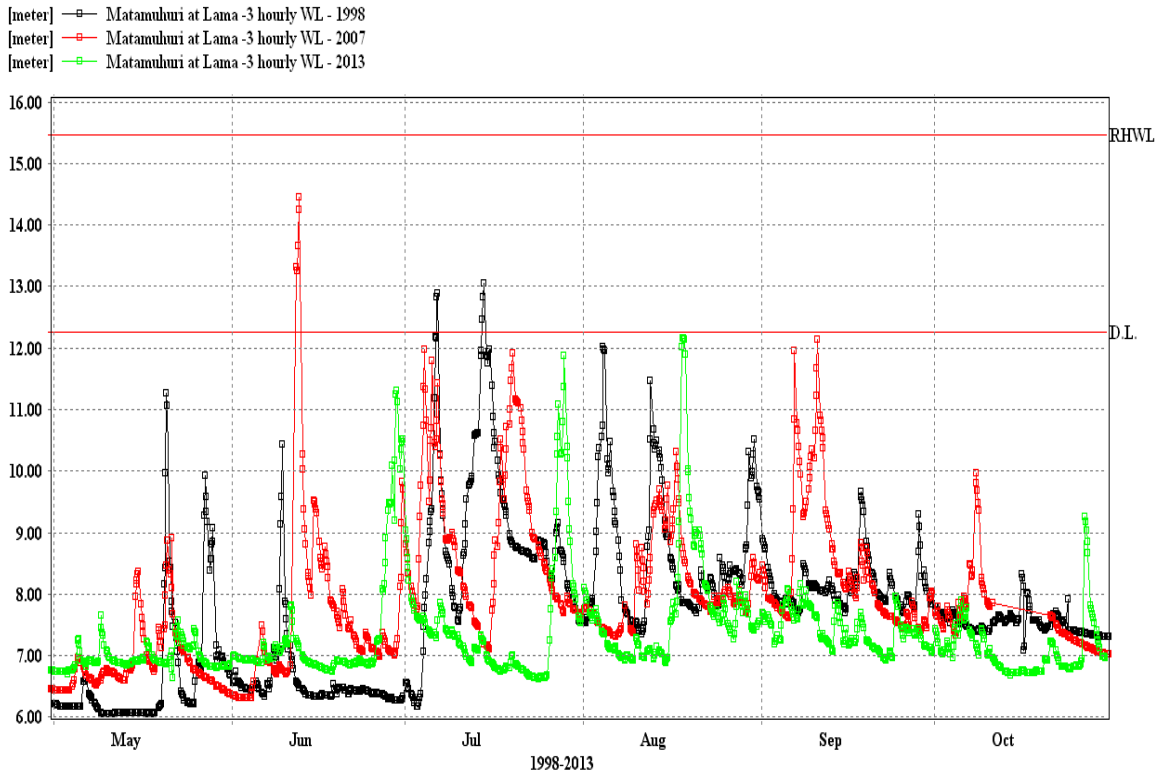



Figure 3.41 : Comparison of Hydrograph on Matamuhuri at Lama

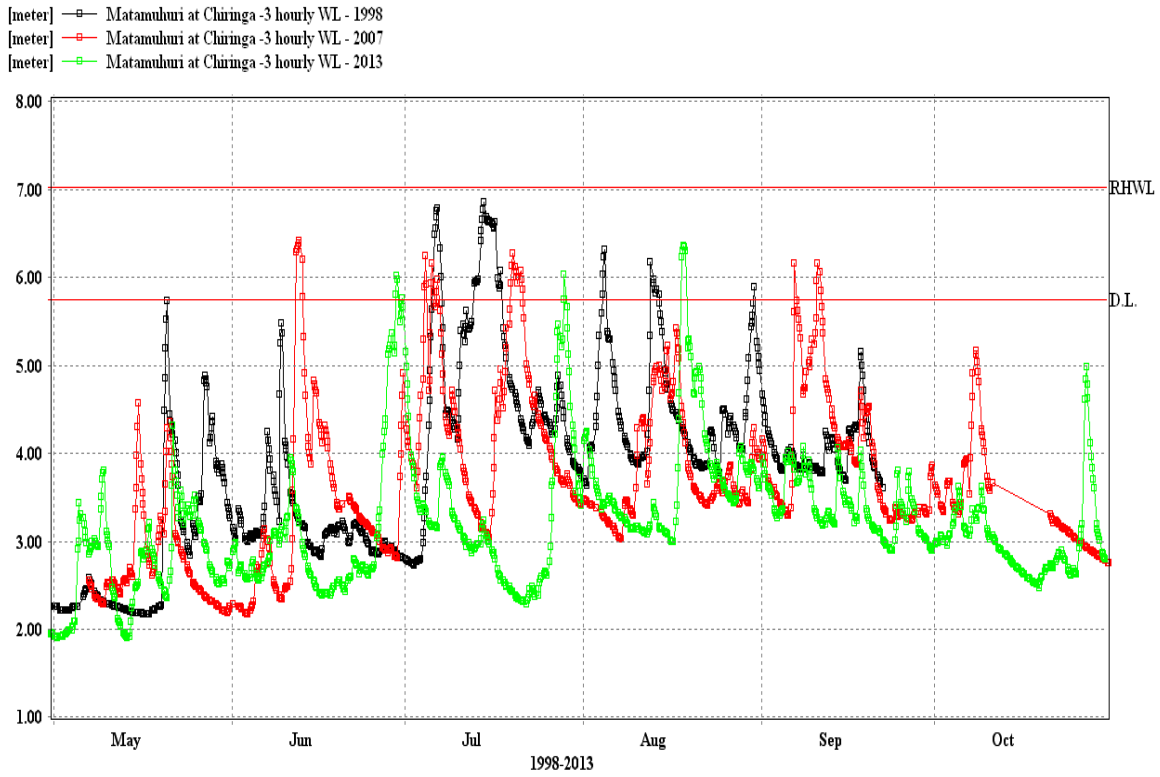



Figure 3.42 : Comparison of Hydrograph on Matamuhuri at Chiringa

# CHAPTER 4: FORECAST EVALUATION, 2013

## 4.1 GENERAL

Flood Forecasting and Warning Centre (FFWC) of BWDB is mandated for preparation of flood forecasting, early warning and its dissemination in Bangladesh (BWDB Act-2000). Flood forecasting models of FFWC are developed on MIKE 11, one-dimensional modeling software used for the simulation of WLs and discharges in the river network and flood plains. The existing early warning on floods provides a lead time of 24, 48 and 72 hours. There are needs and expectations for increasing lead time forecast for cropping decisions, such as early harvesting, or to implement a contingency crop plan or protect infrastructure and preserve livelihoods. A research initiative has been started from July 2011 to increase lead time for deterministic flood forecast upto 5 days (upt 120 hours) from existing 3-days and to extend the Flood Forecast to few selected BWDB projects with support from CDMP-II under Ministry of Food and Disaster Management (MoFDM) (from middle of 2012 renamed as Ministry of Disaster Management and Relief). 5-days extended lead time flood forecast has been generated and disseminated on regular basis since June 2013. Flash flood forecast for 48-hours lead time on pilot basis for the north eastern zone has been generated and disseminated during April May (the flash flood threat for the crop harvest period).

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

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

## 4.2 EVALUATION CRITERIA OF FORECAST PERFORMANCE

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

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

### 4.2.1 MEAN ABSOLUTE ERROR (MAE)

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

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

Where,

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

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

n is the number of *Observed/Forecast* levels

### 4.2.2 CO-EFFICIENT OF DETERMINATION, $R^2$

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

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

Where,

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

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

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

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

n is the number of *Observed/Forecast* levels

## 4.3 PRE-DEFINED SCALES TO EVALUATE FORECAST PERFORMANCE

The forecast performances for the monsoon-2013 have been evaluated from the statistical components $r^2$ (*Co-efficient of Determination*) and *MAE* (*Mean Absolute Error*). Values of the above two components in their ideal case are generally assumed to be in the order of $MAE = 0$

$r^2 = 1$

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

**Table 4. 1 : Scales used for performance evaluation**

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

Simulations were made for maximum 72 hours in the forecast period and forecasts were saved in the database at 24-hour and 48-hour and 72-hour intervals. Usually, the forecast quality gradually deteriorated with higher forecast intervals from the time of forecast. As lead time increases the forecast accuracy decreases. This means that forecasts are the best at 24-hour interval followed by 48-hour interval and then 72-hour interval. Figures from 4.1 to 4.3 are shown the comparison of observed and forecasted WL for 24, 48 and 72 hours. Result of the statistical analysis and performance on the basis of the aforesaid scale are presented in Table 4.2, Table 4.3 and Table 4.4.

## 4.4 FORECAST STATISTICS AND MODEL PERFORMANCE, 2013

### 4.4.1 DETERMINISTIC FORECAST PERFORMANCE

For deterministic forecast, simulations were made for maximum 72 hrs. The forecast quality gradually deteriorated where forecast intervals were moved further away from the time of forecast. Usually as lead time increases the accuracy (variation of forecast & observe value) decreases. This means that forecasts were the best at 24-hour interval (i.e. 24 hrs/1-day lead time) followed by 48-hrs interval and then 72-hrs(3-days). Total 31 stations located within the model area (including some boundary stations) are evaluated. The forecast statistics along with their performance are provided in Tables 4.2 to 4.4 and in Figures 4.1 to 4.3. From the tables it may be seen that the forecast performance was 95.3% (Mean Absolute Error 8.1%), 91.1% (MAE 15.1%) and 85.4% (MEA 22.3%) accurate for 24hrs, 48hrs and 72 hrs respectively for the monsoon of 2013.

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

| Sl. No. | Station | MAE (m) | $r^2$ | Performance |
|---|---|---|---|---|
| 1 | Aricha | 0.05 | 0.98 | Good |
| 2 | Bahadurabad | 0.06 | 0.98 | Good |
| 3 | Bhagyakul | 0.04 | 0.98 | Good |
| 4 | Bhairabbazar | 0.04 | 0.98 | Good |
| 5 | Bhusirbandar | 0.22 | 0.70 | Not satisfactory |
| 6 | Bogra | 0.10 | 0.85 | Good |
| 7 | Chakrahimpur | 0.13 | 0.91 | Average |
| 8 | Chilmari | 0.07 | 0.96 | Good |
| 9 | Demra | 0.08 | 0.95 | Good |
| 10 | Dhaka | 0.06 | 0.96 | Good |
| 11 | Goalundo | 0.04 | 0.98 | Good |
| 12 | Gorai-RB | 0.07 | 0.98 | Good |
| 13 | Hardinge-BR | 0.06 | 0.99 | Good |
| 14 | Jagir | 0.05 | 0.29 | Average |
| 15 | Jamalpur | 0.07 | 0.97 | Good |
| 16 | Kamarkhali | 0.09 | 0.98 | Good |
| 17 | Kaunia | 0.09 | 0.89 | Average |
| 18 | Mirpur | 0.06 | 0.96 | Good |
| 19 | Moulvibazar | 0.26 | 0.70 | Not satisfactory |
| 20 | Mymensingh | 0.08 | 0.97 | Good |
| 21 | Mohadevpur | 0.25 | 0.86 | Poor |
| 22 | Naogaon | 0.17 | 0.93 | Poor |
| 23 | Narayangonj | 0.08 | 0.93 | Good |
| 24 | Nayarhat | 0.05 | 0.97 | Good |
| 25 | Rajshahi | 0.10 | 0.98 | Good |
| 26 | Serajgonj | 0.03 | 0.98 | Good |
| 27 | Sheola | 0.15 | 0.95 | Average |
| 28 | Sunamgonj | 0.07 | 0.92 | Good |
| 29 | Sylhet | 0.09 | 0.95 | Good |
| 30 | Taraghat | 0.05 | 0.98 | Good |
| 31 | Tongi | 0.04 | 0.97 | Good |

**Table 4. 3: Statistics for 48- hour forecast performance**

| Sl. No. | Station | MAE (m) | $r^2$ | Performance |
|---|---|---|---|---|
| 1 | Aricha | 0.09 | 0.98 | Good |
| 2 | Bahadurabad | 0.14 | 0.96 | Good |
| 3 | Bhagyakul | 0.08 | 0.97 | Good |
| 4 | Bhairabbazar | 0.08 | 0.97 | Good |
| 5 | Bhusirbandar | 0.39 | 0.45 | Very Poor |
| 6 | Bogra | 0.20 | 0.64 | Average |
| 7 | Chakrahimpur | 0.23 | 0.81 | Average |
| 8 | Chilmari | 0.16 | 0.95 | Good |
| 9 | Demra | 0.13 | 0.91 | Good |
| 10 | Dhaka | 0.10 | 0.94 | Good |
| 11 | Goalondo | 0.08 | 0.98 | Good |
| 12 | Gorai-RB | 0.13 | 0.98 | Good |
| 13 | Hardinge-BR | 0.12 | 0.98 | Good |
| 14 | Jagir | 0.08 | 0.29 | Average |
| 15 | Jamalpur | 0.11 | 0.97 | Good |
| 16 | Kamarkhali | 0.12 | 0.97 | Good |
| 17 | Kaunia | 0.16 | 0.74 | Average |
| 18 | Mirpur | 0.10 | 0.93 | Good |
| 19 | Moulvibazar | 0.43 | 0.51 | Poor |
| 20 | Mymensingh | 0.15 | 0.95 | Average |
| 21 | Mohadevpur | 0.41 | 0.72 | Poor |
| 22 | Naogaon | 0.31 | 0.82 | Average |
| 23 | Narayangonj | 0.14 | 0.87 | Good |
| 24 | Nayarhat | 0.08 | 0.96 | Good |
| 25 | Rajshahi | 0.20 | 0.98 | Average |
| 26 | Serajgonj | 0.08 | 0.98 | Good |
| 27 | Sheola | 0.34 | 0.90 | Average |
| 28 | Sunamgonj | 0.14 | 0.83 | Average |
| 29 | Sylhet | 0.21 | 0.89 | Poor |
| 30 | Taraghat | 0.08 | 0.98 | Good |
| 31 | Tongi | 0.07 | 0.96 | Good |

**Table 4. 4: Statistics for 72- hour forecast performance**

| Sl. No. | Station | MAE (m) | $r^2$ | Performance |
|---|---|---|---|---|
| 1 | Aricha | 0.13 | 0.96 | Good |
| 2 | Bahadurabad | 0.22 | 0.91 | Good |
| 3 | Bhagyakul | 0.11 | 0.96 | Good |
| 4 | Bhairabbazar | 0.11 | 0.94 | Good |
| 5 | Bhusirbandar | 0.48 | 0.28 | Very Poor |
| 6 | Bogra | 0.29 | 0.44 | Not satisfactory |
| 7 | Chakrahimpur | 0.35 | 0.70 | Not satisfactory |
| 8 | Chilmari | 0.23 | 0.90 | Average |
| 9 | Demra | 0.18 | 0.85 | Average |
| 10 | Dhaka | 0.14 | 0.90 | Good |
| 11 | Goalondo | 0.12 | 0.96 | Good |
| 12 | Gorai-RB | 0.21 | 0.97 | Average |
| 13 | Hardinge-BR | 0.21 | 0.97 | Average |
| 14 | Jagir | 0.11 | 0.28 | Average |
| 15 | Jamalpur | 0.16 | 0.95 | Good |
| 16 | Kaunia | 0.18 | 0.96 | Average |
| 17 | Kamarkhali | 0.21 | 0.62 | Not satisfactory |
| 18 | Mirpur | 0.15 | 0.89 | Good |
| 19 | Moulvibazar | 0.53 | 0.36 | Very Poor |
| 20 | Mymensingh | 0.20 | 0.92 | Not satisfactory |
| 21 | Mohadevpur | 0.52 | 0.61 | Not satisfactory |
| 22 | Naogaon | 0.47 | 0.69 | Not satisfactory |
| 23 | Narayangonj | 0.19 | 0.80 | Good |
| 24 | Nayarhat | 0.12 | 0.93 | Good |
| 25 | Rajshahi | 0.31 | 0.96 | Average |
| 26 | Serajgonj | 0.14 | 0.95 | Good |
| 27 | Sheola | 0.50 | 0.80 | Not satisfactory |
| 28 | Sunamgonj | 0.21 | 0.70 | Not satisfactory |
| 29 | Sylhet | 0.34 | 0.77 | Average |
| 30 | Taraghat | 0.12 | 0.98 | Good |
| 31 | Tongi | 0.11 | 0.93 | Good |

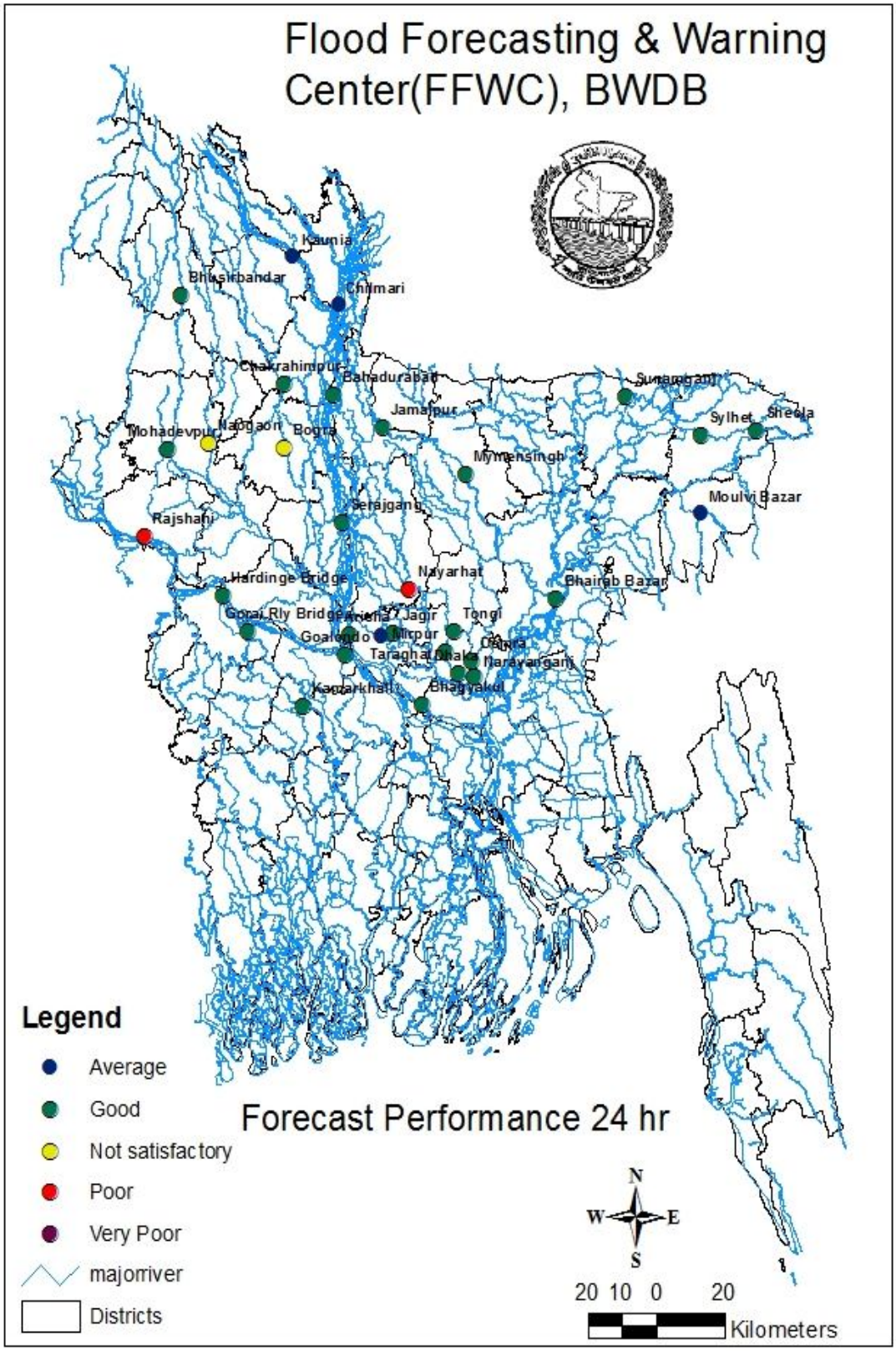



**Figure 4.43 : 24 hr Forecast Evaluation (Year, 2013)**

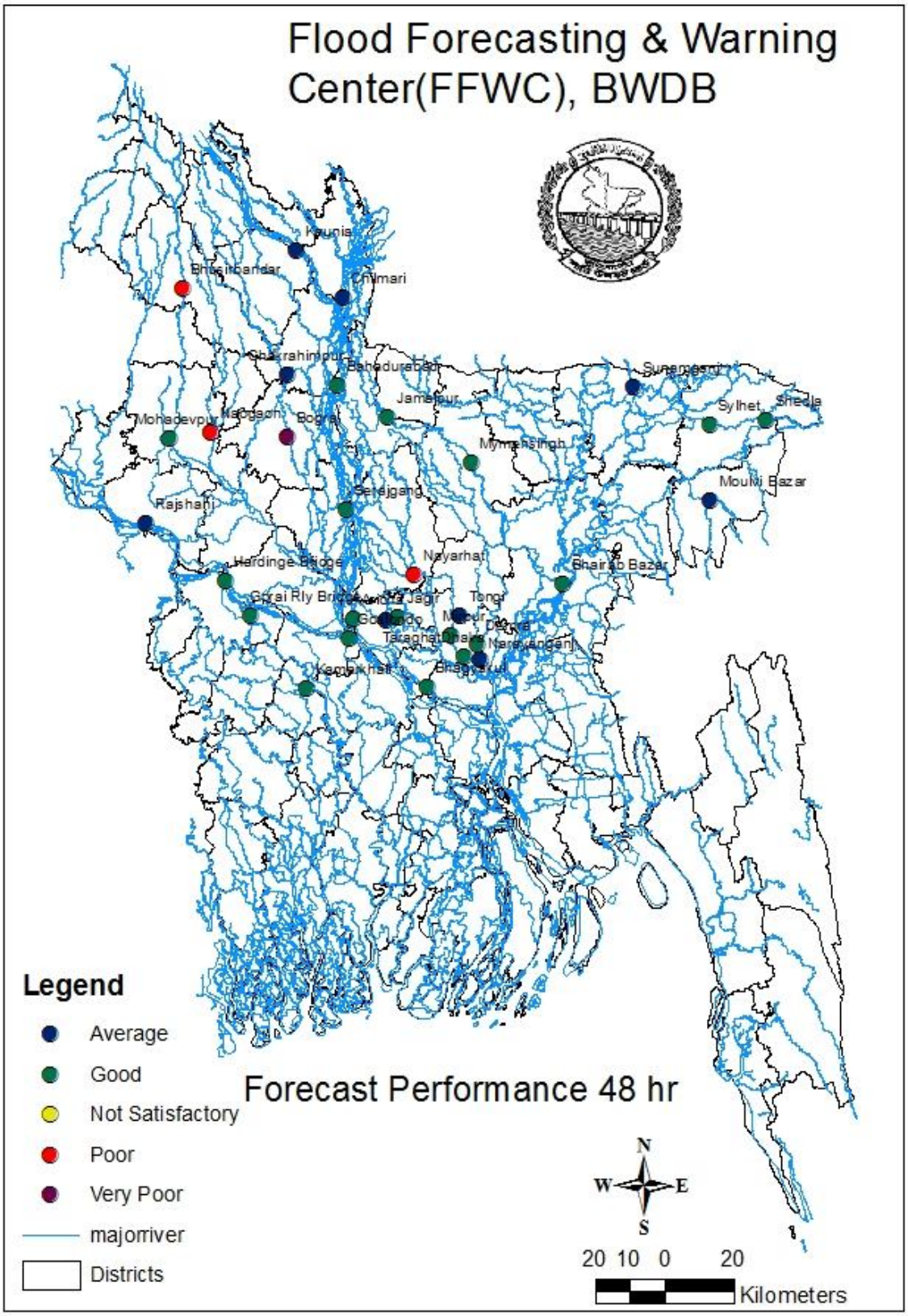



**Figure 4.44 : 48 hr Forecast Evaluation (Year, 2013)**

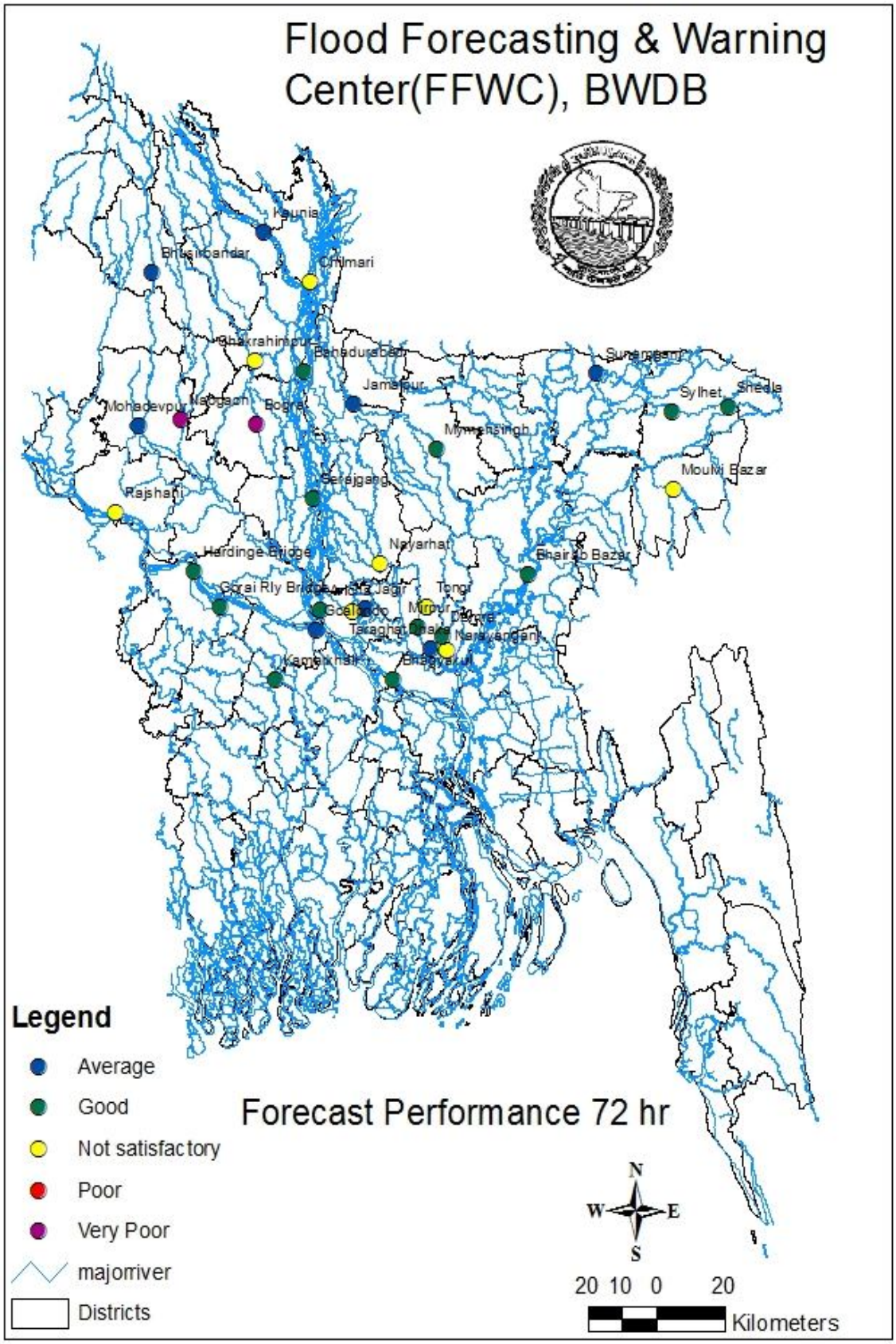



**Figure 4.45 : 72 hr Forecast Evaluation (Year, 2013)**

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

CFAN (Climate Forecast Application Network) utilizes ECMWF (European Centre for Medium-Range Weather Forecasts) weather prediction data in their model to generate 51 sets of ensemble discharge forecasts data on the Brahmaputra at Bahadurabad and on the Ganges at Hardinge-Bridge in Bangladesh. The updated FFWC model was taken for customization for real-time flood forecasting utilizing CFAN predictions. The customized FFWC model used for the flood forecasting of extended lead-time (medium range upto 10-days) using climate forecast application data has been named CFAB-FFS (CFAB Flood Forecasting Study) model.

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

The statistics of forecast performance based on the MAE, RMSE and $r^2$ at different time-scale upto 10 days for the 18 number of stations under FFWC system have been presented through Table 4.5 to Table 4.8.

**Table 4. 5 : Performance of 3-day Probabilistic Forecast**

| 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 | 0.15 | 0.20 | 0.95 | 0.13 | 0.17 | 0.95 | 0.19 | 0.24 | 0.95 |
| Bhagyakul | 0.12 | 0.15 | 0.95 | 0.10 | 0.13 | 0.96 | 0.15 | 0.19 | 0.95 |
| Bhairabbazar | 0.10 | 0.13 | 0.93 | 0.10 | 0.13 | 0.93 | 0.10 | 0.13 | 0.93 |
| Demra | 0.12 | 0.17 | 0.83 | 0.13 | 0.18 | 0.83 | 0.13 | 0.18 | 0.82 |
| Dhaka | 0.10 | 0.14 | 0.92 | 0.10 | 0.13 | 0.92 | 0.10 | 0.13 | 0.92 |
| Goalondo | 0.24 | 0.35 | 0.94 | 0.22 | 0.33 | 0.95 | 0.32 | 0.45 | 0.94 |
| Gorai-RB | 0.14 | 0.18 | 0.95 | 0.10 | 0.15 | 0.96 | 0.17 | 0.22 | 0.95 |
| Kamarkhali | 0.21 | 0.31 | 0.92 | 0.19 | 0.27 | 0.93 | 0.25 | 0.34 | 0.92 |
| Mirpur | 0.11 | 0.15 | 0.90 | 0.12 | 0.15 | 0.90 | 0.12 | 0.15 | 0.90 |
| Mohadevpur | 0.57 | 0.85 | 0.60 | 0.57 | 0.85 | 0.60 | 0.57 | 0.85 | 0.60 |
| Moulvibazar | 0.48 | 0.63 | 0.44 | 0.48 | 0.63 | 0.44 | 0.48 | 0.63 | 0.44 |
| Naogaon | 0.45 | 0.69 | 0.50 | 0.45 | 0.69 | 0.50 | 0.45 | 0.69 | 0.50 |
| Serajgonj | 0.23 | 0.30 | 0.88 | 0.21 | 0.26 | 0.89 | 0.30 | 0.35 | 0.88 |
| Sheola | 0.11 | 0.14 | 0.87 | 0.11 | 0.14 | 0.87 | 0.11 | 0.14 | 0.87 |
| Sherpur | 0.46 | 0.60 | 0.76 | 0.46 | 0.60 | 0.76 | 0.46 | 0.59 | 0.76 |
| Sunamgonj | 0.19 | 0.29 | 0.72 | 0.19 | 0.29 | 0.72 | 0.19 | 0.28 | 0.72 |
| Sylhet | 0.25 | 0.41 | 0.82 | 0.25 | 0.41 | 0.81 | 0.25 | 0.38 | 0.82 |
| Tongi | 0.10 | 0.12 | 0.93 | 0.10 | 0.12 | 0.93 | 0.10 | 0.12 | 0.93 |

**Table 4. 6: Performance of 5-day Probabilistic Forecast**

| 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 | 0.32 | 0.40 | 0.80 | 0.20 | 0.27 | 0.80 | 0.20 | 0.27 | 0.80 |
| Bhagyakul | 0.22 | 0.28 | 0.77 | 0.15 | 0.21 | 0.76 | 0.15 | 0.21 | 0.76 |
| Bhairabbazar | 0.16 | 0.20 | 0.87 | 0.15 | 0.19 | 0.88 | 0.15 | 0.19 | 0.88 |
| Demra | 0.20 | 0.27 | 0.67 | 0.19 | 0.26 | 0.68 | 0.19 | 0.26 | 0.68 |
| Dhaka | 0.16 | 0.20 | 0.86 | 0.14 | 0.18 | 0.86 | 0.14 | 0.18 | 0.86 |
| Goalundo | 0.38 | 0.55 | 0.87 | 0.37 | 0.53 | 0.88 | 0.37 | 0.53 | 0.88 |
| Gorai-RB | 0.31 | 0.42 | 0.86 | 0.21 | 0.29 | 0.84 | 0.21 | 0.29 | 0.84 |
| Kamarkhali | 0.35 | 0.52 | 0.82 | 0.33 | 0.45 | 0.82 | 0.33 | 0.45 | 0.82 |
| Mirpur | 0.17 | 0.21 | 0.82 | 0.17 | 0.21 | 0.82 | 0.17 | 0.21 | 0.82 |
| Mohadevpur | 0.73 | 1.10 | 0.31 | 0.74 | 1.11 | 0.32 | 0.74 | 1.11 | 0.32 |
| Moulvibazar | 0.63 | 0.81 | 0.24 | 0.63 | 0.80 | 0.27 | 0.63 | 0.80 | 0.27 |
| Naogaon | 0.65 | 0.95 | 0.19 | 0.66 | 0.70 | 0.18 | 0.66 | 0.70 | 0.18 |
| Serajgonj | 0.50 | 0.64 | 0.74 | 0.29 | 0.38 | 0.80 | 0.29 | 0.38 | 0.80 |
| Sheola | 0.15 | 0.20 | 0.77 | 0.15 | 0.16 | 0.77 | 0.15 | 0.16 | 0.77 |
| Sherpur | 0.63 | 0.78 | 0.61 | 0.63 | 0.78 | 0.61 | 0.63 | 0.78 | 0.61 |
| Sunamgonj | 0.27 | 0.37 | 0.58 | 0.27 | 0.37 | 0.58 | 0.27 | 0.37 | 0.58 |
| Sylhet | 0.36 | 0.50 | 0.72 | 0.36 | 0.50 | 0.72 | 0.36 | 0.50 | 0.72 |
| Tongi | 0.15 | 0.19 | 0.84 | 0.15 | 0.19 | 0.84 | 0.15 | 0.19 | 0.84 |

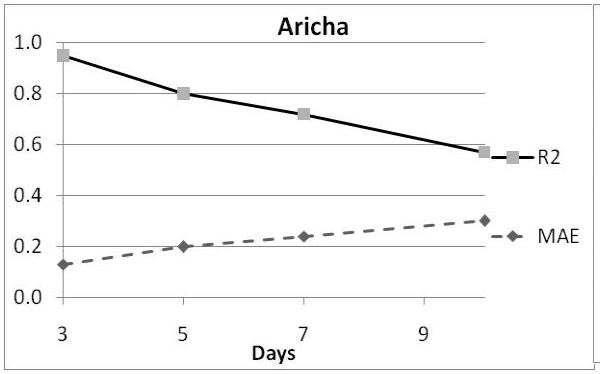
**Table 4. 7: Performance of 7-day Probabilistic Forecast**

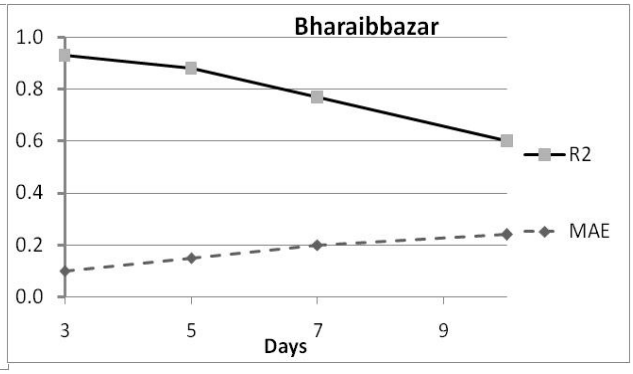
| Stations | Standard Deviation(-1) | | | Mean | | | Standard Deviation(+1) | | |
|---|---|---|---|---|---|---|---|---|---|
| | MAE(m) | RMSE(m) | $r^2$ | MAE (m) | RMSE(m) | $r^2$ | MAE (m) | RMSE(m) | $r^2$ |
| Aricha | 0.49 | 0.57 | 0.71 | 0.24 | 0.31 | 0.72 | 0.30 | 0.40 | 0.69 |
| Bhagyakul | 0.34 | 0.41 | 0.81 | 0.18 | 0.23 | 0.83 | 0.27 | 0.36 | 0.77 |
| Bhairabbazar | 0.20 | 0.25 | 0.77 | 0.20 | 0.24 | 0.77 | 0.19 | 0.23 | 0.77 |
| Demra | 0.23 | 0.32 | 0.52 | 0.24 | 0.32 | 0.52 | 0.24 | 0.33 | 0.51 |
| Dhaka | 0.21 | 0.26 | 0.77 | 0.19 | 0.24 | 0.76 | 0.19 | 0.24 | 0.74 |
| Goalondo | 0.53 | 0.81 | 0.80 | 0.44 | 0.64 | 0.81 | 0.61 | 0.83 | 0.82 |
| Gorai-RB | 0.47 | 0.58 | 0.82 | 0.24 | 0.30 | 0.84 | 0.33 | 0.43 | 0.79 |
| Kamarkhali | 0.47 | 0.73 | 0.73 | 0.39 | 0.54 | 0.75 | 0.50 | 0.68 | 0.72 |
| Mirpur | 0.22 | 0.27 | 0.71 | 0.22 | 0.26 | 0.70 | 0.22 | 0.27 | 0.69 |
| Mohadevpur | 0.78 | 1.21 | 0.17 | 0.78 | 1.21 | 0.17 | 0.78 | 1.21 | 0.17 |
| Moulvibazar | 0.76 | 0.94 | 0.15 | 0.76 | 0.94 | 0.15 | 0.76 | 0.94 | 0.15 |
| Naogaon | 0.78 | 1.12 | 0.59 | 0.78 | 1.12 | 0.06 | 0.78 | 1.12 | 0.59 |
| Serajgonj | 0.81 | 0.96 | 0.58 | 0.41 | 0.52 | 0.67 | 0.34 | 0.44 | 0.71 |
| Sheola | 0.17 | 0.23 | 0.68 | 0.17 | 0.23 | 0.68 | 0.17 | 0.23 | 0.68 |
| Sherpur | 0.72 | 0.84 | 0.52 | 0.72 | 0.84 | 0.52 | 0.72 | 0.84 | 0.52 |
| Sunamgonj | 0.17 | 0.23 | 0.66 | 0.17 | 0.23 | 0.66 | 0.17 | 0.23 | 0.66 |
| Sylhet | 0.41 | 0.56 | 0.64 | 0.41 | 0.56 | 0.64 | 0.41 | 0.56 | 0.64 |
| Tongi | 0.19 | 0.23 | 0.73 | 0.82 | 0.23 | 0.73 | 0.19 | 0.24 | 0.72 |

**Table 4. 8: Performance of 10-day Probabilistic Forecast**

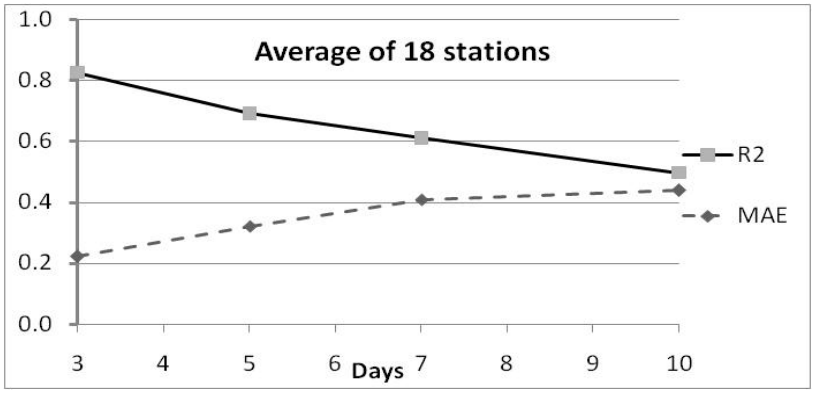
| Stations | Standard Deviation(-1) | | | Mean | | | Standard Deviation(+1) | | |
|---|---|---|---|---|---|---|---|---|---|
| | MAE (m) | RMSE(m) | $r^2$ | MAE (m) | RMSE(m) | $r^2$ | MAE (m) | RMSE(m) | $r^2$ |
| Aricha | 0.62 | 0.70 | 0.56 | 0.30 | 0.37 | 0.57 | 0.35 | 0.50 | 0.49 |
| Bhagyakul | 0.39 | 0.46 | 0.81 | 0.19 | 0.24 | 0.85 | 0.30 | 0.40 | 0.76 |
| Bhairabbazar | 0.25 | 0.31 | 0.61 | 0.24 | 0.29 | 0.60 | 0.23 | 0.29 | 0.59 |
| Demra | 0.33 | 0.41 | 0.23 | 0.33 | 0.42 | 0.23 | 0.33 | 0.41 | 0.23 |
| Dhaka | 0.26 | 0.31 | 0.67 | 0.21 | 0.27 | 0.67 | 0.21 | 0.28 | 0.63 |
| Goalondo | 0.66 | 1.01 | 0.72 | 0.45 | 0.71 | 0.77 | 0.73 | 1.03 | 0.75 |
| Gorai-RB | 0.65 | 0.82 | 0.73 | 0.32 | 0.39 | 0.75 | 0.39 | 0.54 | 0.64 |
| Kamarkhali | 0.58 | 0.90 | 0.70 | 0.39 | 0.57 | 0.72 | 0.56 | 0.76 | 0.67 |
| Mirpur | 0.26 | 0.31 | 0.58 | 0.24 | 0.29 | 0.58 | 0.24 | 0.31 | 0.55 |
| Mohadevpur | 0.73 | 1.28 | 0.10 | 0.83 | 1.28 | 0.10 | 0.83 | 1.28 | 0.10 |
| Moulvibazar | 0.92 | 1.06 | 0.14 | 0.92 | 1.06 | 0.14 | 0.92 | 1.06 | 0.14 |
| Naogaon | 0.88 | 1.17 | 0.02 | 0.88 | 1.17 | 0.02 | 0.88 | 1.17 | 0.02 |
| Serajgonj | 1.05 | 1.24 | 0.36 | 0.48 | 0.68 | 0.47 | 0.48 | 0.60 | 0.45 |
| Sheola | 0.22 | 0.27 | 0.56 | 0.22 | 0.27 | 0.56 | 0.22 | 0.27 | 0.56 |
| Sherpur | 0.75 | 0.91 | 0.45 | 0.75 | 0.91 | 0.45 | 0.75 | 0.91 | 0.45 |
| Sunamgonj | 0.42 | 0.53 | 0.31 | 0.42 | 0.53 | 0.31 | 0.42 | 0.53 | 0.31 |
| Sylhet | 0.22 | 0.27 | 0.56 | 0.22 | 0.27 | 0.56 | 0.22 | 0.27 | 0.56 |
| Tongi | 0.75 | 0.91 | 0.45 | 0.75 | 0.91 | 0.45 | 0.75 | 0.91 | 0.45 |

Following charts showing the MAE and $r^2$ plots for the Aricha and Bhairabbazar for monsoon 2013, indicated that as the longer the lead tie, the $r^2$ is reducing and MAE increasing.




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



# CHAPTER 5 : INUNDATION STATUS

The country as a whole experienced normal flooding during the monsoon-2013. The flood during 2013 was not a severe one and stayed for short (1-day) to medium duration in all the four basins, the Brahmaputra, the Ganges, the Meghna and South Eastern Hill Basin, except Jhikorgacha on Kobodak of the south west part of the country. The South Western part of the country experienced prolong flooding in few stations longer than the previous flood years, specially part of Khulna, Jessore and Satkhira districts, the most affected Upozillas are Keshobpur, Kalaroa, Tala, Monirumpur and Stakhira Sadar. Water Level at Jhikorgacha on Kobodak was flowed above the danger level for continuous 120 days. During the monsoon-2013 there were less flash floods in the North-Eastern part and South-Eastern part of the country.

Out of 23 Water Level (WL) monitoring stations in the Brahmaputra basin, at 7 stations WL was crossed the respective DLs, these are Ghagot at Gaibandha for 4 days, Jamuna at Bahadurabad for 8 days, Sariakandi for 5 days, Aricha for 5 days and Serajgonj for 3 days during August and September. As a result, low-lying areas of Kurigram, Lalminiorhat, Gaibandha, Bogra, Rangpur, Serajgonj, Tangail, Jamalpur and Narayangonj districts were flooded for short period such as one week.

In the Ganges basin out of 22 WL monitoring stations, at 9 stations river exceeded their respective DLs during monsoon 2013, these are Pankha and Rajsgahi on Ganges, Goalondo on Ganges/ Padma, Bhagyakul on Padma, Kamarkhali on Gorai, Panchgarh on Karatoa, Chapai-nawabganj on Mohananda, Thakurgaon on Tangon and Jhikorgacha on Kobodak during the monsoon 2013. The WL of river Padma at Bhagyakul was flowed for 7 days above DL. The low lying areas of Chapai-Nawabgonj, Rajshahi, Kustia, Magura, Rajbari, Faridpur, Panchagr, Thakurgain, Dinajpur, Manikgonj, Munshigonj, Sariatpur and Noagaon districts was affected by normal flooding during beginning of the month of September. It may be mentioned that, a moderate duration of flooding situation was prevailing around the Bhagyakul WL gauge stations. Prolong flooding situation was prevailing in part of Satkhira, Khulna and Jessore districts due to very poor drainage condition along with very high rainfall during August. The WL of Kobodak river at Jhikorgacha flowed above the DL for continuous 120 days. Flood caused immense suffering of the people of the locality.

Out of 20 WL monitoring stations in the Meghna basin, at 8 stations flowed above their respective DLs, these are Kanaighat on Surma River, Amalshid and Sheola on Kushyara River, Manu Railway Bridge on Manu river, Habigonj and Bullah on Khowai river, Kamalgonj on Dhalai river and Nakuakaon on Bhugai river for less than 1 day (Manu at Manu Railway Bridge) to 13 days (Sheola on Kushiyara River). As a result, floods of

short to moderate duration was experienced in the districts of Sylhet, Sunamgonj, Netrokona, Sherpur, Moulvi Bazar, and Habigonj during the monsoon 2013.

In the South Eastern Hill basin WL of the rivers Muhuri, Halda and Matamuhuri crossed their respective DLs for 1 to 2 days during this monsoon-2013. As a result, short duration flood occurred at Parshuram (Muhuri), Narayanhat (Halda river) and Lama (Matamuhuri river) during the monsoon 2013. Total 3 WL monitoring stations in the South Eastern Hill basin crossed DLs during the Monsoon-2013.

In flood period, Flood Inundation Map has been developed at FFWC as a part of routine output based on the result file/data of the Flood Forecasting Model and digital elevation map (DEM). This was done by using MIKE 11 FF module and GIS, where the results were found from MIKE 11 Rainfall-Runoff and Hydrodynamic modelling simulation. In addition to that rainfall surface of Situation Map for past 24 hours has also been developed in the FFWC on routine basis. Flood inundation for whole country is a macro level product showing a general overview of flood situation of the whole country. A detail and authentic DEM shall improve significantly showing inundation status map. Sample of Flood Inundation Maps based on 24 hour and 48 hours forecast respectively are presented in the following pages (Fig 5.1 and Fig 5.2).

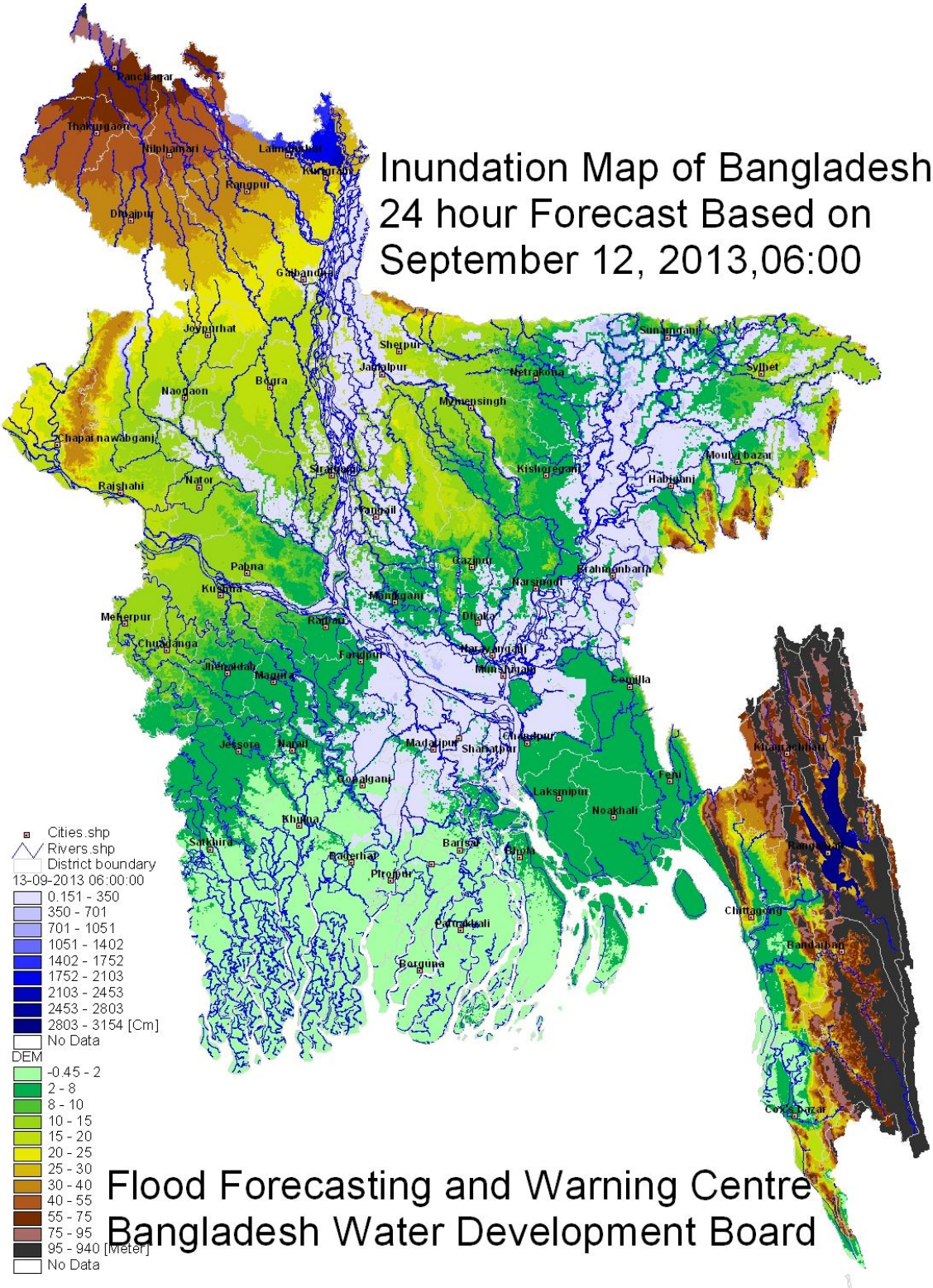



**Figure 5.46 :** Flood Inundation Map of Bangladesh (24hr Forecast Based on 12 September 2013)

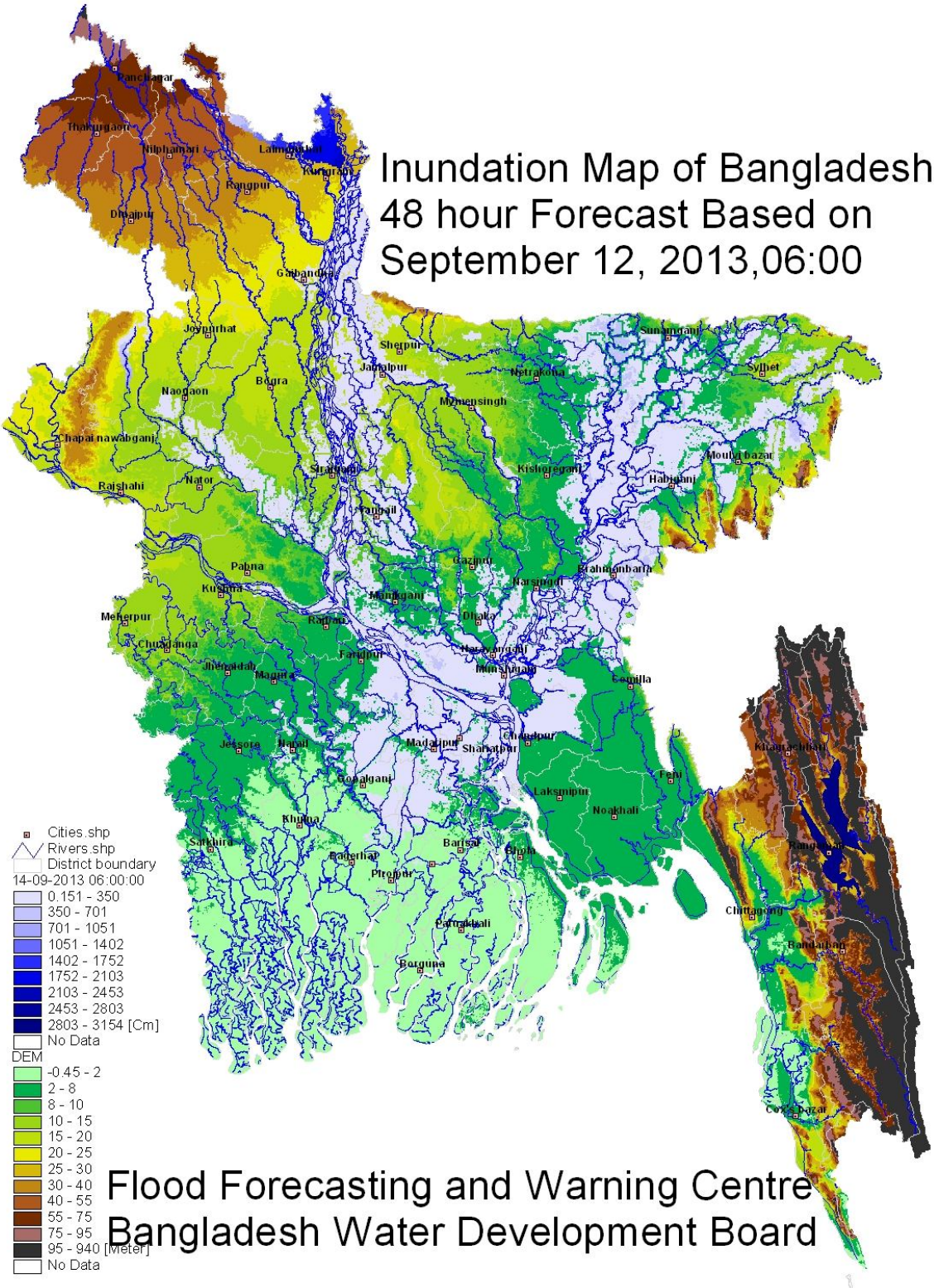



**Figure 5.47 : Flood Inundation Map of Bangladesh (48hr Forecast Based on 12 September 2013)**

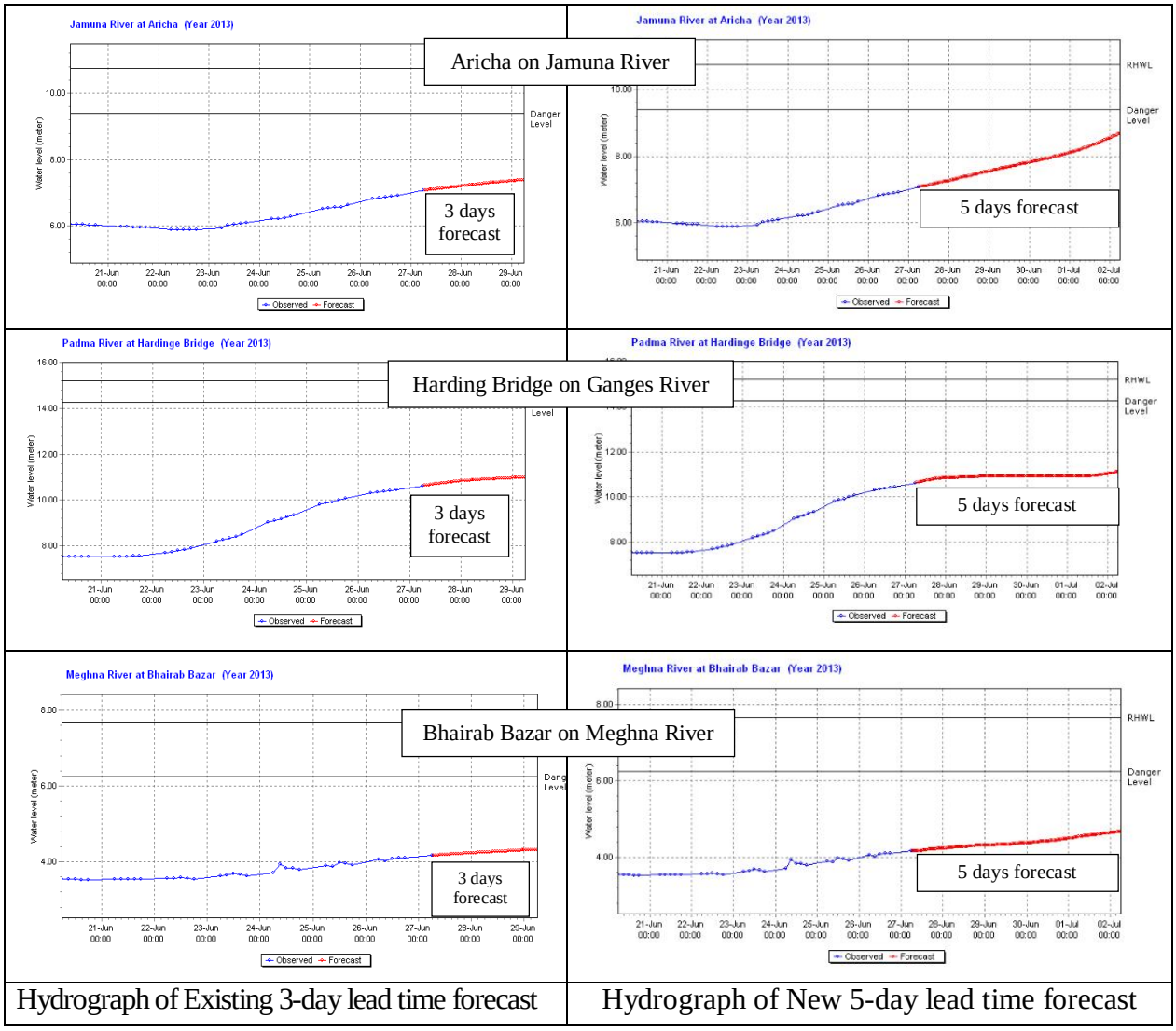
# CHAPTER 6: RESEARCH AND DEVELOPMENT

## 6.1 Extended Flood Forecast Lead Time

Mathematical model-based forecasting system for the generation of flood forecasts is being used, is known as customized "MIKE11-GIS Super Model". During monsoon period (May to October), FFWC has been providing upto 3-days (24, 48 & 72 hours) lead time deterministic flood forecasts in the form of water level at 38 gauge stations situated in the 21 major rivers of the country on daily basis. The forecasted water level explains the amount of increase or decreases of water level with respect to the current level(day of forecast issue) and how much above or below the water level will be with respect to the DL in next 3 days at each selected station/point.

With financial support from the Comprehensive Disaster Management Programme, phase-II (CDMP-II), FFWC-BWDB initiated a research work in collaboration of Institute of Water Modelling (IWM) as consultant to extend deterministic flood forecasting lead time upto 5-days(120 hrs) from 3-days(72hrs). The CDMP-II program is lead by the Ministry of Disaster Management and Relief with financial support from UNDP (Australian Aid, European Union, Norwegian Embassy, SIDA and UK Aid). A part of financial contribution of CDMP-II program has been utilizing for strengthening of FFWC, BWDB. Under the approved Project Implementation Plan (PIP), the CDMP-II supported activity entitled "Strengthening Flood Forecasting and Warning Centres' Early Warning Capacity" started since June 2011. During the September-October 2012 (end of last year monsoon) the 5-days lead time deterministic flood forecast was generated on daily basis in the Brahmaputra basin and performance was evaluated.

The lead time of the flood forecasting has been extended by using the Ganges-Brahmaputra-Meghna (GBM) basin model. This GBM basin model is capable of generating the flows of major trans-boundary rivers using meteorological data of the basin as input. Rainfall measurement data and forecasts/prediction are available in the web-site. Water level data at limited number of sites from upstream gauges inside India is also available during flood period (June to October). The gauge data (measured) along with measured and forecasted/predicted rainfall data has been utilized to generate the major inflows and thus extended deterministic flood forecast lead time upto 5-days has been generated at 38 numbers of flood forecasting points/stations. From the beginning of the monsoon (June 2013) 24hr, 48hr, 72hr, 96hr and 120 hours (upto 5-days) lead time experimental deterministic flood forecast & warning has been generated and disseminated on daily basis. Initial evaluation indicated that upto the 4th day the forecast performance is satisfactory. At the 5th day (120 hours) the performance has to improve further. Improvement and fine tuning of the model is being continued upto the end of 2014. A sample flood bulletin upto 5-days lead time flood forecast at 38 points is presented in **Annex-3** and hydrographs of different stations/points is enclosed in Figure 6.1. Two more days lead time, from 3-days (72 hours) to 5-days (120 hours), is a major step-forward for the Flood Forecasting and Warning Services (FFWS) of the country.




Hydrograph of Existing 3-day lead time forecast | Hydrograph of New 5-day lead time forecast

**Figure 6.48 :** Sample hydrograph with forecast, 3-days vs 5-days

Performance of flood forecast with lead time of five days at 38 stations has been done for round the season (June to 15th October 2013), presented in Table 6.1 and Table 6.2. Performance of flood forecast has been classified as specified in Table 4.1

**Table 6.1:** Performance status of flood forecast with lead time of 5 days

| Stations | Performance Status | | | | |
|---|---|---|---|---|---|
| | Day-1 | Day-2 | Day-3 | Day-4 | Day-5 |
| Aricha | Good | Good | Good | Average | NS |
| Bahadurabad | Good | Good | Average | NS | Poor |
| Baider Bazar | Good | Good | Good | Good | Average |
| Bhagyakul | Good | Good | Good | Average | Average |
| Bhairab Bazar | Good | Good | Good | Good | Average |
| Bogra | Average | NS | Very poor | Very poor | Very poor |
| Chakrahimpur | Good | Average | Poor | Very poor | Very poor |
| Chilmari | Good | Average | Average | NS | Poor |
| Demra | NS | NS | Poor | NS | NS |
| Dhaka (Hariharpara) | Good | Good | Good | Good | Good |
| Dhaka (Mill Barrack) | Good | Average | Average | Average | Average |
| Goalondo | Good | Good | Good | Average | NS |

| Stations | Performance Status | | | | |
|---|---|---|---|---|---|
| | Day-1 | Day-2 | Day-3 | Day-4 | Day-5 |
| Gorai Rly Bridge | Good | Good | Average | Average | NS |
| Hardinge Bridge | Good | Good | Average | Average | Poor |
| Jamalpur | Good | Good | Average | NS | Poor |
| Kamarkhali | Good | Good | Average | Average | NS |
| Kaunia | NS | Very poor | Very poor | Very poor | Very poor |
| Kazipur | Good | Good | Average | NS | NS |
| Mawa | Good | Good | Good | Good | Average |
| Meghna Bridge | Good | Average | Good | Average | Average |
| Mirpur | Good | Good | NS | Average | NS |
| Mohadevpur | NS | Poor | Very poor | Very poor | Very poor |
| Mymensingh | Good | Average | NS | Poor | Very poor |
| Naogaon | Average | Poor | Poor | Very poor | Very poor |
| Narayanganj | Good | Average | Average | NS | NS |
| Nayerhat | Good | Good | Average | NS | Average |
| Porabari | Good | Good | Good | Average | NS |
| Rajshahi | Good | Good | Average | Average | Poor |
| Serajganj | Good | Good | Average | NS | NS |
| Sheola | Average | Poor | Poor | Very poor | Very Poor |
| Sunamganj | Average | Poor | NS | Poor | Very Poor |
| Sylhet | Good | NS | Poor | Very poor | Very Poor |
| Talbaria | Good | Good | Average | Average | NS |
| Taraghat | Good | Good | Good | Average | NS |
| Tongi | Good | Good | Good | Average | Average |

NS – Not Satisfactory

**Table 6.2:** Summary of forecast performance at 38 stations with lead time of 5 days

| Forecast Lead time | Performance Status obtained at no. of stations out of 38 | | | | |
|---|---|---|---|---|---|
| | Good | Average | Not satisfactory | Poor | Very Poor |
| Day-1 Forecast (24 hrs) | 28 | 4 | 3 | - | - |
| Day-2 Forecast(48 hrs) | 22 | 5 | 3 | 4 | 1 |
| Day-3 Forecast(72 hrs) | 11 | 13 | 3 | 5 | 3 |
| Day-4 Forecast(96 hrs) | 4 | 14 | 8 | 2 | 7 |
| Day-5 Forecast(120 hrs) | 1 | 8 | 12 | 5 | 9 |

Effort is continuing for improvement of performance of the 5-days lead time deterministic flood forecast, it is expected the performance will be improved in the next monsoon.

### 6.2 Structure Based Flood Forecast

Another component of the Research on Prediction modelling is "Structure Based Flood Forecast" for selected BWDB projects. Based on the extended 5- days deterministic flood forecast, structure based flood forecast for selected projects (i) Brahmaputra Right Embankment(BRE) (ii) Dhaka-Mawa Road, (iii) Pabna Irrigation and Rural Development Project (PIRDP) and (iv) Meghna Dhonagoda Irrigation Project (MDIP) has been generated and disseminated from July 2013 on experimental basis (location map Fig A.3). The experimental output of the Structure Based Flood Forecast for 24, 48, 72, 96 and 120 hours for the PIRDP is shown in the **Figure 6.2.** This is more localised flood forecasting system from point based forecast to along the structure (embankment and road) water level profile for observed and forecast for next 5-days.

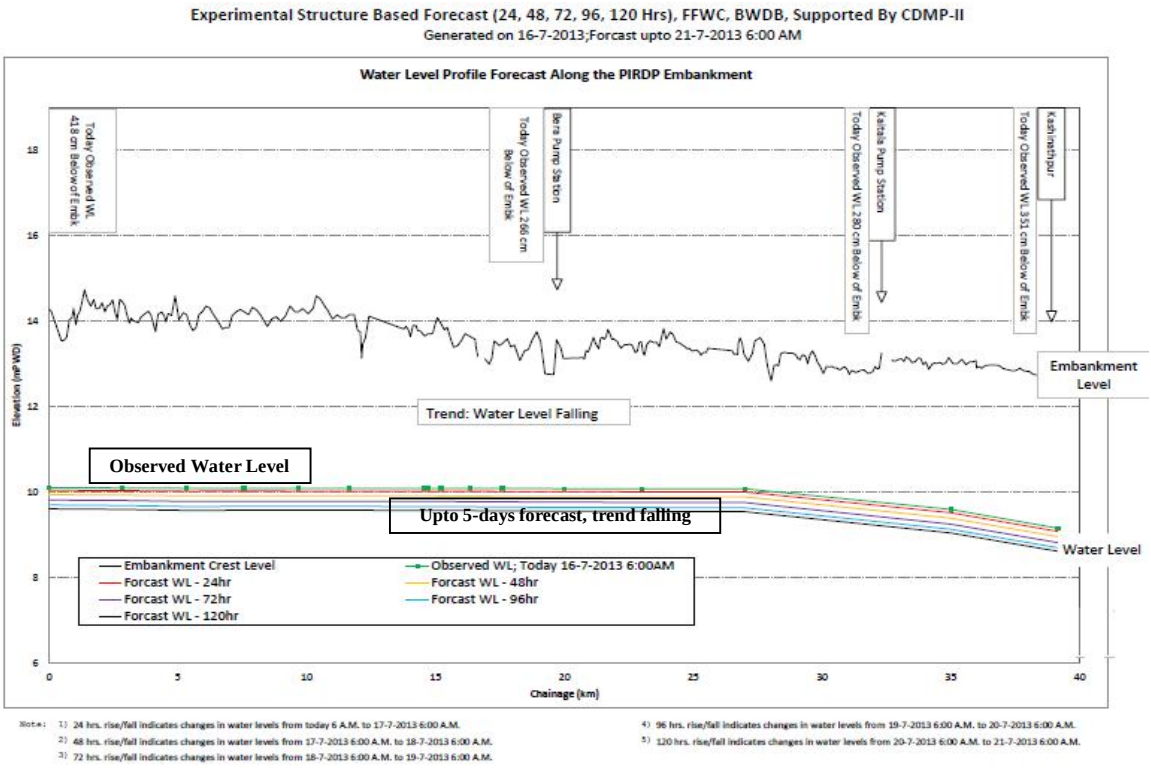



**Figure 6.49 :** Structure based flood forecast along the Embankment of PIRDP

## 6.3 Interactive Voice Response (IVR)

IVR system for Flood Early Warning message dissemination through mobile has been initiated with the support of CDMP-II. During monsoon recorded voice message on Flood Early Warning in Bangla has been uploaded daily. Anyone may call at **10941** number from mobile to hear that voice message (charge applicable). Experimentally it was started through Teletlk in June 2011. From monsoon 2013 all the mobile services have introduced this IVR facility.

## 6.4 Flash Flood Forecast for North East Part

Experimental flash flood forecast has been generated and disseminated through e-mail and FFWC website (www.ffwc.gov.bd) during April-May period (period of threat for disaster) for the North East region. Flood forecast is produced with lead time of 2 days at eight stations. The initial evaluation for the forecast during April May period indicated good performance and acceptable. Further improvement is in progress and will be tested in the next season during April May 2014. Sample flash forecast hydrographs for Sunamgonj & Jariajanjail is shown in **Figure 6.3.** A bulletin of Experimental Flash Flood is shown in the next page.

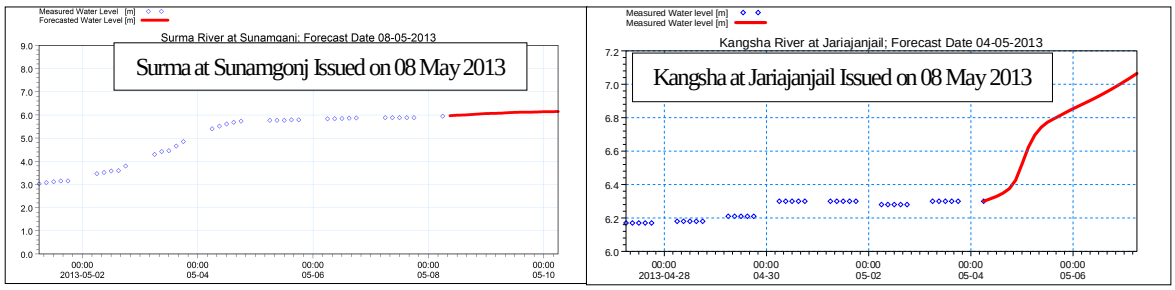



**Figure 6.50 :** Sample flash flood forecast

FLOOD INFORMATION CENTRE
FLOOD FORECASTING AND WARNING CENTRE
BANGLDESH WTER DEVELOPMENT BOARD
WAPDA BUILDING, 8TH FLOOR MOTIJHEEL C/A, DHAKA-1000
e-mail-ffwcbwdb@gmail.com; web site-www.ffwc.gov.bd, phone 9550755
EXPERIMENTAL FLASH FLOOD CONDITION IN THE NORTH EAST RGION AS ON
7 MAY 2013

RAIFALL

No significant rainfall (more than 50mm) observed in the region and its adjoining areas in India during last 24 hours. There is possibility of occurring slight rainfall today and tomorrow(8 May 2013) in the adjoining Meghalya area.

OUTLOOK

The Surma, Kushiyara and Kangsha Rivers are in normal condition. Model indicted rising trend of Water Level for Today and Tomorrow in Surma, Kushiyara & Kangsha rives. Possibility of **No Flash Flood** for next two days in Sylhet & Snamgonj areas.

STATIONS ABOVE DANGER LEVEL(DL)

No Water Level stations of the rivers observed above DL during last 24 hrs ending at 06:00 hrs today

GENERAL RIVER CONDITION

| | | | |
|---|---|---|---|
| Monitored Water Level Stations | 17 | Steady | 0 |
| Rise | 12 | Not Reported | 1 |
| Fall | 4 | Above Danger Level | 0 |

Model Forecast : 6, 12, 24, & 48 hours

| | | | 07 May 2013 | | | | 08 May 2013 | | 09 May 2013 | |
|---|---|---|---|---|---|---|---|---|---|---|
| River | Station | DL(m) | Today 06:00hrs | 6-hr. Forecast 12:00hrs | 12-hr. Forecast 18:00hrs | 12-hr. +rise -fall | 24-hr. Forecast 6:00hrs | 24-hr. +rise -fall | 48-hr. Forecast 6:00hrs | 48-hr. +rise -fall |
| | | | (m) | (m) | (m) | (cm) | (m) | (cm) | (m) | (cm) |
| Kushiyara | Amalshid | 15.85 | 12.19 | 12.23 | 12.23 | 4 | 12.33 | 14 | 12.34 | 15 |
| Kushiyara | Sheola | 13.50 | 10.16 | 10.23 | 10.26 | 10 | 10.32 | 16 | 10.40 | 24 |
| Kushiyara | Sherpur | 9.00 | 5.58 | 5.64 | 5.69 | 11 | 5.81 | 23 | 5.98 | 40 |
| Surma | Kanaighat | 13.20 | 10.07 | 10.14 | 10.20 | 13 | 10.30 | 23 | 10.47 | 40 |
| Surma | Sylhet | 11.25 | 8.05 | 8.07 | 8.09 | 4 | 8.14 | 9 | 8.31 | 26 |
| Surma | Sunamgonj | 8.25 | 5.88 | 5.89 | 5.90 | 2 | 5.95 | 7 | 6.05 | 17 |
| Kalni | Markuli | - - | 6.13 | 6.18 | 6.23 | 10 | 6.32 | 19 | 6.47 | 34 |
| Kangsha | Jariajanjail | 9.78 | 6.98 | 7.04 | 7.13 | 15 | 7.30 | 32 | 7.63 | 65 |

This activity Supported by the CDMP-II

**6.5 Increased number of Flood Forecast Point/Stations Within the existing network**

There are many cities, even district headquarters and flood vulnerable areas in the country needed to be included under flood forecasting system. Since extension of model covering entire country and inclusion of all flood vulnerable areas need huge resources and time, thus a gradual advancement of the forecasting system found to be a sustainable way. Therefore BWDB decided to increase flood forecasting at additional 16 no stations in addition to existing 38 stations. The 16 new points under the existing model coverage has been selected with the Technical Working Group (TWG, headed by the Chief Engineer Hydrology) meeting. The initiation of flood forecast at 16 new points/stations upto 5-days lead time has been generated & disseminated since September 2013. This may be considered as the more localized flood forecast and step-forward for the FFWS of the

country. The list of the new 16 stations is presented in Table 6.3 and a map is shown in Figure-6.4.

**Table 6.3:** List of new stations/points included/added in the present flood forecasting system

| Sl. No | River Name | Station Name | District | Upazilla | Danger Level (mPWD) |
|---|---|---|---|---|---|
| 01 | Jamuna | Sariakandi | Bogra | Sariakandi | 16.70m |
| 02 | Baulai | Khaliajuri | Netrokona | Khaliajuri | 8.534(8.50m) |
| 03 | Surma Old Course | Derai | Sunamganj | Derai | Not Available |
| 04 | Kalni | Markuli | Hobiganj | Ajmiriganj | 5.791 (5.80m) |
| 05 | Manu | Moulovibazar** | Moulovibazar | Moulovibazar Sadar | 13.25 |
| 06 | Dhaleswari | Elasin Ghat | Tangail | Tangail Sadar | Not Available |
| 07 | Jamuna | Dewanganj | Jamalpur | Dewanganj | Not Available |
| 08 | Dhaleswari | Rekabibazar (Munshiganj) | Munshiganj | Munshiganj Sadar | 5.185 (5.20m) |
| 09 | Dharala | Kurigram** | Kurigram | Kurigram Sadar | 26.50m |
| 10 | Shitalakhya | Lakhpur | Narayanganj | Rupganj | 5.791 (5.80m) |
| 11 | Meghna | Narsingdi | Narsingdi | Narsingdi Sadar | 5.182 (5.20m) |
| 12 | Mohananda | Chapai Newabganj** | Chapai Newabganj | Chapai Newabganj | 21.00m |
| 13 | Ghagot | Gaibandha** | Gaibandha | Gaibandha Sadar | 21.70m |
| 14 | Atrai | Chanhkair | Natore | Gurudaspur | 12.497 (12.50m) |
| 15 | Hurasagar | Baghabari | Sirajganj | Shahazadpur | 10.363 (10.40m) |
| 16 | Padma | Sureswar | Shariatpur | Naria | 4.42 (4.40m) |

** Existing water level monitoring stations added as new Flood Forecast stations/points

Note – Existing monitoring and forecast points/stations 73, added 12 new points/stations, increased to 85 points/stations. Existing Flood Forecast points/stations 38, added 16 new points/stations increased to 54 points/stations.

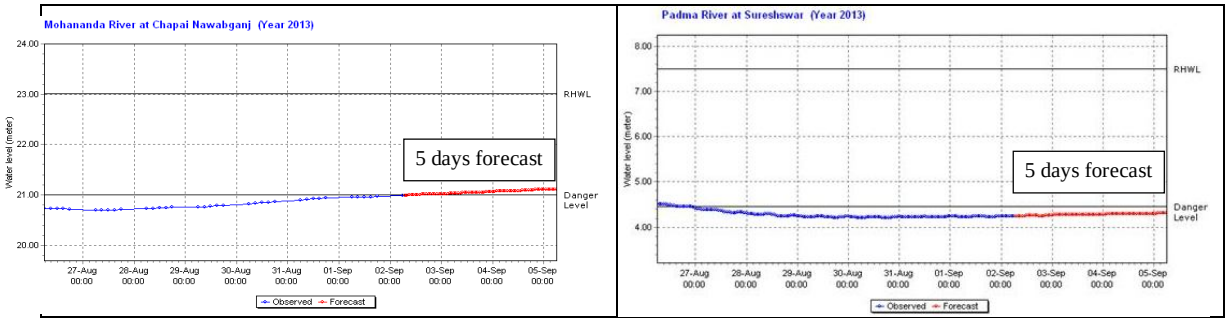



**Figure 6.51 :** Sample Flood Forecast (upto 5-days) Hydrogrph for newly added stations Chapai Nwabgonj on Mohananda (left) and Sureshswar on Padma(right)

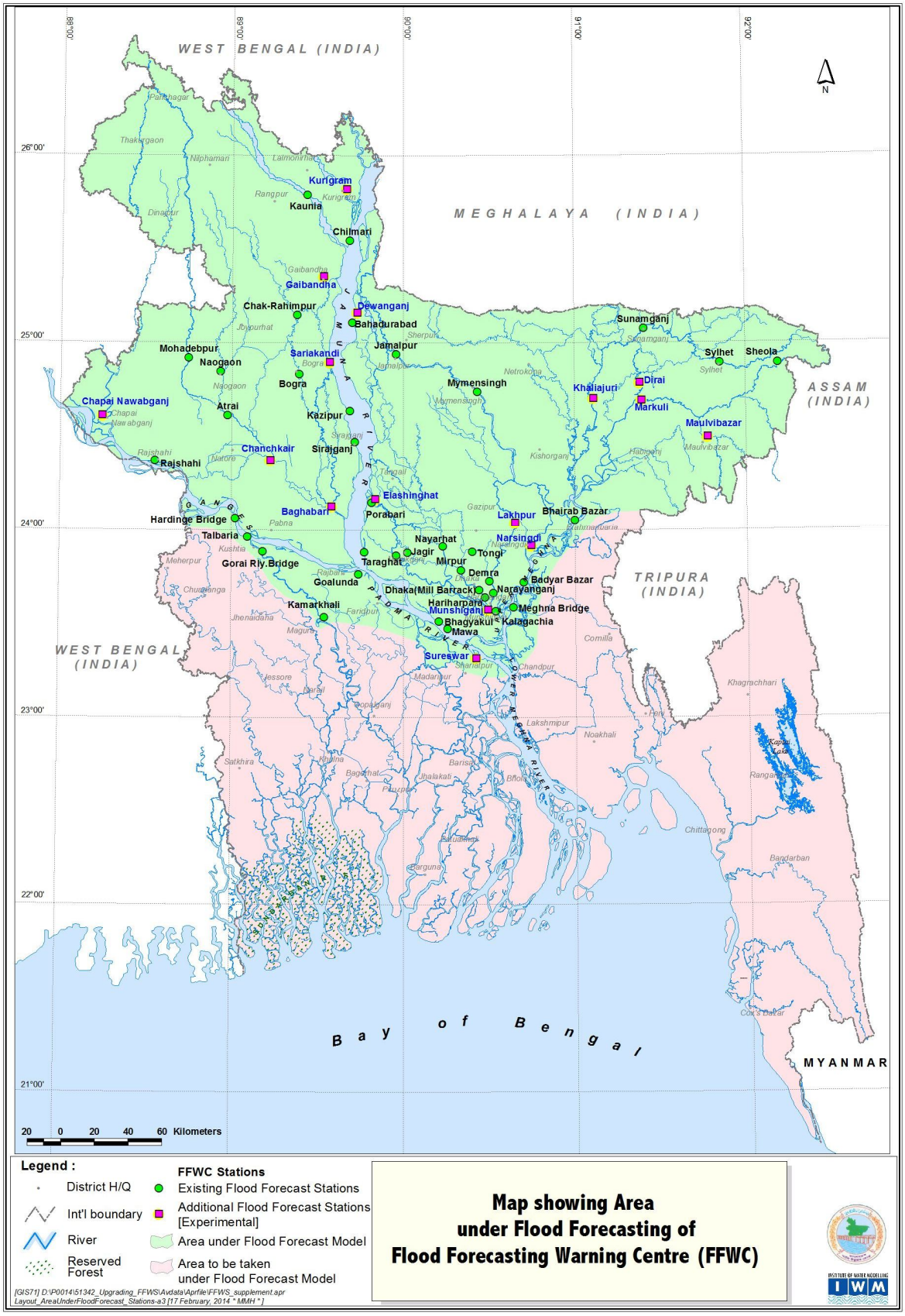



**Figure 6.52 :** Location with river network of 16 new flood forecast points/stations

**FLOOD BULLETIN with ADDITIONAL 16 NEW Flood Forecast STATIONS/POINTS**

Data available up to 02-09-2013

| | | | today | 24-hrs fore-cast | 24-hrs +rise -fall | 24-hrs +above -below D.L. | 48-hrs fore-cast | 48-hrs +rise -fall | 48-hrs +above -below D.L. | 72-hrs fore-cast | 72-hrs +rise -fall | 72-hrs +above -below D.L. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 02-09 | 03-09 | 03-09 | 03-09 | 04-09 | 04-09 | 04-09 | 05-09 | 05-09 | 05-09 |
| River | Station | D.L. (meter) | 0600 (meter) | 0600 (meter) | 0600 (cm) | 0600 (cm) | 0600 (meter) | 0600 (cm) | 0600 (cm) | 0600 (meter) | 0600 (cm) | 0600 (cm) |
| Mohananda | Chapai Nawabganj | 21.00 | 20.99 | 21.03 | + 4 | + 3 | 21.07 | + 4 | + 7 | 21.11 | + 4 | + 11 |
| Ghagot | Gaibandha | 21.70 | 19.89 | 19.70 | -19 | -200 | 19.70 | 0 | -200 | 19.71 | + 1 | -199 |
| Dharala | Kurigram | 26.50 | 24.91 | 25.00 | + 9 | -150 | 25.05 | + 5 | -145 | 25.10 | + 5 | -140 |
| Manu | Moulvibazar | 11.75 | 9.08 | 9.02 | -6 | -273 | 8.99 | -3 | -276 | 8.93 | -6 | -282 |
| Dhaleswari | Rekabibazar | 5.20 | 4.33 | 4.37 | + 4 | -83 | 4.36 | -1 | -84 | 4.37 | + 1 | -83 |
| Atrai | Baghabari | 10.40 | - | 9.00 | - | -140 | 9.01 | + 1 | -139 | 9.04 | + 3 | -136 |
| Nandakuja | Chanchkair | 12.50 | - | 10.63 | - | -187 | 10.63 | 0 | -187 | 10.64 | + 1 | -186 |
| Old Surma | Derai | 5.00 | - | 6.46 | - | +146 | 6.46 | 0 | +146 | 6.45 | -1 | +145 |
| Jamuna | Dewanganj | 18.50 | - | 16.96 | - | -154 | 17.07 | + 11 | -143 | 17.19 | + 12 | -131 |
| Dhaleswari | Elasin Br | 7.40 | - | 10.07 | - | +267 | 10.09 | + 2 | +269 | 10.16 | + 7 | +276 |
| Baulai | Khaliajuri | 8.50 | - | 5.76 | - | -274 | 5.77 | + 1 | -273 | 5.78 | + 1 | -272 |
| Lakhya | Lakhpur | 5.80 | - | 5.24 | - | -56 | 5.18 | -6 | -62 | 5.12 | -6 | -68 |
| Kushiyara | Markuli | 5.80 | - | 7.23 | - | +143 | 7.22 | -1 | +142 | 7.20 | -2 | +140 |
| Arialkhan-NC | Narsingdi | 5.20 | - | 5.14 | - | -6 | 5.09 | -5 | -11 | 5.04 | -5 | -16 |
| Jamuna | Sariakandi | 16.70 | - | 14.43 | - | -227 | 14.51 | + 8 | -219 | 14.63 | - | -207 |
| Padma | Sureshwar | 4.40 | - | 4.27 | - | -13 | 4.29 | + 2 | -11 | 4.31 | + 2 | -9 |

Note: 1)24 hrs. rise/fall indicates changes in water levels from today 6 A.M. to tomorrow 6 A.M.
2)48 hrs. rise/fall indicates changes in water levels from tomorrow 6 A.M. to day after tomorrow 6 A.M.
3)"+above" and,"-below" means water level flowing above and below danger level respectively.

## 6.6 Improved/Upgraded FFWC Web-Site

New upgraded, improved and more user friendly web-site adding Summary both in Bangla & English launched since June 2013 with financial support from the CDMP-II. The homepage of the FFWC website presents a map of the country along with river network, marked with flood forecasting points/stations in Bangladesh with following important features:

(i) For a first time visitor it gives a good idea of the rivers in Bangladesh and their flood forecasting sites.

(ii) When the cursor stops at a particular forecasting site, a pop up site appears with location details, water level, highest water level and danger level at that particular site.

(iii) with locations of forecasting sites on the same river clearly marked, one can get an overview of the situation across the river basin.

(iv) colour code of the symbol at each FF location gives an idea if the water level is above/ below warning or danger level or High Flood level.

The homepage of FFWC offers an option to view the whole website in Bangla. This is welcomed by the users and useful since this important information can be accessed and used by people in Bangla language.

The home page also provides information on the sites where water level is currently on the rise or above the danger mark. Below the line of tabs of the website, name of the sites where water level is on the rise keeps on scrolling. Clicking in any of the sites in the scroll, leads to a pop-up where the rise in water level is presented in graph for the previous one week. The rise in water level for each day is also showed according to time which appears when the cursor is kept on any of the dots of the graph. This pop up can also be saved either as a photo, as a PDF or as a SVG vector image.

The FFWC website provides rainfall data and water level data of every designated site in the four river basins of Bangladesh under the 'data' tab. The rainfall data table gives rainfall of the day, along with previous two days rainfall, normal monthly rainfall and cumulative rainfall for the month.

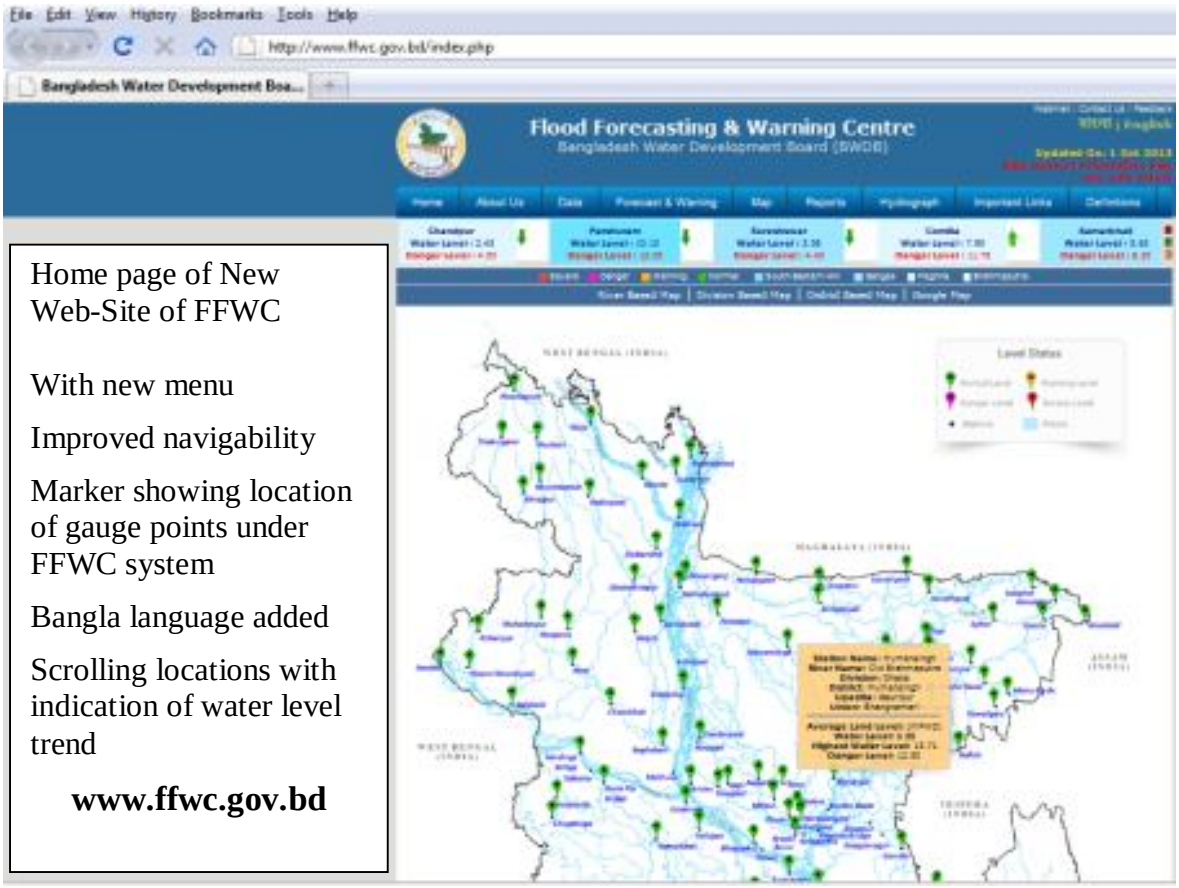
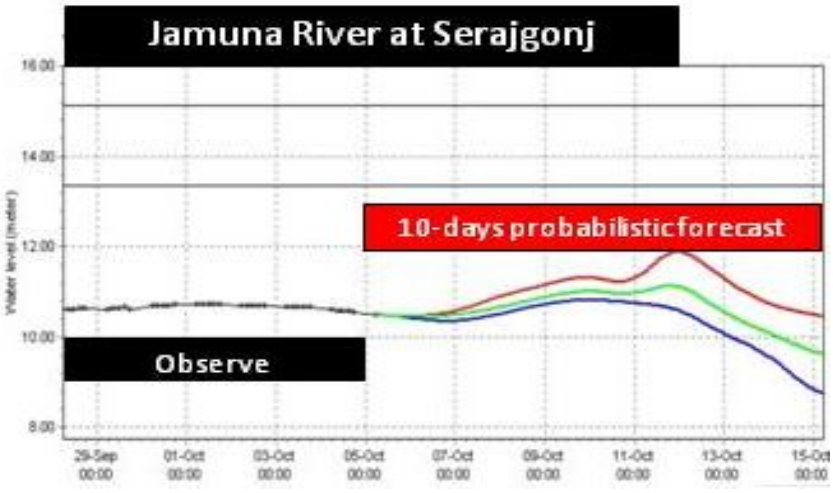



**Figure 6.53 :** Home page of the FFWC new web site

### 6.7 Medium Range Upto 10 days lead time Flood Forecast

To improve the medium and longer lead time flood forecast, Flood FFWC of BWDB and RIMES initiated a joint research programme entitled "Enhancing early warning system for community based response in Bangladesh" with financial support from the USAID through SHOUHARDO-II programme under CARE-Bangladesh since 2012. Objective of this research programme is to (i) Increase number of upto 10 days lead time flood forecasting stations/points from 18 locataions to 38 locations to expand area coverage; (ii) Introduce longer lead time (20-25 days) and seasonal flood forecasts scheme on



experimental basis at the community level at 5-locations; (iii) Enhance flash flood early warning system with longer lead time; and (iv) Capacity development. The computational model for medium range upto 10-days lead time (at 38 locations), long range 20-25 days lead time and seasonal flood forecast for 5 locations have been developed during monsoon of 2013. The systems are ready, from the next monsoon (2014) it will be operational, to be generated & disseminated on regular basis.

## 6.8 Key Achievements

### 6.7.1 Prediction Model Development

Using the newly developed model, 5-days lead time deterministic flood forecast for the 38 points has been generated and disseminated on regular basis since June 2013.

Flash flood forecast on pilot basis for North East part (Sylhet and Sunamgonj) has been disseminated during April May 2013 covering the pre-monsoon flash flood period.

Structure based flood forecast upto 5-days has been generated for the targeted projects, Brahmaputra Right Embankment(BRE), Pabna Irrigation & Rural Development Project (PIRDP), Meghna Dhonagoda Irrigation Project(MDIP) and Dhaka Mawa Highway.

Additional 16 flood forecast points has been added in the Flood Forecast system within the existing model network and disseminated on regular basis. With this development the FFWC system now able to generate and disseminate flood forecast on 54 points/stations on 29 rivers.

Medium range (upto 10-days) and linger lead time flood forecasting model is ready and to be operational in the next monsoon (2014).

### 6.7.2 Dissemination

New web-site (beta version) has been hosted and more than 30,000 visitors visited the site since June 2013(after hoisting).

Mobile based IVR system for flood early warning dissemination introduced.

Improved LAN at the FFWC office with new high speed data transmission facility and improved Briefing/Training room with new projector and LCD display system.

Improved Lobby Display system in Bangla during flood/monsoon season. Continuous display system in Bangla helped a lot during the peak flood time, reducing the interruption due to question answering. It reduces the personnel inquiries and question answer during the working hour, specially from the visiting media persons. This specially improves the quality of services of the professionals of the FFWC.

# CHAPTER 7: CONCLUSIONS

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

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

The runoff from GBM catchments of about 1.76 million sq-km passes through the intricate network of river systems of Bangladesh where only 7% area lies within the country. The characteristic of river varies from river to river and differs from region to region. Usually, in the Brahmaputra basin, flood begins in the late June while in the Ganges basin it starts from the second half of July. The part of Meghna, North and South-Eastern Hill basins is vulnerable to flash flood at the beginning or even pre-monsoon causing loss of standing crops and source of hardship for the population.

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

Updated/improved more user friendly web-site has been in operation since June-2013 (beginning of monsoon) with the financial support of CDMP-II. The upgraded web-site having easy to operate menu and Bangla language option is added with flood warning message in Bangla. Improvement of the web-site is on-going.

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

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

The special type of flood bulletin has been issued during the critical time and disseminate through different mass media, news agencies, fax, e-mail, web-site and IVR through mobile phone. The IVR system using mobile is a new way of dissemination started from July 2011, in cooperation of DDM, anyone can call 10941 number from mobile and hear a short voice message on flood warning in Bangla. The information has been used by various communities and organizations: national and international disaster management operators, many Government agencies, NGOs and BWDB itself.

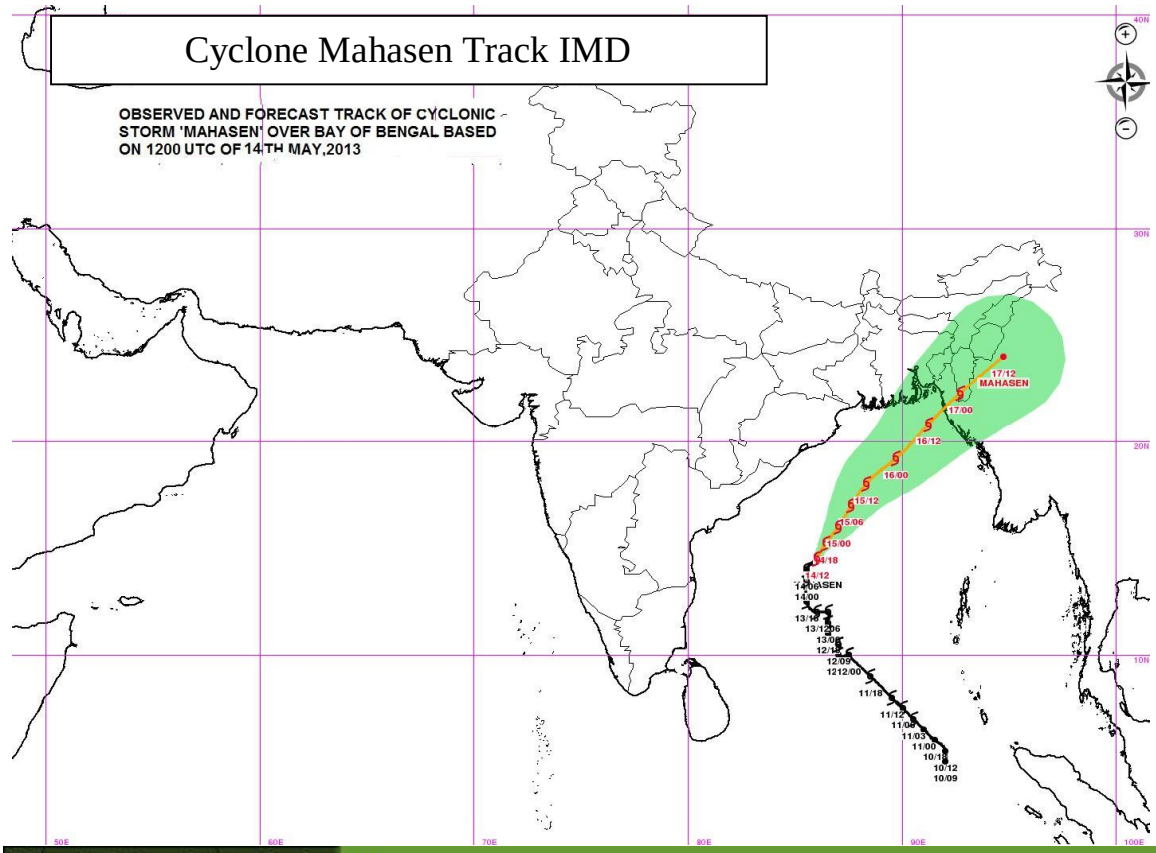
However, due to different shortcomings including limited upstream hydro-meteorological information, detail & accurate digital elevation model (DEM) and limited technological development of the center itself, the services were fully not satisfactory to all corners. Area-inundation forecast have been indicative,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

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

The FFWC of BWDB took the privileged to reflect the flood situation as accurate and reliable as possible. All these combined efforts may have played an effective role in minimizing people sufferings and damages of the infrastructures during the flood of 2013.

As a whole the flood of 2013 was fairly normal compare to devastating flood of 1987, 1988, 1998, 2004 and 2007. The maximum flooded area was 10.6% of the whole country (15,650 sq-km approximately).

Evaluation indicated that, the accuracy of deterministic flood forecasts issued by FFWC for monsoon-2013 on Major River is around 91.6%, 86% and 80.2% accurate for 24hrs, 48hrs and 72hrs 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.



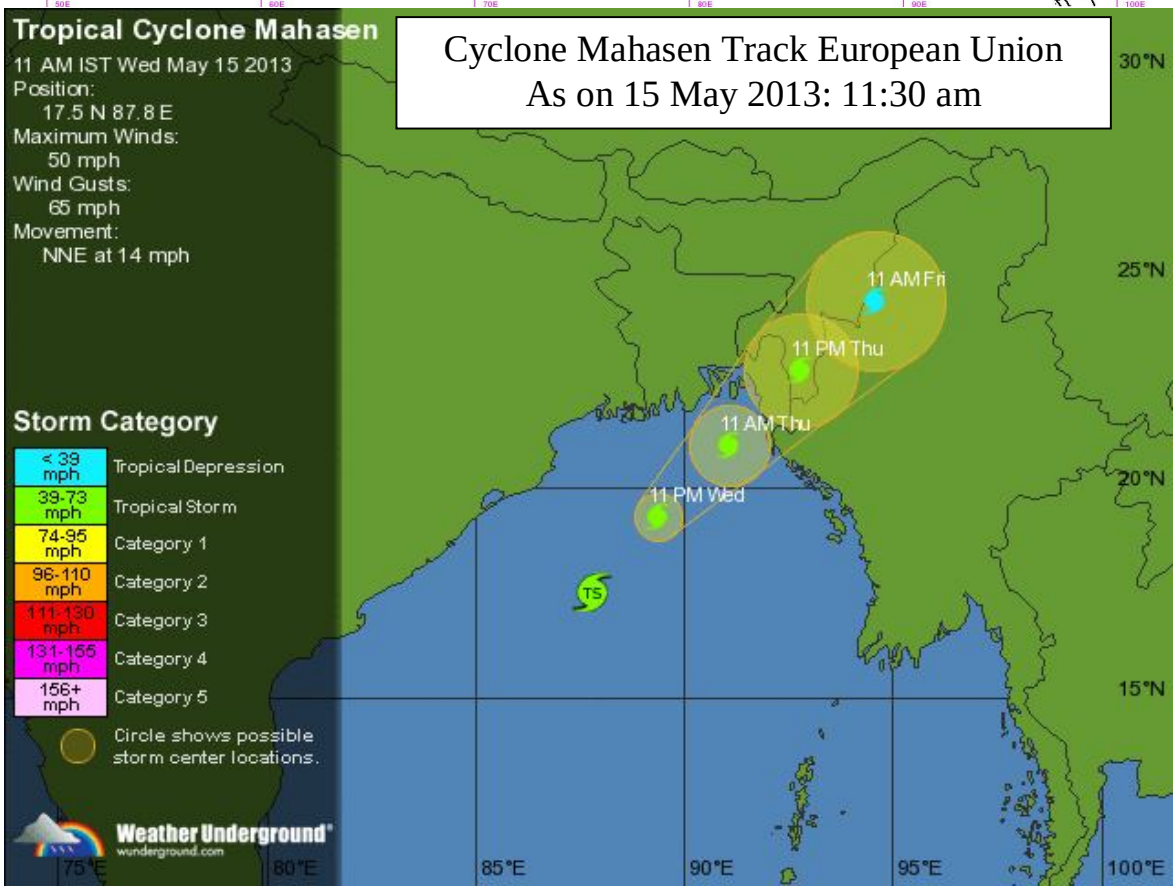




**Figure A.54 :** Cyclone Mahasen track

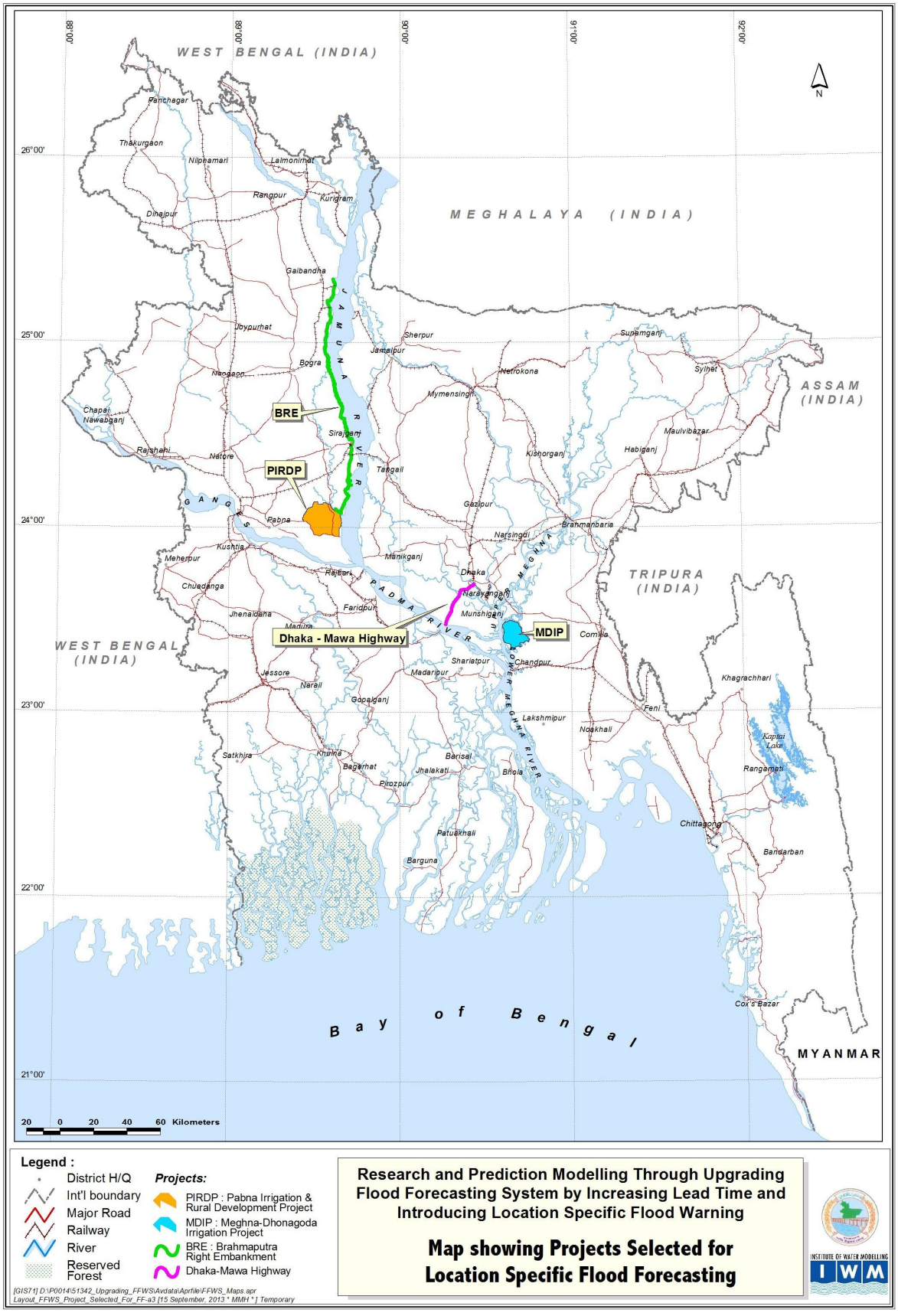



**Figure A.55 :** Projects location of structure based flood forecast

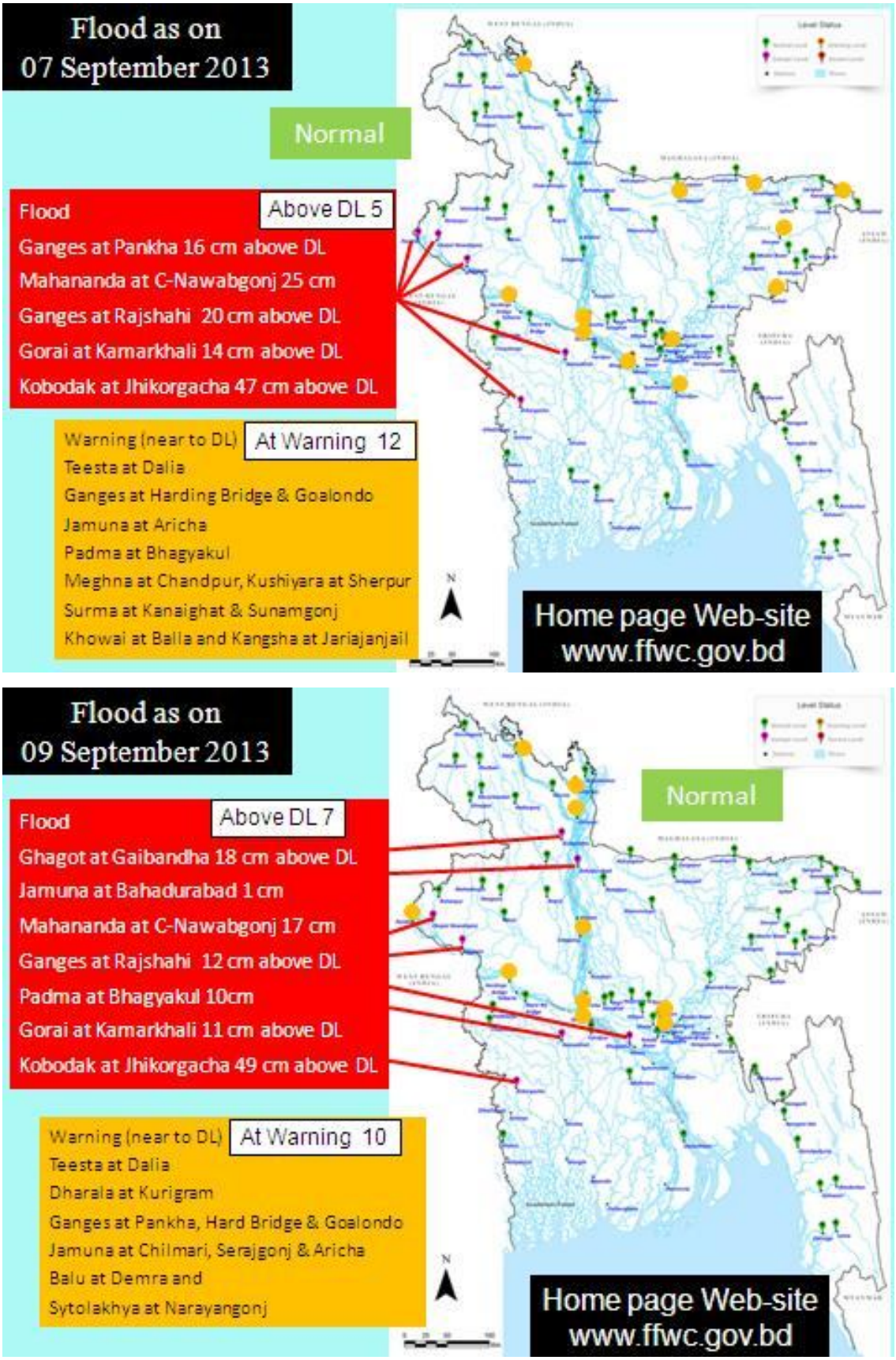



**Figure A.56 :** Snapshots of the FFWC new web site home page on two particular dates

Sample 5-days Flood Forecast Bulletin

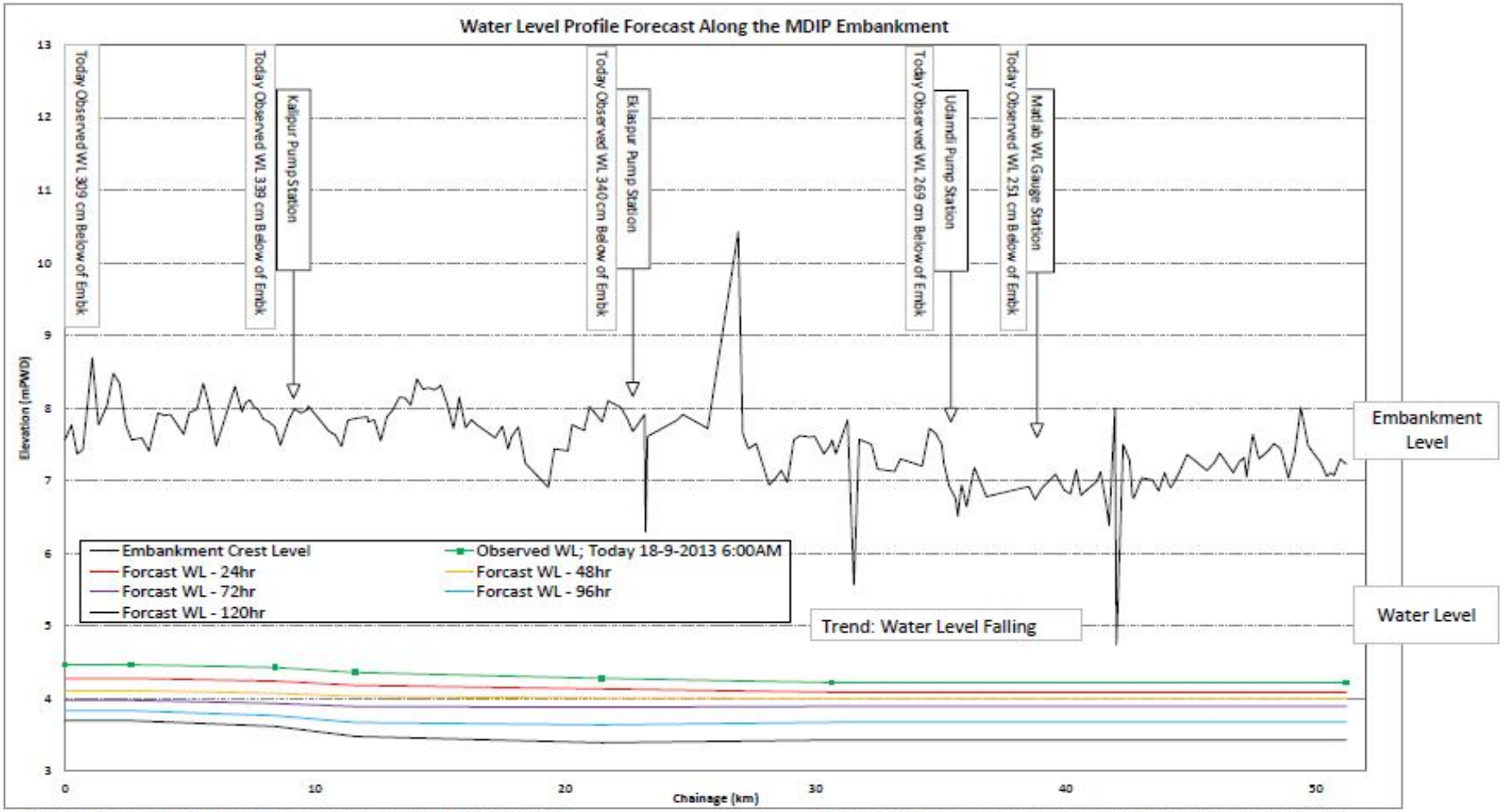
## EXPERIMENTAL 5 Days Forecast (24, 48, 72, 96 & 120 Hrs), FFWC, BWDB
### Supported by CDMP-II

| River | Station | D.L. | Today | 24-hrs forecast | 24-hrs +Rise -fall | 24-hrs +above -below D.L. | 48-hrs forecast | 48-hrs +Rise -fall | 48-hrs +above -below D.L. | 72-hrs forecast | 72-hrs +Rise -fall | 72-hrs +above -below D.L. | 96-hrs forecast | 96-hrs +Rise -fall | 96-hrs +above -below D.L. | 120-hrs forecast | 120-hrs +Rise -fall | 120-hrs +above -below D.L. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 10-09 | 11-09 | 11-09 | 11-09 | 12-09 | 12-09 | 12-09 | 13-09 | 13-09 | 13-09 | 14-09 | 14-09 | 14-09 | 15-09 | 15-09 | 15-09 |
| | | | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM | 6:00 AM |
| | | (meter) | (meter) | (meter) | (cm) | (cm) | (meter) | (cm) | (cm) | (meter) | (cm) | (cm) | (meter) | (cm) | (cm) | (meter) | (cm) | (cm) |
| Atrai | Mohadevpur | 18.59 | 15.56 | 15.34 | -22 | -325 | 15.13 | -21 | -346 | 14.95 | -18 | -364 | 14.82 | -13 | -377 | 14.60 | -22 | -399 |
| Atrai | Atrai | 13.72 | - | 12.12 | - | -160 | 12.14 | +2 | -158 | 12.13 | 0 | -159 | 12.12 | -1 | -160 | 12.09 | -3 | -163 |
| Little Jamuna | Naogaon | 15.24 | 12.93 | 12.91 | -2 | -233 | 12.93 | +2 | -231 | 12.96 | +3 | -228 | 12.97 | +2 | -227 | 12.96 | -1 | -228 |
| Karatoya | Chakrahimpur | 20.15 | 18.25 | 18.18 | -7 | -197 | 18.16 | -2 | -199 | 18.16 | 0 | -199 | 18.11 | -4 | -204 | 18.02 | -9 | -213 |
| Karatoya | Bogra | 16.32 | 12.39 | 12.42 | +3 | -390 | 12.49 | +7 | -383 | 12.54 | +5 | -378 | 12.56 | +2 | -376 | 12.56 | +1 | -376 |
| Teesta | Kaunia | 30.00 | 28.26 | 28.33 | +7 | -167 | 28.16 | -17 | -184 | 27.96 | -21 | -204 | 27.73 | -23 | -227 | 27.51 | -22 | -249 |
| Brahmaputra | Chilmari | 24.00 | 23.87 | 23.83 | -4 | -17 | 23.71 | -13 | -29 | 23.52 | -18 | -48 | 23.27 | -25 | -73 | 22.99 | -28 | -101 |
| Jamuna | Bahadurabad | 19.50 | 19.80 | 19.85 | +5 | +35 | 19.74 | -11 | +24 | 19.61 | -13 | +11 | 19.41 | -19 | -9 | 19.18 | -24 | -32 |
| Jamuna | Kazipur | 14.85 | 14.74 | 14.96 | +22 | +11 | 14.92 | -4 | +7 | 14.80 | -12 | -5 | 14.64 | -16 | -21 | 14.44 | -20 | -41 |
| Jamuna | Serajganj | 13.35 | 13.34 | 13.59 | +25 | +24 | 13.57 | -2 | +22 | 13.45 | -12 | +10 | 13.29 | -16 | -6 | 13.09 | -21 | -26 |
| Jamuna | Porabari | 12.27 | 11.16 | 11.42 | +26 | -85 | 11.44 | +2 | -83 | 11.34 | -10 | -93 | 11.19 | -15 | -108 | 10.99 | -20 | -128 |
| Jamuna | Aricha | 9.40 | 9.55 | 9.72 | +17 | +32 | 9.73 | +1 | +33 | 9.64 | -9 | +24 | 9.51 | -13 | +11 | 9.33 | -17 | -7 |
| Old Brahmaputra | Jamalpur | 17.00 | 15.02 | 15.39 | +37 | -161 | 15.39 | 0 | -161 | 15.24 | -15 | -176 | 15.02 | -22 | -198 | 14.73 | -29 | -227 |
| Old Brahmaputra | Mymensingh | 12.50 | 8.90 | 9.47 | +57 | -303 | 9.89 | +42 | -261 | 10.05 | +16 | -245 | 10.04 | -2 | -246 | 9.92 | -12 | -258 |
| Bangshi | Nayerhat | 7.32 | 5.02 | 5.15 | +13 | -217 | 5.30 | +15 | -202 | 5.43 | +13 | -189 | 5.50 | +8 | -182 | 5.55 | +5 | -177 |
| Old Dhalesari | Jagir | 8.23 | - | 7.03 | - | -120 | 7.30 | +27 | -93 | 7.52 | +22 | -71 | 7.67 | +15 | -56 | 7.77 | +11 | -46 |
| Dhaleswari | Kalagachia | 4.88 | - | 4.43 | - | -45 | 4.48 | +5 | -40 | 4.46 | -2 | -42 | 4.41 | -5 | -47 | 4.33 | -8 | -55 |
| Kaliganga | Taraghat | 8.38 | 7.25 | 7.62 | +37 | -76 | 7.95 | +33 | -43 | 8.16 | +21 | -22 | 8.27 | +11 | -11 | 8.31 | +4 | -7 |
| Tongi Khal | Tongi | 6.08 | 5.29 | 5.38 | +9 | -70 | 5.48 | +11 | -60 | 5.57 | +9 | -51 | 5.62 | +5 | -46 | 5.64 | +2 | -44 |
| Turag | Mirpur | 5.94 | 4.95 | 5.05 | +10 | -89 | 5.15 | +10 | -79 | 5.22 | +7 | -72 | 5.25 | +3 | -69 | 5.26 | +1 | -68 |
| Buriganga | Dhaka (Mill Barrack) | 6.00 | 4.75 | 4.86 | +11 | -114 | 4.91 | +5 | -109 | 4.91 | 0 | -109 | 4.87 | -4 | -113 | 4.81 | -6 | -119 |
| Buriganga | Dhaka (Hariharpara) | 5.79 | 4.44 | 4.55 | +11 | -124 | 4.60 | +5 | -119 | 4.59 | -1 | -120 | 4.55 | -4 | -124 | 4.49 | -6 | -130 |
| Balu | Demra | 5.75 | 4.93 | 5.03 | +10 | -72 | 5.10 | +8 | -65 | 5.15 | +4 | -60 | 5.16 | +1 | -59 | 5.15 | -1 | -60 |
| Lakhya | Narayanganj | 5.50 | 5.12 | 5.23 | +11 | -27 | 5.30 | +6 | -20 | 5.30 | +1 | -20 | 5.28 | -3 | -22 | 5.23 | -5 | -27 |
| Ganges | Rajshahi | 18.50 | 18.46 | 18.29 | -17 | -21 | 18.08 | -21 | -42 | 17.81 | -27 | -69 | 17.51 | -30 | -99 | 17.21 | -30 | -129 |
| Ganges | Hardinge Br | 14.25 | 14.05 | 13.89 | -16 | -36 | 13.70 | -19 | -55 | 13.45 | -24 | -80 | 13.18 | -28 | -107 | 12.89 | -28 | -136 |
| Ganges | Talbaria | 12.80 | 13.88 | 13.72 | -16 | +92 | 13.54 | -19 | +74 | 13.30 | -23 | +50 | 13.02 | -29 | +22 | 12.71 | -31 | -9 |
| Padma | Goalondo | 8.65 | 8.78 | 8.89 | +11 | +24 | 8.89 | -1 | +24 | 8.79 | -10 | +14 | 8.66 | -13 | +1 | 8.49 | -17 | -16 |
| Padma | Bhagyakul | 6.30 | 6.52 | 6.62 | +10 | +32 | 6.64 | +2 | +34 | 6.58 | -6 | +28 | 6.49 | -10 | +19 | 6.37 | -12 | +6 |
| Padma | Mawa | 6.10 | 6.23 | 6.34 | +11 | +24 | 6.37 | +2 | +27 | 6.31 | -6 | +21 | 6.21 | -10 | +11 | 6.08 | -13 | -2 |
| Gorai | Gorai Rly Bridge | 12.75 | 12.16 | 12.11 | -5 | -64 | 12.04 | -7 | -71 | 11.97 | -8 | -78 | 11.81 | -16 | -94 | 11.63 | -18 | -112 |
| Gorai | Kamarkhali | 8.20 | 8.29 | 8.21 | -8 | +1 | 8.10 | -11 | -10 | 7.97 | -13 | -23 | 7.81 | -17 | -39 | 7.56 | -24 | -64 |
| Surma | Sylhet | 11.25 | 10.03 | 10.18 | +15 | -107 | 10.37 | +19 | -88 | 10.45 | +8 | -80 | 10.45 | -1 | -81 | 10.41 | -4 | -84 |
| Surma | Sunamganj | 8.25 | 7.52 | 7.51 | -1 | -74 | 7.48 | -3 | -77 | 7.44 | -4 | -81 | 7.39 | -4 | -86 | 7.35 | -5 | -90 |
| Kushiyara | Sheola | 13.50 | 13.07 | 13.57 | +50 | +7 | 13.93 | +36 | +43 | 14.09 | +16 | +59 | 14.11 | +2 | +61 | 14.08 | -3 | +58 |
| Meghna | Bhairab Bazar | 6.25 | 5.47 | 5.53 | +6 | -72 | 5.57 | +4 | -68 | 5.59 | +1 | -66 | 5.58 | 0 | -67 | 5.57 | -2 | -68 |
| Meghna | Baider Bazar | 5.18 | 4.31 | 4.43 | +12 | -75 | 4.48 | +5 | -70 | 4.46 | -2 | -72 | 4.41 | -5 | -77 | 4.33 | -8 | -85 |
| Meghna | Meghna Bridge | 5.03 | 4.05 | 4.19 | +14 | -84 | 4.25 | +6 | -78 | 4.24 | -2 | -79 | 4.18 | -5 | -85 | 4.12 | -7 | -91 |

Note:
1) 24 hrs. rise/fall indicates changes in water levels from today 6 A.M. to 11-9-2013 6:00 A.M.
2) 48 hrs. rise/fall indicates changes in water levels from 11-9-2013 6:00 A.M. to 12-9-2013 6:00 A.M.
3) 72 hrs. rise/fall indicates changes in water levels from 12-9-2013 6:00 A.M. to 13-9-2013 6:00 A.M.
4) 96 hrs. rise/fall indicates changes in water levels from 13-9-2013 6:00 A.M. to 14-9-2013 6:00 A.M.
5) 120 hrs. rise/fall indicates changes in water levels from 14-9-2013 6:00 A.M. to 15-9-2013 6:00 A.M.
6) + above means water level flowing above danger level, "-below" means water level flowing below danger level.

## Experimental Structure Based Forecast (24, 48, 72, 96, 12 hours) FFWC, BWDB, Supported by CDMP-II

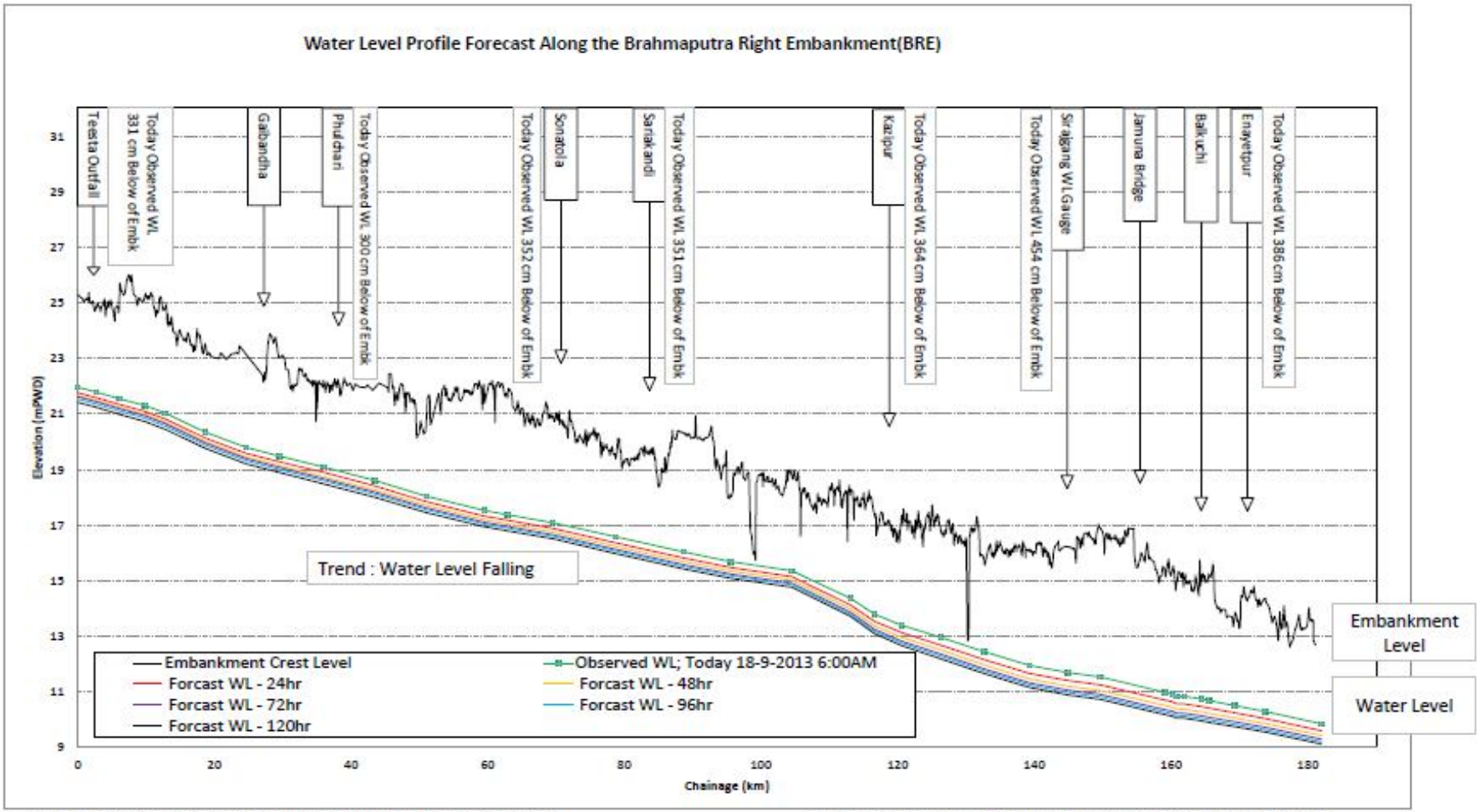
Generated on 18-09-3013; Forecast upto 23-09-2013 at 06:00 hrs




Note:
1) 24 hrs. rise/fall indicates changes in water levels from today 6 A.M. to 19-9-2013 6:00 A.M.
2) 48 hrs. rise/fall indicates changes in water levels from 19-9-2013 6:00 A.M. to 20-9-2013 6:00 A.M.
3) 72 hrs. rise/fall indicates changes in water levels from 20-9-2013 6:00 A.M. to 21-9-2013 6:00 A.M.
4) 96 hrs. rise/fall indicates changes in water levels from 21-9-2013 6:00 A.M. to 22-9-2013 6:00 A.M.
5) 120 hrs. rise/fall indicates changes in water levels from 22-9-2013 6:00 A.M. to 23-9-2013 6:00 A.M.

**Experimental Structure Based Forecast (24, 48, 72, 96, 12 hours) FFWC, BWDB, Supported by CDMP-II**

Generated on 18-09-3013; Forecast upto 23-09-2013 at 06:00 hrs




Note: 1) 24 hrs. rise/fall indicates changes in water levels from today 6 A.M. to 19-9-2013 6:00 A.M.

2) 48 hrs. rise/fall indicates changes in water levels from 19-9-2013 6:00 A.M. to 20-9-2013 6:00 A.M.

3) 72 hrs. rise/fall indicates changes in water levels from 20-9-2013 6:00 A.M. to 21-9-2013 6:00 A.M.

4) 96 hrs. rise/fall indicates changes in water levels from 21-9-2013 6:00 A.M. to 22-9-2013 6:00 A.M.

5) 120 hrs. rise/fall indicates changes in water levels from 22-9-2013 6:00 A.M. to 23-9-2013 6:00 A.M.