Development of the Flood Forecasting and Warning System in Bangladesh

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Abstract
Bangladesh has one of the largest and flattest river deltas in the world. Three major rivers, the Ganges, the Brahmaputra, and the Meghna, pass through Bangladesh, but 93% of their total catchment area of about 1.7 million sq.km. rivers lies outside the country in India, China, Nepal, and Bhutan. Bangladesh has an average annual rainfall of about 2,300 mm, with a range of 1,500 to 5,000 mm. It also has a unique coast line with a conical shape that causes the sea level to be higher during the monsoon months. As a result of the unique topography, river system, and rainfall pattern, floods occur in Bangladesh almost every year and devastating floods once every 5 to 10 years. Bangladesh has taken many structural and non-structural measures in order to manage floods. One of the main non-structural measures is its flood forecasting and warning system, which has undergone continuous improvement since the 1970s. What started as a very rudimentary system of food forecasting has now developed into a system which uses the most advanced real-time flood forecasting tools including the Mike'00 Hydrodynamic Model, which uses interactive GIS and can show flood inundation with a digital elevation map. This paper discusses the development of the flood forecasting and warning system in Bangladesh from its inception in the 1970s through to the latest and most advanced systems now in use.

Introduction

Bangladesh contains one of the largest deltas in the world with three major river systems, the Ganges, the Brahmaputra, and the Meghna, flowing through the country. The total catchment area of these three rivers is 1.7 million sq. km but nearly 93% of this lies beyond Bangladesh in Bhutan, China, India, and Nepal (Figure 1). The combined maximum flow of the two major rivers, the Ganges and the Brahmaputra, is about 120,000 cumecs and their estimated combined annual sediment flow is about 1.8 billion tonnes. Almost all of Bangladesh's land area was formed through siltation of these river systems. As a result, the land is very flat and prone to flooding every year. At times when there is excessive rainfall simultaneously in all three catchments, the flood situation becomes critical and can be devastating. At least 10 major flood events have occurred in Bangladesh during the last half century, and of these, four were devastating. The incidence of flooding has increased over the last two decades with an accompanying increase in flood damage compared to earlier floods. Since the early 1960s Bangladesh has implemented a good number of small, medium, and large flood control and drainage (FCD) projects and these now cover about 30% of the land area. Even so, these structural measures still cannot restrict flooding. Experience over the years has shown that complete flood control in a country like Bangladesh is neither possible nor feasible. Realising this, Bangladesh started developing a flood forecasting and warning system (FFWS) as a major non-structural measure for flood management.

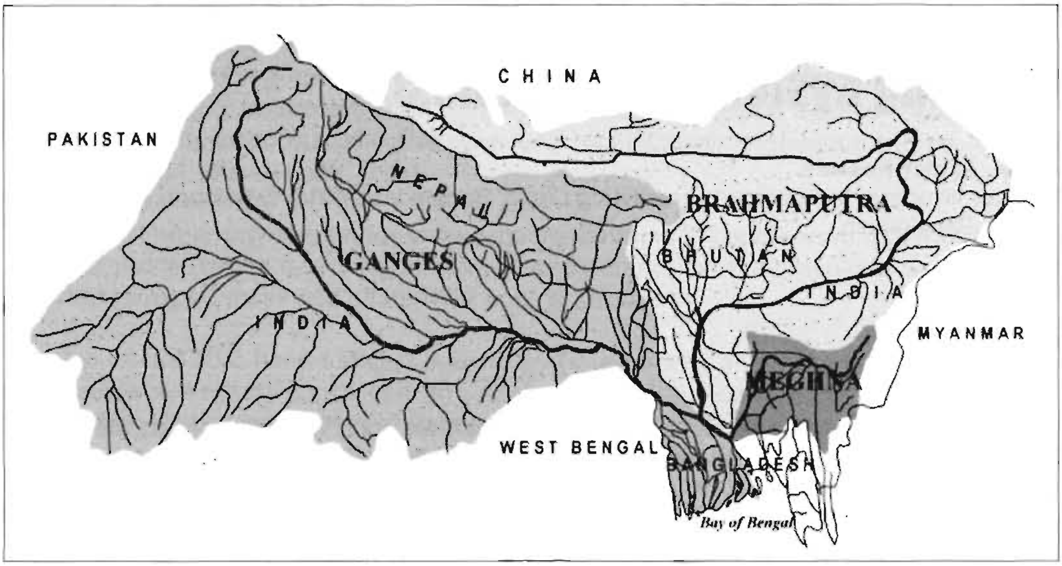

Figure 1: The Ganges, the Brahmaputra and the Meghna River Basins (Source: IWM & BWDB)

Types of Flood

Floods are generally classified according to their cause. In Bangladesh, four types of floods are common: river floods, rain-fed floods, flash floods, and tidal floods and floods due to storm surges (Figure 2).

River Floods

River floods are the most common type of flood in Bangladesh and occur in all three of the major river catchments in the country. When excessive rainfall occurs in the river catchments outside Bangladesh the river course cannot hold the flow within its banks and the water spills out onto the neighbouring flood plains. Overflow of the river banks is a very common phenomenon in Bangladesh. When the water level rises simultaneously in all three river catchments, the flooding can become devastating. In normal years about 30% of the land area is inundated, rising to about 50 to 70% in the case of devastating floods. The areas susceptible to river floods are shown in Figure 3. The flood in 1998 was the most devastating flood of the last century; it affected about 70% of the land area and lasted for 60 days, the longest time ever recorded. The major floods of the last 50 years are summarised in Table 1.

Table 1: Statistics of major floods since 1953

Year	Affected Area	
	sq.km	%
1954	36,800	25
1955	50,500	34
1974	52,600	36
1987	57,300	39
1988	89,970	61
1998	100,250	68

Flash Floods

Flash floods are characterised by a rapid rise and fall in the water level of a river. This type of flooding can occur in the flood plains, along the river course in hilly regions, and in foothill areas. Flash flooding occurs in all the transboundary rivers in the northern and the northeastern part of Bangladesh and in many rivers of the southeastern part of the country. The catchments of the transboundary rivers in the northern and the northeastern parts lie in India and flash flooding occurs as a result of excessive short-term rainfall in the Indian part of the catchments.

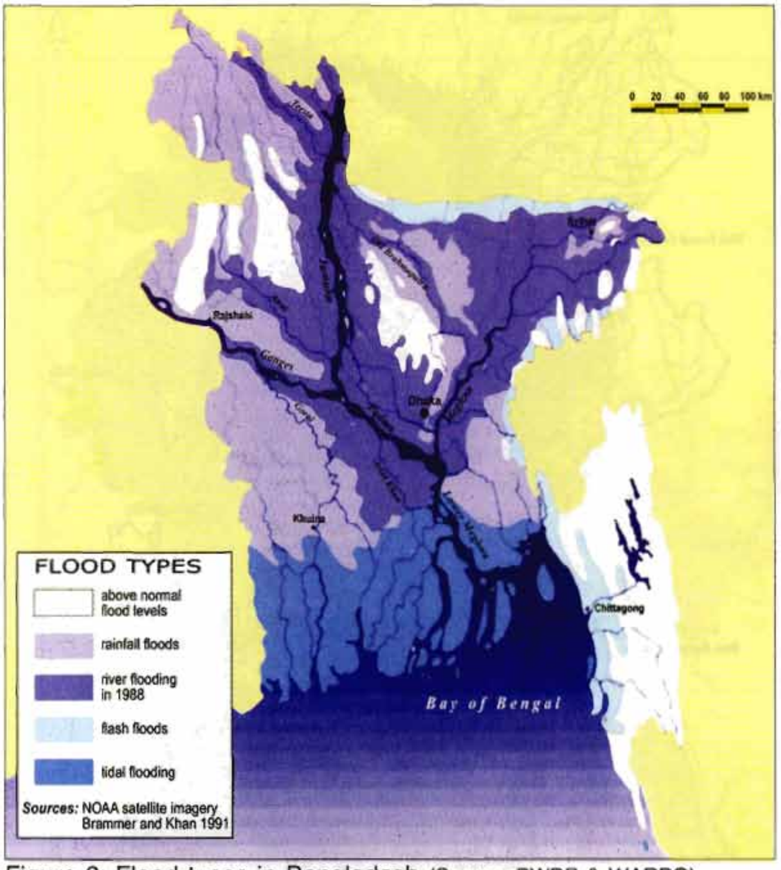

Figure 2: Flood types in Bangladesh (Source: BWDB & WARPO)

Rain-fed Floods

Rain-fed floods are most common in those parts of the country where the land elevation is relatively low and drainage is restricted. Occurrence of this kind of flood is increasing because the hydrological regime in the flood plains is changing as a result of unplanned construction of infrastructure like roads, bridges, culverts, embankments, and irrigation canals. Another important factor contributing to this phenomenon is the continuous reduction in flow in rivers and drainage channels which is leading to increased sedimentation and a concomitant rise in the bed levels. This situation can become critical when there is unprecedented rainfall inside or outside the country. One such unprecedented event occurred In September 2000 in the southwestern part of the country. There were heavy transboundary inflows resulting from extreme climatic events that occurred in some parts of Bihar and West Bengal, India. The overland flows entered Bangladesh following the natural topography, but runoff into the sea was obstructed by major changes that had taken place in the hydrological regime due to both natural and human interventions. Floodwaters, which are normally evacuated within days, stagnated for 2-8 weeks in some parts of the region. The natural topography and human interventions in the region are shown in Figure 4.

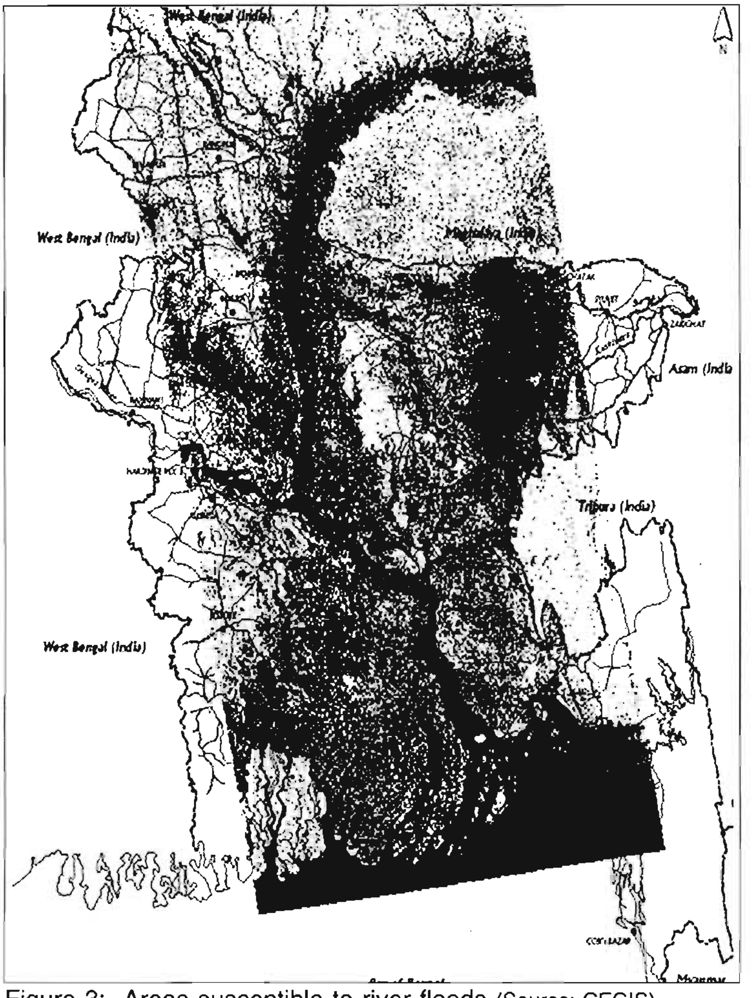

Figure 3: Areas susceptible to river floods (Source: CEGIS)

Tidal Floods

Tidal floods and floods due to storm surges occur in the tidal flood plains along the coastal areas of the country. The land elevation in the coastal areas is around 1-2 m in most parts, and the sea level rises by about 1m during the monsoon months, i.e. from June to mid-September. As a result, when the spring tide occurs during the monsoon, most of the tidal plains are susceptible to flooding. The situation is worse when storm surges occur at the same time as tropical cyclones. The loss of life which resulted from the storm surges and tropical cyclones of 1970 and 1991 exceeded a few hundred thousands. In order to prevent tidal flooding and provide protection against cyclonic surges, Bangladesh has started building polders all along the tidal estuary in the coastal areas of the country. In spite of this, newly accreted lands in the estuary and along the coast are still subject to tidal flooding. The storm surges that accompany severe cyclones still pose the threat of breaching the coastal polders endangering the lives of those in the high-risk zones.

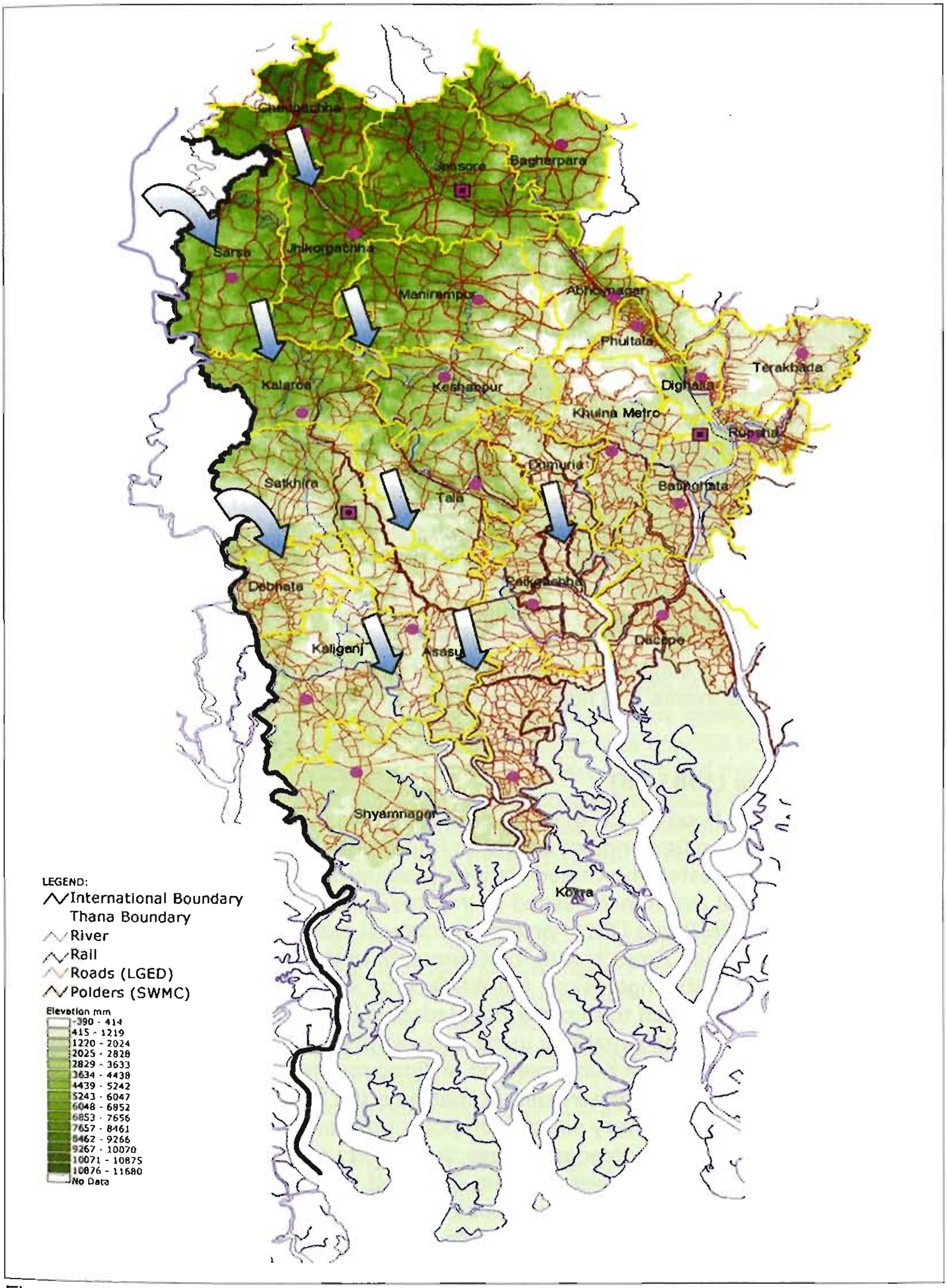

Figure 4: Natural topography and human intervention (Source: IWM & BWDB)

Development of the Flood Forecasting and Warning System

The FFWS in Bangladesh is in a state of continuous development. There have been four distinct stages of development during the past thirty years: an Initial Stage from 1972-80; a Second Stage from 1981-88; a Third Stage from 1989-99, and a Fourth Stage from 2000 up to the present.

The Initial Stage (1972-80)

During the 1960s, policy planners for water resources development and management considered that structural measures such as embankments and regulators were the most effective means of controlling flooding and did not consider any non-structural means of flood management. At the end of the 1960s and the beginning of the 1970s, policy planners realised that complete flood control is neither possible nor feasible and that whatever benefits could be gained by any flood control measures that were undertaken would take a long time to accrue. They also realised that if any major flood occurred, they would not be able to mitigate the suffering of the people. This realisation prompted policy makers to look for alternative flood management measures and eventually to come to the conclusion that a flood forecasting and warning system might be the most suitable non-structural alternative to mitigate flood losses and damage. The Bangladesh Flood Forecasting and Warning Centre (FFWC) was established in 1972 under the Bangladesh Water Development Board (BWDB). It started very humbly with only four flood monitoring stations: Bahdurabad and Serajganj on the Brahmaputra, and Hardinge Bridge and Gualnando on the Ganges. Initially the FFWC tried to develop an indigenous method based on past water level records to compute the travel time and flood attenuation. The main responsibility of the FFWC in the initial stage was to compile information on floods and publish annual reports on the flood events and flood damage that had occurred in different parts of the country.

The Second Stage (1981-88)

After the disastrous flood of 1974, which subsequently caused one of the worst famines on record, the Government sought to improve its flood forecasting services. The government requested the United Nations Development Programme (UNDP) to provide the technical assistance needed to improve flood forecasting and warning services. In 1977, WMO and UNDP provided technical assistance to the Hydrological Survey and Investigation Project, with improvements to the FFWS included as a small component. Realising its importance, the WMO came separately in 1981 to provide the technical assistance needed to improve Bangladesh's FFWS. WMO experts tried to develop a flood forecasting capability using a gauge-to-gauge statistical correlation method and the Muskinghum-Kunje method of flood routing. Initial tests did not succeed in developing a suitable model. At that time the first generation of desktop computers appeared. Using very simple computer programming, a straightforward, indigenous method for flood forecasting was developed using data from 10 water level stations, mainly on the major river systems. This first programme used only gauge-to-gauge correlation and the travel time of flood waves between the selected stations. This method enabled the peak water level and time to peak to be forecasted. During the disastrous floods of 1987 and 1988, this method was used to forecast the water level at the 10 selected stations.

The Third Stage (1989-99)

After the two consecutive devastating floods of 1987 and 1988, the government realised that non-structural measures like flood forecasting and warning systems can play a vital role in reducing flood damage and protecting human lives. Bangladesh's development partners took the issue of flood management seriously and they were determined to find non-structural means to mitigate flood damage. As a result of initiatives by the Organisation for Economic Cooperation and Development (OECD) countries, a flood action plan (FAP) was formulated. The United Nations Development Programme (UNDP) and the World Meteorological Organization (WMO) then commissioned the Danish Hydraulics Institute (DHI) to develop a flood forecasting (FF) model for Bangladesh. The DHI was already engaged in developing national and regional level surface water simulation models for the whole of Bangladesh. DHI customised the national and regional models to develop an FF model based on the NAM (rainfall-run-off) and System-II (hydrodynamic) models. A System II Model was developed on the basis of St. Venant's continuity and conservation of mass equations. During 1989-91, DHI developed the first deterministic FF Models and in 1991 flood forecasting was started for 16 water level stations. The lead times of forecast were 24 and 48 hours. The model performance was evaluated and the forecasts achieved a confidence level of greater than 90%. The FF model was further developed under the Expansion of Flood Forecasting and Warning Project (FAP 10) in 1995-99 and the number of forecasting stations was expanded to 30.

The Fourth Stage (2000 onwards)

Many lessons were learnt from the experience of the 1998 flood. People living in vulnerable communities wanted to receive flood information with adequate lead-time and they wanted the information to be made available to them in terms they could understand. They wanted to know when their homesteads were going to be inundated and for how long, in other words they were demanding area-specific flood forecasting. Moreover, many different groups were interested in receiving flood information. Many of these demands related to improved formulation and dissemination of flood information. As the credibility of the FF program grows, so does people's demands for information. With these demands in mind, the government is now trying to harvest the fruits of science for the benefit of society.

Work on the fourth stage was started in January 2000 under a project titled 'Consolidation and Strengthening of Flood Forecasting and Warning Services'; assisted by the Danish Agency for Development Assistance (DANIDA), and will continue until December 2004. The objectives of the project are:

- to improve the accuracy and lead time for flood forecasting;
- to upgrade the flood forecast model;
- to expand the real-time flood monitoring stations to all flood prone areas of the country;
- to improve the dissemination of flood information to vulnerable communities;
- to build up a sustainable institution; and
- to ensure transfer of technology.

All these activities have been started. The accuracy of forecasts has significantly improved, but so far it hasn't been possible to increase the lead time because of the lack of continuous access to upstream data on a real-time basis. Whatever data was available has been used to improve the boundary estimation of the model and thus improve the accuracy of forecasts. The FF model has been upgraded. It now includes the MIKE ZERO version, uses a Windows platform, and has many additional features like a geographic information system (GIS), flood inundation mapping (Figures 5, 6) geo-referencing of real-time data acquisition, forecasting points, and rainfall mapping (Figure 7), among others. The FF network has been extended to all flood prone areas of the country and now has 50 forecast points and an additional 30 monitoring points. Although flash floods continue to plague many parts of the country, it has not been possible to develop a reliable forecasting system for this kind of flood everywhere. However, work is continuing to improve the warning system for water levels on a real-time basis using modern technology.

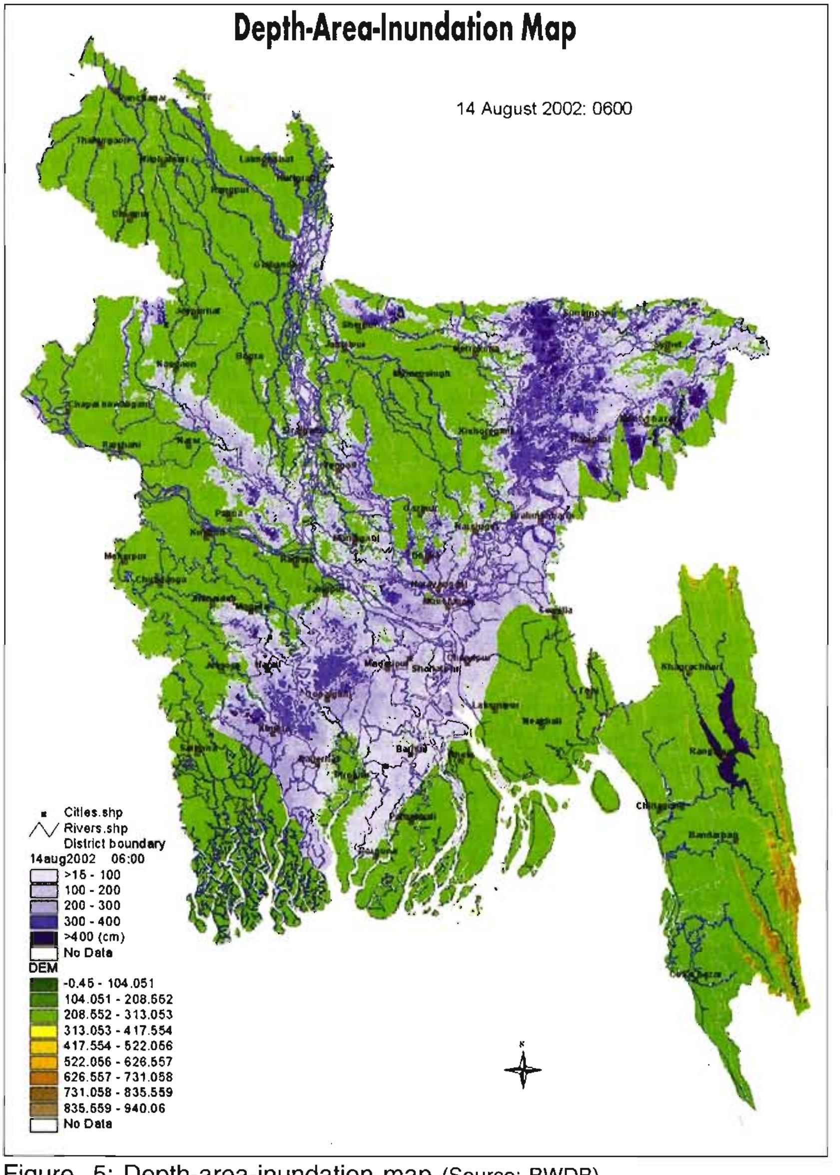

Figure 5: Depth-area-inundation map (Source: BWDB)

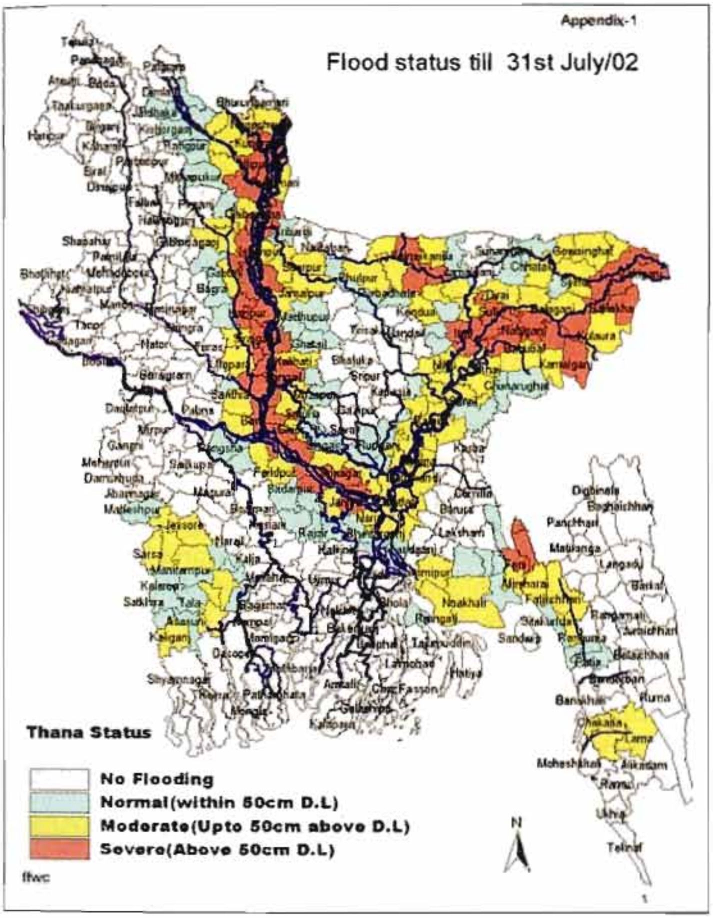

Figure 6: Daily flood status map (Source: BWDB)

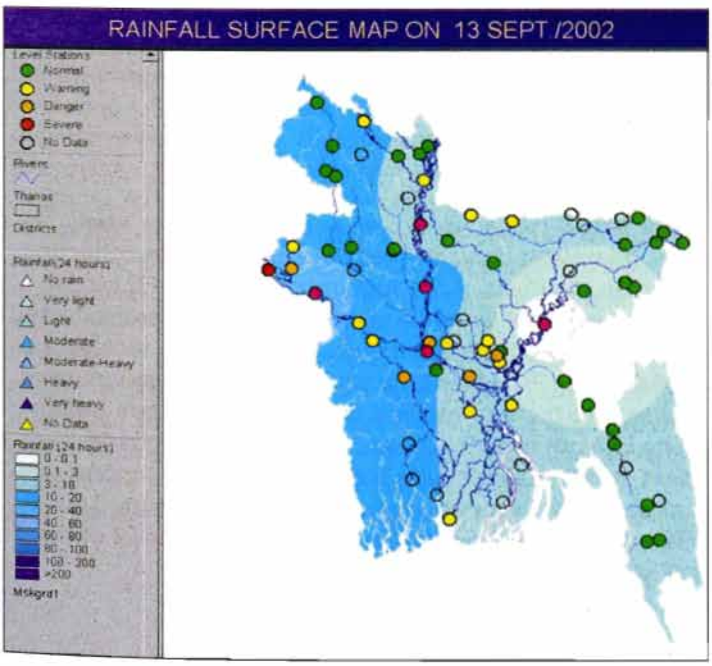

Figure 7: Daily rainfall distribution map (Source: BWDB)

Evaluation of the Flood Forecasting and Warning Services

Flood forecasting period

Flood forecasting and warning activities are mainly conducted during the monsoon months of June through September. In the beginning, there were no strict guidelines or rules governing the activities of the FFWS. Currently, these activities are conducted as per directives laid down in the government's 'Standing Orders on Disaster Management, 1994'. Both the field offices and the FFWC itself are closely involved in all the activities related to FFWS. The FFWC remains open every day during this period and 24 hours a day during extreme flood events.

Flood Forecasting Methods

Over the past two decades, Bangladesh has markedly improved its FFWS and now uses very sophisticated FF models. Maintenance of the models requires much care and attention, especially since the model was developed to cover almost the entire river system of the country. The model inputs include water level, discharge, river cross section, topography, soil information, and vegetation. The rivers of Bangladesh are morphologically very active and dynamic and many morphological features change continuously. Moreover, with the continuous developments in the flood plains, topographical features are also prone to change. If these changes are not incorporated in the models at regular intervals, the performance of the model will deteriorate. Model performance has been continuously evaluated since 1991. The absolute mean error of the forecast was relatively high during the early stages in 1991 and 1992, went down in 1995, '96, and '97, and again increased after the 1998 flood. This later increase suggests that changes occur every year in a dynamic process and that if the model is not updated regularly the results will be compromised.

Boundary Estimations

Boundary estimates for the model are very important since most of the major flows come from transboundary rivers. The quality of forecasts depends in part on the accuracy of the boundary estimates. The quality of boundary estimates depends on the flow range; they have been improved recently with some limited data from upstream.

Data Transmission from the Field

The Hydrology Organisation of the BWDB has an extensive network of water level, rainfall, flow, sediment, and water quality stations all over the country. Data collection from the field has been established on the basis of the requirements of the FF model; real-time operation of this model requires that water level and rainfall data are collected regularly. The FFWC starts its daily activities from 6 a.m. when it begins by receiving daily water level gauge readers' data from 70 water level stations. Gauge readers send the 6 a.m. water level data together with the four records of the previous day's 3-hour data. Rainfall records for the 24 hours ending at 9 a.m. are also collected from 46 stations. Most of the data are sent by SSB (single side band) wireless sets; more recently mobile phones are also being used. A pilot telemetry network covering 16 stations was established in 1996 and is used mainly to monitor the water level of the major rivers at border stations (Figure 8).

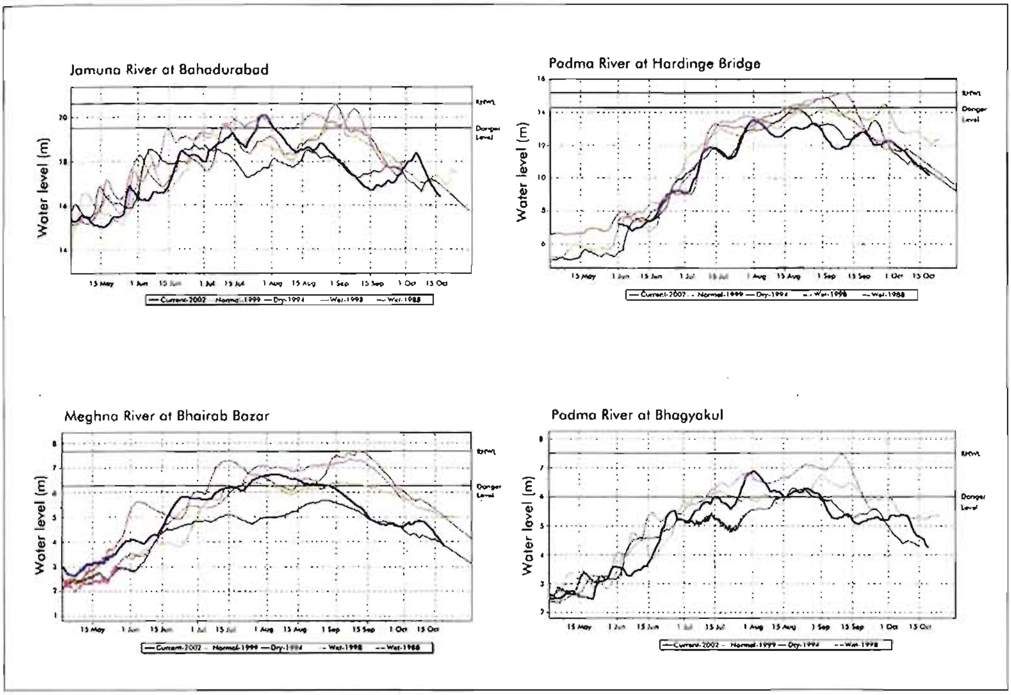

Figure 8: Water level hydrograph for major stations

Flood Forecast and Warning Dissemination

Over the past 20-30 years, Bangladesh has recognised that an early warning system can save lives and property by helping the mobilisation of an advance disaster preparedness programme – as amply demonstrated during the floods of 1987, 1988, and 1998. FFWC disseminates flood information daily using different media including the Internet, fax, and telephone. The FFWC flood information dissemination has certain limitations, however. Whereas timely information is provided to different government departments, agencies, disaster managers, NGOs, and the news media, the poorest and most vulnerable are sometimes missed. A recent study by the Centre to assess the response to its information by people living in flood prone areas showed that the most vulnerable communities often have no effective means of receiving timely information. In spite of the fact that the technological level of flood forecasting in Bangladesh, as in many countries, has reached a high degree of sophistication, the dissemination of this information to the vulnerable communities is still wanting. This aspect of flood information dissemination needs serious attention and here local government organisations (LGOs) and community-based organisations (CBOs) can play an important role. Bangladesh has had a successful experience with its cyclone preparedness programme where these organisations were involved. At present, pilot studies are being conducted to discover the best way for disseminating flood information in a timely fashion to vulnerable communities.

Conclusion

In order to maximise the benefits of timely flood forecasting information, the requirements of the different users needs to be examined carefully and met judiciously. Moreover, it will always be important to remain vigilant in providing accurate and timely forecasts for a country like Bangladesh, which is a lower riparian country with three major river systems and drains huge run-off from large catchments. The extent to which close cooperation can be developed among the co-riparian countries will also determine the extent to which the lead-time and accuracy of flood forecasting can be improved. Timely dissemination of flood information to the vulnerable communities is vital to the success of the flood forecasting and warning system of any country. It is also important to keep pace with technological innovations, which requires continuous updating of the technical capacity.

Reference

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