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Forecasting and warning of water related disasters in a complex hydraulic setting the case of Bangladesh

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Abstract

Bangladesh is situated in the active delta of the world's three major rivers- the Ganges, the Jamuna and the Meghna. Occurrence of water induced disasters is a regular phenomena in Bangladesh. The various types of disasters, all related to water, are floods, cyclones, erosion and sedimentation in rivers, salinity in the estuaries during low flows, degradation of water quality etc.

Reducing the magnitude of damage to life and property and minimising environmental impacts has been the major concern of disaster management activities in Bangladesh. Due to the complex nature of the river system and their hydrological / hydraulic characteristics, the tasks of predicting the effects of disasters and planning and designing mitigation measures are quite difficult. However, recently, use of mathematical models has been found to be very promising in studying the processes of various water induced disasters and evaluating alternative mitigation measures- both structural and non-structural.

This paper presents an overview of mathematical models developed and applied to study and predict floods and cyclones. Practical examples of model applications to disaster management and mitigation activities are presented.

INTRODUCTION

Decision makers world wide face a difficult challenge in developing an effective response to the threat of water induced disasters. In Bangladesh, this task is more complex not only because of the multitude of water induced disasters but also due the very vulnerable geographic setting of the country (see Figure 1). Major parts of Bangladesh occupy the deltaic plain of the Ganges-Brahmaputra-Meghna river system. Bangladesh is criss-crossed by a labyrinth of rivers. Being located at the lowest reach of the fluvial system, the reaches of Bangladesh rivers have various multivariate environmental controls which are associated to various water induced disasters. They range from basin-wide control variables to local conditions.

Bangladesh through its intricate network of river system (Figure 2) drains a catchment of about 1.76 million sq.km. of which only 7 percent lies within its territorial limits. The characteristics of the rivers are different from one region to the other. Flood problem in the Ganges area in Bangladesh is mainly due to over bank spilling. The flood situation deteriorates when the Brahmaputra remains in spate forcing backwater into the Ganges. Flooding in the Brahmaputra is characterized by large scale inundation of its banks, erosion at various places and conveyance of heavy silt load from upstream. In the north eastern part of the country, the water level of the Meghna is controlled by the high water level of the Padma during the flood season.

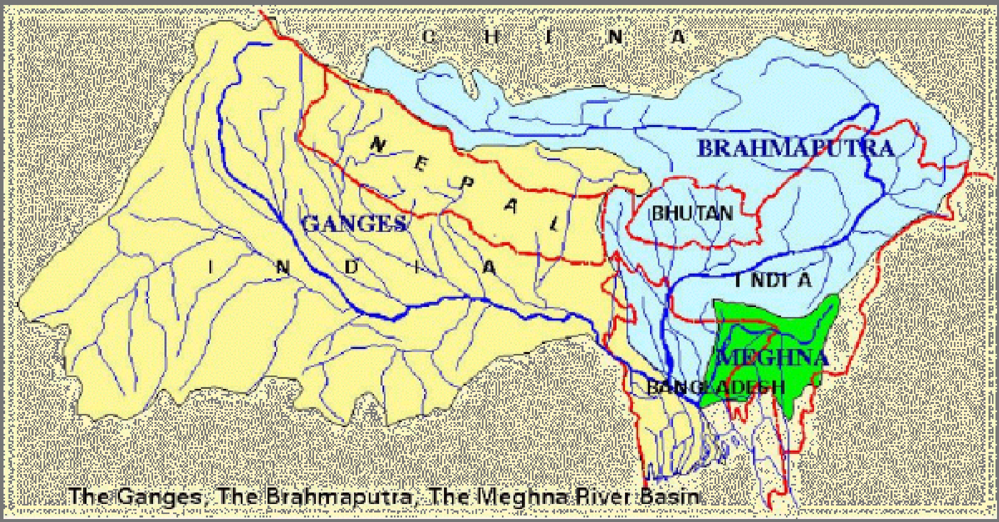

Figure 1. The Regional Setting.

In order to understand and predict the behaviour of the complex hydrological/hydraulic phenomena of the river systems, modern information technology based models have been developed and applied in Bangladesh. These models have been used to study some of the water induced disasters and to evaluate alternative measures adopted in disaster mitigation. Figure 2 shows the various regional models developed and applied for the purpose of studying water induced disasters in Bangladesh.

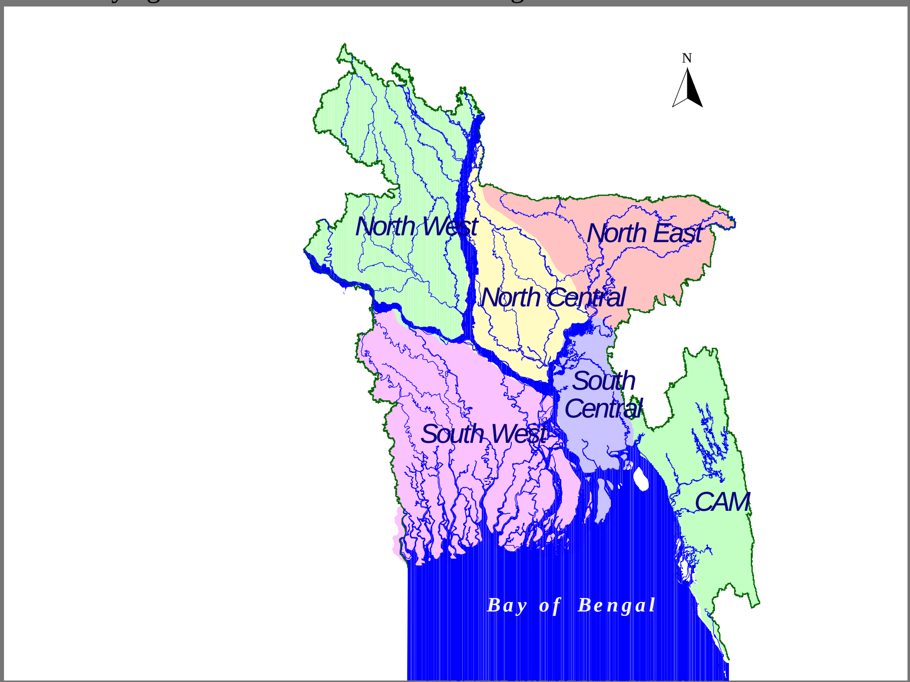

Figure 2. River Network Showing Regional Hydraulic Model Areas.

FLOOD DISASTERS

Every year during the monsoon season catastrophic flooding occurs in Bangladesh. The recent floods of 1998 have been of unprecedented magnitude and duration. Colossal damages to crops, property and infrastructure and losses of life have been reported. Opinions about the causes of flood events are highly divergent. Besides the natural reasons, the causes often sited range from deforestation in the upper catchments in Nepal and India to misuse of flood plains and inappropriate river control structures.

The country is subject to four types of flooding:

1. **River Flooding:** The major rivers slowly rise from snow melt in the Himalayas and the high regions to the north. As the flood waters arrive from upstream, locally heavy rains help increase the river levels. The rivers can be above flood stage anywhere from a few days up to several months.

2. **Flash Floods:** Heavy rains in the Khasia, Jaintia, Garo and Tripura Hills cause local rivers and small streams to rise to dangerous levels within six to twelve hours. In addition, heavy and continuous rains can cause flash flooding in local areas.

3. **Urban Flooding:** Locally heavy rains of 100 mm or more over the cities and larger towns can cause damaging and disruptive flooding as a result of poor or blocked drainage and rapid runoff.

4. **Tidal Or Storm Surge Flooding:** On the average, 12-13 tropical disturbances develop in the Bay of Bengal every year. Of these, five develop into cyclones and cross surrounding coastlines with the possibility of one of these storms curving towards Bangladesh. Cyclone-induced storm surges have devastating consequences for Bangladesh and the surge induced floods may extend as far as 200 km inland.

The Bangladesh coast has been hit by 14 major cyclones over the last 35 years causing large scale loss of human life, livestock and severe damage to crops, properties and infrastructure. While some coastal areas are protected by a network of embankments, they provide only partial protection from storm surges and resulting floods. A compilation of damages caused by the 1998 Flood is shown in Table 1.

FLOOD FORECASTING AND WARNING

Flood mitigation options planned and implemented in the past have been very controversial. However, since, it is neither possible nor desirable to control the floods completely, a new approach of flood management based on information technology has been recognised as the most effective measure to reduce flood damages. Flood management includes flood forecast and advance warning.

Flood Forecasting is the Prediction of water levels, areas and depths of flooding in rivers and flood plains. Flood Warning is the preparation of forecasts in a meaningful format which can be numerical or visual. In order to be effective, the warning has to be disseminated to media for broadcast, to concerned organisations who are prepared to provide relief, and to vulnerable communities.

Table 1. Damages Incurred in the 1998 Flood (Imtiaz Ahmed, 1999).

Total Area Affected	100,000 sq. km.
No. of Districts	52
No. of Police Stations	366
No. of Affected Union Parishads	3,323
No. of People Affected	3.1 million
Affected Standing Crops	1.4 million acres
No. of Affected Homesteads	980,000
No. of Death	980
Cattle Heads Killed	26,000
Road Damaged	16,000 km
Embankment Damaged	4,500 km
No. of Damaged Bridges/Culverts	6,890
No. of Affected Educational Institutions	1,718
No. of Flood Shelters	2,716
No. of People Taken Refuge	1.05 million

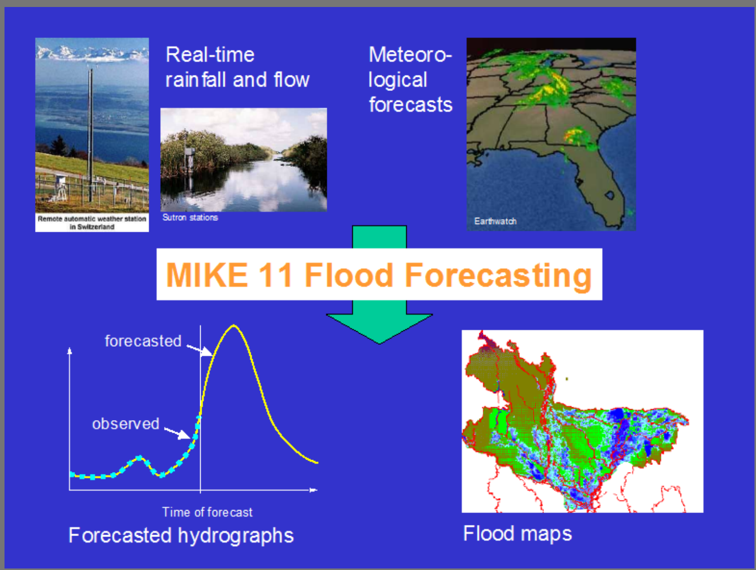

Figure 3. Model Based Flood Forecasting System.

For the purpose of reliable flood forecast and timely warning computer based advanced mathematical models have been developed and implemented in Bangladesh. The main input to the flood forecasting model is real time data on rainfall and water levels at various key locations (model boundaries and forecast points). The output is forecast of water levels at key location in the river systems as well as possible area inundation on a GIS (see Figures 3).

The first step in flood forecasting is the collection of real time data. In Bangladesh a real time data network is developed as shown in Figure 4. Data from 60 water level and rainfall stations are entered in the field and transmitted to the Flood Forecasting and Warning Centre (FFWC) located at Dhaka every morning. After a quality check the data is transferred to the database and then to the modelling system which includes the Mike11 model and the Flood Watch System. The model is calibrated based on recent observed data (Figure 5).

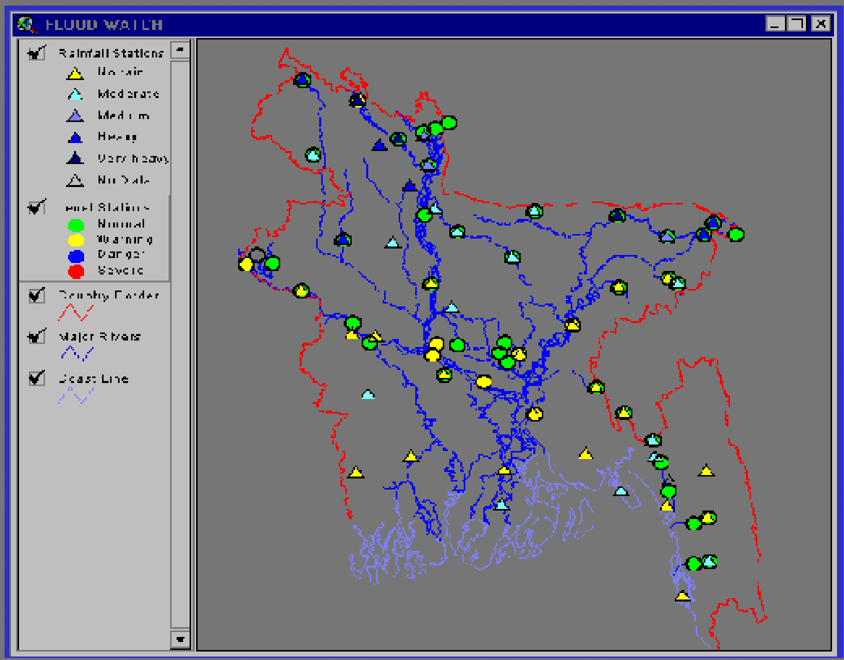

Figure 4. Real time Data Network of Bangladesh.

RIVER SEDIMENTATION

The rivers of Bangladesh carry a huge sediment load causing adverse effects on the conveyance capacity of river channels and hampering water transport activities. While the country is ideally suited to river transport from an economic and environmental viewpoint even during periods of flooding, sedimentation of the rivers poses severe constraints on the reliability of the navigation routes and ferry crossings.

One of the very serious effects of river sedimentation has been observed at the off-take of the Gorai River. It is the main distributary of fresh water from the River Ganges which serves the south west region of Bangladesh including the Sunderbans. In recent years it has been drying up and is now closed for several months every dry season due to substantial sedimentation of the river at its off-take from the Ganges. The funnel shaped wide mouth and tortuous planform of the Gorai point to a dying river and all indications are that the Gorai in the near future will become detached from the Ganges. Such a situation will cause catastrophic damage to the agro-socio-economic conditions, ecology and environment of the whole south west region. It will also affect adversely the sustainability of the world’s largest mangrove forest, the Sunderbans.

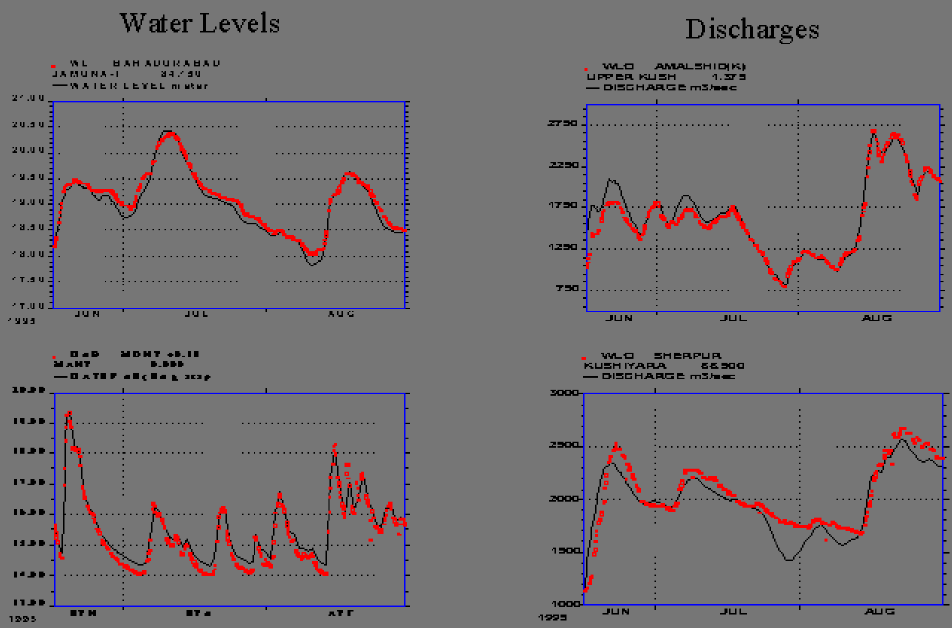

Figure 5. Model Calibration.

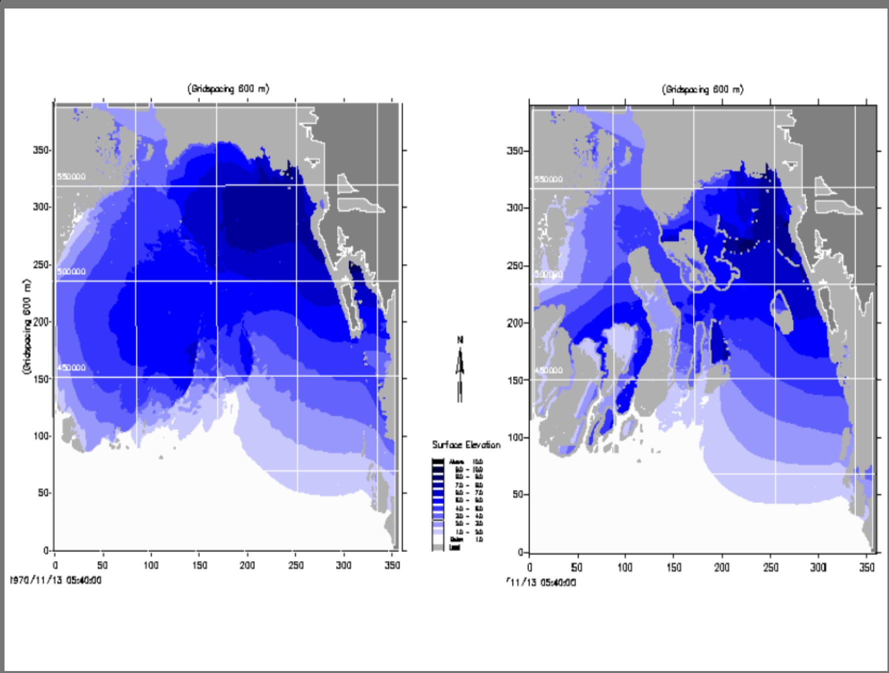

Figure 6. Simulated 1970 Cyclone Induced Floods with and without Embankments.

A set of mathematical morphological models (one and two-dimensional) have been developed for the Ganges-Gorai system to study the sedimentation process as well as evaluate alternative options considered for the restoration of the Gorai river. The restoration options including dredging of the river mouth and provision of river training structures.

CYCLONES

A mathematical model has been developed to simulate the storm surges and resulting inundation depths and extent inland. A two dimensional hydrodynamic model based on the MIKE21 system has been developed to cover the bay of Bengal and the cyclone affected coastal region. As an example of the model out put, Figure 6 shows simulated floods depths during the cyclone of 1970. The model has been applied to indicate high risk areas of the coastal region for planning cyclone shelters as well as in designing coastal embankments. Various scenarios to prevent inundation have been investigated. This model has also a potential use in real time forecasting of storm surges and induced flooding.

CONCLUSION

A suite of mathematical models, based on the modern information technology have been developed and applied in Bangladesh to study the various water induced disasters. These models are used in providing reliable and timely information on the effects of the disasters. The models are also being used in planning and management of both structural and non-structural disaster mitigation measures.

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