Modelling of Urban Flooding in Dhaka City

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Abstract

Flooding in urban areas is an inevitable problem for many cities in Asia. In Bangladesh, Dhaka has serious problems related to urban flooding. The situation was highlighted in September 1996 when residences experienced ankle to knee-deep water on the streets. Daily activities in parts of the city were nearly paralyzed and heavy traffic jams occurred due to stagnant water on the streets.

The study has depended on a combined approach of physically based modeling and GIS. The urban drainage is structured by MOUSE for the basis of two networks, one simulating the free-surface flow over the streets and one for the sewer pipe system. The interaction between street and pipe system is modeled in a simple way, but allows for a detailed representation of the real-life situation in which free-surface flows over the streets are significant.

In 1997, Surface Water Modelling Centre carried out a pilot study about Storm Water Drainage Modelling for Dhaka City. This study is performed as an extension and improvement of pilot study in terms of updating and analysing drainage system together with suggestion of alleviation scenarios to relieve flood problems, i.e. feasibility study of applying real time control to urban drainage system to reduce flood problem.

Keywords:

ArcView, DEM, Dhaka, flood inundation map, GIS, modeling, MOUSE, real time control, urban flooding, urban drainage.

Introduction

Dhaka has experienced water logging for the last few years. Even a little rain may cause severe problems for certain city areas, which are inundated for several days. The water depth in some areas may be as much as 40-60 cm, which creates large infrastructure problems for the city and a huge economical loss in production together with large damages of existing property and goods.

The city of Dhaka is protected from river flooding by an encircling embankment. Most of the time during the monsoon season the water level in the river remains higher than the water level inside the city area, consequently the city drainage depends very much on the water levels of the peripheral river systems. The situation becomes worse when monsoon runoff generated from short duration and high intensity rainfall combines with high water level in river system. Main causes of floods in Dhaka City can be classified into two types. The first one results from high water level of peripheral river system and the other caused by rainfall in the city. Flooding in Dhaka City in 1996 caused by local high rainfall occurred in the built-up areas of the city. The severe water logging in September 1996 is believed to originate from insufficient drainage capacity of drainage system.

Description of the System

Segunbagicha canal catchment includes the most important commercial areas and the government offices of Dhaka City, hence most of areas are impervious. Collected stormwater from each sub-catchment is drained by sewer pipes to Segunbagicha canal and finally it is drained to river system by pumps at the basin in front of the sluice gate, as shown in Figure1.

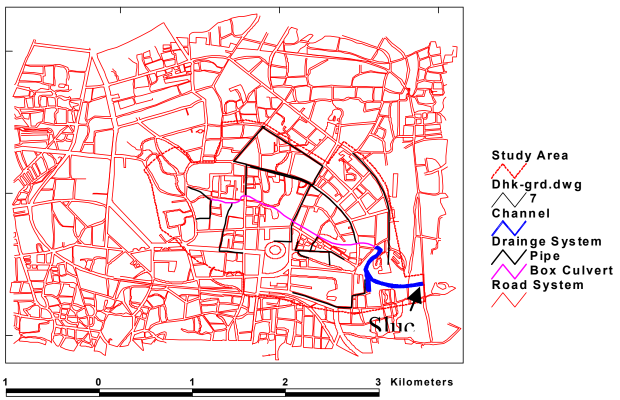

Figure1 Drainage System in Study Area

Developing of DEM

DEM represents land elevation data, which are crucial for estimating storage volume of surface flooding. In addition, result presentation in form of flood inundation map is performed based on application of ArcView and the DEM.

Hence, the quality of the output depends on the quality of the DEM. Available DEM from pilot project has 50 m resolution, which is too rough for urban flooding analysis as the dimension of typical features in the city are around 5-20 m. By using 50 m resolution, which cannot cover significant details in study area, it may lead to inaccurate results. Establishing new DEM with the resolution of 5 m, which yield sufficient accuracy is performed based on the application of MIKE 11 GIS. For simulating real-life situation of urban flooding, the major roads, where floods occur are included in the DEM. Figure 2 shows the developed DEM with road system.

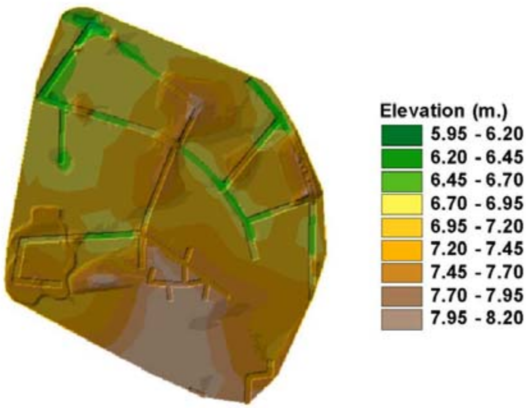

Figure 2 Developed DEM with Major Road System

Storage of Surface Flooding

If water from pipe network flows through manhole and reaches ground level of street, then surface flooding will take place. The surface area of surface flooding is gradually increased following the DEM and hence describing the rising water level along the street, therefore simulating the surface inundation. To find storage capacity of surface flooding as input of the model, area – elevation relation is required for MOUSE input data. This relation is developed from DEM with the application of MIKE11 GIS.

Simulation of Urban Drainage System

- **Simulation of September 1996 Flooding**

The analyses of the 1996 and present urban flooding problem and the development of the technical solution for the problem alleviation have been carried out based on the load of the September 1996 rain events. In 1996, box culvert could not be implemented at some locations due to land dispute problem between the government and public. Collected stormwater was drained along box culvert to the pond, the water flowed along open channel to the basin in front of the sluice gate as shown in Figure 3.

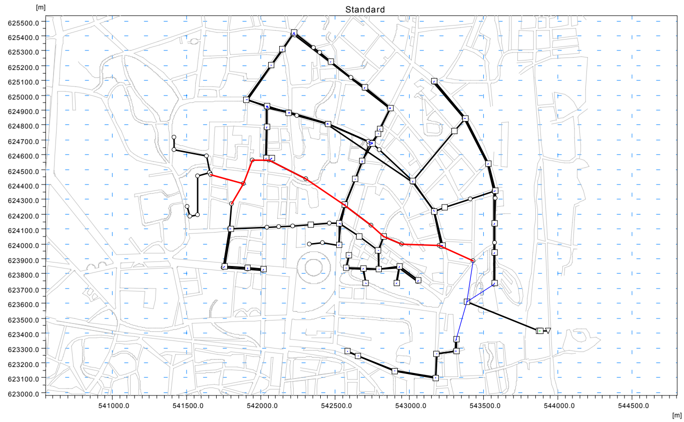

Figure 3 Drainage System in 1996

The pump with capacity of 2.55 m3/s started operating when water level in the basin reached 3.8 m and stopped when water level reached 1.4m. The sluice gate was closed whenever water level in river system remained higher than water level in the city side.

- **Simulation of Present Flooding**

As an extension of September 1996 condition, the drainage system has been improved by complete construction of box culverts, replacing the open channel parts. To provide more downstream storage capacity and prevent backwater effect, the pump is operated when water level reaches 3.8 m and stopped when water level reaches 0.3 m.

The results of simulations of the 1996 and present drainage system are identical and they have shown a pronounced deficit in drainage capacity which results in flooding of large areas as shown in Figure 4. The simulated flood depths both 1996 and presnt condition achieves locally (Shantinagar) up to 55 cm and the inundations lasts approximately 16 hours. The reason of significant local flooding and flows in the streets is due to an insufficient upstream drainage capacity of sewer pipe and manhole.

Alleviation Schemes

An attempt was made to identify the possible alleviation scenarios for the present drainage system. The following measures were carried out.

- **Applying of Real Time Control to Drainage System**

A concept of real time control may be used as a tool to reduce flooding. An urban drainage system is operated in real time if process data, e.g. water level or discharge currently monitored following local site situation are used to operate the pump in the real-life situation. To utilize the existing capacity of drainage system efficiently, the pump in front of sluice gate is operated according to water level at inundated area, Shantinagar crossing. When flood occurs at problem area, the pump will be operated to provide downstream storage capacity. However, the result of simulation can be concluded that applying real time control to this drainage system cannot relieve flood problem because upstream drainage capacity of pipe and manhole are insufficient.

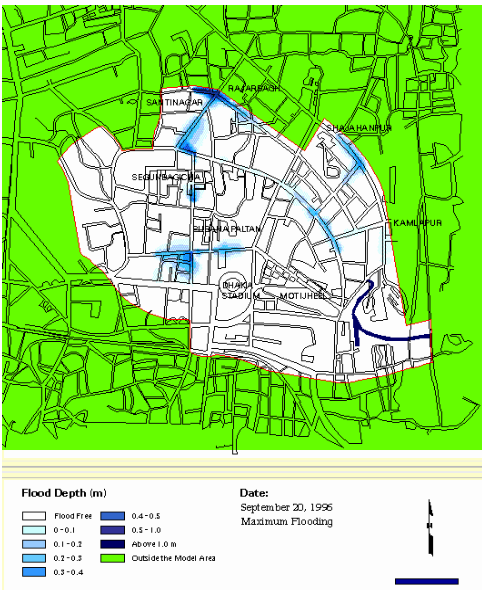

Figure 4 Inundated locations in Study Area

- **Increasing of Drainage Capacity**

The reason of long lasting flood situation in study area is owing to inadequate drainage capacity, meaning of small pipe and inappropriate lining of pipe. These lead to backwater effect including bottleneck problem. Hence, increasing the pipe diameter and realigning of pipes at flooded locations are carried out. Compared to the present condition, the simulated maximum depth and flood duration at each locations are shown in Table 1.

It can be concluded that the main concept of solving the urban flooding in this area is to improve the drainage capacity locally. Applying real time control and increasing pump capacity cannot alleviate flood situation unless upstream drainage capacity is improved.

Table 1 Comparison between Present Condition and Increasing Drainage Capacity

Implementation in terms of Maximum Flood Depth and Flood Duration

Implementation Scheme	Shantinagr Crossing		Kakrail Crossing		Topkhana Road		Pirjangi Mazar	
	Max. Depth (cm.)	Duration (hour)	Max. Depth (cm.)	Duration (hour)	Max. Depth (cm.)	Duration (hour)	Max. Depth (cm.)	Duration (hour)
Present Condition	55	16	19	6	25	12	18	9
Increasing Drianage Capacity	42	7	13	5	15	8	15	9

Result Presentation

The model results are geo-referenced and related through a coordinate system common with the DEM grid. The results are presented in the GIS system as flood inundation maps, based on the water levels computed by the urban drainage model. This has been chosen as Flood Inundation maps provide a most effective media for visualizing flooding. Results (ere water levels) from the simulation are available in the streets and along the pipes as shown in Figure 5.

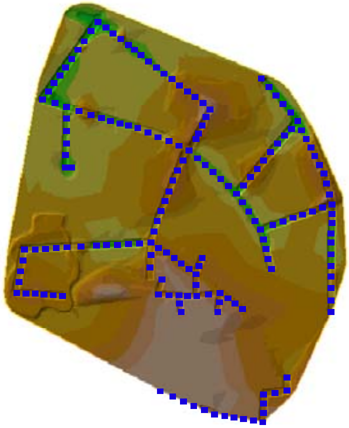

Figure 5 Locations of Simulated Water Level along the Streets

The water levels on the streets mainly cause flooding on the streets and the adjoining areas. Using interpolation routines in MIKE 11 GIS continuous 3-D water surfaces were constructed based on the simulated street water level. The DEM elevations were subsequently subtracted from the water level surface delineating inundated areas by flood extent and flood depth. The maximum flooding at present condition as inundation map is shown in Figure 6.

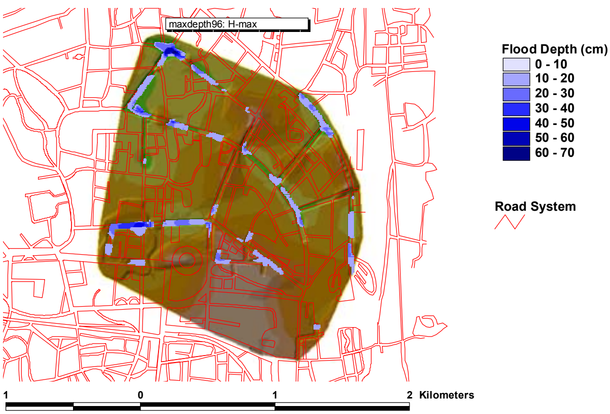

Figure 6 Simulated Flood Inundation Map with Maximum Flooding at Present Condition

For better understanding of alleviation scheme, a comparison between present and increasing drainage capacity implementation is show in form of flood inundation map as shown in Figure 7.

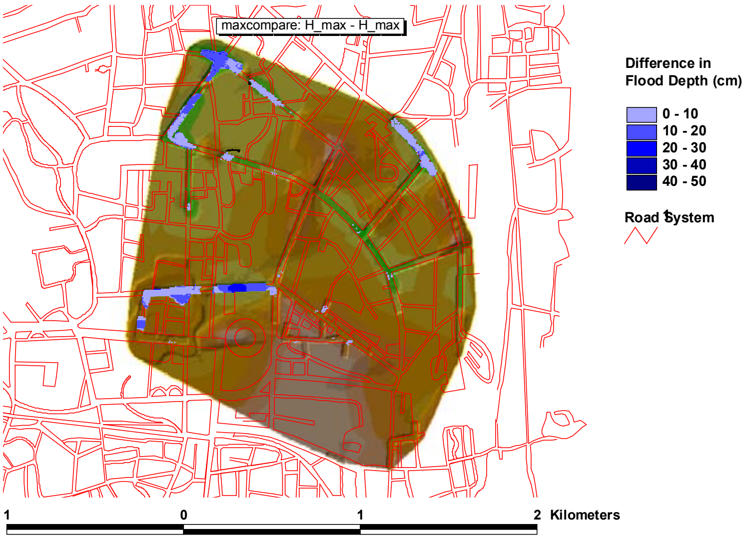

Figure 7 Difference of Flood Depth between Present Condition and Increasing Drainage Capacity Implementation

Conclusion

The study of urban flooding in Dhaka City has proved the capacity of the modeling system for urban drainage in a combination with GIS as a powerful analyses tool for urban flooding problems. A special modelling technique was applied, where a hydrodynamic model built in two layers describes both flows in pipe and street network. The analyses of urban flooding problem and the development of the technical solution for the alleviation schemes have been carried out based on simulating the system performance by MOUSE. With the application of GIS and model results, a simply understandable result presentation in form of flood inundation map can be carried out. Further integration of mathematical modeling and GIS will contribute to even more cost-efficient and versatile studies in the future.