IMPACT ASSESMENT OF ROAD CONSTRUCTION ON THE FLOOD INUNDATION IN DHAKA, BANGLADESH

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ABSTRACT

Dhaka, the capital and the most populated city of Bangladesh, is now one of the largest cities with high populated density in the world. Dhaka is surrounded by some satellite cities and the urban growth may cause several effects upon the environment. Increase of inundation area is one of the most serious problems in Dhaka. The aim of this study is to evaluate a future urban development from the view point of flood inundation. 2D model has been selected as simulation model and verification has successfully done by adding rainfall and evaporation values. To confirm the future development, an interview with the government official of Bangladesh who is responsible for the urban development was conducted. It is clear from the interview that the main factor of the urban growth is the road and highway construction. Therefore, Strategic Transportation Plan (STP) has been selected as the future scenario for the simulations. The simulation in the future scenario is conducted by inputting the location of roads and highways. The result shows that the inundation condition will be changed after construction of the new road and highway. To evaluate the situation from the view point of residents, the interview was conducted to 10 people. According to the result of the interview, the residents in those areas are damaged by flood every year and they have to evacuate for the period of 3 months. It causes damage to their economic and daily life and if the duration becomes longer, they will suffer from worse situations. However, the result of the simulation shows that depth of inundation will keep flow capacity if outlet (bridges) is added to the new road with 4500m interval. It should be noted that this evaluation is made on the condition the land-filling works is not done in the wetland. Therefore if this condition is changed, the situation will change worse accordingly. The government should make the strict guideline for the future land filling and development.

Keywords: Inundation simulation, Interview, Road construction

INTRODUCTION

Dhaka, one of the most populated cities in the world, is facing rapid urban development. The urban growth may cause several effects to the environment and the increase of flood damage is one of the most serious problems in Dhaka. Some government officers of Bangladesh are seriously worried about its effect on the drainage capacity. It is necessary to evaluate future development which may cause adverse effect to the changes of

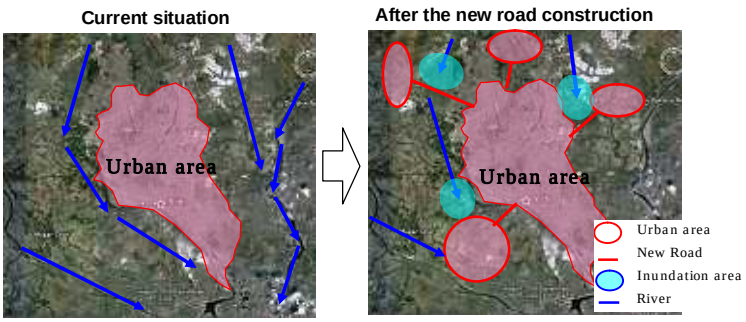

Fig. 1 The problem in the future

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drainage capacity (Fig. 1). The effect on the capacity of flood protection is one of the important issues which government has to consider. There is a possibility that future development will cause drainage congestion and reduce drainage capacity during a flood. The aim of this study is to evaluate the road construction, which is one of the important factors of urban development from the view point of flood inundation.

METHODOLOGY

This study has three parts of analysis, which are simulation, interview to the government and interview to the residents (field survey). Firstly, the suitable model for inundation simulation in Dhaka is selected. Secondary, interview with the government officials who are responsible for urban development in Dhaka is conducted to decide the urban development scenario. Thirdly, interviews have conducted with the residents who have experience of flood. Finally, the simulation in future urban development scenario is conducted.

Outline of Interview with the residents

Interview with residents was conducted to see the situation of the flood and their factor of the problems. By questionnaire, it is impossible to listen to their detailed information. On the interview, the detailed information and situation can be known through face-to-face talk.

Outline of Interview with government officials

Interview with government officials was conducted to select the future urban plan. The government officials who have a responsibility for the urban development and town planning (RAJUK, Bangladesh Water Development Board, Road, Highway Department and Dhaka City Office) were selected for the interviewees.

Outline of simulation model

In order to derive the general momentum equation for fluid flow in hydrologic term, control volume approach along with Newton's second law was used. Here, M and N are discharge fluxes (M=uh, N=vh) u is the x-direction flow velocity, v is the y direction flow velocity, h is water depth H is the water level and τ is a share stress.

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}uM+\frac{\partial}{\partial y}vM=-gh\frac{\partial H}{\partial x}-\frac{\tau_b}{\rho} \quad \text{……..(X-direction momentum equation)}$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}uN+\frac{\partial}{\partial y}vN=-gh\frac{\partial H}{\partial y}-\frac{\tau_b}{\rho} \quad \text{……..(Y-direction momentum equation)}$$

The continuity equation shows control volume during the small time interval.

$$\frac{\partial h}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0 \quad \text{…….. (Continue equation)}$$

Difference equations

Difference equation was developed from basic equations. These equations are based on the calculation grid shown in Fig. 2. In this procedure:

- Discharge fluxes M and N at time n+2 are calculated from water depth and level at time n+1 and flux at time n.

- Water depth at time n+3 is calculated from fluxes at time n+2

Momentum equations at x-direction are as follows:

$$\frac{M_{i,j+2}^{n+2}-M_{i,j+2}^{n}}{2\Delta t}+convx(x)+convx(y)=-g\frac{(h_{i-1/2,j+1/2}^{n+}+h_{i+1/2,j+j/2}^{n+1})(H_{i+1/2,j+1/2}^{n+1}-H_{1-i/2,1+j/2}^{n+1})}{2\Delta x}$$

$$-gn_{i,j+1/2}^{2}\frac{(M_{i,j+1/2}^{n}+M_{i,j+j/2}^{n+2})\sqrt{(u_{i,j+1/2}^{n})^{2}+(v_{i,j+1/2}^{n})^{2}}}{2((h_{i-1/2,j+j/2}^{n+2}+h_{i+1/2,j+1/2}^{n+1})/2)^{4/3}}$$

Momentum equations at y-direction are as follows:

$$\frac{N_{i,j+2}^{n+2}-N_{i,j+2}^{n}}{2\Delta t}+convx(x)+convx(y)=-g\frac{(h_{i+1/2,j-1/2}^{n+1}+h_{i+1/2,j+j/2}^{n+1})(H_{i+1/2,j-1/2}^{n+1}-H_{i+1/2,j+1/2}^{n+1})}{2\Delta y}$$

$$-gn_{i,j+1/2}^{2}\frac{(N_{i,j+1/2}^{n}+N_{i,j+j/2}^{n+2})\sqrt{(u_{i,j+1/2}^{n})^{2}+(v_{i,j+1/2}^{n})^{2}}}{2((h_{i-1/2,j+j/2}^{n+2}+h_{i+1/2,j+1/2}^{n+1})/2)^{4/3}}$$

Continue equation are as follows:

$$\frac{h_{i+t/2,j+j/2}^{n+3}-h_{i+i/s,j-j/2}^{n+3}}{2\Delta t}+\frac{M_{t,t+2}^{n+2}+M_{t,t+2}^{n}}{\Delta x}+\frac{N_{t,t+2}^{n+2}+N_{t,t+2}^{n}}{\Delta y}=0$$

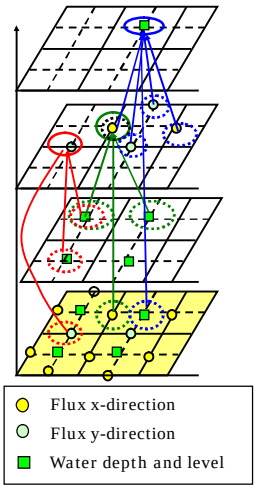
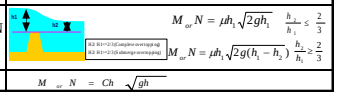


Fig. 2 Outline of interviewees

Boundary conditions

The boundary conditions are shown in Table 1. Which is external boundary condition and internal boundary conditions are applied into the model.

Table 1 Outline of interviewees

	Boundary condition	Flux
External boundary conditions	Levees and mountain adjacent to flooded area:	M or N= 0
	Levees breach point and discharge pump stations: Discharge flux was given.	Discharge flux was given
Internal boundary conditions	W.L is higher than the water level surrendering grids.	M or N= 0
	Discharge flux of a grid with a water depth 0.005m or less.	M or N= 0
	Water depth calculated to be negative.	M or N= 0
	In case of overtopping(Fig.2.5), the equations the M and N is calculated as follows:	
	In case of drop flow	$M_{or}N = Ch\sqrt{gh}$

Topography and discharge data

The discharge of Dhaleswari river is assumed as twice as Kariganga which is tributary of Dhaleswari river. Discharge of Balu river is assumed as half of the discharge in Derma-Balu. Discharge of Meghna river is assumed as 3000m^3/s in rainy season and 700m^3/s in dry season (Fig. 3).

Topography data was selected from HydroShedS (http://hydrosheds.cr.usgs.gov/). The grid size is 300m for x and y directions. By the discussing with government officer in Bangladesh, the Manning's roughness coefficient was decided as 0.030 in flood plain and 0.020 in river bed (Fig. 4).

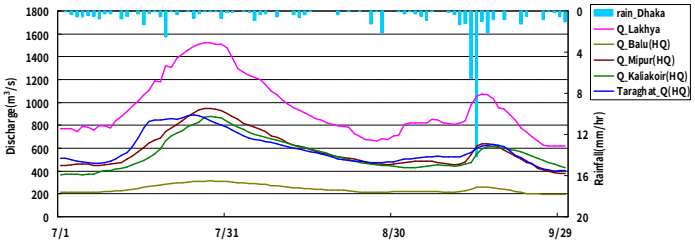


Fig. 3 Discharge and rainfall

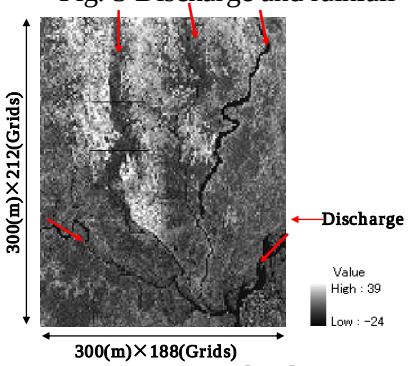


Fig. 4 Topography data

Comparison with the inundation map

In this section, the comparison of the simulation result and observed data on 24 August, 2004 was done. The observed data is taken from Flood Forecasting and Warning Center (FFWC) in Dhaka.

The comparison is shown in Fig. 5. The yellow part of the map shows protected areas (surrounded by embankments). The simulation results are fairly good. Especially, the north eastern and western part of Greater Dhaka (in the red circle) shows almost same water depth.

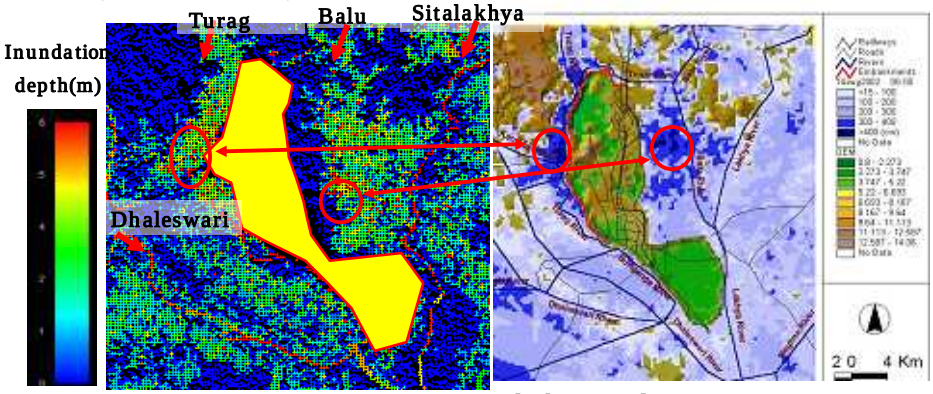


Fig. 5 Comparison with the inundation map

Comparison of simulation result with the water level in Mill Barak

The comparison of the observed data and simulation data at Mill Barak is shown in Fig. 6. The simulated water level of the end of July is little bit lower than that of observed data.
The reasons for these differences are:

- Discharge from the pumping systems has affected to water level.
- Topography data which was selected from SRTM and it grid size is about 300m.

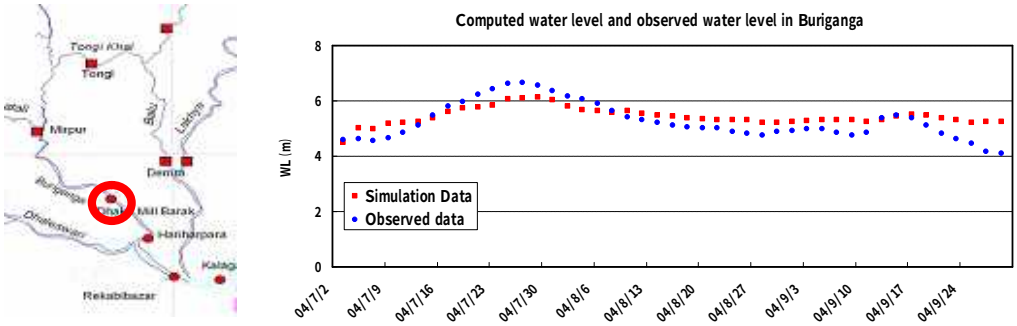


Fig. 6 Comparison with the inundation map

RESULTS AND DISCUSSION

Interview with government officials

According to interview with government officers, Dhaka is rapidly increasing their urban area by land-filling on the wetland which is located outside the embankment. If the roads and bridges connecting suburban area with Dhaka were constructed, a lot of land filling will be done along the road. Therefore, road is one of the main factors in urban growth and there is a possibility that these road will be stop the water flow during the flood. In Dhaka, there are several urban and transportation plans which have been published by the government and ADB. The main plans are Dhaka structure plan, Detail Area Plan and Strategic Transportation Plan. DMDP was published more than 10 years ago and DAP is still under construction. STP describes comprehensive urban plan which considers the future urban structure.

Interview with residents

By pre-interview on 6 June, the interview methods for the field survey was selected. The problems of questionnaires are as follows:

• It is difficult for the residents to choose one reason or factor for the flood damage.

•Some people cannot read questionnaires.

The interview was held to identify the resident ' s opinions. The number of interviewees was 10 people (Table 2). On the interview, the detailed information and situation can be known through face-to-face talk.

•Many people answered that they realize that flood is coming when the water level rises up to 3ft.

•All the residents answered that flood duration is maximum 4month.

•Houses and crops are damaged by the flood every year and it takes several months to recover.

According to the interview, residents realize that flood is coming when the water level rises up 3ft. This can be the criteria of the inundation area in the simulations

Table 2 Interview results

	Interviewee	Sex/ Age	The water depth when they reallize the flood	Situation during flood
1-1		-	3 feets	Too long evacuation time and there werefinghting because of food
1-2		Male/23	2 to 3 feets	I didn't find any problem. People are very kind
1-3		Female	3 feets	I didn't find any problem. People are very kind
1-4		Male/40	Neighbor houses were inundated and I realize that flood comes(about 3ft)	It was tough because of the duration, but people were helping each other
1-5		Male/30	3feets	-
2-1		Male/50	When the water level rise up to my shoulder (4ft)	-
2-4		Female/40	3feets	People were cooperative
2-2		Male/70	Weter level suddenly goes up and I was confused	-
2-3		Male/50	When the water level rise up to ground floor(5ft)	-
2-5		Male/50	3feets	-

Simulation with/without Highway

Future inundation area is calculated by 2D model. Discharge, Manning's roughness coefficient, topography and duration are the same as verification. The new highways, which is inputted into 2D model is based on Strategic Transportation Plan in 2024. Inside of the Greater Dhaka will be protected by the embankment. Therefore, the new highway outside of Greater Dhaka was considered. The planned highways described in STP connect Greater Dhaka to suburban area. According to RHD officer, the bridge is constructed only on the river courses.

Simulation results in 30 July, 2004 (the highest water level in July, August and September in 2004) is shown in Fig. 7. The blue circle shows the area where inundation will be increased and yellow circle shows the area where inundation area will be reduced. Inundation area which water depth more than 1m water depth will decrease after the completion of new highway. It became clear that the current highway construction could change the flood situation. In case of using highway as embankment, detail studies are required to identify the inundation area and strict guideline.

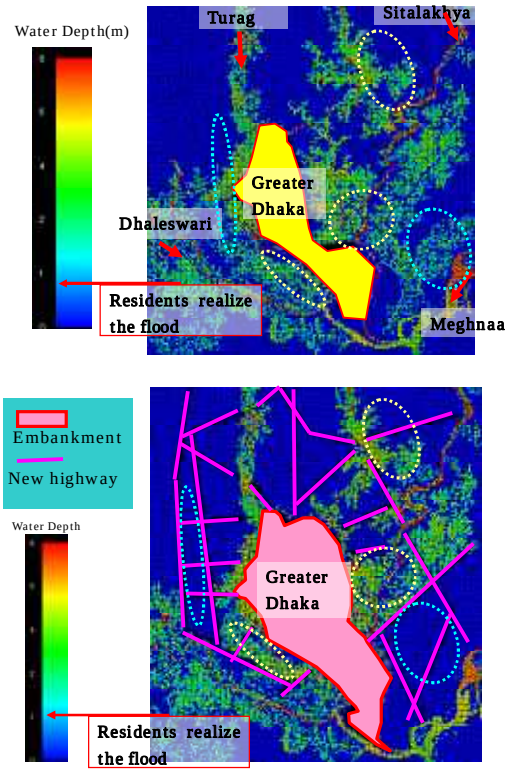


Fig. 7 Simulation with/without highway

Simulation with/without Bridge

Increase the culvert is one option of mitigation the damage. Outlets are used to discharge inland flowed water to outer rivers. It may be used to allow water to pass underneath a road, railway, or embankment.
In this section, simulations with and without outlet were conducted. The interval of the culvert is assumed as approximate 4500m and length of outlet are 400m. The culvert is proposed into the all the highway except for the road inside of the protected area. The discharge and Manning's roughness coefficient are considered to be same as the simulations as verification (Fig. 8).
The blue circle shows the changes of inundation conditions. By constructing bridges, the inundation area will be reduced in up stream side of highway.
By constructing highway without bridge, inundation area in down stream side of highway will be reduced and inundation area in up stream side of highway will be increased. In case of constructing highway without bridges, it is necessary to prepare the guideline to control the land-use in up stream side of highway.

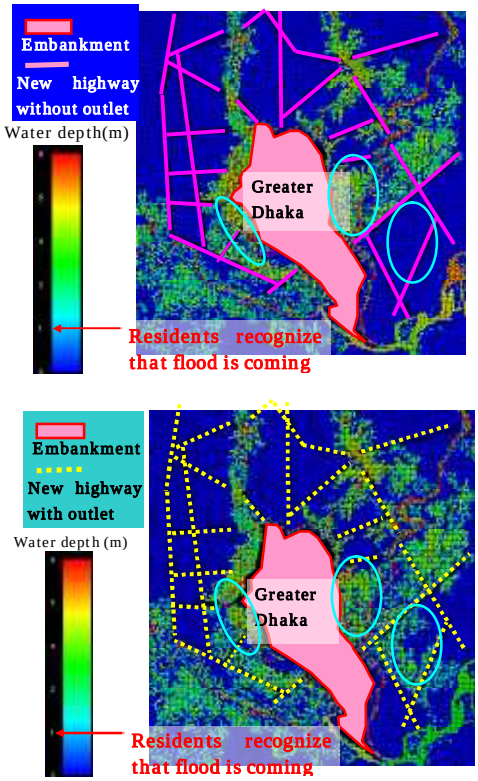


Fig. 8 Simulation with/without bridge

CONCLUSION

By constructing highway without bridge, inundation area in down stream side of highway will be reduced and inundation area in up stream side of highway will be increased. In case of constructing highway without bridges, it is necessary to prepare the guideline to control the land-use in up stream side of highway. By constructing bridge in 4500 m interval, inundation area in up stream side of the highway will not be increased and inundation area in down stream side of highway will not be reduced.

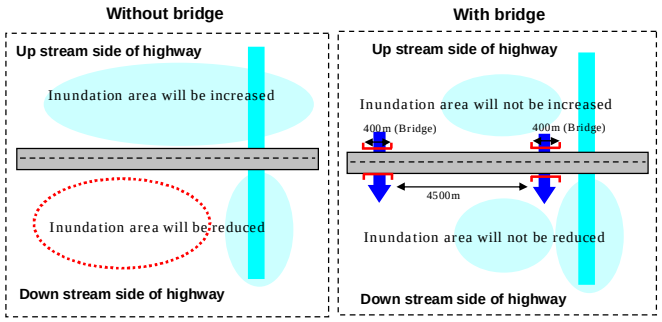


Fig. 9 Implication of countermeasure

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