GENERATION OF INFLOW HYDROGRAPHS FOR A SELECTED SMALL URBAN CATCHMENT OF DHAKA CITY

R. T. Khan&M. A. Matin*

Department of Water Resources Engineering,Bangladesh University of Engineering and Technology, Dhaka, Bangladesh
**Corresponding Author: mamatin@wre.buet.ac.bd*

ABSTRACT
This study deals with a systematic approach for the estimation of urban runoff from a small catchment. An urban catchment in Uttara area, near the Abdullahpur-Mirpur embankment, has been selected. Intense rainfall hydrographs have been generated based on the application of HEC-HMS model using the NRCS unit hydrograph method. Intensity-Duration-Frequency relationship curves are used to generate short duration design rainfall event. Three rainfall events such as 1h 2 year, 2h 5 year and 2h 10 year return period has been used for hydrograph generation. Curve number values obtained from GIS shapefiles of proposed and existing landuse maps are used in the model. The rational method has also been included to estimate the peak discharge and compare with the results obtained from the model. In this study it is found that with increased urban development, peak runoff values are significantly higher than undeveloped conditions. For sub-catchments A, B, C and D, the values of peak runoff varied by 40.2% (10.7 m^3/s-15.0 m^3/s), 2.2% (4.5 m^3/s- 4.6 m^3/s), 23.9% (17.6 m^3/s – 21.8 m^3/s) and 264% (5.0 m^3/s – 18.2 m^3/s) respectively compared to present condition under 2h 5 year return period rainfall. In addition, the time to rise to peak discharge was found to be shorter by 16.7%, 0%, 14.3% and 33.3% respectively, which means that the basin would respond more rapidly to a given rainfall condition. Losses and abstractions from rainfall was found to be lower with increased urbanization, implying that greater part of the rainfall would be converted into rainfall excess. The values of peak discharge from rational method varied from model result by 1.43% in case of sub-catchment B under 1h 2 year return period rainfall in proposed land use condition upto 80.8% in sub-catchment D under 2h 5 year return period rainfall in existing land use condition.The results of this study would be helpful for proper design of drainage structures like culverts, sluice gates, or pumping stations. Identification of local drainage pattern in terms of sub-catchment needs to be addressed for proper planning and management of urban drainage system.

Keywords: Urban catchment, IDF curves, NRCS method, hydrograph, rational Method.

INTRODUCTION
Urban drainage congestion during monsoon due to heavy rainfall causes much inconvenience and economic losses for the Dhaka city residents. The reasons behind this urban flooding can be attributed to heavy rainfall, inadequate drainage system, high water level in the peripheral rivers, unplanned urban development, encroachment and congestion of canals and urban development of local water retention bodies. The various canals passing throughout the city play an important role in carrying out the runoff to the peripheral rivers.

A master plan for flood mitigation and stormwater drainage improvement in Dhaka city was prepared in 1991 for flood protection of approximately 262 km^2 of the city. Partial implementation of this plan has protected the western half of the city from river flood by embankments and raised roads. Although internal stormwater flooding in the western part was expected to be mitigated after rehabilitating the drainage system and installing permanent pump stations, the flooding condition has been deteriorating. This declining situation calls for investigation into the causes of stormwater flooding. The urgent need to resolve urban flooding problem has been felt after a disastrous stormwater flooding caused by unprecedented rainfall in September 2004 and the preceding countrywide flood in July of the same year. At the same time, it appears to be imperative to set forth a realistic plan for flood mitigation and stormwater drainage for the eastern part of the city. The original master plan needs revision because of the unplanned land use changes that took place since the plan was prepared.

METHODOLOGY

Both primary and secondary data were needed to fulfill the study. Primary data includes photographs of salient features to determine the flow paths, and public opinion regarding the current drainage condition of the study area. Secondary data includes GIS shape files of contour maps and existing and proposed land use data obtained from RAJUK Detailed Area Plan. The design rainfall data was generated from IDF curves of Dhaka City for the interval 1984-2013.

The first step was to delineate the boundaries of the sub-catchments. It was done based on observation of existing drainage system, sluice gates and contour map. In case of Catchment C, no outlet was found So, a sluice gate (sluice no. 3) was proposed as shown in fig.2

The lag times for the sub-catchments were determined using the NRCS lag equation, which involves Curve Number, Average Basin Slope, and Hydraulic Length of the principal drainage channel.

In the rainfall-runoff model of HEC-HMS, area, initial abstraction, curve number, imperviousness (%), lag time were given as inputs of catchment parameter. In time-series data manager, rainfall values were input as hyetographs.

For the rational method, the value of the constant, C was obtained from the land use maps, the design rainfall intensity was arbitrarily chosen as 2h 5 year, 2h 10 year and 1h 2 year return period rainfall.

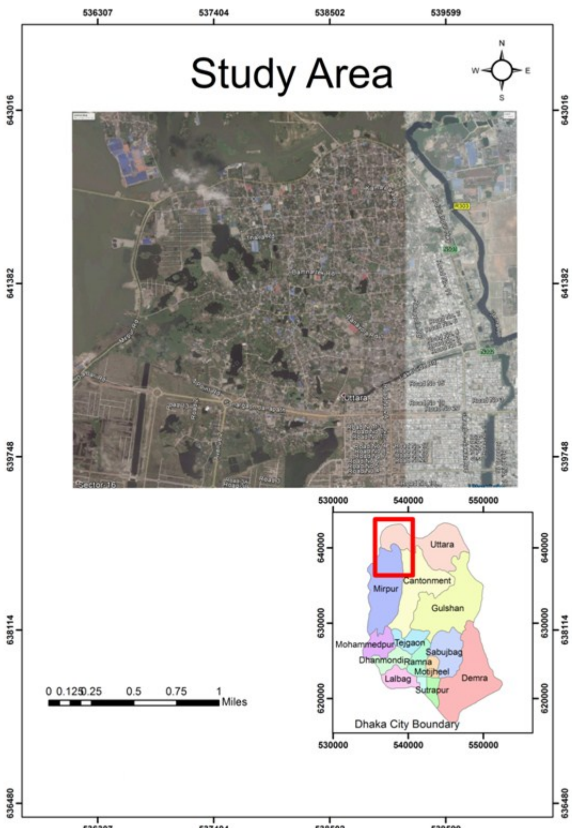

Fig. 1: Location of Study Area

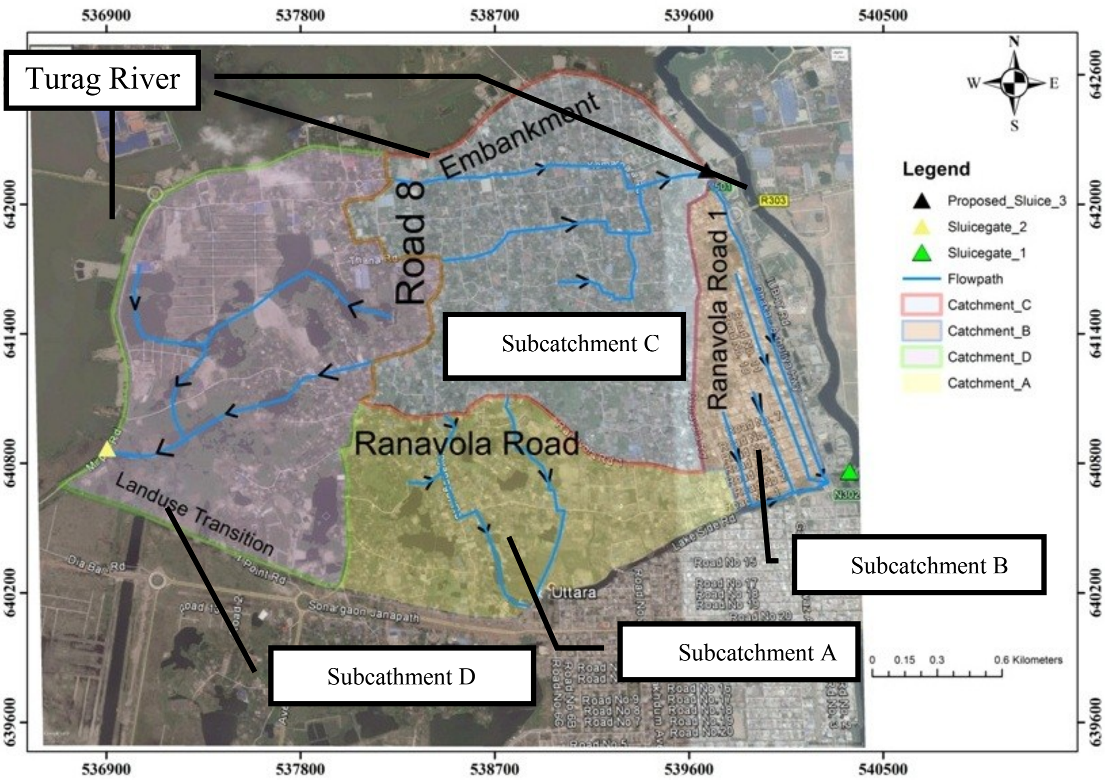

Fig 2: Subcatchments and Drainage Paths

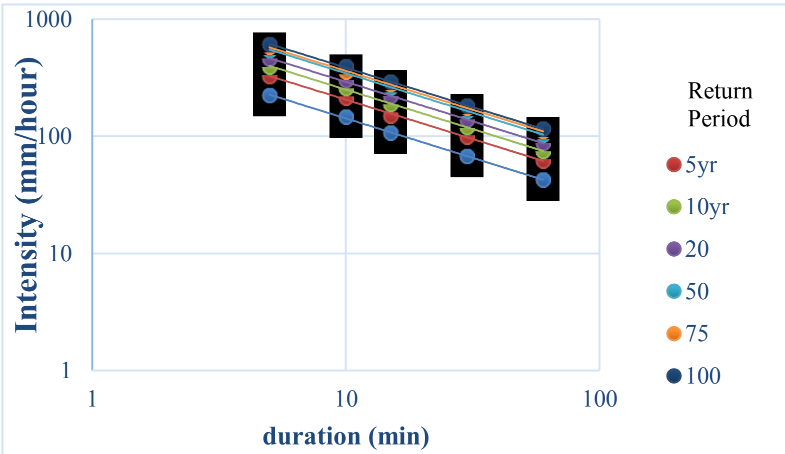

Fig 3: IDF Curve of Dhaka City

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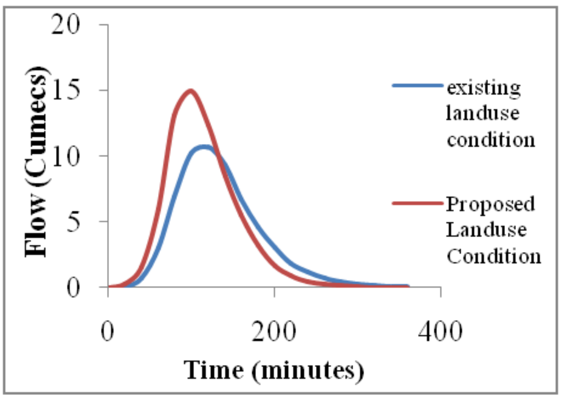

Fig 4: Hydrograph for Subcatchment A

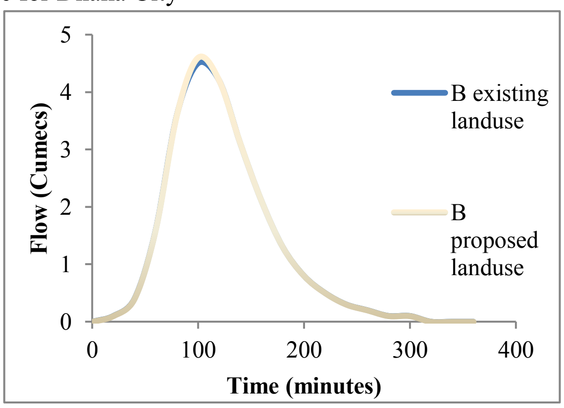

Fig 5: Hydrograph for Subcatchment B

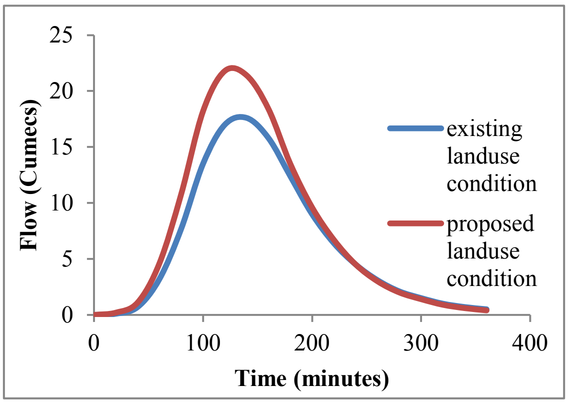

Fig 6: Hydrograph for Subcatchment C

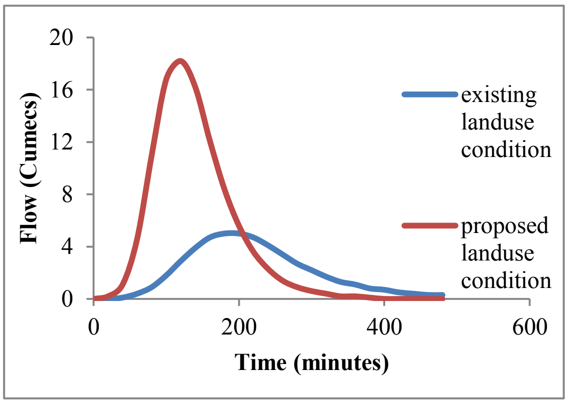

Fig 7: Hydrograph for Subcatchment D

Hydrographs for each subcatchment under different rainfall events in propsed landuse pattern:

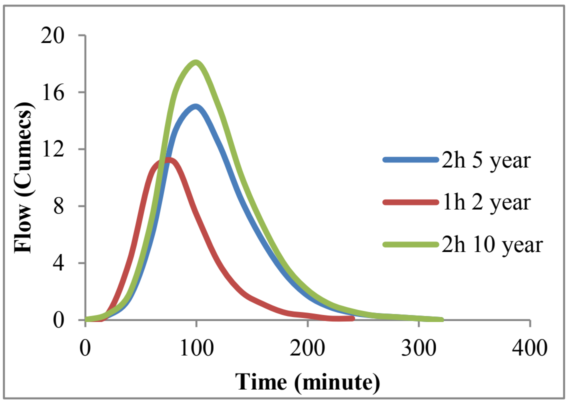

Fig 8: Hydrograph for Subcatchment A

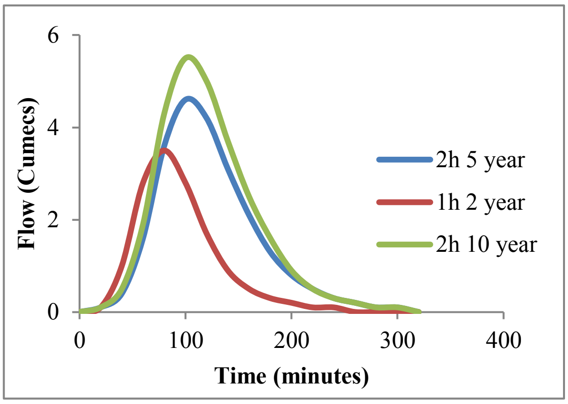

Fig 9: Hydrograph for Subcatchment B

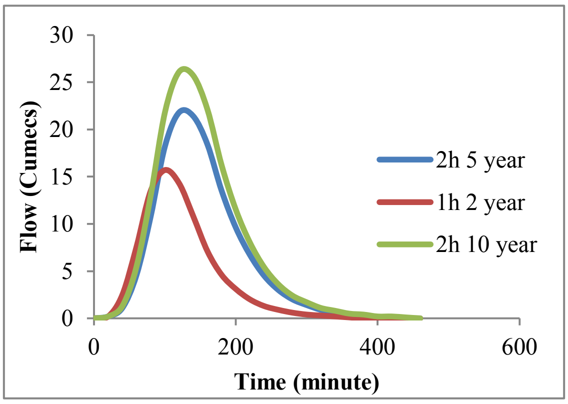

Fig 10: Hydrograph for Subcatchment C

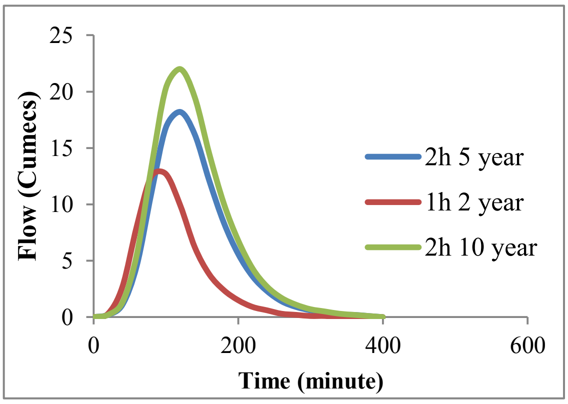

Fig 11: Hydrograph for Subcatchment D

Table 1: Subcatchment Properties

Subcatchment	**Area (km^2)**	**Landuse Condition**	**Lag time, t_L (min)**	**Rational Method, C**
A	1.33	Existing	59.4	0.66
		Proposed	44.2	0.72
B	0.41	Existing	50.7	0.76
		Proposed	50.7	0.77
C	2.24	Existing	78.8	0.74
		Proposed	73.3	0.76
D	2.03	Existing	129.7	0.44
		Proposed	62.6	0.72

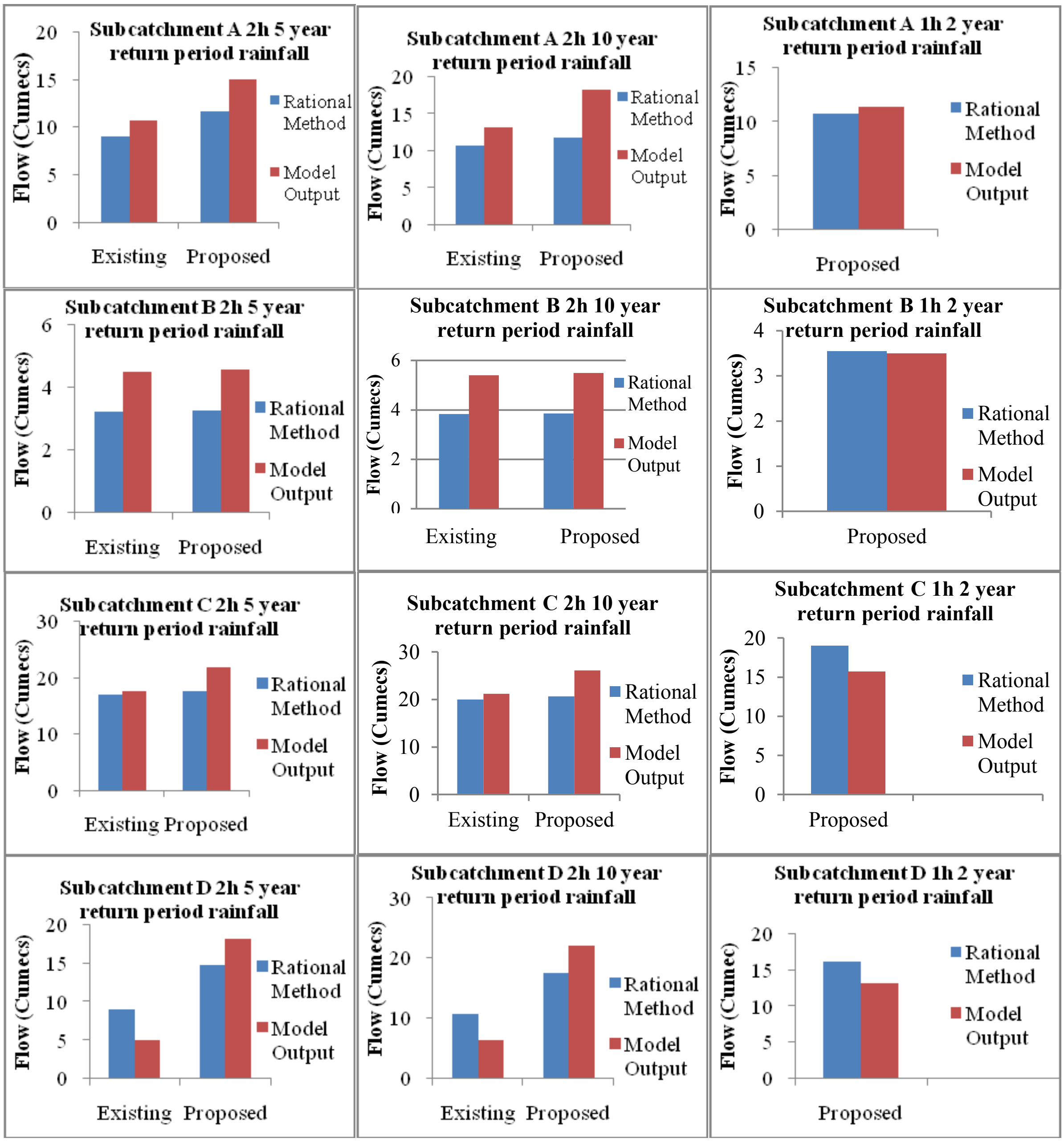

Fig. 12: Comparison between peak discharges from HEC-HMS model and Rational Method under existing and proposed landuse conditions

NRCS Lag equation:

$$t_L = \frac{l^{0.8}(2540 - 22.86CN)^{0.7}}{1410CN^{0.7}Y^{0.5}} \quad (1)$$

Average basin slope,

$Y = 100(CI)/A$ (2)

Y= average land slope, %

C= summation of the length of the contour lines that pass through the watershed drainage area on the quad sheet, ft

I= contour interval used, ft

A= drainage area, ft^2

IDF equation for Dhaka city,

$$I = \frac{629.36 T_r^{0.239}}{T_d^{0.673}} \quad (3)$$

I= intensity in mm/hr; T_r = Return Period, in Years; T_d= Duration, in minutes

RESULTS AND DISCUSSIONS

1. The variations of runoff with changing landuse pattern for the four subcatchments are shown in figures 4-7. Increased urban development produces hydrographs with greater peak discharge, less precipitation losses, and more percentage of the rainfall is converted to rainfall excess due to increased surface imperviousness. Also, the base length of the hydrographs were shorter in case of urbanized catchments, indicating that peak discharge will be reached at shorter interval from beginning of rainfall.
2. The peak design discharge was obtained from arbitrarily chosen 1h 2 year, 2h 5 year and 2h 10 year return period of rainfall. The resulting hydrographs for each subcatchment (for proposed landuse condition) for each return period of rainfall are shown in figures 8-11. It is observed from these results that for design of drainage structures, higher discharging capacities need to be selected for 2h 10 year return period rainfall. A proper return period must be selected based on economic considerations.
3. Peak discharge values obtained from rational method were almost identical in case of 1h 2 year return period rainfall. For other rainfall conditions, the results varied significantly. In urbanized subcatchments, the HEC-HMS model output yields slightly higher values of peak discharge, and in undeveloped subcatchments, the rational method produces higher values of peak discharge. The values of peak discharge from rational method varied from model result by 1.43% in case of subcatchment B under 1h 2 year return period rainfall in proposed landuse condition upto 80.8% in subcatchment D under 2h 5 year return period rainfall in existing landuse condition.

CONCLUSIONS

1. In some subcatchments of the selected area, especially in subcatchment C (2.26 km^2 area) and subcatchment A (1.33 km^2 area), local water retention bodies play an important role in storage of runoff water. Some surface drains also drain into these water bodies. But for long-term urban planning, the runoff water needs to be conveyed across the embankment into the Turag river.
2. Two sluice gates are already installed in the study area. This study reveals that the capacity of these sluice gates seems to be inadequate to drain the generated runoff water. Therefore, more drainage structure is required for this catchment.
3. During high flood levels in the peripheral Turag River, pumping facilities in addition to sluice gates may be necessary for effective drainage system.

ACKNOWLEDGMENTS

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