INTENSE STORM-RUNOFF ROUTING OF HATIRJHEEL-BEGUNBARI LAKE OF DHAKA CITY

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ABSTRACT

Hatirjheel-Begunbari Lake is a large water reservoir situated at the heart of Dhaka city stretching from Panthapath to Rampura serves very important hydrological functions such as draining, detaining of storm water from a large area. These functions are particularly critical during monsoon. During dry season, storm water and illegally discharged waste water drain through the storm diversion system (SDS) located along the bank line of the lake. Hatirjheel-Begunbari Lake is expected to be designed mainly for a detention reservoir to accommodate severe storm runoff from adjoining area. Therefore, routing of the certain storm runoff has become a vital task for proper storm water management. In this paper an attempt has been made to analysis and route the intense storm runoff for Hatirjheel-Begunbari Lake. The overall analyses involved the collection of rainfall data, survey of cross-sectional geometry forming the reservoir, the generation of inflow hydrographs. For different rainfall duration and return periods, peak discharges has been estimated using rational method. Three different inflow events are used for the purpose of routing the reservoir. These events are 1-hour rainfall duration for return periods of 2-year, 5-year and also for event of 2-hour 5-year. Inflow hydrographs for these events have been used to obtain the corresponding outflow hydrographs using storage indication method. The results show that the peak runoff for the given storms are found to be 28.89 m^3/s, 36.12 m^3/s, 25.28 m^3/s respectively. Corresponding peak lag times are found to be 30min., 1-hour and 1-hour respectively. Storage elevation curve for the reservoir has been developed using the recently surveyed 70 No's of cross sections. The maximum storage capacity of the reservoir is estimated as 1.7 Mm^3 for storm event of 1-hour 5-year. However, the physical capacity of the reservoir is 37.1 Mm^3 indicating that the reservoir has the vast capacity to accommodate more storm runoff from adjoining areas. It is expected that the overall study will be useful for storm runoff management of the Hatirjheel-Begunbari reservoir to some extent.

Keywords: *Storm runoff, Hatirjheel-Begunbari lake, Inflow hydrograph, Routing, Reservoir capacity.*

1. INTRODUCTION

A reservoir is a natural or artificial feature designed to store incoming water and release it at regulated rates. Surface water reservoirs store water for diverse uses including rain water retention, flood control, hydropower generation, irrigation, navigation, preserve a lake, water quality and recreation. Routing is a technique used by hydrologist to predict the changes in shape of water as it moves through a river channel or a reservoir. Reservoir routing uses mathematical relations to calculate outflow from a reservoir once inflow, initial conditions, reservoir characteristics operational rules are known (Ponce, 1989). The classical approach to reservoir routing is based on the storage elevation concept.

Hatirjheel-Begunbari Lake is a large area of water reservoir located at the center of the capital city of Bangladesh, Dhaka. It serves very important hydro-logical functions of draining and detaining storm water from a large area of Dhaka city. These functions are particularly critical during monsoon. During dry season, storm water and illegally discharged domestic and industrial waste water drain through this low land into the Balu River by gravity. However, during the rainy season, when river water level rises, the Rampura regulator is closed to prevent back flow of river water into the city. Usually the gates of the regulator remain closed for about two months during the rainy season and are opened again when the river water level falls below the water level of Hatirjheel area within the city. It revealed that the lowlands behind the Sonargaon Hotel and Hatirjheel lake provide an important functions of detention and conveyance of accumulated storm runoff generated from the adjoining catchment area of over 30 sq. Km (RAJUK and DWASA, 2008). Matin and Rahman (2009) studied scale model to understand the flow behavior of Storm Diversion Structure (SDS) of Hatirjheel Begunbari lake project. Hydraulic analysis of storm diversion system of Hatirjheel-Begunbari project was done by Malik (2014) which was mainly dealt with the dry weather flow pipe line system. The project was implemented in very recent past. Assessment of usable storage volume in terms of its capacity and flow routing for intense storm event is now becomes important for proper management of such a urban water body. Review of relevant literatures shows that no notable works has been attempted on the routing aspects of this lake for intense rainfall runoff event. This paper demonstrates a routing procedure applied to Hatirjheel-Begunbari Lake for selected three storm events of given duration and frequency.

2. METHODOLOGY

Methodology adopted in this study can be outlined in a flow diagram as shown in Figure 1.

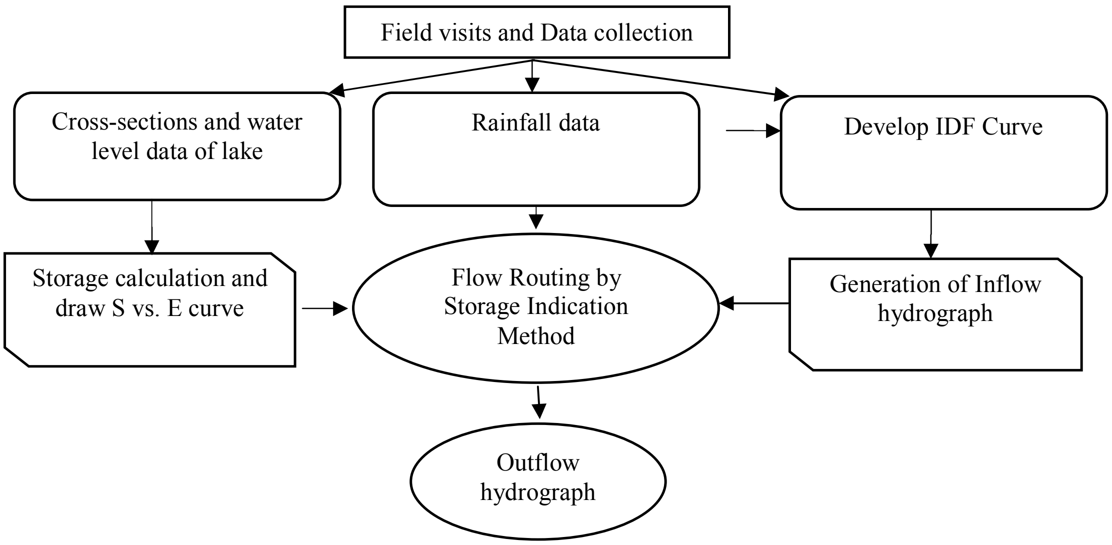

Figure 1: Flow diagram showing methodology

2.1 Data Collection

Number of field visits have been made to collect data of hatirjheel lake project. Measurement of water level have been done to assess the water level fluctuations in the lake. It is important to note that daily water level fluctuates due to domestic and storm inflow from the surrounding areas. Minimum water level of +2.5 m PWD is maintained in this reservoir by regulator at Rampura. Design maximum water level is +5.5 m PWD. Water area of the entire lake surface at maximum water level is found to be 2.186 M m^2 as shown in Google Map (Figure 2) of Hatirjheel-Begunbari lake of Dhaka city.

Figure 2: Location of Hatirjheel-Begunbari Lake (Source: Wikimapia)

Elevations and width of the lake were measured at several locations of the lake. The manhole tops were elevated at +4.5 m PWD from the bed level. The top elevation of the proposed roadway and walkway is at +7.0 m PWD, whereas most built up areas around the system are at a land elevation above +6.0 m PWD (FAP 8b, 1990). Therefore water detention in the system above +6.0 m PWD may retard water inflow into the system from relatively low-lying catchment areas and increase the possibility of flooding in the catchment.

2.2 Intensity-Duration-Frequency

Intensity-duration-frequency curve (IDF) is the graphical representation of the amount of the rainfall within a given period in catchment area. Afrin et al. (2014) studied IDF curves considering future precipitation variability due to climate change. Figure 3 shows the city recently developed IDF curves for dhaka (Islam, et al. 2015). This curve has been used in the study to estimate peak runoff.

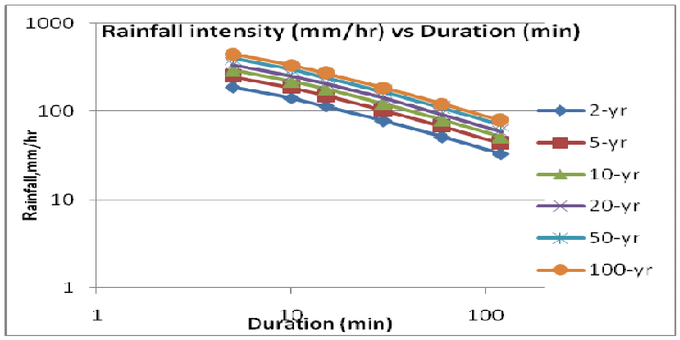

Figure 3: Intensity-Frequency-Duration (IDF) curve for Dhaka City

2.3 Approach Used for Routing

Storage-Indication Method has been used to route the given inflow hydrograph (Chow, 1988, Guo, 2004). This method has been found suitable and simpler for present analyses. The routing equation below is used to derive the downstream hydrograph O_2 when the stage-storage discharge relationship is known. The stage-storage-discharge relationship is used to derive the storage-indication curve, which is the relationship between O and (S + OΔt/2).The following five steps can be used to derive the outflow hydrograph with the storage-time functions: (i) Determine the average inflow: $0.5\Delta t(I_1 + I_2)$, (ii) Compute $S_1 - ½\, O_1\Delta t$, (iii) Using stage storage relation and the values from Steps (i) and (ii) Compute $S_2 + ½\, O_2\Delta t$, (iv) Using the value computed in Step, (iii) Determine O_2 from the storage-indication curve, (v) Use O_2 with the storage-discharge relationship to obtain S_2 . The five steps are repeated for the next time-increment using I_2, O_2, and S_2 as the new values of I_1, O_1, and S_1, respectively. The process is solved iteratively until the entire outflow hydrograph is compiled. Once the stage-storage-discharge relationships and the storage-indication curve data are determined and plotted, a mathematical expression can be developed for each and used in a spreadsheet computation. The procedure is an iterative solution and does involve a number of calculation steps. Inflow hydrographs were generated and the flow was routed by the storage-indication method. From the variation of inflow and outflow discharges with time, the peak lag and the peak attenuation have been determined and compared.

3. ANALYSES, RESULTS AND DISCUSSION

3.1 Storage Capacity

A total of 70 cross sections (Figure 4) were taken at approximately 50 m interval to calculate the total volume of the reservoir. From the variation of storage with the elevation, the storage versus elevation curves have been plotted.

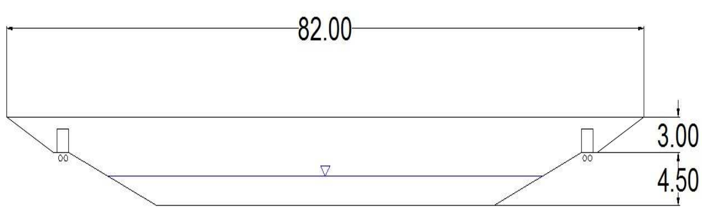

Figure 4: A typical cross section of the lake

Storage volume calculated for different elevations are shown in Figure 5. It is found that storage volume for 2 m elevation is 1.24 Mm^3, for 5m elevation storage volume is 3.23 Mm^3, for 7.5 m elevation storage volume is 5.06 Mm^3. The total storage volume is found to be 37.11 Mm^3 for maximum elevation of 7.5 m when the lake is about to fully stored.

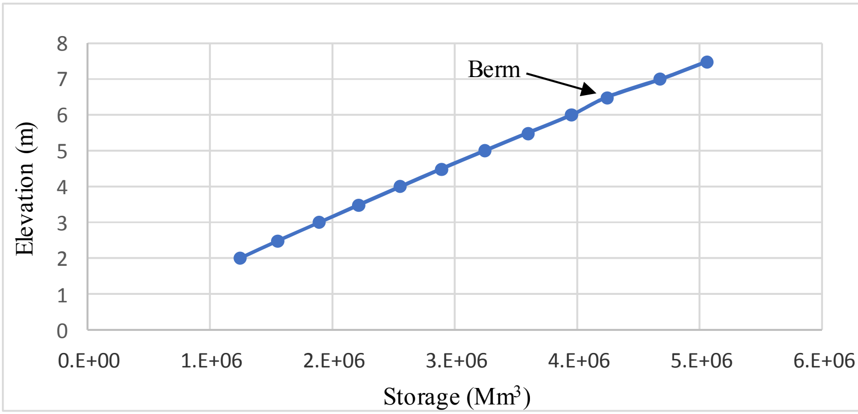

Figure 5: Elevation vs. Storage curve

3.2 Calculation of Peak Discharge

Peak discharge Q, through the culvert outlet was calculated using the rational formula, Q =CIA, where C = runoff coefficient, I = rainfall intensity, and A = catchment area. A composite runoff coefficient of 0.6 is estimated (FAP 8B, 1990) and land use pattern observed in the satellite images. Using the IDF relationship (Figure 3) estimated peak discharge has been shown in Table 1 for different return periods and rainfall durations.

Table 1: Peak discharges with given duration and return period

Duration (hours)	Return Period (T-year)	Intensity (mm/hr)	PeakDischarge, Q (m^3/s)
1	2	80	28.9
1	5	100	36.1
2	5	70	25.3

For storm duration of 1-hour and 2-years return periods, rainfall intensity is about 80 mm/hr and the corresponding peak discharge is 28.9 m^3/s. The value of peak discharge is 36.1 m^3/s for duration of 1 hour with a frequency of 5 years having a rainfall intensity of 100mm/hr. Similarly, the value of peak discharge is found to be 25.3 m^3/s for duration 2-hour 5-years having rainfall intensity of 70 mm/hr.

3.3 Inflow and Outflow Hydrographs

Inflow and outflow hydrographs were generated from the peak discharges of different rainfall durations and frequency (return period in year).

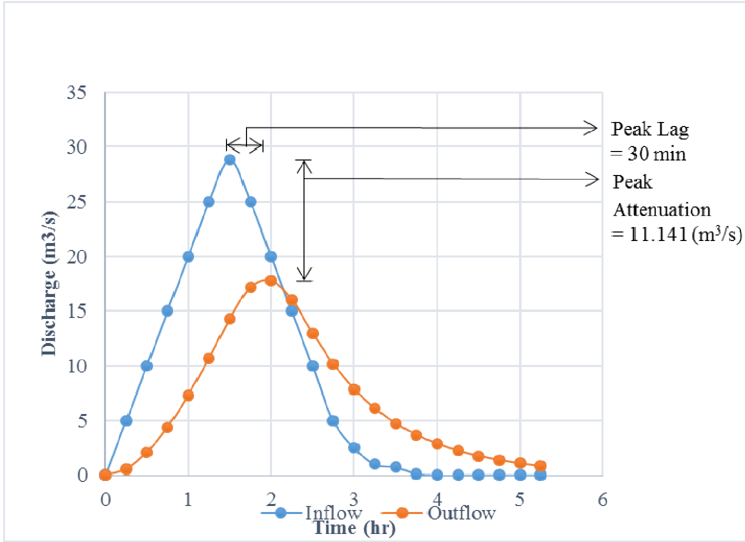

Figure 6: Inflow and outflow hydrograph for 1-h 2 year return period

Figure 6: shows generated inflow and routed outflow hydrographs. It is seen that, for storm event of 1- hour duration 2-year return period, the peak lag time is 30 min and peak attenuation is 11.14 m^3/s . This discharge will cause to increase the water level from +2.5 m to +2.74 m.

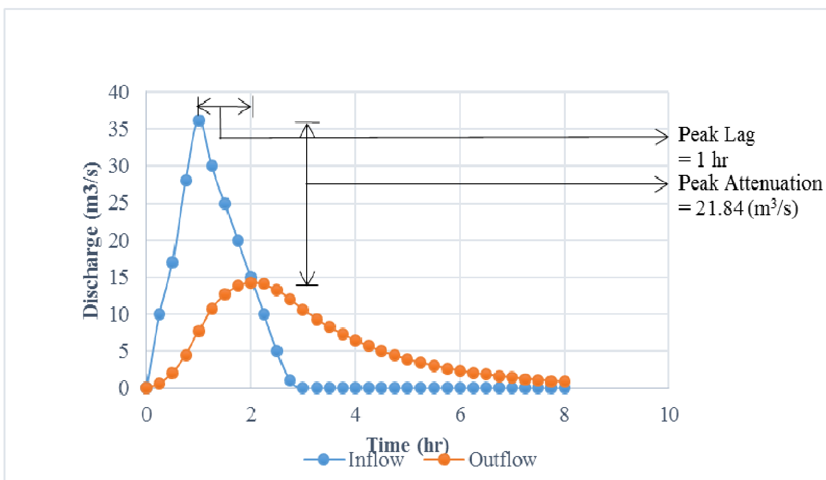

Figure 7: Inflow and outflow hydrograph for 1-h 5 year return period

Outflow hydrograph (Figure7) shows that the peak lag is 1 hour and peak attenuation is 21.84 m^3/s for rainfall events of 1-hour duration and 5-year return period. This storm will cause to rise water levels from +2.5 m to +2.77 m.

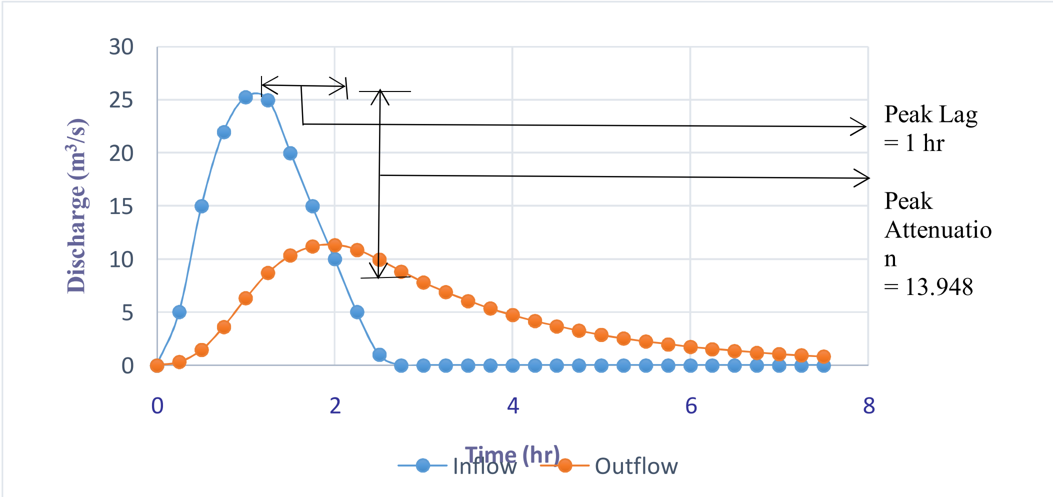

Figure 8: Inflow and outflow hydrograph for 2-h 5 year return period

Similarly, for storm event 2-hour 5-year return period, it is seen in Figure 8 that the peak lag is 1 hour and peak attenuation is 13.9 m^3/s ; corresponding water level in the lake has been increased to 2.7 m from 2.5 m. All results are summarised in Table 2.

Table 2 summarises the results obained from inflow and outflow hydrographs.

Storm Events Senerios	Peak inflow (m3/s)	Peak outflow (m3/s)	Peak lag time	Peak attenuation (m^3/s)
1-h 2-year	28.9	17.5	30 min	11.40
1-h 5-year	36.1	14.3	1 hour	21.84
2-h 5 year	25.3	11.3	1 hour	13.95

4. CONCLUSIONS

This study has been undertaken to estimate the storm runoff volume, inflow and outflow hydrograph for Hatirjheel Begunbari Lake. Three storm events such as 1-hour 2-year, 1-hour 5-year and 2-hour 5-year return period have been selected for the generation of inflow hydrographs. The routed outflow hydrographs the peak discharges are found to be 17.5 m^3/s, 14.3 m^3/s, 11.3 m^3/s respectively. Peak lag time for selected three storm options are 30 min, 1 hour and 1 hour and corresponding water level rise of +2.77m, +2.74m and +2.70m respectively from the initial water level +2.5m PWD For the selected three options the storage capacity increases to 1.73 Mm^3, 1.71 Mm^3 and 1.69Mm^3 respectively from the initial storage of 1.55 Mm^3. The maximum retention capacity of the Hatirjheel Begunbari Lake has been estimated as big as 5.0 Mm^3 which indicates that the lake has enough capacity to take care more intense storm runoff from the adjoining area of the project.

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