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ESTIMATION OF HYDROLOGICAL PARAMETERS FOR DESIGNING STORM WATER DRAINAGE SYSTEM AT BAGERHAT POURASHAVA

Afia Mahjabin[1], Onisha Hoque[2], Md. Ataur Rahman[3], Silwati Al Womera[4*]

[1]Department of Environmental, Water Resources and Coastal Engineering, MIST. Email: afiamahjabin2311@gmail.com
[2]Department of Environmental, Water Resources and Coastal Engineering, MIST. Email: onishahaque75@gmail.com
[3]Department of Water Resources Engineering, BUET. Email: mataur@wre.buet.ac.bd
[4]Department of Water Resources Engineering, BUET. Email: silwati@wre.buet.ac.bd

***Corresponding Author**

ABSTRACT

Management of storm water runoff from urban areas is an increasingly important environmental issue for urban communities. This study investigates the existing drainage system of Bagerhat Pourashava which is a small town in the Bagerhat district of Khulna division. Inadequate drainage network in the study area causes waterlogging in some parts of the city during the rainy season almost every year. Drains blocked by garbage dumping, encroachment of drainage canals and missing links in the drainage network result in insufficient capacity of the storm water system to carry the runoff from seasonal heavy rainfall and high tide level at surrounding Bhairab River. Moreover, being near to the coastal area and surrounded by the tidal river Bhairab, drainage water can only be discharged into the river at the time of low tide and at the time of high tide the outfalls have to be shut down by the use of sluice gates. Daily rainfall data of Bagerhat area during the period of 1968 to 2019 have been analyzed to develop Intensity-Duration-Frequency (IDF) curves. IDF curves of long duration rainfall data ranging from 1 day to 7 days of annual maximum rainfall for different return periods (i.e., T=2, 5, 10, 25, 50, 100 years) are converted to generate short duration rainfall ranging from 10 minutes to 120 minutes duration. For 2 hour duration rainfall, design rainfall intensity has been found as 28.36 mm/hour and 33.75 mm/hour for 5 years and 10 years return period respectively. Hourly water level data (1980-2019) of Bhairab River have been analyzed in this study. Tidal range of both spring tide and neap tide of each year is calculated from which the average tidal range is computed for both spring tide and neap tide. Average high and low water levels for various return periods (i.e., T=2, 5, 10, 25, 50, 100 years) are computed by using Gumbel's Distribution method. For 50 years and 100 years return periods, design high water levels in Bhairab River are found as 2.83 mPWD and 2.98 mPWD correspondingly. Hydrological design parameters (rainfall intensity and river water level) obtained from this study can be used for designing storm water system of Bagerhat Pourashava.

Keywords: *Urban Drainage System, Waterlogging, IDF curve.*

1. INTRODUCTION

Urban drainage system network that prevails was developed many years ago to serve a number of people in a community. But with the passage of time population has increased. Natural canals and outlets are constricted too due to manmade construction projects. These adverse conditions have also affected the environment. Climate change effects have caused excessive rainfall and higher tides than before. Thus the previous drains are required to get widened to fit in with heavier monsoon rainfall. Urban water logging is responsible for menaced daily life, disordered transportation, and transmission of water borne diseases (Datta et al., 2017). Therefore study of urban drainage system has become an imperative and got great priority. There are number of studies assessing hydrological parameters for designing urban drainage system for different urban areas (Khan 2015, Nargis 2003).

The study area, Bagerhat Pourashava (Figure 1), faces high tide flash flood due to the surrounding tidal river Bhairab. Moreover, the heavy rainfall during monsoon causes urban flooding. Among the 9 Wards in the Pourashava, Ward no. 1, 3, 6 and 9 have been found to be the low lying areas that get inundated even at little rainfall. Ward no. 4, 5 and 7 get inundated too during heavy rainfall. Drainage lines are mostly constricted and cannot carry the huge volume of storm water through them. No recent study has been found that investigates the drainage system of Bagerhat Pourashava. Therefore, to evaluate the existing drainage system of Bagerhat Pourashava, this study has assessed the existing drainage network of Bagerhat Pourashava. Moreover, two hydrological parameters such as design rainfall intensity and design river water level of Bhairab River for 50 years and 100 years return periods have been estimated. Findings of this study can be used for designing the drainage system and flood mitigation measures for the study area.

Figure 1: Map of Bagerhat Pourashava.

2. STUDY AREA AND DATA COLLECTION

Bagerhat Pourashava is in the south western part of Bagerhat district and geographically located between 22°39'46.05" north latitude and 89°47'58.93" east longitude (Fig. 1). It is one of the Municipalities among the GOB declared 316 municipalities. The average elevation of the city is 2.53 m (from MSL), average annual minimum temperature is 22.5 °C, average annual rainfall is 296.23 mm (1968-2019) and average annual humidity is about 86% (June-2010). The municipality was established in 1958. It consists of 9 Wards with an area of 15.89 square kilometers. The low lying areas are mainly comprised of Ward no. 1, 3, 6 and 9. The study area is stood by a tidal river Bhairab at the east. The highest flood level of Bhairab river is 2.46m,PWD. Bagerhat Municipality has one embankment of length 3.63 km with reduced level of its crest as 2.70 m,PWD. Pourashava has 11 bridges and 38 culverts. There are 31 sluice gates to control discharge of drainage water into the Bhairab River. The municipality has 6 natural khals. There are roadside lined and unlined drains covering total length of 104 kilometers. Length covering by primary, secondary and tertiary drains are 63.72 km, 10.57 km and 29.94 km respectively. But the capacity of the drains are reduced due to the encroachments. Plastic and solid wastes from households, industries, commercial areas and construction sites have reduced the capacity of drains too. In this study, data of bridge, culvert, embankment and drainage lines are collected from the survey conducted under Coastal Towns Environmental Infrastructure Project (CTEIP) of LGED (2016). Daily rainfall data for 51 years (1968-2019) at CL501 (Bagerhat Station) and water level data of Bhairab river for 39 years (1980-2019) at station SW1 (Alaipur Khal Doratana, Bhairab river) have been collected from the Bangladesh Meteorological Department (BMD) and Bangladesh Water Development Board (BWDD) respectively.

3. METHODOLOGY

In this study, a methodology was developed for the design of storm water drainage based on an assessment of existing drainage conditions and hydrological data analysis. Existing condition of storm water drainage at Bagerhat Pourashava has been investigated by analyzing the data collected from field visits and summarizing information from previous studies conducted by LGED under CTEIP.

For hydrological data analysis, the daily rainfall data have been collected from January 1968 to June 2019. 1-Day annual maximum rainfall of each year is identified from the data. Gumbel’s extreme value distribution method is used to perform frequency analysis to determine the probable rainfall intensity for 5 years and 10 years return periods. Long duration Intensity-Duration-Frequency (IDF) curves are generated from rainfall data ranging from 1 day to 7 days of annual maximum rainfall for different return periods (i.e., T=2, 5, 10, 25, 50, 100 years). As short duration rainfall intensity is required in designing an urban drainage system, Bernard (1932) equation ($I = C.Tm/de$) is used to calculate short-duration rainfall intensity. Short duration IDF curves are generated for the duration ranging from 10 minutes to 120 minutes.

For water level analysis, hourly water levels for 39 years (from 1980-2019) of the Bhairab river have been analyzed. The highest water level during spring tide and the highest level during neap tide for each year are identified from these data. Using these values average high water level for each year is calculated. Similarly, the lowest water level during spring tide and lowest water level during neap tide are also identified. From these values, the average lowest water level of the Bhairab river has been calculated for each year. Then the average annual maximum and minimum water levels (mPWD) for various return periods (i.e., T=2, 5, 10, 25, 50, 100 years) are computed using Gumbel's extreme value distribution method.

4. RESULTS AND DISCUSSIONS

4.1 Assessment of Existing Drainage Conditions of Bagerhat Pourashava

Due to urbanization, inadequate drainage capacity and the increase in population, Bagerhat Pourashava requires immediate improvement of the drainage system. The first step of improving an urban drainage system is to assess the existing drainage condition of cities and towns. From the previous studies and field visits, it is found that the current drainage system in Bagerhat Pourashava is consisting of (i) six open natural khals and (ii) limited roadside katcha and pucca drains (around 104 km total length). The east and west parts of the Pourashava are the major low-lying areas. The low-lying areas are mainly comprised of Ward no. 1, 3, 6 and 9. Ward no. 4, 5 and 7 are comparatively higher than surrounding areas, but these are inundated during heavy rainfall due to a lack of drainage system and outfalls. From the field observations, it is also found that some khals are draining out water effectively, but the conditions of some other khals have been found poor. Those are disconnected by roads and in some places connected with culverts of inadequate size. Cross-sections of the khals seem bad for draining out storm water runoff. Artificial pucca drains have been functioning in the major parts of the study area. Due to lack of proper maintenance and garbage dumping, some drains are not functioning effectively. The condition of sluice gates at the drains outlet is also poor. From CTEIP's (2016) study based on a household survey on drainage conditions of the Bagerhat Pourashava, it is found that 86% of the households' have some proper local drainage. Of these, about 21% are not connected to any more significant drain or khal. About 88% of both local and main drains contain silt, solid waste, or vegetation, while an average of 40% is more than half full. Inquiries about the extent to which dwellings are affected by flooding reveal that about 6.5% suffer flooding every year, while a further 15% suffer only some years. Approximately 44% of households suffer from waterlogging in their locality every year, up to 8 times a year. The following pictures were taken during the field visits expose these situations (Figure 2).

Figure 2: Conditions of drainage system: garbage dumping (left) and blockage of natural drainage (right). (Source: Field visit)

4.2 Estimation of Hydrological Parameters for Designing Drainage System of Bagerhat Pourashava

4.2.1 Estimation of Design Rainfall Intensity

To solve waterlogging problems, improvement of existing drainage systems is required. For the hydrological design of the storm water drainage volume, an accurate measure of hydrological parameters is essential. For accurate hydrologic analysis, reliable rainfall intensity estimation is needed (Basnet and Neupane, 2018, Mishra and Tanwer, 2020). As estimation of peak runoff by using the Rational approach ($Q = 0.278CIA$) greatly depends on peak rainfall intensity (I). For estimating the design rainfall intensity, the daily rainfall data at Bagerhat station (station ID: CL501) is collected from the Bangladesh Meteorological Department (BMD) for a period of 51 years (1968-2019). From the daily rainfall data of each year, 1-D annual maximum rainfall events are extracted (Figure 3). Similarly, the highest annual rainfall events for 2 to 7 consecutive days for each year are extracted. Then the Gumbel's distribution method is used for developing the long duration IDF curves. It is the most widely used distribution method for generating the IDF curve. It is relatively simple and uses only extreme events (maximum values or peak rainfalls).

Intensity-Duration-Frequency (IDF) curves from maximum rainfall values of 1-day to 7-days are developed for the 6 different return periods (T=2, 5, 10, 25, 50, 100 years). Then the Bernard equation converts long-duration IDF curves to short-duration IDF curves (10 minutes to 120 minutes). Long and short duration IDF curves are shown in Figure 4. Usually an urban drainage system is designed based on 2 hours rainfall duration for both 5 years and 10 years return periods. In this study, the estimated design rainfall intensities are given in Table 1.

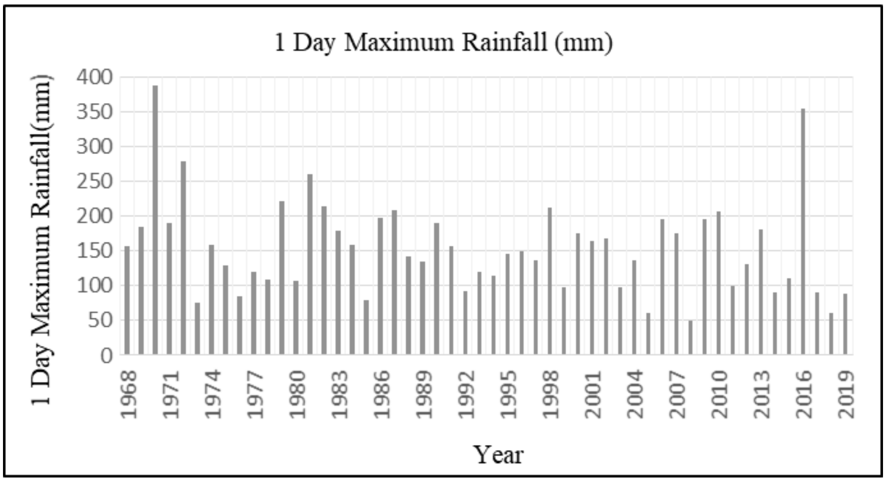


Figure 3: 1-D (one day) annual maximum rainfalls with time at Bagerhat Pourashava.

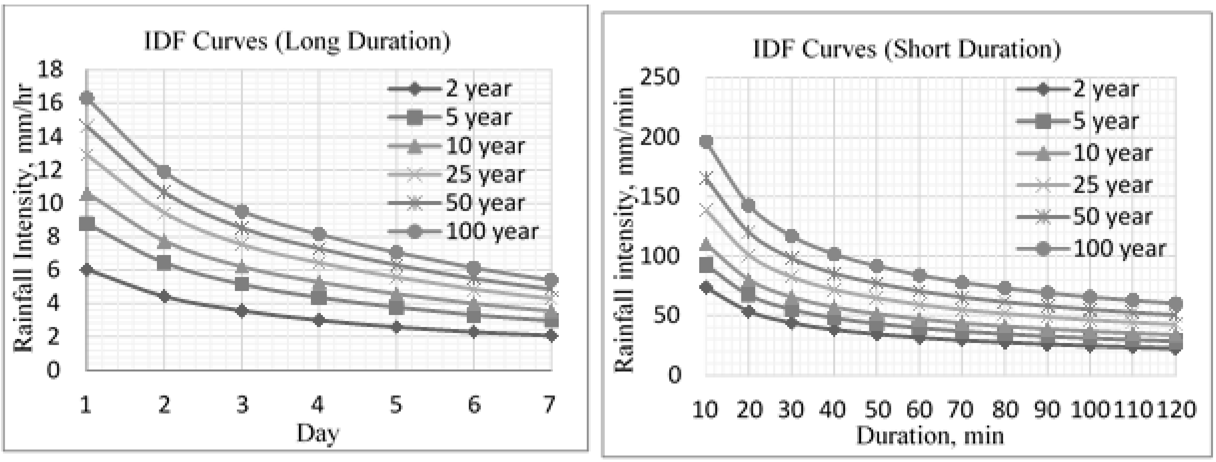


Figure 4: Long and short duration IDF curves for rainfall analysis of Bagerhat Pourashava.

Table 1: Estimated design rainfall intensities for 5 years and 10 years return periods.

Rainfall duration	Rainfall intensity (mm/hr)	
	5 years return period	10 years return period
2 hours	28.36	33.75

4.2.2 Estimation of Design Water Level

Analysis of water level data is required to design a drainage system if there is any river adjacent to the urban area (Awal and Islam, 2020). Bagerhat Pourashava is located adjacent to the Bhairab River (tidal river). It is a significant outfall location for the Pourashava area. That's why this river greatly influences the existing drainage condition of the study area. For water level analysis, water level data of the Bhairab River have been collected from the Bangladesh Water Development Board (BWDB) (Station of BWDB at Alaipur khal Doratana, Bagerhat Pourashava) for the year 1980 to 2019 and has been plotted as shown in Figure 5. From this figure, the highest water levels during spring and neap tides are found out for each year. Also average high water levels are calculated for each year. Similarly, the lowest water levels during spring neap tides for each year are also extracted. Then the average low water levels are calculated for each year. These average high and low water levels for various return periods (i.e., T=2, 5, 10, 25, 50, 100 years) are computed using Gumbel's Distribution method. In an urban drainage system, 50 years or 100 years return period is considered as the design water level. In this study, estimated design river water levels for 50 years and 100 years return periods are shown in Table 2 and Figure 6.

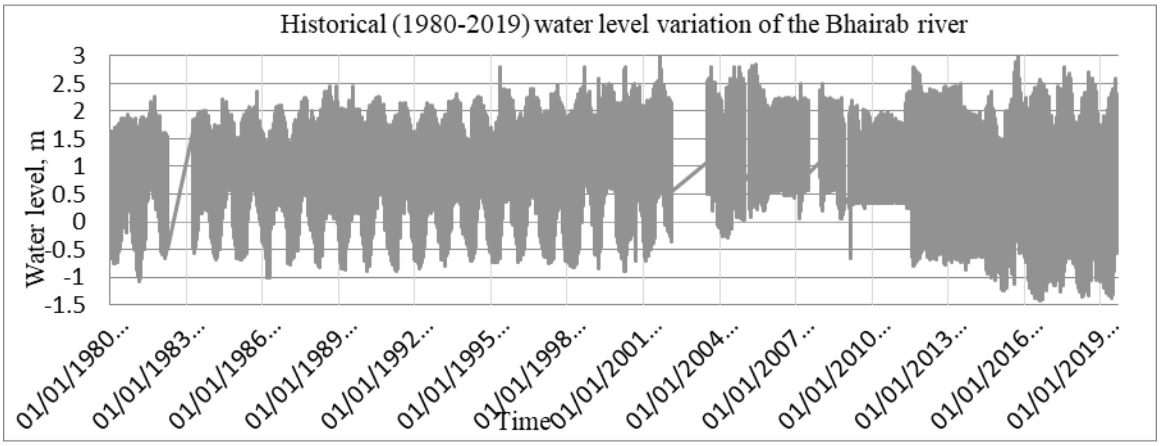
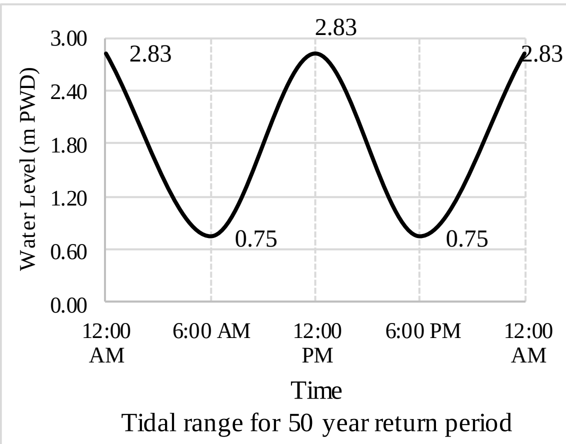


Figure 5: Water level variation of the Bhairab River from 1980 to 2019.

Table 2: Estimated design water levels for 50 and 100 year return periods.

Return period	Average high WL (mPWD)	Average low WL (mPWD)
50 years	2.83	0.75
100 years	2.98	1.01



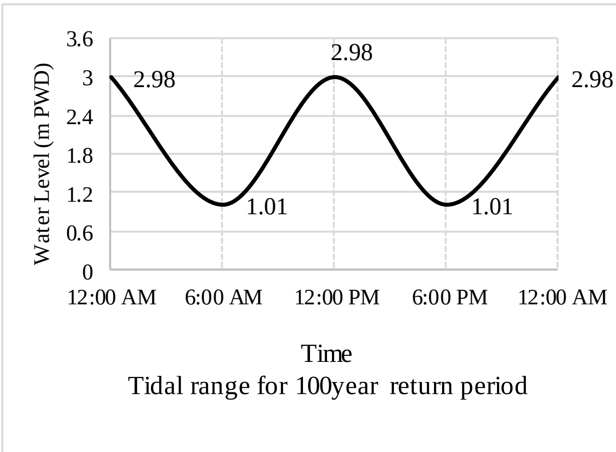


Figure 6: Average tidal range of Bhairab river for 50 and 100 year return period.

5. CONCLUSION

To design a proper urban drainage system, it is essential to know the existing drainage system's conditions and estimate various hydrological parameters. In this study, an assessment of existing drainage conditions of Bagerhat Pourashava has been done. From the evaluation, it is found that the existing drainage system of the Pourashava is poorly maintained and inadequate. As a result, the lower part of the Pourashava area faces flooding and waterlogging problems every year. The causes of flooding and waterlogging problems are mainly due to unplanned and haphazard development, human activities like garbage dumping, changes in land use, blockage of natural drainage systems, silt arising from construction activities and lack of maintenance etc. Moreover, in some areas local drains are not connected to the primary drainage system. So to improve this situation, it is necessary to have a sustainable storm water drainage system. For designing the drainage system, hydrological analysis such as rainfall and river water level data analysis has been accomplished. In this study, daily rainfall data are analyzed, and the IDF curve is generated to estimate the design rainfall intensity for 2-hour duration rainfall for 5 years and 10 years return periods. Also, hourly tidal water level data of Bhairab River has been analyzed, and design water level data of 50 years and 100 years return periods have been estimated. This design rainfall intensity can be used to design the new drain size and capacity using the rational approach. Similarly, the estimated design water level can be used to create a new sluice gate opening at the outlets of the khals and drains discharge into Bhairab River. The approach developed in this study can also be served as a platform for the guidelines of estimation of design parameters for designing storm water drainage systems in other municipalities in Bangladesh.

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