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DESIGN OF STORMWATER DRAINAGE SYSTEM FOR PATUAKHALI POURASHAVA USING GEOSWMM

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ABSTRACT

Effective urban storm water management is an increasingly important environmental issue for urban communities. This study investigates the existing drainage system of Patuakhali Pourashava which is a small town in the Patuakhali district of Barisal division. At present there are waterlogging in some parts of the city during the rainy season almost every year. This happens mainly due to inadequate drainage network, seasonal heavy rainfall and high tide level at surrounding Laukathi and Golachipa River, blocked drains by garbage dumping, encroachment of drainage canals and missing links in the drainage network. Moreover, being near to the coastal area and surrounded by the tidal river Laukathi and Golachipa, 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 Patuakhali area during the period of 1979 to 2018 have been analyzed and IDF curve has been developed. From the curve, the design rainfall intensity has been estimated for 2 hour duration rainfall of 5 years and 10 years return period. Hourly water level data (2000-2019) of Laukathi River have been analyzed and design high and low water level have been estimated by Gumbel's distribution. To estimate the drainage flow for the design rainfall, GeoSWMM model has been developed for two Wards (Ward No. 8 and 9, as these two wards are found frequently waterlogged even by light rainfall) of Patuakhali Pourashava. The model is calibrated with the estimated runoff coefficient for the sub-catchments from the land use map. Then validation is done for the obtained outfall loading from the model with the estimated peak discharge. Finally, required cross-sectional areas of drainage canals have been estimated.

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

1. INTRODUCTION

Stormwater drainage systems in the past were designed for a particular peak rainfall intensity. Whenever rainfall of higher intensity has been experienced, these capacities are getting very easily overflowed. With a sharply increasing rate of population, the natural drains are needed to be widened to accommodate the higher flows of stormwater. But on the contrary, there have been large scale encroachments on the natural drains which decreases the capacity of the carriers, resulting in flooding. Urban flooding and waterlogging result in damage to properties, disruption in transport and power, expose infection or in extreme case, cause epidemic. Therefore, management of urban flooding has to be accorded top priority. A good number of previous studies have designed urban drainage system by developing stormwater runoff model (like GeoSWMM, MIKE SWMM, EPA SWMM) with GIS having necessary hydrological and topography data as input (Khodashenas and Tajbakhsh, 2016; Kibria and Biswas, 2019).

Efficient storm water management is required to protect the health of the public, welfare and safety of the public, conservation of water, need to strive for sustainable environment etc. To design a storm water catch basin functional requirements, technical requirements, and social and economic considerations need to be considered (Dieter H, 2013).

A storm water drainage system receives, conveys, and controls storm water runoff from precipitation and snowmelt. A storm water drainage system includes: ditches, culverts, subsurface interceptor drains, roadways, curb and gutters, catch basins, manholes, pipes, attenuation ponds and service lateral lines (EPWDR, 2011).

A major drainage system comprises of the natural streams, manmade streets, channels and ponds. The main purpose is to reduce the risk of loss of life and property damage due to flooding (Needhidasan.S et al., 2013).

Rapid urbanization increases the volume of storm water runoff by increasing the imperviousness of the basin. Managing the drainage system to safely and adequately drain this excess runoff is a major issue. Due to urban growth and and infrastructural development the drainage congestion in Bogra city has increased. A study was performed to assess the drainage condition of Bogra city for 5-year and 10-year return period (Maliha, M. & Khan, S. M., 2017).

Patuakhali Pourashava consisting of nine number of Ward, located near to the coastal prone area, is frequently subjected to high tide flash flood from the surrounding tidal rivers: Laukathi and Golachipa. Also, heavy rainfall during the rainy season easily causes urban floods as major portion of the primary drainage system of the pourashava is blocked, cannot carry the huge volume of storm water. To date, we have not found any recent study which comprehensively investigates the drainage system of Patuakhali Pourashava to solve out the existing problems. Therefore, reviewing the existing drainage condition of Patuakhali Pourashava, this study estimates the hydrological parameters (rainfall intensity, river water level) for the study area, then GeoSWMM model has been set up to design drainage system for both 5 years and 10 years return period. Specifically, present study models storm water management of Ward no. 8 and 9 of the Patuakhali Pourashava as these two wards are found frequently waterlogged even by light rainfall. The findings of this work can be useful for designing drainage system and flood mitigation measures in the study area.

2. STUDY AREA AND DATA COLLECTION

Patuakhali Pourashava is in the south western part of Bangladesh. The study area lies between 90º18'30" and 90º21'30" East longitude and 20º20' and 20º22' North latitude (shown in Figure 1). The town has flat landscape with medium high land at its central part. The minimum and maximum ground level varies from 0.06 m to 5.27 m PWD where mean height is 2.25 m PWD. The low-lying areas are mainly comprised of Ward no. 1 and 9. The study area is surrounded by two tidal rivers: Laukathi River in north and Golachipa River in the east. The highest flood level of the bordering rivers is 2.96 m PWD. Patuakhali municipality has one embankment, which is mainly used as road. The embankment is about 3.29 km long and passed through the Ward no. 1, 2 and 3, along the river Golachipa. There are 39 sluice gates installed in the embankment to control discharge of drainage water into river based on the tidal periods. There are good number of khals in Patuakhali municipality. In addition, there are manmade drains, which include unlined canal of 26.55 km length, and lined canal of 9.23 km. The lengths of primary, secondary and tertiary drains are 38.63 km, 6.64 km and 10.36 km respectively. There have been encroachments on the natural drains and also improper disposal of solid waste, including domestic, and commercial waste and dumping of construction debris into the drains also contributes significantly to reducing their capacities. The Land use of the municipality area is mostly comprising of residential buildings (about 38.85% of the total) followed by agricultural land use (about 21.68% of the total).

For this study, data of elevation, drainage and land use of Patuakhali Pourashava are collected from LGED and household survey of CTEIP. Data for digital elevation modeling (DEM) is collected by land surveying. For hydrological analysis of the study area, 40 years daily rainfall data from BMD (1979 -2018) and 20 years long hourly water level data (2000-2019) of Laukathi River from BIWTA (station SW 184) are collected.

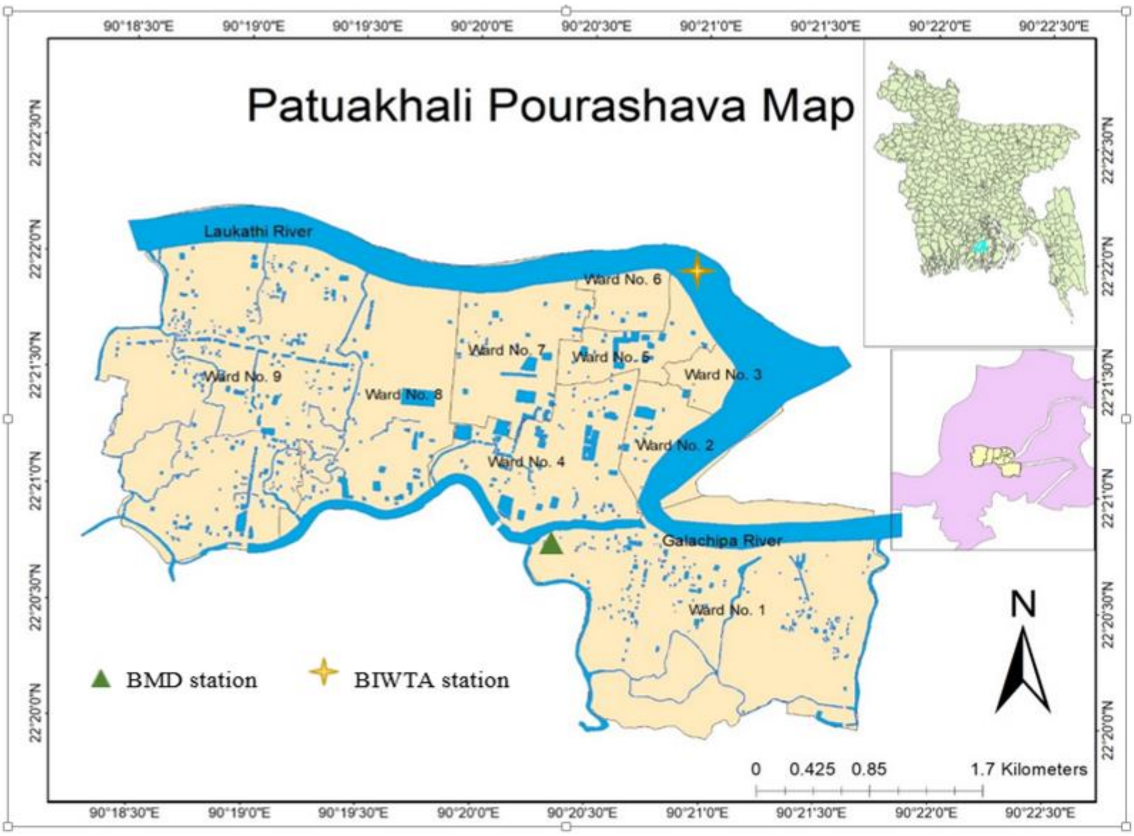

Figure 1: Study area- Patuakhali Pourashava (source: LGED)

3. METHODOLOGY

Existing condition of the drainage system of Patuakhali Pourashava is investigated by field visits and summarizing information from different sources like LGED and CTEIP. For hydrological analysis, annual maximum rainfall of each year is identified from the data and then frequency analysis of the peak rainfall data are performed by Gumbel's extreme value distribution to find out the probable rainfall magnitude for 5 years and 10 years return periods. To estimate peak outfall by rational method, peak intensity of rainfall is needed. To evaluate the rainfall intensity, Intensity-Duration-Frequency (IDF) curves from the rainfall data are generated for 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). As short duration rainfall intensity is required in urban drainage system, Bernard (1932) equation is used to calculate short-duration rainfall intensity for the same return periods to generate IDF curves for short duration rainfall ranging from 10 minutes to 120 minutes duration.

To establish design water level, hourly water levels of Laukathi river is analyzed for 20 years from 2000-2019. To identify the design annual maximum water level, the average of the spring tide high water level and neap tide high water level of each year is identified and then the average of these 20 years is calculated. Similarly, to find out the design minimum water level the average of the spring low water level and neap low water level of each year is taken and then the average of these 20 years is calculated. 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 annual maximum and minimum water levels (m PWD) for various return periods (i.e., T=2, 5, 10, 25, 50, 100 years) are computed by Gumbel's Distribution.

For modeling of the drainage system of the Ward no 8 and 9 of the Pourashava, the rainfall intensity of return period of 5 years and 10 years for a duration of 2 hours are used. According to JICA (1987) report, daily rainfall data is distributed to 4 hourly rainfall data and used in the model. Design tidal water levels are selected as average annual maximum tidal range of 50 years return period. DEM file is created in ArcGIS from the elevation data collected by land surveying. The study area has been delineated into 10 sub-catchments and 15 streams and 6 outlet points from the sub-catchments are delineated (shown in Figure 2). At the outfalls design water level data is given as boundary condition of the model to consider the effects of tidal river Laukathi. Manning's N for impervious and pervious areas is assumed to be 0.024 and 0.15 respectively. The model is calibrated with the estimated runoff coefficient for the sub-catchments from the land use map. The value of the outfall loading has been validated with the help of rational method of discharge calculation.

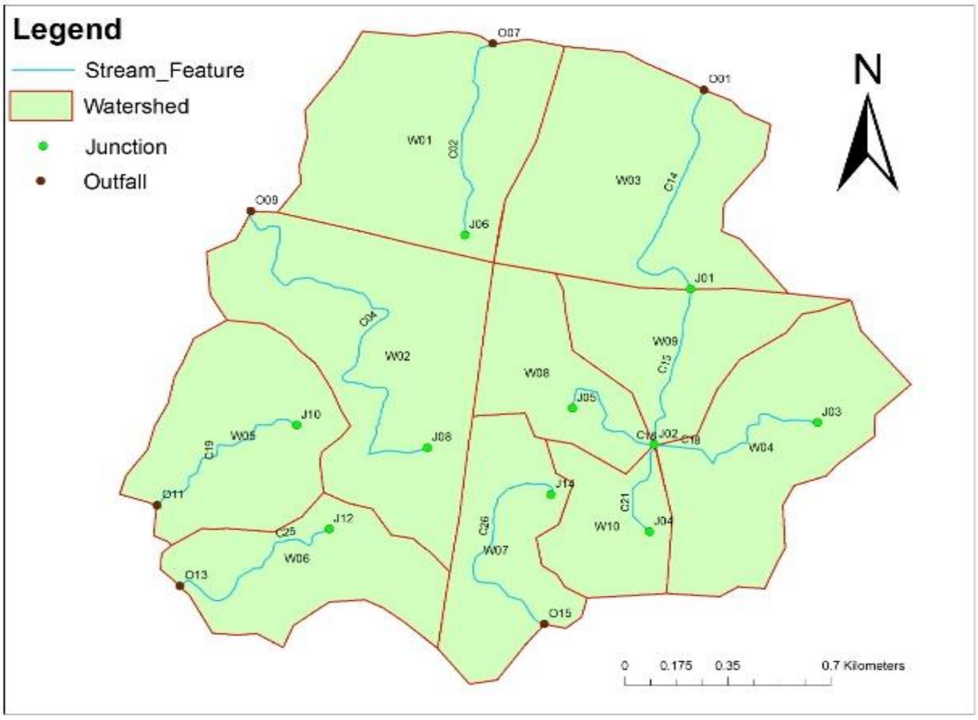

Figure 2: Delineated Watershed in GeoSWMM for Ward no. 8 and 9 of Patuakhali Pourashava

4. RESULTS AND DISCUSSIONS

4.1 Investigation of existing drainage system of Patuakhali Pourashava

The key findings from the field visit are that the existing cross-sections of the drainage canals are not enough for the passage of drainage water. About 82% of the households' have local drains of which 14% is not connected to main drainage lines. About 22% of local drains and 17 % of main drains are more than half full containing silt, solid waste or vegetation. Approximately 32% of households suffer urban flood every year and about 17% of households suffer from frequent waterlogging up to 7 times a year. The causes of water logging problem are mainly due to inadequate drainage network, seasonal submergence due to heavy rainfall and high tide level at surrounding Laukathi and Golachipa River, blocked drains by garbage dumping, encroachment of drainage canals and missing links in the drainage network in all wards. The pictures taken during the field visits expose these situations

(Figure 3). It shows the water logging map of Patuakhali Pourashava where both the east (Ward no. 8 and 9) and west side (ward no. 1) of the study area are found as waterlogged even by light rainfall.

Figure 3: Conditions of drainage system: encroachment (left) and garbage dumping (right) (source: Field visit in December 2019)

4.2 Estimation of hydrological parameters for designing drainage system of Patuakhali Pourashava

4.2.1 Estimation of design rainfall intensity

Figure 4 shows 1-day annual maximum rainfall data from 1979 to 2018. 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). Long duration IDF curves are converted to shorter duration IDF curves (10 minutes to 120 minutes) by using Bernard equation. Figure 5 shows IDF curves for various return periods (i.e., T=2, 5, 10, 25, 50, 100 years) for both longer and shorter durations.

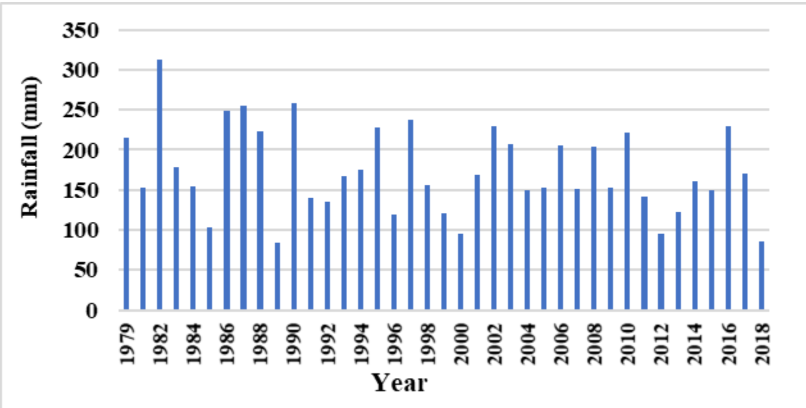

Figure 4: Maximum daily rainfall (mm) of Patuakhali (1979-2018)

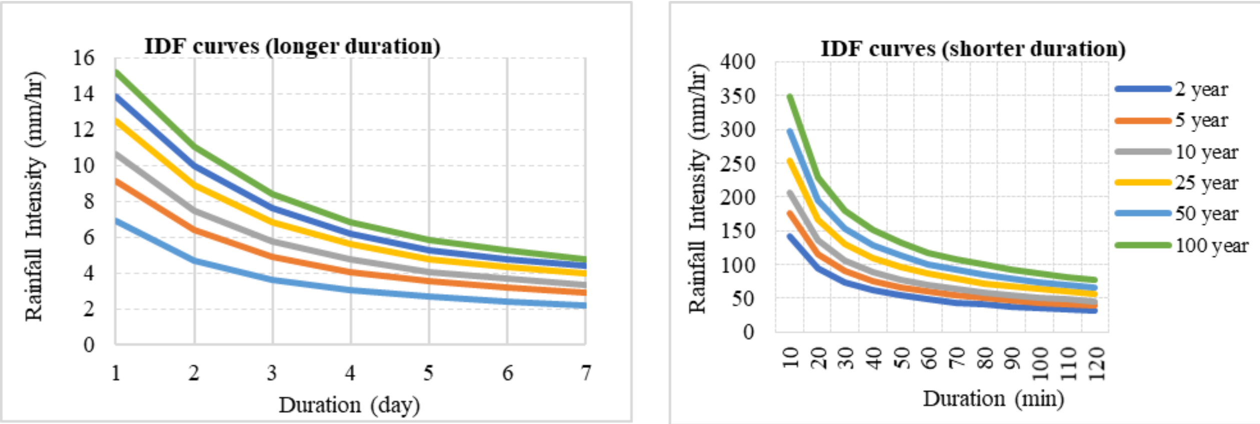

Figure 5: IDF curves for rainfall at Patuakhali for longer and shorter duration

4.2.2 Estimation of design water level data

Analysis of historical hourly water levels (2000-2019) of tidal river Laukathi shows that the maximum, average and minimum water levels are 2.7 mPWD, 0.46 mPWD and -1.2 mPWD respectively. Average annual maximum and minimum water levels for various return periods (i.e., T=2, 5, 10, 25, 50, 100 years) are computed by Gumbel's Distribution. For 50 years return period, annual maximum and minimum water level are identified as 2.15 m PWD and -0.7 m PWD. Figure 6 represents the average tidal range of Laukathi River for 50-year return period which is used as design water levels.

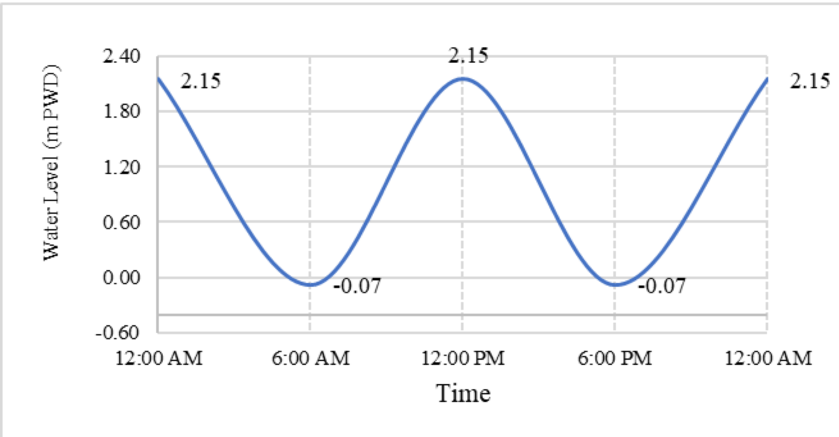

Figure 6: Average tidal range of Laukathi River for 50-year return period

4.3 Designing Drainage System of Ward no. 8 and 9 of Patuakhali Pourashava Using GeoSWMM

This study develops a GeoSWMM model to determine the sub-catchment runoff of the Ward no. 8 and 9 of the Pourashava. The model is calibrated for runoff coefficients of 10 different catchments that come in the range of 0.502 – 0.565 which is in good agreement with the runoff coefficients estimated using the land use map which lies in the range of 0.500-0.565 (Figure 7). For validating the model, peak discharge obtained from rational method for 5-year 1-hour rainfall is 34.815 m3/s whereas from the simulated model, total outfall discharge is found as 37.369 m3/s which shows good agreement between the two results.

At different nodes such as junctions, outfalls and dividers, obtained results from the model simulation are water depth, stored water volume, total inflow, average velocity, etc. The peak storage observed for 5-year return period is 39,433.69 m3 and 10-year return period is 44,733.51 m3. The peak runoff for 5-year return period is 21.35 m3/s and for 10-year return period is 25.83 m3/s. Stream cross-sections are calculated from continuity equation having velocity as 0.8 m/s (non-silting, non-scouring velocity).

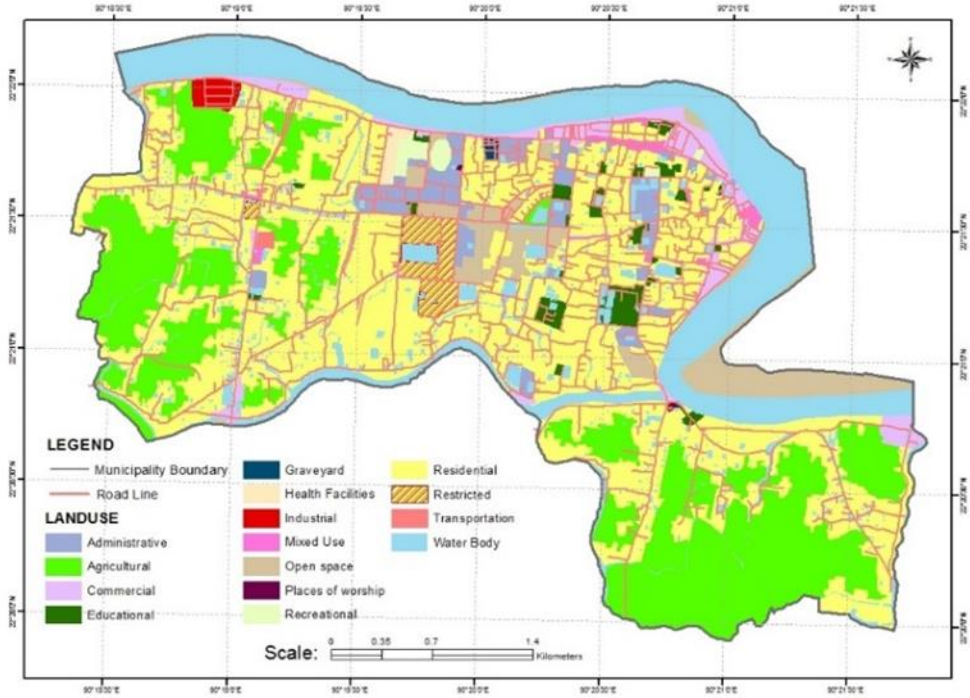

Figure 7: Existing Land use map of Patuakhali Pourashava (Source: LGED report)

Table 1 shows required drainage cross-sections in Patuakhali Pourashava based upon 2-hour duration rainfall for return periods of 5 years and 10 years respectively. Being a small modeled area (3.99 km2) design cross-sections are almost similar for both 5 years and 10 years return period.

Table 1: Design Drainage Cross sections for Return Period, T= 5 years and 10 years

		Return period, T = 5 years		**Return period, T = 10 years**	
Stream (Fig. 2)	**Velocity, V (m/s)**	**Discharge, Q (m^3/s)**	**Area, A (m^2)**	**Discharge, Q (m^3/s)**	**Area, A (m^2)**
C02	0.8	5.282	6.60	5.282	6.60
C04	0.8	5.752	7.19	5.752	7.19
C14	0.8	9.282	11.60	11.306	14.13
C16	0.8	3.081	3.85	3.081	3.85
C18	0.8	7.567	9.45	7.567	9.45
C19	0.8	6.229	7.78	6.229	7.78
C21	0.8	3.615	4.51	3.615	4.51
C25	0.8	6.282	7.85	6.282	7.85
C26	0.8	4.542	5.67	4.542	5.67
C15	0.8	7.229	9.03	7.504	9.38

5. CONCLUSION

The storm drainage system of Patuakhali Pourashava has been analyzed in the present study. The condition of the existing drainage networks is inadequate to dispose of the runoff as a result the lower part of the study area is facing flooding and water logging every year. The drains are chocked due to throwing of garbage, polythene bags, and wastages of vegetable, etc. and in many areas local drains are not connected to the main drainage system. Daily rainfall data are analyzed and IDF curve is generated to estimate the design rainfall intensity for 2- hour duration rainfall for 5 years and 10 years return periods. Hourly water level data of tidal river Laukathi have been analyzed and design water level data of 50 years return period has been estimated. GeoSWMM model is developed to estimate design cross-sectional areas of the drainage system at Ward no. 8 and 9 of Patuakhali Pourashava. The findings of this work can be useful for designing drainage system and flood mitigation measures in the study area.

REFERENCES

Dieter, H.L., (2013), 'Surface water drainage design considerations practices', Canadian Water Resources Journal,Vol. 12, No. 3, Pp. 67-78.

EPWDR (2011): Storm Water Design Criteria Manual for Municipal Services, Engineering and Public Works Department, Riverview.

JICA (1987), "Study on Storm water Drainage System Improvement Project in Dhaka City". Main report, DPHE, GOB, Dhaka.

Khodashenas. S. R. and Tajbakhsh. M. (2016). "Management of Urban Drainage System Using Integrated MIKE SWMM and GIS", Journal of Water Resource and Hydraulic Engineering, Mar. 2016, Vol. 5 Iss. 1, PP. 36-45.

Kibria. S. and Biswas. R. (2019). "Design of Stormwater Drainage Network with Limited Rainfall Data Using GeoSWMM: Case Study for Dinajpur City", Proceedings on International Conference on Disaster Risk Management, Dhaka, Bangladesh, January 12-14, 2019.

LGED-ADB, Final Report on Integrated Drainage Plan (IDP) for Patuakhali Pourashava, CTEIP, DWRE, BUET, 2021.

Maliha, M., & Khan, S. M. (2017). Design of stormwater drainage network with limited data using GeoSWMM: a case study for Bogra city (Doctoral dissertation, B. Sc. thesis, Department of Water Resources Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh).

Needhidasan, S., Nallanathel, M., (2013); 'Design of Storm Water Drains by Rational Method – an Approach to Storm Water Management for Environmental Protection', International Journal of Engineering and Technology (IJET), Vol. 5, No. 4, Pp. 3203-3214.

Streams Tech, Inc. (2015) User's Manual, GeoSWMM, Stormwater and Wastewater Management Model.