A Feasibility Study of Stormwater Management for a Campus University in Semenyih, Malaysia

Ming Yuan Ting, Fang Yenn Teo, Ivan Kwong Hieng Theng and Boon Hoe Goh

Abstract Sustainable stormwater management is one of the techniques used for managing water runoff as a measure to minimize the consequences of peak discharges, extension of flooding, and deterioration of surface water due to land use changes. The best management practices (BMPs) of sustainable stormwater management endorsed a more effective and environmentally storage-oriented approaches which focus on detention, retention, and recharge in terms of water quantity and quality control. This study has established the information on hydrological parameters and estimations of the existing water conveyance system in a campus university in Semenyih, Malaysia. Based on the hydrological analysis, a thorough review into the BMPs has been carried out. The study presents a proposed stormwater management solution towards the prevention of flash flood in the study area. Wet detention pond has been selected as the BMPs and introduced in the proposed stormwater facilities for quantity and quality control measures. The hydraulic analysis were performed on the proposed solution by referring to the guidelines depicted as in Urban Stormwater Management Manual for Malaysia (MSMA). From the results, the proposed wet detention pond can cater with a maximum storage of 18,579 m^3. The pond can handle a surge of floodwater to prevent the backflow of water in the existing drainage system. The two outlet structures of the wet detention pond are able to drain the stormwater runoff at a peak discharge rate which is lower than the pre-development peak discharge rate. The results also revealed that the proposed solution is adequate to cater for the 100-year average recurrence interval (ARI) storm events.

Keywords Stormwater management · Wet detention pond · Best management practices

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1 Introduction

Urban development has changed the land use activities in Malaysia rapidly. Urbanisation increases the impervious area from natural vegetation removal, grading and built facilities. The rising number of the impervious area increases both the total runoff, total discharge and bedload sediment transport rates. In addition, urbanisation also decreases the time of concentration of runoff hydrograph [4].

Subsequently, urbanisation led to the changes in peak discharge and water pollution. The number of the rivers that can handle the surface runoff are declining. The stormwater that using the traditional approach of drainage system will be experienced problems of increase the magnitude two times and quickly discharge to the closest river system. Many urban cities in the West Coast of the Peninsula Malaysia are facing these problems [8].

In order to mitigate these problems, the Urban Stormwater Management Manual for Malaysia (MSMA) was introduced by the Department of Irrigation of Drainage (DID), Malaysia. The new guideline aims to control the quantity and quality of the stormwater and achieve zero development impact contribution. One of the runoff quantity control requirements in MSMA is to maintain the peak discharge rate and quantity of the runoff from the developed area to be the same or lower than the pre-development condition. This is known as uncontaminated zero increase in peak discharge that has been implemented over several decades in the other developed countries [3].

A wet detention pond is considered as one of the most important measures in the stormwater management and manages quantity and quality impacts resulting from the urban catchment through BMPs [2]. Persson [6] concluded that elongated pond shapes and baffled systems could provide a very high hydraulic efficiency [6]. Furthermore, wet detention pond is also configured to hold the flood storage and release it over 2 to 5 days [5]. The efficiency of pollutants removal via sedimentation depends primarily on the hydraulic retention time (HRT), with longer HRT leading to higher removal rates [7].

This study establishes the information on runoff estimations of the existing water conveyance system in a campus university in Semenyih, Malaysia. Based on the hydrological analysis, a thorough review into the BMPs has been carried out to propose a stormwater management solution for prevention of flash flood and sedimentation in the study area. Wet detention pond has been selected as solution of BMPs for water quantity and quality control measures. The hydraulic analysis were performed on the proposed solution by referring to the guidelines depicted as in Urban Stormwater Management Manual for Malaysia (MSMA).

2 Study Area and Methodology

The study area is located at the University of Nottingham Malaysia Campus, Semenyih in the State of Selangor of Malaysia as shown in Fig. 1. The means annual rainfall for astation nearby to this study area is found to be 2234.35 mm [1]. The study focuses on the existing water body with an area of 1.05 ha and its catchment area. Figure 2 shows the orthomosaic map of the project area. The existing water body is selected as the project area to implement stormwater management facilities. By converting this piece of land to a detention pond would serve the goals of stormwater management practices. The catchment of the project area covers an area of 41.70 ha and is dominated by institutional building, student hostels and palm oil plantations.

The rainfall intensity were calculated by using intensity-duration-frequency (IDF) empirical equation. The orthomosaic map and digital surface model of project area were generated from the data of aerial photogrammetric survey. The pre-development and post-development land cover types were determined from the historical satellite image that found in the Google Earth Pro. The delineations of the subcatchments were made based on the grouping of relatively similar types of land use. All the measurements of land use area were obtained from Google Earth Pro. The study area is found to be less than 80 ha. Thus, the Rational Method was used in this study to estimate the peak flow discharge. The preliminary sizing of storage capacity of the wet detention pond, grading of the pond and the outlets have been

Fig. 1 Location for University of Nottingham Malaysia Campus

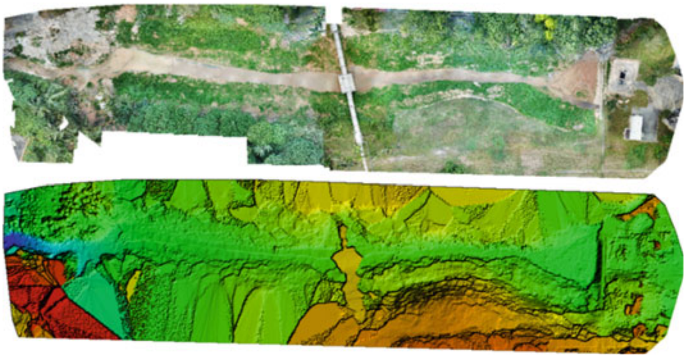

Fig. 2 Orthomosaic map and digital surface model of the project area

designed based on MSMA 2nd edition. The hydrological pond routing in this study was performed with a time step of 1.0 min.

3 Results and Discussion

Figure 3 shows the satellite image of the pre-development catchment area in 2002. A cover type of agriculture area for minor system, the runoff coefficient value was found to be 0.3 for subcatchment S1, S2, S3 and S4. The land use of the entire catchment area is classified average grassed with Horton's roughness, n* value is 0.045. The highest pre-development time of concentration obtained is at subcatchment S1 at 37.72 min. The reason for the high time of concentration is because subcatchment S4 has the longest overland sheet flow path among the rest of the subcatchments. The rainfall intensity used in the runoff computation was 122.30 mm/hr for 10-year ARI storm and 177.19 mm/hr for 100-year ARI storm. The pre-development peak discharge for this catchment area were determined to be 3.78 m^3/s for 10-year ARI storm and 5.47 m^3/s for 100-year ARI storm. The pre-development flows obtained will then become the post-development flow limits in the drain right at the downstream of the wet detention pond.

Based on Fig. 4, the catchment area has been developed with apartment, commercial and business centre and also agriculture area. Subcatchment S1 contains three different types of land use which are apartment, open space (i.e. bare soil) and agriculture area. In the other hand, for subcatchments S2 and S3, both subcatchments made up of two different lands which are commercial and business centre and also forest cover. Site clearing and earthwork were carried out in the entire subcatchment S4 for a development project. Thus, it was categorised as bare soil open space with a runoff coefficient of 0.60. The average runoff coefficient value of subcatchment S1 was found to be 0.57, for subcatchment S2 is 0.65, subcatchment S3 is 0.78 and subcatchment S4 is 0.60. The highest post-development time of concentration obtained is from subcatchment S4 to the inlet, the agriculture area at 28.45 min.

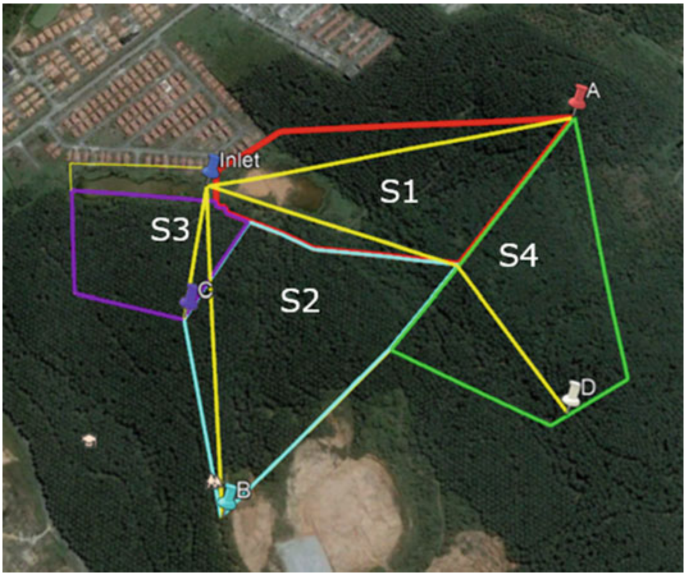

Fig. 3 Satellite image of pre-development catchment area in 2002

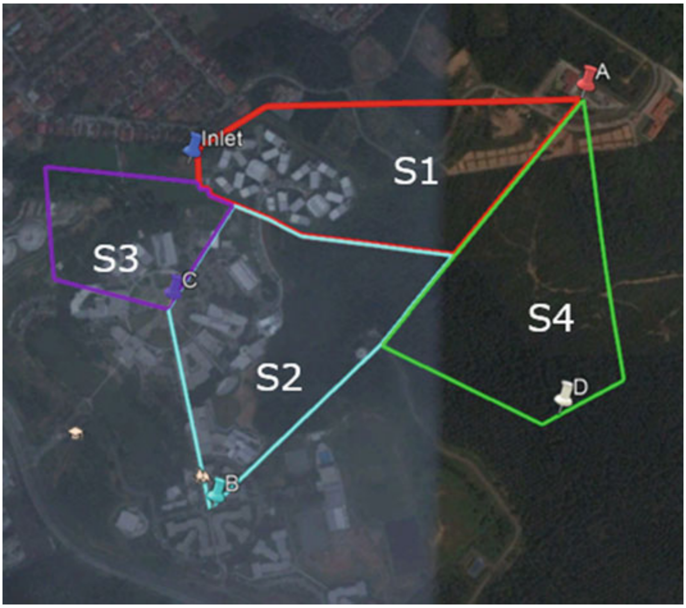

Fig. 4 Satellite image of post-development catchment area in 2019

Table 1 shows the 10-year and 100-year ARI storm inflow hydrographs over a range of storm duration from t_c to 2.5 t_c were computed. All the inflow hydrographs were examined and the inflow hydrograph that has the largest estimated volume from the same year of ARI storm would be selected. The results show that the inflow hydrographs with lowest storm duration produced the highest peak discharge.

The average elevation in the project area measured relative to local mean sea level is found to be 55.00 m. Thus, the wet detention pond was designed to be 4.00 m deep with a slope of 0.33 and the bed level starts at 55.00 m. The wet detention pond has a permanent pool with the height of 2.00 m. Thus, the flood storage starts at 57.00 m. The details of stage storage relationship is shown in Table 2. The maximum storage volume of the wet detention pond is found to be 18,579 m^3.

Figure 5 shows the layout plan of the proposed wet detention pond. A square orifice with 1.10 m of width and 1.10 m of depth was chosen as the primary outlet of the wet detention pond. The 10-year ARI post-development storm orifice produced a maximum discharge of 2.97 m^3/s which is acceptable as it is more than the 10-year ARI storm pond outflow limit of 3.78 m^3/s. Figure 6a shows inflow and outflow hydrograph of 10-year ARI storm event. The maximum water elevation in the wet detention pond is 58.42 m that relative to a maximum water depth of 1.42 m. It is considered adequate since the maximum water depth is lower than the maximum allowable elevation of 59.50 m. The secondary outlet is designed to be a 3 m wide broad-crested weir spillway. The weir has a side slope with a horizontal to vertical ratio of 2:1. The spillway was allocated at an elevation of 58.90 m. The embankment crest elevation is set at 59.50. The 10-year ARI storm orifice and

Table 1 10-year and 100-year ARI storm inflow hydrographs over a range of storm duration from tc to 2.5 tc

ARI (year)	Storm duration, d	d (min)	i (mm/hr)	Area (ha)	Q_{post} (m^3/s)
10	tc	28.45	131.16	41.70	9.58
	1.5 tc	42.67	99.78	41.70	7.29
	2.0 tc	56.89	81.35	41.70	5.94
	2.5 tc	71.11	69.12	41.70	5.05
100	tc	28.45	190.02	41.70	13.88
	1.5 tc	42.67	144.56	41.70	10.56
	2.0 tc	56.89	117.86	41.70	8.61
	2.5 tc	71.11	100.13	41.70	7.31

Table 2 Stage-storage relationship of proposed wet detention pond

Stage (m)	Elevation (m)	Area (m^2)	Storage volume (m^3)
0.00	57.00	7781	0
0.50	57.50	8206	3997
1.00	58.00	8636	8421
1.50	58.50	9070	13,280
2.00	59.00	9509	18,579

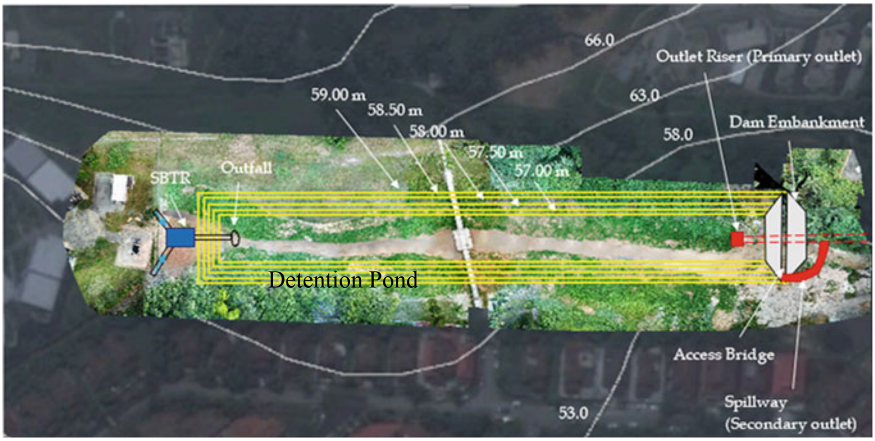

Fig. 5 Layout plan of the proposed wet detention pond

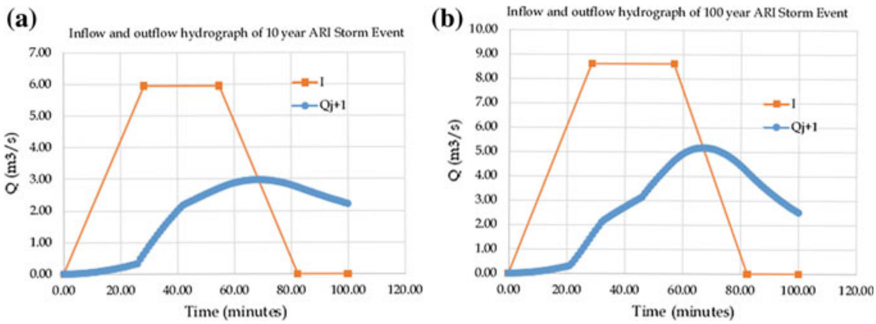

Fig. 6 Inflow and outflow hydrograph of 10 year ARI storm event (**a**) and 100 year ARI storm event (**b**)

100-year ARI storm spillway produced a maximum discharge of 5.17 m^3/s which is acceptable as it is less than the 100-year ARI pond outflow limit of 5.47 m^3/s. The inflow and outflow hydrograph of 100-year ARI storm event is shown in Fig. 6b. The maximum water elevation in the basin is 58.90 m which has a maximum water depth of 1.90 m. It is acceptable since it is lower than the maximum allowable elevation of 59.50 m.

4 Conclusion

The study has performed a series of hydrological and hydraulic analysis in the study area. All the hydrological calculation and design of the proposed solution of BMPs for stormwater and flood management are based on MSMA 2nd edition. From the analysis results, the proposed BMPs of wet detention pond with a maximum storage of 18,579 m^3 and two different drainage outlets can cater for 100-year ARI storm event. It can be concluded that the proposed wet detention pond can alleviating flood problems in the study area. The pond can handle a surge of floodwater, thus prevent the backflow of water in the existing drainage system. It can also ensure no recurrence of flooding in the study area after the project is completed. The two outlet structures of the wet detention pond are able to drain the stormwater runoff at a peak discharge rate which is lower than the pre-development peak discharge rate. The results show the proposed solutions for stormwater and flood management are capable of improving the quality of runoff and alleviating flood problems in the study area. It is hopeful that the findings could help the developers or local authorities in planning a proper flood mitigation plan.

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