#56 - Urban hydrological responses to blue-green infrastructures in subtropicalclimates

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Highlights

- inconsistency in relative change of total and peak discharge at event scale
- location of outfalls and upper BGIs obviously influence total and maximum discharge and hydrograph shape

Introduction

Hydrograph is essential for hydrological response analysis. In this study, the Anderson Road Quarry Site, Hong Kong SAR is set as a study area (Figure 1). A set of typical blue-green infrastructures (BGIs) such as Green roof, stormwater attenuation lake and porous pavement are under construction within this site. As the study site is located at subtropical climates, this study uses hydrological modelling, field monitoring and statistical analysis methods to find out the hydrological responses to BGIs under this specific climate. In conclusion, this study aims to explore: (1) what are the event-scale effectiveness of BGIs on hydrograph characteristics? (2) what are the long-term scale effectiveness of BGIs on hydrograph characteristics? (3) are peak and total stormflow affected in the same way by BGIs?

Methodology

Urban hydrological modelling

Hydrological modelling will be implemented to simulate urban hydrological cycle under the impacts of blue-green infrastructures (BGIs). Storm Water Management Model (SWMM) will be adopted for simulating urban hydrological cycle. SWMM has complete drainage routing simulation functions, Low Impact Development (LID) and water quality simulation functions, which has been widely used in urban stormwater formation and mechanism research (Rossman, 2010). The Anderson Road Quarry which is located on the southwestern slope of Tai Sheung Tok at East Kowloon, Hong Kong was chosen as study catchment. The catchment is about 40 ha and was delineated into 46 subcatchments based on terrain characteristics or land use. For urban stormwater network, it is assumed that the pipe to be used are uPVC pipe and the Manning's roughness ranging from 0.009 to 0.011 according to different experimental studies (https://www.lmnoeng.com/manningn.htm). LID Controls module was added to the corresponding subcatchments and parameters were set based on designed situations. In SWMM, excess rainfall was converted into surface runoff and the surface runoff was calculated based on Manning's Equation (Sarminingsih et al., 2019):

$$Q = 1.49\frac{A}{n}R_h^{\frac{2}{3}}S_0^{\frac{1}{2}} \tag{1}$$

where Q: Surface Runoff (ft^3 /s), n: Manning's Roughness, A: Channel Area, S_0: Channel Slope, R_h: Hydraulic Radius.

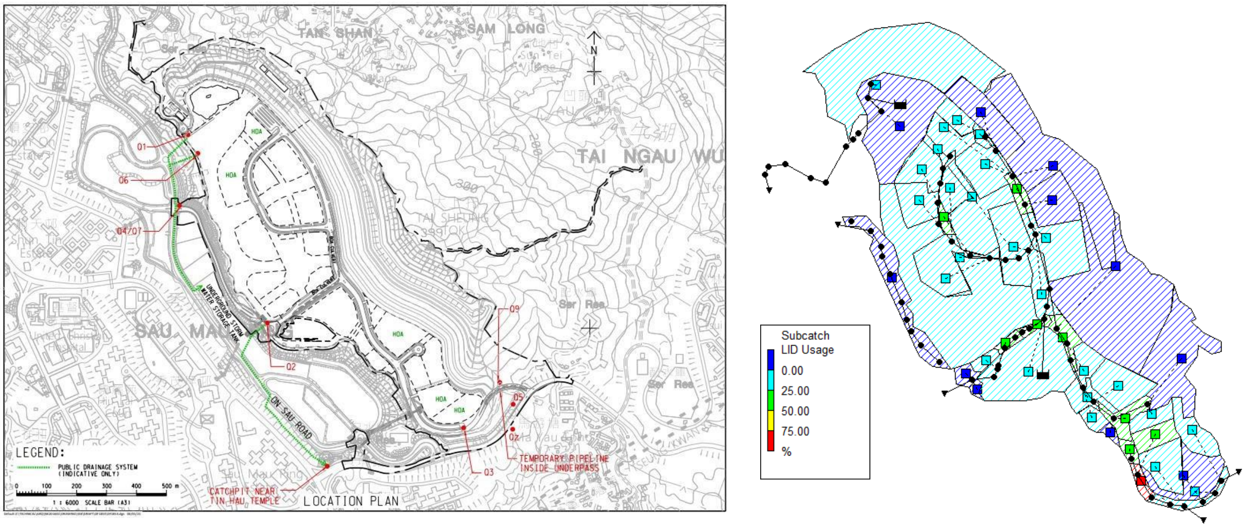


Figure 1. left: Layout plan of temporary drainage outlets of ARQ Site (2020); right: LID usages of subcathments in SWMM model

Field monitoring

Flowmeters will be installed in two monitoring points representing two main outlets within the site for discharge monitoring. Since the BGIs are under construction throughout the whole site (Figure 1), a comparison of hydrological responses between two points where the runoff go through different kinds of BGIs can be carried out. The measurement period is expected to be mid 2021-mid 2024, thus the event-scale and long-term-scale hydrograph analysis can both be implemented.

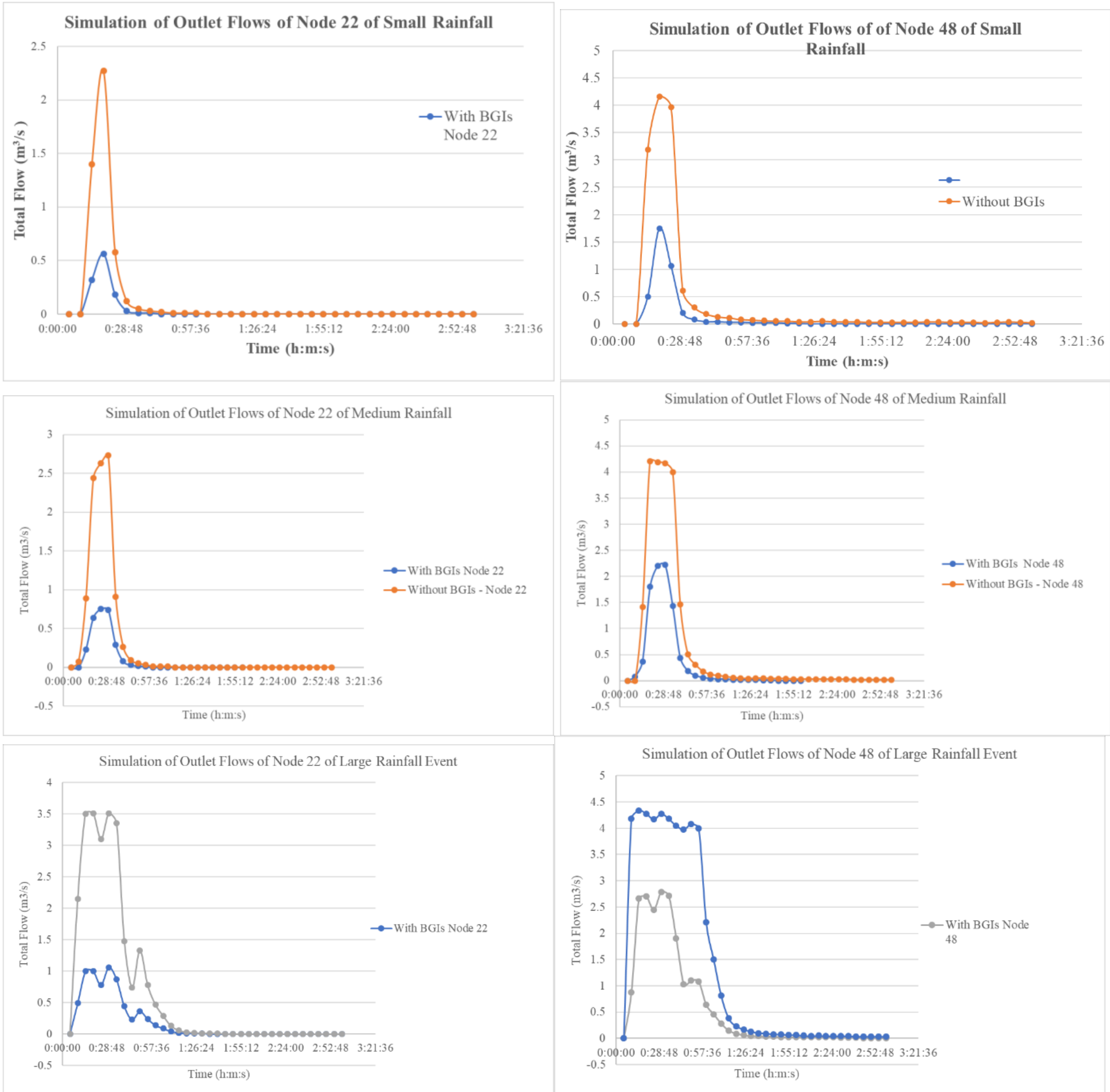
Preliminary results and discussion

A hydrological model including various LID modules has been established based on land use, DEM and urban drainage system at the site. Five representative precipitation events from historic observation data were selected and modelled. And the study conducted an event-scale evaluation on effectiveness of BGIs on hydrograph characteristics. From Table 1, we can see clear differences between phase1 and phase2 of maximum discharge and total discharge. Relative change was used for comparing the changes between two hydrograph characteristics (i.e., maximum discharge and total discharge). For event 4, the relative change of total discharge is not as much as that of maximum discharge. Thus, in this study, the null hypothesis was set as that peak and total stormflow affected in the same way by BGIs in subtropical climate.

Intensity-Duration-Frequency curves were derived based on GEV distribution model for determining synthetic hyetographs in 5-min intervals. In order to explore hydrograph characteristics under extreme precipitation, the comparisons between two typical outfalls were conducted (Figure 2). In all, all extreme precipitation events show prominent maximum discharge changes with BGIs compared with those without BGIs except for the event with the return period equals to 50 years at node 48. However, owing to the changes in hydrograph shape at the same event, the total discharge shows distinct differences between two scenarios. Thus, for extreme precipitation events, the changes for total and maximum discharge also present inconsistency due to changes in hydrograph shapes. Furthermore, the differences between two outfalls are obvious (Figure 2). Under the same synthetic hyetographs, the corresponding hydrographs show entirely different total and maximum discharges. Especially for the event with return period equal to 21 years, without BGIs, the hydrograph pattern changes at two nodes. Thus, under the same rainfall pattern, the location of the outfalls which are also associated with upper BGIs significantly influence all hydrograph characteristics.

Table 1. maximum discharge and total discharge under five precipitation events in two phases, wherein, phase1 represents BGIs implementation stage; phase2 represents BGIs before-implementation stage.

precipitation event	total precipitation (mm)	precipitation duration (h:mm)	maximum discharge (l/s)		relative change	total discharge (m^3)		relative change
			phase1	phase2		phase1	phase2	
1	48	2:15	5.17	5.47	0.06	9.84	10.34	0.05
2	43.5	4:05	1.72	1.82	0.06	5.08	5.29	0.04
3	72.5	6:45	4.78	5.04	0.05	15.44	16.18	0.05
4	9.5	9:05	1.05	1.10	0.05	2.19	2.20	0.01
5	85.5	6:20	5.03	5.25	0.04	14.59	14.99	0.03



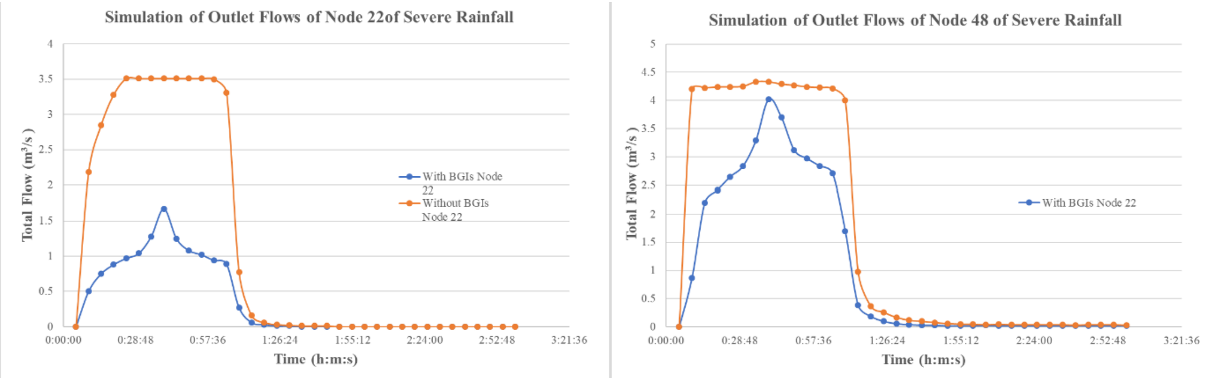


Figure 2. hydrographs under synthetic hyetographs based on Intensity-Duration-Frequency (IDF) curves at two typical outfalls under two scenarios: one with BGIs and another without BGIs. The return periods are 2, 10, 21 and 50 years for the four synthetic hyetographs, respectively.

Conclusions and future work

Inconsistency is shown in the relative change between total discharge and maximum discharge at event scale using historic rainfall data. For extreme precipitation events, the changes for total and maximum discharge also present inconsistency due to changes in hydrograph shapes. Under the same rainfall pattern, the location of the outfalls and upper BGIs obviously influence hydrograph characteristics including total and maximum discharge and hydrograph shape.

Future work will be done using hydrograph analysis to investigate the event-scale and long-term-scale changes in total runoff, maximum discharge and lag time. We will collect precipitation and discharge data using field monitoring and do calibration and validation for hydrological modelling. More robust simulation results will be conducted to support our research aims. Furthermore, we will also answer the question that if peak and total stormflow are affected in the same way at both event and long-term scales.

Acknowledgement

The work is supported by the Environment and Conservation Fund, Hong Kong (grant number: 108/2019) and the General Research Fund of Hong Kong RGC (grant number: 17202020).

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