The impact of surface representation methods on urban hydrological modeling

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1. INTRODUCTION

Urbanization have increased storm water runoff volume, flow rates and peak flows and decreases flow time and low flows (Shuster et al,2005). However, this method lead to an uneven sampling because the same density of sampling points were used in both flat areas and dramatically changed areas. This may hamper the accuracy of model simulation results. The triangle irregular network (TIN) method, which use variable size elements, may better handle this problem. Using a variable mesh size, a better description of the runoff path and accurate representation the slope can be achieved, which also provided flexibility for the representation of man-made structures (Schubert and Sanders, 2012). The developments in computer capability and the availability of remote sensing data largely boosted the use of distributed hydrological models in urban area, but hydrological modelling of urban catchments is highly challenging as urban catchments are strongly heterogeneous and have very specific hydrological processes (EPA, 2014; Krebs et al, 2014; Petrucci and Bonhomme, 2014). Urban surface is often dominated by a large number of man-made structures, such as roofs, roads, drainage pipes, urban blocks, and so on. These structures actually have a great impact on urban hydrological processes. Therefore, how to properly represent these structures is a very important issue. UHEs are usually based on urban structures, such as urban parcels, or urban blocks or building roofs, miniature plots such as yards. In practice of urban hydrological simulation, there are many cases in which the UHE division method is actually used. In this study, we investigated the effect of different terrain representation method for rainfall-runoff simulation of small urbanized catchments in cities.

2. MATERIAL AND METHOD

2.1 Study site

We chose the Kunimigaoka Area in Sendai City, Japan for the case study (Fig.1(a)). KA is located in the north-western part of the uptown of Sendai City, which covers approximately 50 hector with a medium gradient slope topography. KA is featured with a temperate monsoon climate and the annual average rainfall and temperature are 1254 mm and 12.4C, respectively. KA is an old uptown where urbanization degree is rather complete and the land use shows little change after 2000. The urban land use accounts for over 90% of the total in this region. The storm water was firstly drained to a regulating pond and then to a downstream river. The drainage system of KA can be divided into two parts, one being the sewer network in the Northern part of KA which accounted for most of the drainage areas; the other is a located in the southern part beside the regulating pond.

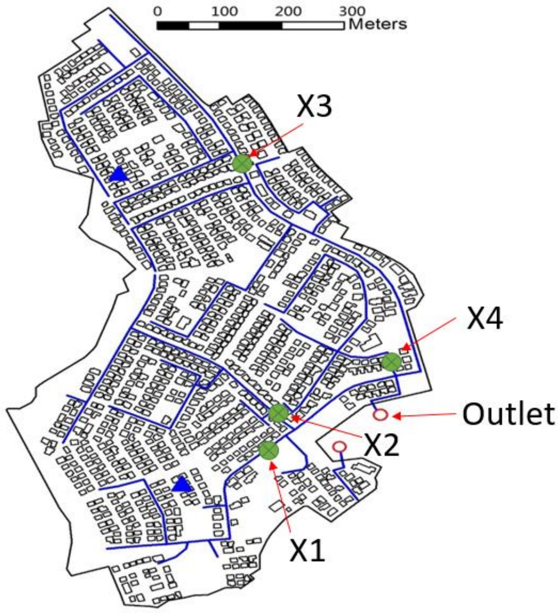

Fig.1. Watershed of Kunimigaoka Area

2.2 Data and preparation

The DEM of KA was available in the form of a high-resolution (5x5m) elevation data set, which was provided and quality controlled by the Land and Resources Department of Japan. In order to represent the blockage effect of buildings on surface flows, the building profiles were distinguished using the planar graph and Google satellite image. The underground pipeline data were obtained from Sewer Administration Office of Sendai City which contained geographic and geometric information of more than 400 pipelines and manholes. Most of the pipes are circular with diameters ranging from 0.3 to 2.4 m, while some pipes are rectangular whose widths and heights vary from 0.4 to 0.8 m. The pipe slopes show a wide range, varying from 0.5 to 38%.

2.3 Hydrological simulation design

The EPA Storm Water Management Model (SWMM) was selected for this study, as it provides all features required to meet the aims of this research. SWMM is widely used for single- or long-term event simulation of runoff quantity and quality in urban areas (Zoppou, 2001; Rossman, 2010). The spatially explicit character of SWMM allowed us to build high-resolution model to characterize the complicated overland flow routing. The core process in SWMM delineates the targeted catchment into a collection of sub-catchments that receive rainfall and generate runoff, then transport excess storm water from sub-catchments to assigned outlets through sewer networks (Rossman, 2010). General runoff routing described in the SWMM model was generated from upstream disconnected impervious sub-catchments and flowed through down-stream pervious sub-catchments.

Keywords: Urban hydrology, representation method, UHE, DEM, TIN
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2.4 method for terrain subdivision

DEM gridded data are derived from elevation data, which in turn are available from many sources at various spatial resolutions. The 10 m resolution of grid scale has been used herein. The UHE method utilized urban geographic objects relevant to a hydrological description of a city are cadastral parcels, houses, streets (including street segments and street surface polygons), the storm sewer system and streams, and topographical features with points. A triangular irregular network (TIN) is an irregular grid composed of three types of geometry. A TIN is built by using a delaunay triangulation (DT). In this study the TIN is obtained from the original DEM model using the RASTER to TIN transformation in ArcGIS.

3. RESULT AND DISCUSSION

In this study, we apply one rainfall of 8th Aug 2018, into the model.

We have found that different terrain representations have a certain impact on the flow of the discharge. Peak flow and total flow have a decreasing trend when using the TIN and Raster methods compared with the UHE method. While the difference between TIN and Raster methods was relatively small (fig.2).

And also we found that at local scale, there are also clear differences on peak and total discharge. However, compared with the differences at the outlet, the difference at local scale is relatively larger and showed more randomness (fig.3).

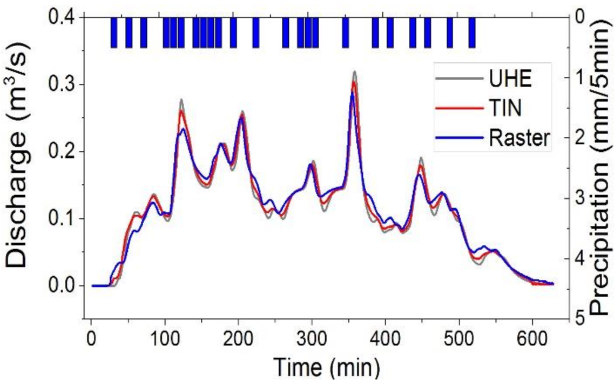

Fig.2 hydrograph at outlet for the simulated rainfall event

4. CONCLUSIONS

From the above explanation, we can conclude as follows:

1. In urban catchment, the terrain representation method have an impact on model performance while same parameters were used.
2. The use of TIN and Raster method lead to a decrease in peak and total discharge compared with the UHE method. These impacts are larger at the local scale and relatively smaller at basin scale.

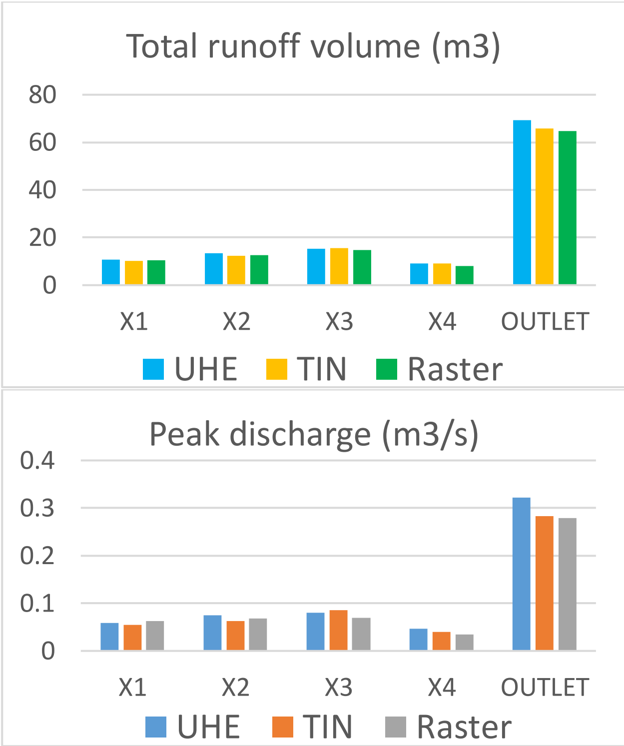

Fig.3 differences for total runoff volume and peak discharge at outlet and local point.

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