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Insights into the Models of MUSIC and Hydrus to Catch Stormwater

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Abstract

With the development of urbanization in recent years, better stormwater catchment design is required in everywhere. Nowadays, bioretention tanks, bioswales, and other useful emerging technologies, are popular for good stormwater catchment design. And This review summarized previous literatures about MUSIC and Hydrus modelling about these technologies. MUSIC, which simulates long-term and single events, is more convenient than Hydrus. And Hydrus, which contains more functions, is more complex than MUSIC. Anyway, MUSIC and Hydrus are useful to simulate and evaluate the effectiveness of different technologies. And they can be improved for better modelling in future.

Keywords

Model; MUSIC; Hydrus; Stormwater Catchment.

1. Introduction

With the development of urbanization in recent years, the impermeability of stormwater catchment has increased greatly. A large amount of runoff resulted by rainfall makes the drainage system bear more pressure than the designed capacity, and brings lots of pollutants into the water system, which affects the safety of water resources (Hilten, Lawrence & Tollner 2008, p.288). Furthermore, traditional rainfall catchment technology quickly distributes too much rainwater to sewers and river channels, which can easily lead to flash floods and degradation of the landscape of aquatic systems (Carter & Rasmussen 2005, p.1). And flora and fauna in native stream cannot grow well with these aquatic systems alterations (Hilten, Lawrence & Tollner 2008, p.288).

For better stormwater catchment design, some efficient technical systems were proposed by different countries, including low-impact development (LID), water sensitive urban design (WSUD) and sustainable urban drainage system (SUDS) (Jia, Yao & Shaw 2013, p.1). Through stormwater infiltration, storage, treatment and transportation, these systems effectively limit the total runoff and runoff pollution (Chen, Samuelson & Tong 2016, p.1).

In this review, MUSIC and Hydrus, two stormwater catchment modelling software were analyzed and compared for better catchment design with different technologies application.

2. Typical Stormwater Catchment Technologies

Nowadays, as proposed by LID, WSUD, and so on, bioretention tanks, bioswales, green roofs, artificial permeable grounds and other technologies are abundantly applied in stormwater catchment design (Traver & Ebrahimian 2017, p.2). As shown in Table 1, several typical technologies widely used in MUSIC and Hydrus modelling were summarized. Notably, as land area in most city centers is not enough for construction of large wetlands, and so on, green roofs and porous pavement are popular in ultra-urban stormwater catchment design (Hilten, Lawrence & Tollner 2008, p.288).

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3. Stormwater Catchment Design by MUSIC Modelling

The model for urban stormwater improvement conceptualization (MUSIC), a decision support system, was developed by the Cooperative Research Center for Catchment Hydrology (CRCCH) (Wong et al. 2002, p.1). As a modelling tool based on lots of research results of CRCCH and other organizations, MUSIC models the quantity and quality of stormwater and related runoff in different areas.

Table 1. Typical stormwater catchment technologies used in MUSIC and Hydrus modelling

Technology	Basic description	Example(s) of modelling
Bioretention tanks	Runoff and rainwater are stored and purified through plant, soil and microbial systems.	(Dotto et al. 2011; Imteaz & Ahsan 2015; Imteaz, Nguyen & Kuok 2015; Li, J et al. 2018; Meng et al. 2014)
Bioswales	Runoff and rainwater are treated by physical, chemical and biological synergy of soil, artificial medium, plant and microorganism.	(Marin et al. 2013); (Hermosilla 2019; Imteaz & Ahsan 2015)
Green roofs	Overflow of rainwater and the drainage pressure is reduced by planting plants on the roof.	(Hilten, Lawrence & Tollner 2008; Li, Y & Babcock Jr 2015; Principato, Carbone & Piro 2016)
Porous pavement	The accumulation of stormwater is quickly eliminated by the infiltration of rain water	(Dotto et al. 2011; Imteaz & Ahsan 2015)

MUSIC, which can be used freely within 30 days for users, is friendly for users when compared with other famous modelling software (e.g., more than 50000 dollars per year for license of MIKE URBAN). As MUSIC has ability to simulate the process in stormwater catchment systems, software users can evaluate the effects of conceptual systems design and decide whether its useful and suitable for selected areas. Notably, MUSIC is a random model rather than a physics-based deterministic model, which may be not reliable in realistic situations (Imteaz, Nguyen & Kuok 2015, p.1). There are some literatures recorded the process of MUSIC modelling in stormwater catchment design, including bioretention tanks and porous pavement, and so on. Imteaz, Nguyen and Kuok (2015, p.80) used MUSIC to measure the clogging ability of two bioretention systems which constructed in Melbourne. And Dotto et al. (2011, p.1) applied MUSIC to ensure that pervious area parameters are not much influential for the stormwater and runoff systems in highly urbanized catchments.

Apart from basic evaluation of effects of stormwater catchment design, MUSIC is also used to estimate costs of different design. Imteaz, Nguyen and Kuok (2015, p.302) used MUSIC for cost optimization of three types of stormwater catchment systems, including bioswales, bioretention tanks and porous pavement. On the one hand, costs to achieve the same efficiency were compared. On the other hand, cost verses pollutants (e.g., total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP)) removal efficiency were drawn in figures. The results showed that bioretention tanks are more relatively efficient in pollutants removal than other two technologies, and porous pavement are more relatively expensive than other two technologies. Nonetheless, sometimes MUSIC cannot work well without specific reliable parameters measured onsite. For example, MUSIC could not produce the effects of clogging in

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bioretention tanks without lower value of hydraulic conductivity measured onsite (Imteaz & Ahsan 2015, p.80).

4. Stormwater Catchment Design by Hydrus Modelling

As a detailed modelling software based on Windows, Hydrus can be used to model the transportation of flow, heat, and soluble matters in different media by providing related graphs (Li, J et al. 2018, p.1). For stormwater catchment design, it is mainly used in modelling of these systems with soil, such as bioretention tanks. And Hydrus-1D is a famous sub-product of Hydrus, which simulates in one-dimension.

As shown in Table 2, some typical examples of Hydrus-1D modelling applied in stormwater catchment design are summarized in detail. In this examples, better design can be achieved after estimating impacts of related parameters.

Table 2. Summary of Hydrus-1D modelling applied in stormwater catchment design

Technology	Basic process	Results	References
Bioretention tanks	Hydrus-1D was used to analyze basic influencing factors of operation effects of bioretention tanks.	Return intervals, thickness of media layer and matter concentrations are important factors.	(Li, J et al. 2018, p.38)
Bioretention tanks	Hydrus-1D was used to optimize parameters to achieve better hydrologic performance.	Return intervals, types of media layer and surface area are important factors.	(Meng et al. 2014, p.1)
Green roofs	Hydrus-1D was used to model the stormwater performance of selected roofs.	Green roofs cannot work well with large amounts of rain.	(Hilten, Lawrence & Tollner 2008, p.230)

Notably, Hydrus-1D, which is more mechanistic and complex than other modelling software, can be used to compare with results of other models as a validation tool. Marin et al. (2013, p.1) used Hydrus-1D to model the performance of wetlands to compare with the modelling results of two proposed simple models derived from MUSIC. And Hydrus-1D was also applied to validate the conceptual model, which simulate and evaluate the effectiveness of green roofs (Lindgren 2019, p.1).

As a modelling software based on one dimension, Hydrus-1D cannot simulate the situation with more than one dimension. For example, many simulations in structures of modern green roofs are complex with two or three dimensions, and Hydrus-1D is not able to model them (Radcliffe & Simunek 2010, p.2). Apart from Hydrus-1D, Hydrus-2D, which simulates in two dimensions, is also useful in stormwater catchment design. Li, Y and Babcock Jr (2015, p.1) developed a method to derive specific equations of three media for predicting hydrologic performance by using Hydrus-2D for the first time. And the modelling results also met the requirements of energy and environmental design.

Anyway, Hydrus-1D or Hydrus-2D, which are famous for complexity, cannot perfectly model or replicate every condition in real world. And observations and measurement are required for

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better stormwater design. For example, temperatures and biology are both related to stormwater recharge, which are not considered in Hydrus (Hermosilla 2019, p.70)

5. Discussion

After analyzing previous literatures about MUSIC and Hydrus modelling for better stormwater catchment design, it is clear these models for stormwater catchment design have one main knowledge gap (i.e., high dependency on validation). Though enough calibration is important in modelling, too much validation can be avoided by enhancing accuracy of models. For example, effects of aging still need consideration when applying artificial materials to catch stormwater, which is not considered in MUSIC and Hydrus (Li, Y & Babcock Jr 2015, p.6). Thus, more observed results are required to validate the modelling results, which is a burden for related institutions.

There are two future directions for MUSIC and Hydrus modelling. On the one hand, more options (i.e., lifespan) can be provided for users to choose for better modelling. And these options are not mandatory for modelling. On the other hand, more useful models can be derived from these existing models. Hydrus-3D may be more useful than Hydrus-1D/2D in future. And more simple models can be obtained from MUSIC and Hydrus for simplicity and convenience.

6. Conclusion

Bioretention tanks, bioswales, and other useful emerging technologies are popular for good stormwater catchment design. And This review summarized previous literatures about MUSIC and Hydrus modelling for better stormwater catchment design. In short, MUSIC, which simulates long-term and single events, is more convenient than Hydrus. And Hydrus, which contains more functions, is more complex than MUSIC. Anyway, MUSIC and Hydrus are useful to simulate and evaluate the effectiveness of different technologies. And they can be improved for better modelling in future.

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