ICUD-0566 Modifying the green-ampt method to model different types of infiltration systems

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Summary

The uncertainty of the input data for infiltration systems (e.g. estimates of stormwater flow, pollution, terrain characteristics) favors the use of simple physically based models, such as the Green-Ampt method. The modification of the method, presented in this paper refers to the introduction of a time-changing ponding depth, which allows for continuous calculation of the position of the wetting front in the system, without changes in the boundary conditions at every time step (an analytical solution). Initial testing shows promising results for the infiltration basin, and future results will include testing of a biofiltration unit.

Keywords

infiltration system, stormwater biofilter, green-ampt method, modelling

Introduction

Stormwater infiltration is extensively being used as one of the measures to alleviate both the flooding effects of stormwater, as well as to decrease its pollution potential. Stormwater infiltration systems include infiltration trenches, swales, permeable pavements and raingardens, all of which are considered Water Sensitive Urban Design (Wong et al., 2006) or Low Impact Development (Dietz, 2007) systems. The difficulty in managing these systems, including their sizing and placement, arises from the uncertainties in estimates of stormwater flow, pollution, and terrain characteristics, and builds up in their intrinsic lack of human control. However, the importance of good management of these systems, particularly assurance of their effective impact on the reduction of diffusive pollution to water bodies, drives the research for most effective models: capable of reproducing the impact of infiltration systems using the least amount of data with desired certainty. Although there are many types of models that can be applied to infiltration systems (mechanistic, regression, empirical etc.), the uncertainty of the input data favors the use of simple physically based models, such as the Green-Ampt method. This paper presents modified application of the original Green-Ampt method that includes the change in water head above the soil layer. Method is applied to one infiltration basin and one raingarden both located in highly urbanized catchments in two different climates (Humid continental and Temperate oceanic).

Methods and Materials

Modified Green-Ampt method

The Green-Ampt method (Green and Ampt, 1911) is typical representative of simplistic-physically based methods for calculation of the unsteady infiltration rate q(t). It is derived under the assumption of a sharp boundary wetting front penetrating into the unsaturated soil. The position of the front is defined as the depth from the surface in time t since the start of infiltration - y(t), when there is a constant ponding depth.

The modification presented in this paper refers to the introduction of a time-changing ponding depth– H(t) (Eq. 1), which allows for continuous calculation of the position of the wetting front in the system, without changes in the boundary conditions at every time step.

$$q(t) = K_f \left(1 + \frac{H_k + H(t)}{y(t)}\right) \quad (1)$$

Combining the momentum equation (Eq. 1) with the continuity equation for the infiltration system produces an ordinary differential equation. This equation can be solved to give an analytical solution of the problem - the water level in the infiltration system (H(t)).

Model calibration procedure

The infiltration model has three parameters that have to be determined by calibration: Kf – saturated hydraulic conductivity [m/s], Hk – characteristic soil suction head at the position of wetting front [cm] and Δw=(wmax -wo) - initial saturation deficit [-]. The model is calibrated using experimental data from two different infiltration systems with the help of the PEST software package (Doherty, 2010). The output data of the calibration algorithm includes the sensitivity analysis.

Field experiment data

Field experiments were conducted on an infiltration basin located at University of Belgrade, Serbia, and a stormwater raingarden located at Monash University, Australia. The filtration layer of the infiltration basin includes gravel and sand, and drains to a low permeable silt (Vasilic, 2013). The raingarden is lined with a sandy filter with a submerged zone and planted with Melaleuca ericifolia (Randelovic et al., 2016). The data collected during experiments includes measurements of water levels at the ponding layer, input and output flows, and soil moisture and different points.

Results and Discussion

Preliminary Results

Initial testing shows promising results for the infiltration basin (Fig. 1). The raingarden has so far been modelled using another type of a conceptual model (Randelovic et al., 2016), and this paper will present the benefits of using the modified Green-Ampt method.

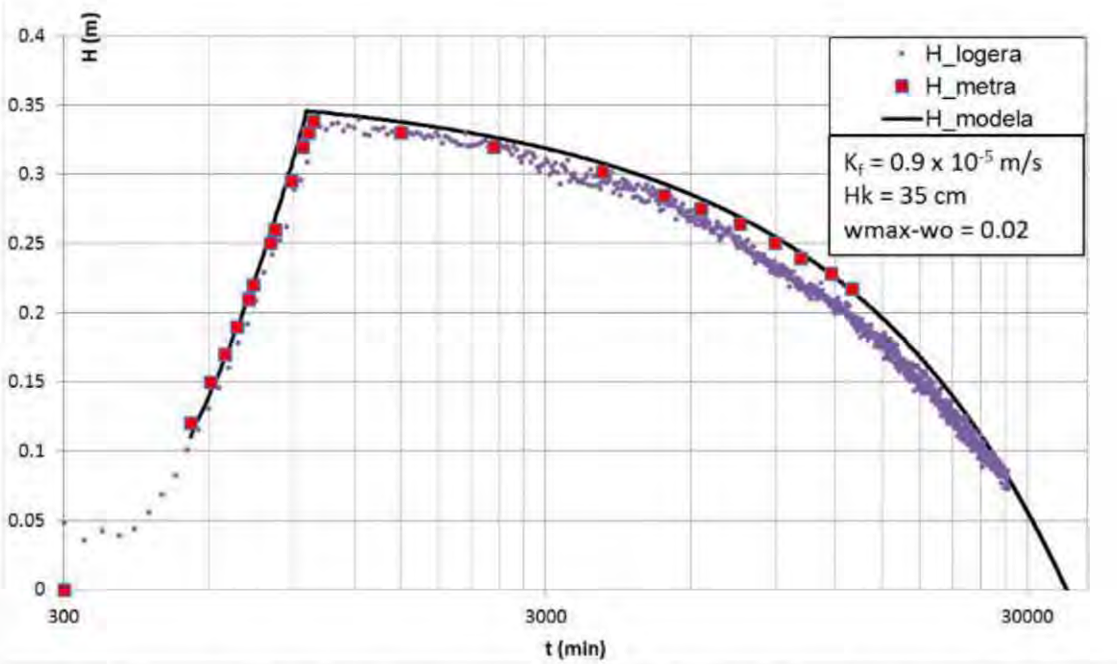

Fig. 1. *Measured and modelled ponding water level during one storm event in an infiltration basin in Belgrade using the Modified Green-Ampt method*

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