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Modelling impervious pavements with the Low Impact Development module of the Storm Water Management Model

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ABSTRACT

During the last few decades, resolution for hydrologic models has increased considerably. In addition, the growing development of Sustainable Urban Drainage Systems (SUDS) has led to the implementation of new parameters and modules in those models. For example, Storm Water Management Model (SWMM) implemented the Low Impact Development (LID) module, which is designed to model SUDS techniques. However, hydrological modelling with the LID module presents relevant differences from the general SWMM model procedure. This research proposes a new approach for modelling the hydraulic response of impervious pavements in urban areas, based on the model provided by the SWMM LID module, instead of the general model. Results show that, when modelling with the SWMM LID module, it is possible to obtain runoff hydrographs that match those obtained by the general SWMM model, modifying just one parameter: the pavement permeability. This approach would be useful to compare alternatives that can be implemented in a given area by modifying only one model parameter. It would be possible to switch from pervious to impervious surfaces without changing the model itself.

1. Introduction

Authorities are increasingly trying to implement environmentally sustainable solutions in new and existing developments, and urban drainage systems are no exception. In this field, the Sustainable Urban Drainage Systems (SUDS) techniques have multiple advantages: for example, they reduce the volume and peak of generated runoff, as well as the amount of discharged pollutants. To this end, several types of SUDS have been developed and can be implemented, permeable pavements being one of them.

Often, SUDS performance analysis relies on hydrological models. These hydrological tools are sometimes combined with digital terrain models available under Geographic Information System (GIS) software packages, allowing the identification of subcatchment's main characteristics and properties (Allende-Prieto et al., 2018). However, several processes, including build up, wash-off and transport of pollutants, soil erosion rates, flood hazard and risk evaluation, require high-resolution models in order to properly simulate complex dynamics (Lopez and Maxwell, 2016).

Therefore, as resolution is being improved, it becomes feasible to individually model SUDS, that is, to associate a SUDS element to a single subcatchment in the model. Modelling SUDS individually would not only facilitate the modelling process, but also the comparison between scenarios (switching from a pervious SUDS subcatchment to an impervious one). Storm Water Management Model (SWMM) introduces SUDS by implementing the Low Impact Development (LID) module. However, adding that module leads to a dual modelling option: the general hydrologic-hydraulic model or the LID module. Therefore, the implementation of a model to compare the performance of different SUDS scenarios requires, generally, both models.

This research proposes a new approach for modelling the hydraulic response of impervious pavements in urban areas using directly the LID module. It defines the key parameter (pavement permeability) to model both permeable and impermeable pavements based on the model provided by the SWMM LID module, so that runoff matches results calculated with the general hydrologic-hydraulic SWMM model. That would be useful to compare alternatives that can be implemented in a given area, by just modifying one parameter of the model, without changing the model itself.

2. Methodology

Comparison between the general model and the LID module has been done by (a) creating two subcatchments with the same area, shape and slope, (b) defining one as completely impervious with the general SWMM model, which was called *General*, and the other one as a permeable pavement with the LID module, which was called *LID*. Finally, (c) the runoff hydrograph for the General subcatchment was estimated for a given rainfall, and (d) the pavement permeability of the LID module was calibrated to match the previous one.

Hydrographs were calibrated under several conditions, to test if they had any influence on the results: three slopes (1%, 2%, 6%) and three subcatchment shapes (narrow, square, width) were considered. Pavements on the LID module were also tested with three cross sections (asphalt, concrete and pavers), with different layer characteristics. Calibration was done for a symmetric 2 hour storm, 150 mm depth. For calibration purposes, Nash-Sutcliffe Efficiency (NSE) coefficient was selected. Calibration was done in R software, using the differential evolution algorithm provided by *DEoptim* package.

3. Results and discussion

In the general model, the subcatchment runoff is very sensitive to these parameters: depth of the depression storage (*Dstore-Imperv*) and percentage of the area with no depression storage (*%Zero-Imperv*). Therefore, and for the purposes of this study, two values recommended by Rossman and Huber (2016) were selected: 1.5 mm and 25%.

While calibrating the runoff results with the square subcatchment, NSE values close to 1 were obtained for three slopes and three types of pavement. The calibrated value for pavement permeability was 0.55 mm/h, for all cases. Figure 1 shows calibrated hydrograph for 6% slope and asphalt cross-section.

As shown, calibrated peak values were close to those obtained with the general model. A difference was observed in the first 20 minutes, due to a delay in generated runoff for the *General* subcatchment. This difference is affected by the previously mentioned two values, depth of the depression storage and percentage of the area with no depression storage.

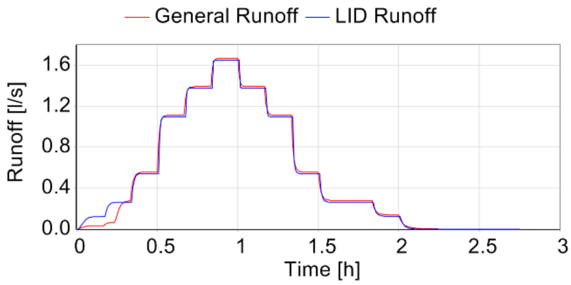

Fig. 1. Runoff calculated by general model (red) and LID module (blue) for 6% slope for asphalt cross-section.

4. Conclusion

The results show that it is possible to obtain runoff hydrographs from impervious pavements using the SWMM LID module, similar to those obtained by the general hydrologic-hydraulic SWMM model, by only modifying one parameter: the pavement permeability. Among other applications, this will simplify the comparison between the hydraulic response of a traditional impervious surface and a pervious one, since it will not be necessary to change the model itself.

References

Allende-Prieto C, Mendez-Fernandez BI, Sanudo-Fontaneda LA, Charlesworth SM (2018) Development of a Geospatial Data-Based Methodology for Stormwater Management in Urban Areas Using Freely-Available Software, International Journal of Environmental Research and Public Health, 15(8), 1703.
Lopez SR, Maxwell RM (2016) Identifying urban features from LIDAR for high-resolution urban hydrologic model, Journal of the American Water Resources Association, 52(3), 756–768.
Rossman LA, Huber WC (2016) Storm Water Management Model Reference Manual Volume III Water Quality, U.S. EPA Office of Research and Development, 159 pp.