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DESIGN OPTIMIZATION FOR ENHANCED POLLUTANT REMOVAL EFFICIENCY OF BIORETENTION CELLS

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ABSTRACT

Consulting engineers, conservation authorities, and municipalities are looking for methods of stormwater management control that not only restore pre-development hydrological cycles, but also offer the benefit of runoff quality treatment. As a result, Low Impact Development (LID) approaches, which are often applied at the source, have been gaining in popularity. The objective of this research is to develop guidance for the design of bioretention cells for runoff water quality treatment, evaluating bioretention cells' ability to perform such treatment function through modelling. A number of different modelling tools have been developed to simulate the performance of bioretention cells. These models are utilized to aid in the analysis of how bioretention cell design and layout affect the runoff treatment, for the purpose of providing engineering guidance on the optimal design of bioretention cells for stormwater runoff quality enhancements.

Keywords: Low Impact Development, Bioretention, Total Suspended Solids, EPA SWMM

1. BACKGROUND AND OBJECTIVE

The vast majority of stormwater best management practices (BMPs) in Ontario have been implemented at the point of discharge, which often result in high runoff volumes and adverse effects on the health of the receiving waters. Consulting engineers, conservation authorities, and municipalities are looking for methods of stormwater management control that not only restore pre-development hydrological cycles, but also provide runoff quality treatment, amongst other benefits. As a result, Low Impact Development (LID) approaches, which are often applied at the source, have been gaining in popularity. Currently, most conservation authorities and municipalities in Ontario are moving toward encouraging and even mandating the use of LID practices for stormwater management.

A common LID technology and subject of this study, the bioretention cell, consists of an excavated and filled filter bed and storage layer topped with organic material and native vegetation. While design guidelines are present for the sizing of bioretention cells, there is little guidance available to quantify the bioretention cell's ability to improve water quality through reduction of pollutants. The lack of guidance creates a large number of unknowns for design engineers and creates difficulties in both the design and the approval processes. Understanding the performance of LID features is very important for their evaluation against minimum stormwater management criteria; hence, in the approval process of new and retrofit developments. The objective of this study is to develop and validate tools that will provide a better estimate of the pollutant removal efficiency of infiltration-based LIDs, such as bioretention cells, providing engineering guidance on the optimal design of bioretention cells for stormwater runoff quality enhancements.

2. EVENT-BASED MODEL

A model that incorporates each unique site's characteristics into the calculation of the runoff treatment, i.e. removal of Total Suspended Solids (TSS), is developed. Filtration equations developed by Yao et al. (1971) are selected to model the TSS removal efficiency of bioretention cells. Bioretention cell design is often completed using a design storm approach, for which the Yao et al. (1971) filtration model is appropriate. This model has been previously applied to bio-retention cell modeling (Li and Davis, 2008, Liu and Davis, 2014), where it was found to provide adequate results in spite of its relatively simple underlying assumptions. The assumptions that are made for its use are: 1) steady-state conditions; 2) single filter media grain size (weighted average); and 3) retained particles do not change filter properties. The equations are adapted to integrate with the widely used EPA SWMM, through its Add-in Tools feature, which performs post-processing of the results of the hydraulic performance simulation of the cell. The model is calibrated and validated using the field monitoring data collected by the Toronto and Region Conservation Authority (TRCA). Simulation results are benchmarked against the results from WinSLAMM, another software that has the capability of calculating pollutant removal by LIDs. WinSLAMM's methods are based upon field observations, with as little use of purely theoretical processes as possible. The simulation results showed good agreement with the monitoring data. Challenges in event-based model development include calibration of the event-based inflows and high removal efficiency of the monitored bio-retention cell, which prevents calibrating and validating against a wider range of observed data.

3. CONTINUOUS SIMULATION

O'Melia and Ali (1978) considered the case where the captured particles would enhance the removal properties of the filter media by behaving as additional collectors (i.e. filter ripening). These enhancements cause the state of the filter to change over time. Continuous modelling is applied to investigate the long term performance of bioretention cells, including enhancement by captured particles as well as clogging of the filter media. The bioretention model is expanded to include other infiltration-based LID practices. Recently developed unsaturated flow functions for the filter media (Barbu and Ballestero, 2015), which are important for routing water through the unsaturated soil, are incorporated into the model. Monitoring data for various LID practices has been collected and are available through different institutions, including University of Alberta and University of New Hampshire Stormwater Management Centre. This data is used to calibrate and verify the developed model, indicating that a close match between the predicted removal efficiency of different LIDs and monitoring results can be obtained. Simulation results are also benchmarked against the results from other available software. The developed model simulates the physical processes of pollutant removal by the filter media.

4. CONCLUSIONS

The developed model may be used by designers to calculate the pollutant removal efficiency of LID practices, considering the specific site conditions. The results of this study may be used to provide engineering guidance on the optimal design of bioretention cells for stormwater runoff quality enhancements as well as a reference in the approval process of the proposed stormwater management facilities for new and retrofit developments.

REFERENCES

Barbu, I.A. and Ballestero, T.P. 2015. Unsaturated Flow Functions for Filter Media Used in Low-Impact Development—Stormwater Management Systems. *ASCE J. Irrigation and Drainage Engineering*, 141 (1).

Li, H. and Davis, A. 2008. Urban Particle Capture in Bioretention Media - 1: Laboratory and Field Studies. *Journal of Environmental Engineering*, 134: 409-418.

Liu, J. and Davis, A. 2014. Phosphorus Speciation and Treatment Using Enhanced Phosphorus Removal Bioretention. *Environmental Science and Technology*, 48: 607-614.

O'Melia, C. and Ali, W. 1978. The Role of Retained Particles in Deep Bed Filtration. *Progress in Water*, 10 (5/6): 123-137.

Yao, K.-M., Habibian, M., and O'Melia, C. 1971. Water and Waste Water Filtration: Concepts and Applications. *Environmental Science & Technology*, 5 (11): 1105-1112.